THE CITY OF SAN DIEGO

Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall 2008

City of San Diego Ocean Monitoring Program

Metropolitan Wastewater Department Environmental Monitoring and Technical Services Division

June 30, 2009

Mr. John Robertus
Executive Officer
Regional Water Quality Control Board
San Diego Region
9771 Clairemont Mesa Blvd. Suite B
San Diego, CA 92124
Attention: POTW Compliance Unit

Dear Sir:

Enclosed is the 2008 Annual Receiving Waters Monitoring Report for NPDES Permit No. CA0107409, Order No. R9-2002-0025 for the City of San Diego Point Loma Wastewater Treatment Plant, Point Loma Ocean Outfall. This report contains data summaries and statistical analyses for the various portions of the ocean monitoring program, including oceanographic conditions, microbiology, sediment characteristics, benthic macrofauna, demersal fish and megabenthic invertebrate communities, and bioaccumulation of contaminants in fish tissues.

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

Sincerely,

ALAN C. LANGWORTHY
Deputy Metropolitan Wastewater Director

ACL\akl

Enclosures: 1. Annual Receiving Waters Monitoring Report
2. CD containing PDF file of this report

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

Annual Receiving Waters Monitoring Report
for the
Point Loma Ocean Outfall
2008

Prepared by:

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

June 2009

Table of Contents

Table of Contents
(continued)

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Chapter 1. General Introduction
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Chapter 2. Oceanographic Conditions
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Chapter 3. Microbiology
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Chapter 4. Sediment Characteristics
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Chapter 5. Macrobenthic Communities
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Chapter 6. Demersal Fishes & Megabenthic Invertebrates
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Chapter 7. Bioaccumulation of Contaminants in Fish Tissues
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Cover Photos (clockwise from top left): *Mediaster aequalis*, *Spatangus californicus*, flag rockfish (*Sebastes rebrivinctus*), *Astropecten ornatissimus, Glyptolithodes cristatipes, Pisaster giganteus capitatus, Randalia ornata*, Speckled sanddabs (*Citharichthys stigmaeus*), *Crossata californica* (center image). Photos by Nick Haring.

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Executive Summary

Executive Summary

The Monitoring and Reporting Program (MRP) requirements for the City of San Diego (City) Point Loma Wastewater Treatment Plant (PLWTP) are outlined in Order No. R9-2002-0025, NPDES Permit No. CA0107409, and as subsequently modified by Addendum No. 1 in 2003 and Addendum No. 2 in 2008 (see Chapter 1). The primary objectives of the Point Loma ocean monitoring program are to a) fulfill NPDES permit requirements for receiving waters monitoring, b) measure compliance with water-contact standards specified in the 2001 California Ocean Plan (COP), and c) assess the impact of wastewater discharged through the Point Loma Ocean Outfall (PLOO) on the marine environment off San Diego, including any effects on ocean water quality, sediment conditions, and marine organisms. The study area encompasses approximately 184 km^2 of coastal waters centered around the PLOO discharge site, which is located approximately 7.2 km offshore of the PLWTP at a depth of nearly 100 m. Monitoring at stations along the shoreline extends from Mission Beach southward to the tip of Point Loma, while offshore monitoring occurs in an adjacent area overlying the continental shelf at sites ranging from 9 to 116 m in depth.

The City conducts other types of studies in addition to its regular monitoring for Point Loma that are useful for evaluating patterns and trends over time or that span broader geographic regions, thus providing additional information to help distinguish reference areas from sites that may be affected by anthropogenic influences. For example, prior to the initiation of wastewater discharge at the present deepwater location in late 1993, the City conducted a 2½-year baseline study designed to characterize background environmental conditions in the PLOO region in order to provide information against which post-discharge data could be compared. Additionally, the City typically conducts an annual summer survey of benthic conditions for the San Diego region at randomly selected sites that range from Del Mar to the USA/Mexico border as part of the South Bay Ocean Outfall monitoring program. The City also collaborates with other organizations on larger-scale, regional monitoring projects that span the entire Southern California Bight (SCB). Such previous bight-wide surveys include the Southern California Bight Pilot Project in 1994, and the subsequent Bight'98 and Bight'03 projects in 1998 and 2003, respectively. Currently, the City is participating in the Bight'08 regional monitoring program, which began during the summer of 2008. However, in order to participate in Bight'08, some regular monitoring requirements for both the Point Loma and South Bay regions were relaxed in 2008 (see Chapter 1).

The receiving waters monitoring effort for the Point Loma region is divided into several major components, with each comprising a separate chapter in this report, including: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues. Chapter 1 presents a general introduction and overview of the City's ocean monitoring program, as well as background information on wastewater treatment processes at the PLWTP, including the initiation of chlorination in late 2008. In Chapter 2, data regarding various physical and chemical oceanographic parameters are evaluated to characterize water mass transport potential in the region. Chapter 3 presents the results of water quality monitoring conducted along the shore and in offshore waters, which includes the measurement of fecal indicator bacteria to assess potential effects of both natural and anthropogenic inputs, and to determine compliance with water-contact standards specified in the 2001 COP. The results of benthic sampling and analyses of soft-bottom sediments and their associated macrofaunal communities are presented in Chapters 4 and 5, respectively. Chapter 6 presents the results of trawling activities to assess the status of bottom dwelling (demersal) fish and megabenthic invertebrate communities. Bioaccumulation studies to determine whether contaminants are present in the tissues of local fishes supplement the monitoring of fish populations and are presented in Chapter 7. In addition to the above activities, the City supports other projects relevant to assessing ocean quality in the region (see Chapter 1). One such project is a remote sensing study of the San Diego and Tijuana coastal regions. These results are incorporated herein into interpretations of oceanographic and microbiological data (see Chapters 2 and 3).

The present report focuses on the results of all ocean monitoring activities conducted in the Point Loma region during calendar year 2008. In general, these data indicate that the Point Loma outfall has had only a limited and localized effect on the marine environment off San Diego after 15 years of wastewater discharge at the present deepwater location. An overview and summary of the main findings for each of the major components of the monitoring program over the past year are included below.

Oceanographic Conditions

Overall, there continues to be no evidence of change in any physical or chemical water quality parameter such as dissolved oxygen concentrations or pH levels that can be attributed to the discharge of wastewater off Point Loma. Instead, observed variations in ocean conditions in 2008 were notably consistent with what would be expected due to typical seasonal cycles, as well as with changes in larger patterns reported for the California Current System. Together, this suggests that other factors such as the upwelling of deep, cool, and nutrient-rich waters during the spring months, the occurrence of associated phytoplankton blooms, and the effects of large-scale oceanographic events such as El Niño-La Niña oscillations may best explain most of the temporal and spatial variability observed in these types of water quality parameters for the Point Loma region.

Microbiology

There was no evidence that wastewater discharged to the ocean via the PLOO reached surface waters or contaminated shoreline or near-shore recreational waters in 2008. For example, the wastewater plume was not detected in any aerial and satellite imagery taken during the year. Although elevated counts for fecal indicator bacteria (FIB) such as total coliforms, fecal coliforms and/or enterococcus were occasionally detected along the shore and at a few nearshore stations, concentrations of these bacteria tended to be relatively low overall. In general, elevated FIB densities were limited to instances when contamination was most likely associated with rainfall (i.e., storms), heavy recreational use, or decaying plant material (e.g., kelp and surfgrass along the shore). In addition, all seawater samples collected at the eight kelp bed stations during the year, and from all but one of the eight shore stations (i.e., D8), were 100% compliant with the four COP standards; the few exceedances that did occur at station D8 corresponded to rain events or other sources of contamination unrelated to the PLOO discharge. The elevated FIB counts that could be attributable to wastewater discharge were limited to offshore waters at depths of 60 m or below. This finding supports previous analyses of water quality data for the region, which have indicated that the PLOO waste field has typically remained well offshore and submerged in deep waters ever since completion of the outfall extension in late 1993.

Sediment Characteristics

Ocean sediments at stations surrounding the PLOO in 2008 were comprised primarily of fine sands and coarse silt, which is similar to patterns seen in previous years. Overall, differences in the particle size composition of sediments off Point Loma are likely affected by both anthropogenic and natural influences, including outfall construction materials, offshore disposal of dredged materials, multiple geological origins of different sediment types, and recent deposits of detrital materials. There was no evident relationship between sediment composition and proximity to the outfall discharge site.

Concentrations of various contaminants, including most organic loading indicators (e.g., biochemical oxygen demand or BOD, total nitrogen, total volatile solids), trace metals, pesticides (e.g., DDT), PCBs, and PAHs in sediments off Point Loma remained within the typical range of variability for San Diego and other areas of the southern California continental shelf. The only contaminant that exceeded the Effects Range Low environmental threshold value for southern California was silver, which was present in relatively high concentrations throughout the region. Overall, there were few clear spatial patterns in sediment contaminant concentrations relative to the PLOO discharge site in 2008, with the exception of slightly elevated sulfide and BOD levels near the outfall. Instead, the highest concentrations of several contaminants occurred at sites relatively distant from the outfall. These included the highest copper, mercury, total PCB, and total PAH values, all of which occurred in sediments near the LA-5 dredged materials disposal site. This pattern is consistent with other studies that have suggested that sediment contamination at these and other southern stations off San Diego is most likely due to misplaced deposits (i.e., short dumps) of dredged materials originally destined for LA-5.

Macrobenthic Communities

Benthic communities surrounding the PLOO in 2008 were dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began in 1991. Polychaetes and ophiuroids were the most abundant and diverse taxa in the region. Although many of the assemblages present during the year were dominated by similar species, the relative abundance of these species varied among sites. The brittle star *Amphiodia urtica* was the most abundant and widespread species in the region, while the capitellid polychaete *Mediomastus* sp was the second most widespread benthic invertebrate. Overall, these assemblages were typical of those occurring in other mid-depth areas of the SCB with similar, relatively fine sediment habitats.

Benthic conditions off Point Loma did reflect some changes in 2008 that may be expected near large ocean outfalls, although these effects were restricted to a relatively small, localized region within about 300 m of the outfall diffuser legs. For example, some descriptors of benthic community structure (e.g., infaunal abundance, species diversity) or populations of indicator species (e.g., *A. urtica*) have shown small changes over time between reference areas and sites located nearest the outfall. However, results for the benthic response index (BRI) were characteristic of undisturbed sediments. In addition, changes in macrofaunal community structure that did occur during the year were similar in magnitude to those that have occurred previously and elsewhere off southern California. Overall, macrofaunal assemblages in the region remain similar those observed prior to wastewater discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf. There was no evidence that wastewater discharge has caused degradation of the marine benthos in the PLOO monitoring region.

Demersal Fishes and Megabenthic Invertebrates

Pacific sanddabs continued to dominate fish assemblages surrounding the PLOO during 2008 as they have for many years. This species occurred at all stations and accounted for 45% of the total fish catch. Other characteristic, but less abundant species included halfbanded rockfish, longspine combfish, English sole, Dover sole, shortspine combfish, yellowchin sculpin, plainfin midshipman, pink seaperch, roughback sculpin, and hornyhead turbot. Although the overall composition and structure of the fish assemblages present off Point Loma varied among stations, most differences were due to fluctuations in Pacific sanddab populations.

Assemblages of relatively large (megabenthic) trawl-caught invertebrates in the region were similarly dominated by a single species, the white sea urchin *Lytechinus pictus*. Variations in the overall structure of this invertebrate community off Point Loma generally reflect differences in the abundance of this particular urchin, as well as several other co-dominant species. These other common species include the sea pen *Acanthoptilum* sp, the sea star *Luidia foliolata*, the sea cucumber *Parastichopus californicus*, the brittle star *Ophiura luetkenii*, the octopus *Octopus rubescens*, and the sea urchin *Strongylocentrotus fragilis*.

Overall, results of the 2008 trawl surveys provide no evidence that wastewater discharged through the PLOO has affected either demersal fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of these trawl-caught species were similar at stations located near the outfall and farther away. These results are supported by the findings of another recent assessment of these communities off San Diego. Significant changes in these fish and invertebrate communities appear most likely to be due to natural factors such as changes in ocean temperatures associated with large-scale oceanographic events (e.g., El Niño or La Niña) or to the mobile nature of many species. Finally, the absence of any indicators of disease or other physical abnormalities in local fishes suggests that their populations remain healthy in the region.

Contaminants in Fish Tissues

There was no clear evidence to suggest that tissue contaminant loads in fish captured at the PLOO monitoring sites were affected by the discharge of wastewater in 2008. Several trace metals, three pesticides (i.e., DDT, hexachlorobenzene, chlordane), and various PCB congeners were detected frequently in liver tissues from flatfish and muscle tissues from rockfish sampled in the region during the year. The various contaminants were distributed widely among the stations and showed no patterns that could be attributed to wastewater discharge. Further, all contaminant values were within the range of those reported previously for southern California fishes. Finally, while some muscle tissue samples from sport fish collected off Point Loma had arsenic and selenium concentrations above the median international standard for shellfish, and some samples had mercury levels that exceeded OEHHA fish contaminant goals, concentrations of mercury and DDT were still below U.S. FDA human consumption limits.

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

Chapter 1
General Introduction

Chapter 1. General Introduction

INTRODUCTION

Treated effluent from the City of San Diego's Point Loma Wastewater Treatment Plant (PLWTP) is discharged to the Pacific Ocean through the Point Loma Ocean Outfall (PLOO) according to requirements set forth in Order No. R9-2002-0025, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0107409. The above Order and associated Monitoring and Reporting Program (MRP) were adopted by the San Diego Regional Water Quality Control Board (SDRWQCB) on April 10, 2002. During 2003, the MRP requirements for the Point Loma region were modified with the adoption of Addendum No. 1 to the above Order (see City of San Diego 2004), which became effective August 1, 2003, thus superseding and replacing all prior receiving waters monitoring requirements for the PLWTP. The above Order was further modified by the adoption of Addendum No. 2 on August 13, 2008, which gave the City approval to initiate operation of a prototype disinfection system at the PLWTP.

The MRP for Point Loma defines the requirements for monitoring receiving waters in the region off Point Loma, including the sampling design, compliance criteria, types of laboratory analyses, and data analysis and reporting guidelines. The main objectives of the ocean monitoring program are to provide data that satisfy the requirements of the NPDES permit, demonstrate compliance with the provisions of the 2001 California Ocean Plan (COP), detect movement and dispersion of the waste field in coastal waters, and identify any biological or chemical changes that may be associated with wastewater discharge.

BACKGROUND

The City of San Diego began operation of the PLWTP and original ocean outfall off Point Loma in 1963, at which time treated effluent was discharged approximately 3.9 km offshore at a depth of about 60 m (200 ft). From 1963 to 1985, the plant operated as a primary treatment facility, removing approximately 60% of the total suspended solids (TSS) by gravity separation. Since then, considerable improvements have been made to the treatment process. The City began upgrading the process to advanced primary treatment (APT) in mid-1985, with full APT status being achieved by July of 1986. This improvement involved the addition of chemical coagulation to the treatment process, and resulted in an increased TSS removal of about 75%. Since 1986, treatment has been further enhanced with the addition of several more sedimentation basins, expanded aerated grit removal, and refinements in chemical treatment. These enhancements have resulted in lower mass emissions from the plant. TSS removals are now consistently greater than the 80% permit requirement. Finally, the City began testing disinfection of PLWTP effluent using sodium hypochlorite solution in September 2008 following adoption of Addendum No. 2 to Order No. R9-2002-0025 (see above).

Additional improvements occurred in the early 1990s when the PLOO was extended about 3.3 km further offshore in order to prevent intrusion of the wastewater plume into nearshore waters and to increase compliance with standards set forth in the COP for water-contact sports areas. Construction of the outfall extension was completed in November 1993, at which time discharge was terminated at the original 60 m site. The outfall presently extends approximately 7.2 km offshore to a depth of 94 m (310 ft), where the pipeline splits into a Y-shaped multiport diffuser system. The two diffuser legs extend an additional 762 m to the north and south, each terminating at a depth of about 98 m (320 ft) on the outer continental shelf.

The average daily flow of effluent through the PLOO in 2008 was about 162 mgd, ranging from a low of 150.5 mgd in October to a high of 181.3 mgd in February. This is similar to the 2007 average flow of around 161 mgd. TSS removal averaged about

88% during 2008, with a total mass emissions of approximately 7169 mt/yr relative to 7577 mt/yr in 2007 (see City of San Diego 2009a).

Receiving Waters Monitoring

Prior to 1994, the City conducted an extensive ocean monitoring program off Point Loma surrounding the original 60-m discharge site. This program was subsequently modified and expanded with the construction and operation of the deeper outfall. Data from the last year of regular monitoring near the original inshore site are presented in City of San Diego (1995a), while the results of a 3-year "recovery study" are summarized in City of San Diego (1998). From 1991 through 1993, the City also conducted a voluntary "pre-discharge" study in the vicinity of the new site in order to collect baseline data prior to the discharge of effluent in these deeper waters (City of San Diego 1995a, b). Results of NPDES mandated monitoring for the extended PLOO from 1994 to 2007 are available in previous annual receiving waters monitoring reports (e.g., City of San Diego 2008a). In addition, the City has conducted annual region-wide surveys off the coast of San Diego since 1994 either as part of regular South Bay monitoring requirements (e.g., see City of San Diego 1999, 2008b) or as part of larger, multi-agency surveys of the entire Southern California Bight. The latter include the 1994 Southern California Bight Pilot Project (e.g., Allen et al. 1998, Bergen et al. 1998, 2001; Schiff and Gossett 1998) and subsequent Bight'98 and Bight'03 programs in 1998 and 2003, respectively (e.g., Allen et al. 2002, 2007; Noblet et al. 2003, Ranasinghe et al. 2003, 2007; Schiff et al. 2006), as well as the current Bight'08 regional monitoring survey that began during the summer of 2008 (e.g., Bight'08 CEC 2008). Such large-scale surveys are useful in characterizing the ecological health of diverse coastal areas and may help to identify and distinguish reference sites from those impacted by wastewater or stormwater discharges, urban runoff, or other sources of contamination.

The current sampling area off Point Loma extends from the shoreline seaward to a depth of about 116 m (380 ft) and encompasses an area of approximately 184 km^2 (Figure 1.1). Fixed sites are generally arranged in a grid surrounding the outfall and are monitored in accordance with a prescribed sampling schedule. Results of relevant quality assurance procedures for the receiving waters monitoring activities are included in the EMTS Division Laboratory Quality Assurance Report (City of San Diego 2009b). Data files, detailed methodologies, completed reports, and other pertinent information submitted to the SDRWQCB and U.S. EPA throughout the year are available online at the City's Metropolitan Wastewater Department website (www.sandiego.gov/mwwd).

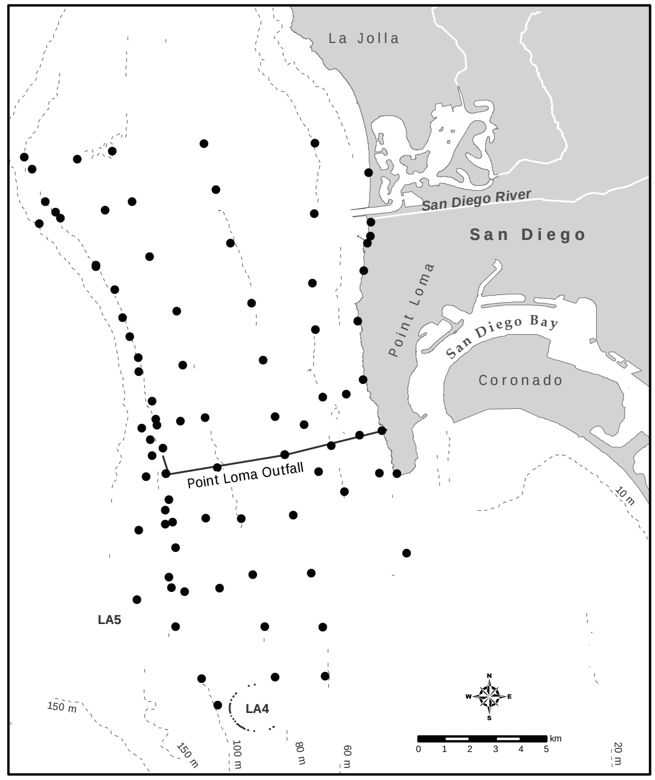

Figure 1.1
Receiving waters monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

In addition to the above activities, the City participates in or supports other projects relevant to assessing ocean quality in the region. One such project is a remote sensing study of the San Diego/ Tijuana coastal region that is jointly funded by the City and the International Boundary and Water Commission (IBWC). A long-term study of the Point Loma kelp forest funded by the City is also being conducted by scientists at the Scripps Institution of Oceanography (see City of San Diego 2003), while the City also participates with a number of other agencies to fund aerial surveys of all the major kelp beds from San Diego and Orange Counties (e.g., MBC 2008). Finally, the current MRP includes plans to perform adaptive or special strategic process studies as determined by the City in conjunction with the SDRWQCB and U.S. EPA. Such studies have included a comprehensive scientific review of the Point Loma ocean monitoring program (see SIO 2004), a large-scale sediment mapping study of both the Point Loma and South Bay coastal regions (see Stebbins et al. 2004), and a pilot study of deep benthic habitats of the continental slope off San Diego (see Stebbins and Parnell 2005). Additionally, in 2004 the City began sampling again at the recovery stations mentioned above as part of a long-term annual assessment project of benthic conditions near the original outfall discharge site. In addition, a multi-phase project, the Moored Observation System Pilot Study (MOSPS), is underway to examine the dynamics and strength of the thermocline and local currents of the receiving waters off Point Loma (Storms et al. 2006). This project includes a system of moored temperature loggers (thermistor strings) and Acoustic Doppler Current Profilers (ADCPs) deployed in the vicinity of the PLOO to begin evaluating the major modes of circulation near the outfall.

This report presents the results of all regular receiving waters monitoring activities conducted as part of the Point Loma ocean monitoring program in 2008. However, in order for the City to participate in the Bight'08 regional monitoring program (see above), a resource exchange agreement was approved by the SDRWQCB that relaxed some regular monitoring requirements for both the Point Loma and South Bay regions. The relevant changes for 2008 included: (1) benthic sampling off Point Loma during July was reduced from 22 stations to the 12 "primary core" stations located along the 98-m depth contour; (2) trawl sampling off Point Loma during July was reduced from six stations to just the two trawl stations located nearest the outfall; (3) no sampling of 40 random stations required by the South Bay permits was conducted during the summer. Results of the remote sensing surveys conducted during the year (Svejkovsky 2009) are also considered and integrated into interpretations of oceanographic and water quality data. Comparisons are also made to conditions present during previous years in order to evaluate any changes that may have occurred related to the outfall or other anthropogenic or natural events. The major components of the monitoring program are covered in the following chapters: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues. A glossary of technical terms is included.

Literature Cited

Allen, M.J., S.L. Moore, K.C. Schiff, S.B. Weisberg, D. Diener, J.K. Stull, A. Groce, J. Mubarak, C.L. Tang, and R. Gartman. (1998). Southern California Bight 1994 Pilot Project: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. (2002). Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., T. Mikel, D. Cadien, J.E. Kalman, E.T. Jarvis, K.C. Schiff, D.W. Diehl, S.L. Moore, S. Walther, G. Deets, C. Cash, S. Watts, D.J. Pondella II, V. Raco-Rands, C. Thomas, R. Gartman, L. Sabin, W. Power, A.K. Groce, and J.L. Armstrong. (2007). Southern California Bight 2003 Regional Monitoring Program: IV. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Costa Mesa, CA.

Bergen, M., S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, R.W. Smith, J.K. Stull, and R.G. Velarde. (1998). Southern California Bight 1994 Pilot Project: IV. Benthic Infauna. Southern California Coastal Water Research Project, Westminster, CA.

Bergen, M., S.B. Weisberg, R.W. Smith, D.B. Cadien, A. Dalkey, D.E. Montagne, J.K. Stull, R.G. Velarde, and J.A. Ranasinghe. (2001). Relationship between depth, sediment, latitude, and the structure of benthic infaunal assemblages on the mainland shelf of southern California. Marine Biology, 138: 637–647.

[Bight'08 CEC] Bight'08 Coastal Ecology Committee. (2008). Southern California Bight Regional Marine Monitoring Survey (Bight'08) Coastal Ecology Workplan. Southern California Coastal Water Research Project, Costa Mesa, CA. [available at www.sccwrp.org]

City of San Diego. (1995a). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1994. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1995b). Outfall Extension Pre-Construction Monitoring Report (July 1991–October 1992). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1998). Recovery Stations Monitoring Report for the Original Point Loma Ocean Outfall (1991–1996). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1999). San Diego Regional Monitoring Report for 1994–1997. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2002. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2004). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008a). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008b). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009a). 2008 Annual Reports and Summary: Point Loma Wastewater Treatment Plant and Point Loma Ocean Outfall. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009b). EMTS Division Laboratory Quality Assurance Report, 2008. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

[MBC] MBC Applied Environmental Services. (2008). Status of the Kelp Beds 2007, San Diego and Orange Counties, Kelp Consortium Region Nine. Final Report, June 2008. MBC Applied Environmental Services, Costa Mesa, CA.

Noblet, J.A., E.Y. Zeng, R. Baird, R.W. Gossett, R.J. Ozretich, and C.R. Phillips. (2003). Southern California Bight 1998 Regional Monitoring Program: VI. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Ranasinghe, J.A., D.E. Montagne, R.W. Smith, T. K. Mikel, S.B. Weisberg, D. Cadien, R. Velarde, and A. Dalkey. (2003). Southern California Bight 1998 Regional Monitoring Program: VII. Benthic Macrofauna. Southern California Coastal Water Research Project. Westminster, CA.

Ranasinghe, J.A., A.M. Barnett, K. Schiff, D.E. Montagne, C. Brantley, C. Beegan, D.B. Cadien, C. Cash, G.B. Deets, D.R. Diener, T.K. Mikel, R.W. Smith, R.G. Velarde, S.D. Watts, and S.B. Weisberg. (2007). Southern California Bight 2003 Regional Monitoring Program: III. Benthic Macrofauna. Southern California Coastal Water Research Project. Costa Mesa, CA.

Schiff, K.C. and R.W. Gossett. (1998). Southern California Bight 1994 Pilot Project: III. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Schiff, K., K. Maruya, and K. Christenson. (2006). Southern California Bight 2003 Regional Monitoring Program: II. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

[SIO] Scripps Institution of Oceanography. (2004). Point Loma Outfall Project, Final Report, September 2004. Scripps Institution of Oceanography, University of California, La Jolla, CA.

Stebbins, T.D. and P.E. Parnell. (2005). San Diego Deep Benthic Pilot Study: Workplan for Pilot Study of Deep Water Benthic Conditions off Point Loma, San Diego, California. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, and Scripps Institution of Oceanography, La Jolla, CA.

Stebbins, T.D., K.C. Schiff, and K. Ritter. (2004). San Diego Sediment Mapping Study: Workplan for Generating Scientifically Defensible Maps of Sediment Conditions in the San Diego Region. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, and Southern California Coastal Water Research Project, Westminister, CA.

Storms, W.E., T.D. Stebbins, and P.E. Parnell. (2006). San Diego Moored Observation System Pilot Study Workplan for Pilot Study of Thermocline and Current Structure off Point Loma, San Diego, California. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, and Scripps Institution of Oceanography, La Jolla, CA.

Svejkovsky, J. (2009). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/Tijuana Region. Annual Summary Report, 1 January, 2008 – 31 December 2008. Ocean Imaging, Solana Beach, CA.

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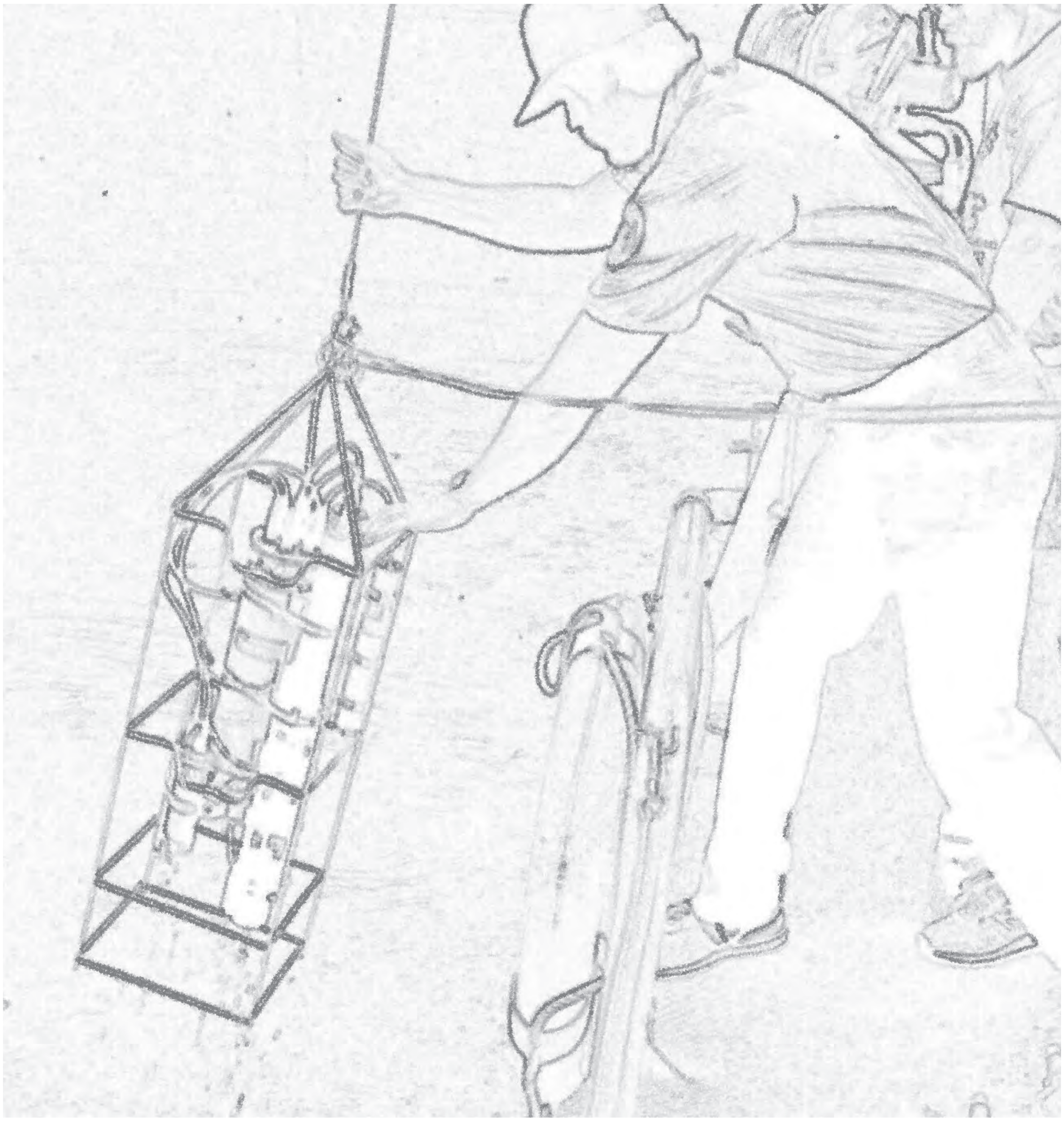
Chapter 2
Oceanographic Conditions



Chapter 2. Oceanographic Conditions

INTRODUCTION

The City of San Diego monitors oceanographic conditions in the region surrounding the Point Loma Ocean Outfall (PLOO) to assist in evaluating possible impacts of wastewater discharge on the marine environment. Treated wastewater is discharged to the Pacific Ocean via the PLOO at depths of ~94–98 m and at a distance of approximately 7.2 km west of the Point Loma peninsula. The fate of wastewater discharged into offshore waters is determined by oceanographic conditions that impact water mass movement, including horizontal and vertical mixing of the water column and current patterns. These same factors can also affect the distribution of turbidity (or contaminant) plumes that originate from various point and non-point sources. In the Point Loma region these include tidal exchange from San Diego Bay and Mission Bay, outflows from the San Diego River, the Tijuana River and northern San Diego County lagoons and estuaries, storm drains or other water discharges, and surface water runoff from local watersheds. For example, flows from San Diego Bay and the Tijuana River are fed by 1075 km^2 and 4483 km^2 of watershed, respectively, and can contribute significantly to nearshore turbidity, sediment deposition, and bacterial contamination (see Largier et al. 2004, Terrill et al. 2009). Overall, these different sources can affect water quality conditions either individually or synergistically.

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

The evaluation and interpretation of bacterial distribution patterns and remote sensing observations (e.g., aerial and satellite imagery) may also provide useful information on the horizontal transport of wastewater plumes (Pickard and Emery 1990; Svejkovsky 2009; also see Chapter 3 of this report). Thus, the City of San Diego combines measurements of physical oceanographic parameters with assessments of fecal indicator bacteria (FIB) concentrations and remote sensing data to provide further insight into the transport potential in coastal waters surrounding the PLOO discharge site.

This chapter describes the oceanographic conditions that occurred in the Point Loma region during 2008. The results reported herein are also referred to in subsequent chapters to explain patterns of FIB distributions (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 fixed sampling sites located in a grid pattern surrounding the PLOO (Figure 2.1). Thirty-six offshore stations (designated F01–F36) were sampled quarterly in January, April, July, and October, usually over a 3-day period. Three of these stations (F01–F03) are located along the 18-m depth contour, while 11 sites are located along each of the following depth contours: 60-m contour (stations F04–F14); 80-m contour (stations F15–F25); 98-m contour (stations F26–F36). Eight additional stations located in the Point Loma kelp bed are subject to the 2001 California Ocean Plan (COP) water contact standards (SWRCB 2001). These

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

stations include three sites (stations C4, C5, C6) located along the inshore edge of the kelp bed paralleling the 9-m depth contour, and five sites (stations A1, A6, A7, C7, C8) located along the 18-m depth contour near the offshore edge of the kelp bed. To meet 2001 COP sampling frequency requirements for kelp forest areas, sampling at the eight kelp bed stations was conducted five times per month.

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

Remote Sensing – Aerial and Satellite Imagery

Coastal monitoring of the PLOO region during 2008 also included aerial and satellite image analysis performed by Ocean Imaging of Solana Beach, CA (see Svejkovsky 2009). All usable images for the monitoring area captured during the year by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and 22 high clarity Landsat Thematic Mapper (TM) images and two Aster images were acquired. High resolution aerial images were collected using Ocean Imaging's DMSC-MKII digital multispectral sensor. The DMSC's four channels were configured to a specific wavelength (color) combination designed to maximize detection of the wastewater discharge signature by differentiating between the waste field and coastal turbidity plumes. Depth of penetration for this sensor varies between 8–15 m depending on water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 m. Fifteen DMSC overflights were conducted in 2008, which consisted of one to five flights per month during winter when the surfacing potential was greatest for the wastewater plume (see below) and when rainfall was also greatest. In contrast, only three surveys were flown during the spring and late summer months.

Data Treatment

The water column parameters measured in 2008 were summarized by quarter in two different ways: (1) means calculated over the entire water column for each station, and (2) means calculated over all stations located along each depth contour (i.e., 9-m, 18-m, 60-m, 80-m, 98-m). In order to get a view of the entire PLOO region for each quarterly survey, these analyses included data from all 36 of the offshore stations, as well as the data from the eight kelp bed stations that were sampled at approximately the same time (i.e., ± one day). Each water column parameter was also summarized over all kelp bed stations each month for surface (≤ 2 m) and bottom depths (10–20 m); this was done to identify seasonal trends not necessarily evident in the quarterly data.

Finally, the spatial distributions of temperature and salinity values at each offshore station were mapped for each quarterly survey, with the data limited to the discrete depths at which seawater samples are collected for bacterial analysis.

In addition to the above, mean temperature, salinity, DO, pH, and transmissivity data from 2008 were compared with historical profile plots consisting of means for 1991–2007 ± one standard deviation. Data for these historical analyses were summarized at 5-m depth increments and limited to the three stations located nearest the outfall discharge site along the 98-m depth contour. These included station F30 located immediately offshore of the center of the outfall wye, station F29 located 1.25 km south of the southern diffuser leg, and station F31 located ~1.42 km north of the northern diffuser leg.

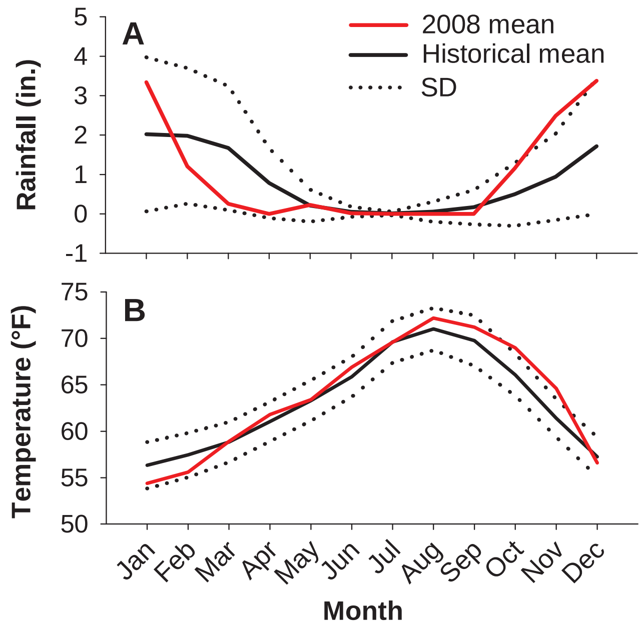


Figure 2.2
Comparison of rainfall (A) and air temperatures (B) at Lindbergh Field (San Diego, CA) for 2008 compared to historical levels. For 2008, rainfall data are expressed as total inches per month, whereas temperature data are monthly averages. Historical rainfall and temperature data are expressed as monthly means ± one standard deviation (SD) for the historical period 1914 through 2007.

Results and Discussion

Climate Factors and Seasonality

Southern California weather can generally be classified into wet (winter) and dry (spring–fall) seasons (NOAA/NWS 2009a), and differences between these seasons affect certain oceanographic conditions (e.g., water column stratification, current patterns and direction). Understanding patterns of change in such conditions is important in that they can affect the transport and distribution of wastewater, storm water, or other types of turbidity plumes that may arise from various point or non-point sources. Winter conditions typically prevail in southern California from December through February during which time higher wind, rain and wave activity often contribute to the formation of a well-mixed or relatively homogenous (non-stratified) water column, and can decrease surface salinity (Jackson 1986). The chance that the wastewater plume from the PLOO may surface is highest during such times when there is little, if any, stratification of the water column. These conditions often extend into March as the frequency of winter storms decreases and the seasons begin to transition from wet to dry. In late March or April the increasing elevation of the sun and lengthening days begin to warm surface waters resulting in increased surface evaporation (Jackson 1986). Mixing conditions diminish with decreasing storm activity, and seasonal thermoclines and pycnoclines become re-established. Once the water column becomes stratified again by late spring, minimal mixing conditions typically remain throughout the summer and early fall months. In October or November, cooler temperatures associated with seasonal changes in isotherms, reduced solar input, along with increases in stormy weather, begin to cause the return of well-mixed or non-stratified water column conditions.

Total rainfall in 2008 was just over 12 inches in the San Diego region, which exceeded the historical average (NOAA/NWS 2009b). Rainfall followed expected seasonal storm patterns, with the greatest and most frequent rains occurring during the winter and fall months (Figure 2.2A). Air temperatures were generally similar during the year to historical values, although exceptions occurred in October and November (Figure 2.2B).

Oceanographic Conditions in 2008

Water Temperature

In 2008, mean surface temperatures across the entire PLOO region ranged from 13.4°C in January to 20.9°C in October, while bottom temperatures averaged from 9.5°C in April to 18.5°C in October (Table 2.1). Water temperatures varied as expected by depth and season, with no discernible patterns relative to wastewater discharge (Appendix A.1, Figure 2.3). For example, the lowest temperatures of the year occurred during April at bottom depths along all of the depth contours (Table 2.1), which probably reflected typical spring upwelling in the region. Thermal stratification at stations within the Point Loma kelp forest also followed normal seasonal patterns with the least stratification occurring during the winter months of January, February and December, and the greatest stratification in July–August (Figure 2.4). Although data for the 36 offshore stations off Point Loma are limited to only four times a year, thermal stratification at these stations appeared to follow typical seasonal patterns as well, with the water column ranging from slightly stratified in January to strongly stratified in July and October (see Figure 2.3). Since temperature is the main contributor to water column stratification in southern California (Dailey et al. 1993, Largier et al. 2004), differences between surface and bottom temperatures were important to limiting the surface potential of the waste field throughout the year. Moreover, the PLOO wastewater plume was not detected in surface waters at any time during the year based on remote sensing observations (see Svejkovsky 2009) or the results of discrete bacteriological samples (see Chapter 3).

Salinity

Average salinities ranged from a low of 33.21 ppt in January to 33.83 ppt during April in surface waters, and from 33.35 ppt in October to 34.14 ppt in April at bottom depths (Table 2.1). As with temperature, salinity values also appeared to follow expected seasonal patterns. Salinities were highest at bottom depths across the region in April. At the kelp bed stations, salinities also peaked in April and then declined through December (Figure 2.4). These relatively high salinities correspond to the lower temperatures that were found at both surface and bottom depths in April as described above, which is likely indicative of some upwelling in the region during the spring months. Salinity values demonstrated no detectable trends relative to the wastewater discharge site (Appendix A.1, Figure 2.5).

Density

Seawater density is a product of temperature, salinity, and pressure, which in the shallower coastal waters of southern California is influenced primarily by temperature differences since salinity is relatively uniform (Bowden 1975, Jackson 1986, Pickard and Emery 1990). Therefore, changes in density typically mirror those in water temperatures. This relationship was true in the Point Loma region during 2008; the differences between surface and bottom water densities resulted in a pycnocline at the offshore stations that was evident in the April, July, and October survey data, with maximum density stratification occurring in July (Appendix A.1).

Dissolved Oxygen and pH

Dissolved oxygen (DO) concentrations averaged from 6.5 to 10.1 mg/L in surface waters and from 2.4 to 7.4 mg/L in bottom waters, while mean pH values ranged from 8.1 to 8.3 in surface waters and from 7.7 to 8.1 in bottom waters across the Point Loma region in 2008 (Table 2.1). Changes in pH patterns were closely linked to changes in DO since both parameters tend to reflect the loss or gain of carbon dioxide associated with biological activity in shallow waters (Skirrow 1975). For example, concentrations of both parameters peaked during June in surface waters at the kelp bed stations, which corresponded to peak concentrations of chlorophyll *a* indicative of seasonal plankton blooms (Figure 2.4). In contrast, the lowest concentrations of both parameters occurred in bottom waters along all depth contours during April (Table 2.1). These low values near the sea floor during spring may be due to regional upwelling as suggested by temperature and salinity data (see above). Changes in DO and pH levels relative to the wastewater discharge were not discernible (Appendix A.1).

Table 2.1

Summary of temperature, salinity, dissolved oxygen, pH, transmissivity, and chlorophyll *a* for surface and bottom waters in the PLOO region during 2008. Values are expressed as means for each survey pooled over all stations along each depth contour.

		Jan	Apr	Jul	Oct			Jan	Apr	Jul	Oct
Temperature						**pH**					
9-m	Surface	13.5	14.7	20.4	19.8	9-m	Surface	8.1	8.3	8.2	8.1
	Bottom	13.4	11.1	15.7	18.5		Bottom	8.1	8.0	8.1	8.1
18-m	Surface	13.4	14.3	19.5	19.6	18-m	Surface	8.1	8.2	8.2	8.2
	Bottom	12.9	10.5	12.8	13.8		Bottom	8.0	7.9	8.0	8.0
60-m	Surface	13.6	15.4	19.5	20.2	60-m	Surface	8.2	8.1	8.1	8.3
	Bottom	11.8	9.9	10.9	12.2		Bottom	7.9	7.7	7.8	8.0
80-m	Surface	13.6	15.6	19.3	20.9	80-m	Surface	8.2	8.2	8.1	8.3
	Bottom	11.4	9.7	10.4	11.9		Bottom	7.8	7.7	7.7	8.0
98-m	Surface	13.8	15.4	19.1	20.7	98-m	Surface	8.2	8.1	8.1	8.3
	Bottom	11.0	9.5	10.0	11.5		Bottom	7.8	7.7	7.7	7.9
Salinity						**Transmissivity**					
9-m	Surface	33.37	33.83	33.65	33.37	9-m	Surface	76	59	80	85
	Bottom	33.41	33.96	33.71	33.51		Bottom	75	59	81	77
18-m	Surface	33.21	33.78	33.63	33.46	18-m	Surface	76	67	83	86
	Bottom	33.52	33.94	33.65	33.35		Bottom	76	78	81	82
60-m	Surface	33.42	33.65	33.61	33.49	60-m	Surface	82	77	87	86
	Bottom	33.68	34.00	33.69	33.39		Bottom	81	84	87	87
80-m	Surface	33.44	33.67	33.57	33.52	80-m	Surface	84	80	87	86
	Bottom	33.78	34.07	33.78	33.50		Bottom	87	88	87	90
98-m	Surface	33.50	33.66	33.52	33.53	98-m	Surface	86	81	88	87
	Bottom	33.86	34.14	33.92	33.58		Bottom	89	89	89	90
Dissovled Oxygen						**Chlorophyll *a***					
9-m	Surface	7.8	10.1	8.7	6.5	9-m	Surface	1.3	8.7	2.6	1.7
	Bottom	7.4	3.7	6.4	6.8		Bottom	1.6	7.0	2.8	2.9
18-m	Surface	8.1	9.0	8.5	7.7	18-m	Surface	3.7	8.4	3.4	2.0
	Bottom	6.8	3.7	6.7	6.6		Bottom	2.7	7.0	5.7	2.1
60-m	Surface	8.0	8.9	8.4	8.0	60-m	Surface	2.7	4.6	1.3	1.0
	Bottom	4.9	2.7	4.8	6.6		Bottom	1.3	2.4	1.1	1.6
80-m	Surface	8.1	8.9	8.3	7.9	80-m	Surface	2.8	3.1	1.3	1.1
	Bottom	3.7	2.5	4.2	6.1		Bottom	0.6	0.6	0.3	0.7
98-m	Surface	8.1	8.7	8.2	7.8	98-m	Surface	3.1	3.6	1.4	1.0
	Bottom	3.3	2.4	3.6	5.6		Bottom	0.4	0.5	0.2	0.4

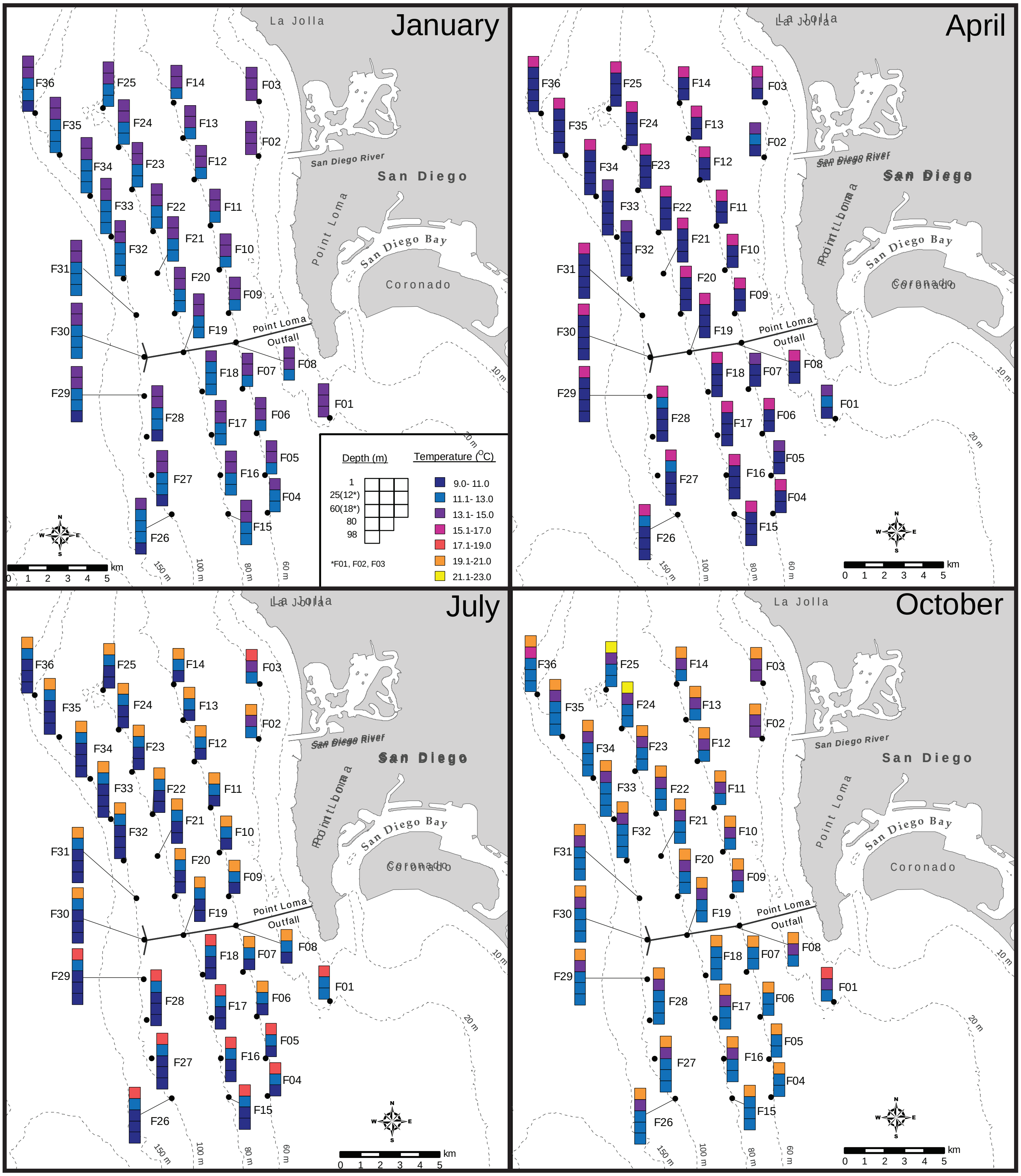


Figure 2.3

Seawater temperatures during quarterly surveys at the offshore PLOO stations in 2008. For each station, data are limited to the discrete depths at which bacterial samples are collected (see Chapter 3).

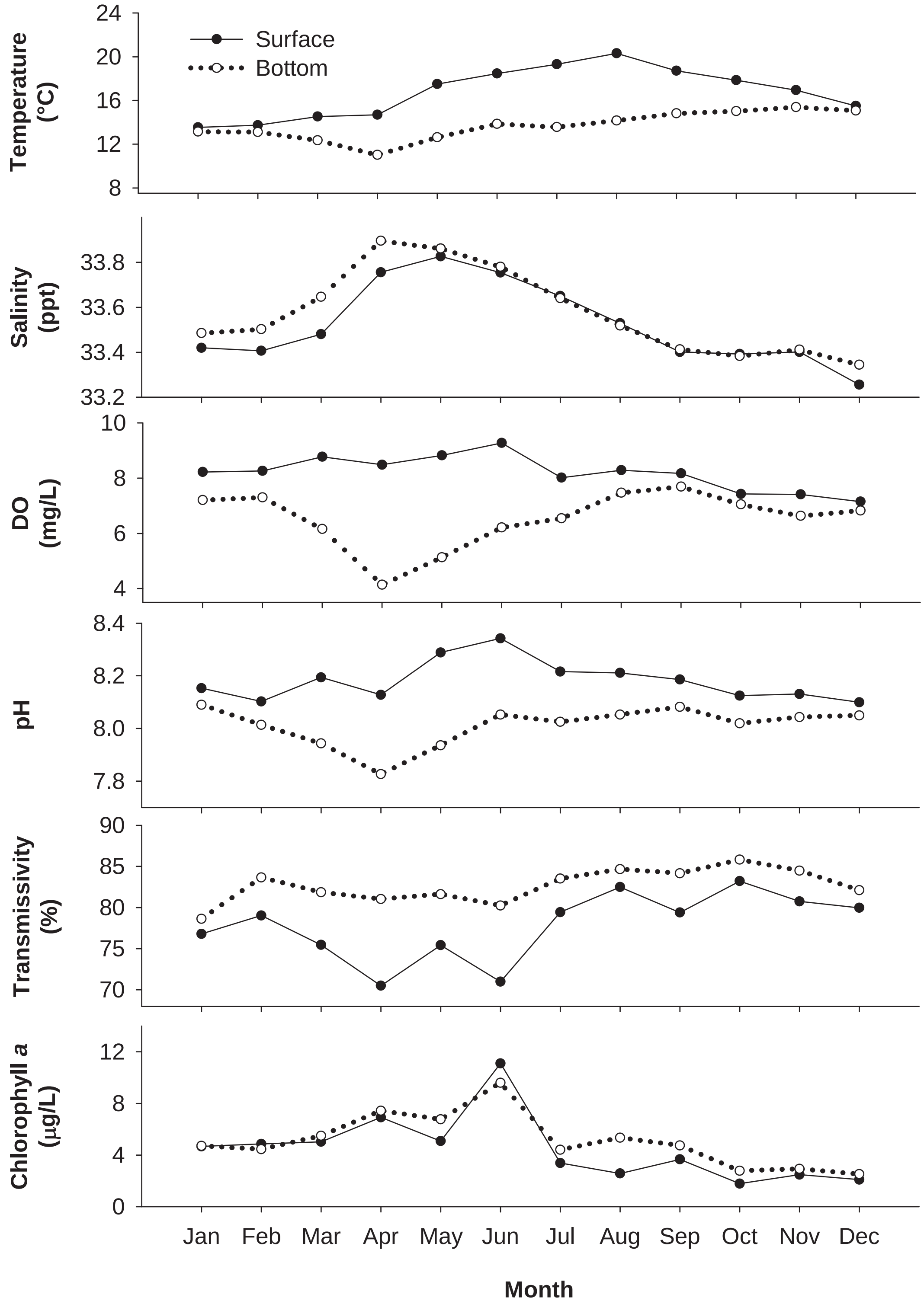


Figure 2.4
Monthly mean temperature, salinity, dissolved oxygen (DO), pH, transmissivity, and chlorophyll *a*. values for surface (≤2m) and bottom (10–20 m) waters at the Point Loma kelp stations during 2008.

Transmissivity

Transmissivity values were within historical ranges in the PLOO region during 2008 and there were no apparent patterns relative to wastewater discharge (Appendix A.1). For example, transmissivity averaged between about 59 and 90% over all depths during the year (Table 2.1). Additionally, water clarity was consistently greater at the offshore stations when compared to inshore stations by as

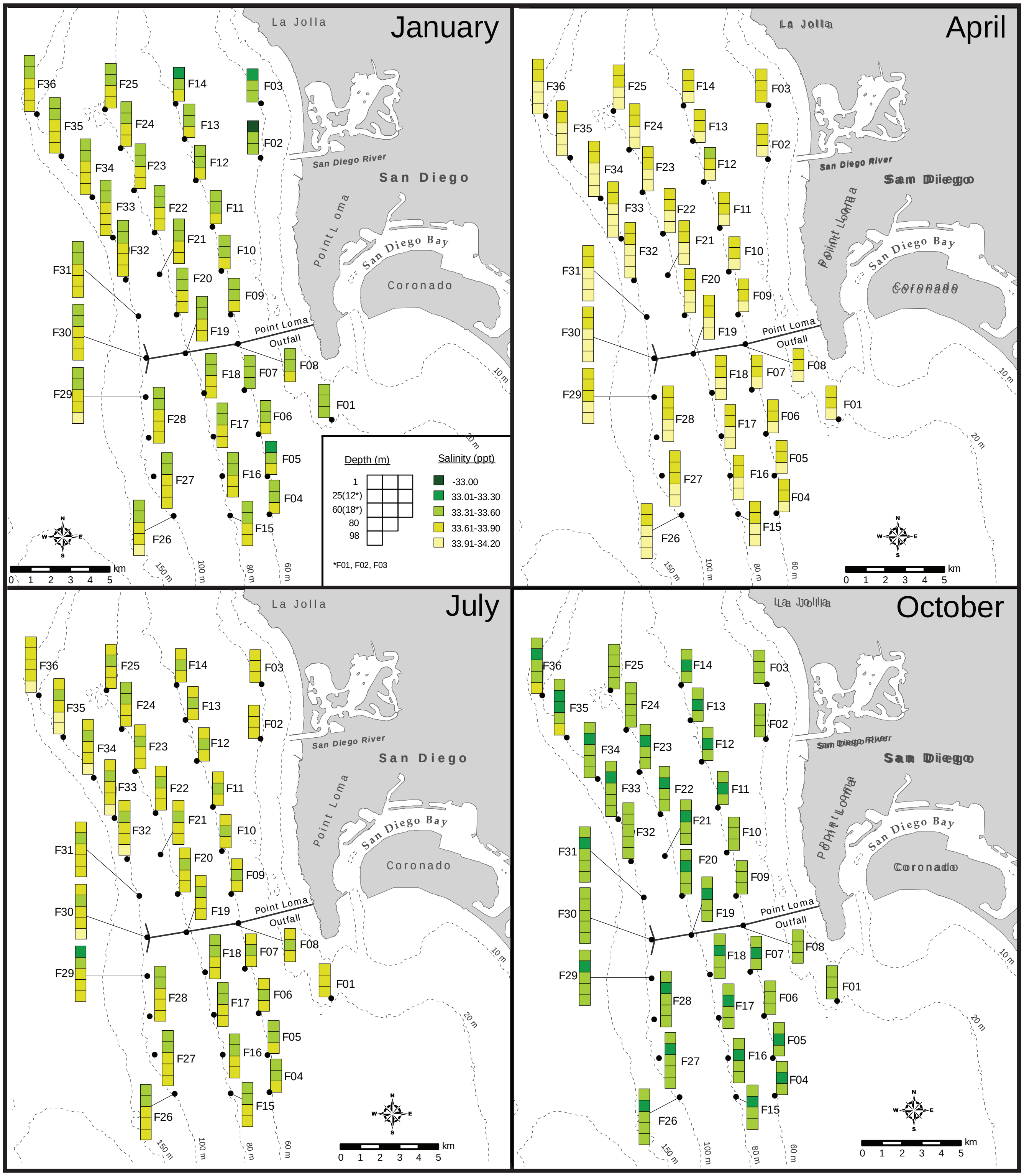


Figure 2.5
Salinity concentrations during quarterly surveys at the offshore PLOO stations in 2008. For each station, data are limited to the discrete depths at which bacterial samples are collected (see Chapter 3).

much as 20% at the surface and 30% at the bottom. Lower transmissivity values in January along the 10-m and 20-m depth contours were likely due to storm and wave activity, while reductions in water clarity in April co-occurred with peaks in chlorophyll *a* values (i.e., phytoplankton blooms). In fact, surface transmissivity values at the kelp bed stations strongly reflect fluctuations in chlorophyll *a* concentrations, which were relatively high in April but peaked in June at these stations (Figure 2.4) (see discussion below).

Chlorophyll a

Mean chlorophyll *a* concentrations ranged from a low of 0.2 μg/L in bottom waters at the offshore sites during July to a high of 8.7 μg/L at inshore surface waters in April (Table 2.1). Chlorophyll concentrations were fairly low at the offshore stations throughout the year. In contrast, monthly averages at the kelp bed stations demonstrate that chlorophyll *a* concentrations were relatively high in this area during April, but were highest in June (Figure 2.4). Such spring blooms are likely related to upwelling events that typically occur during this time of year (Jackson 1986). Unlike past years, no large plankton blooms were visible during the summer months in 2008 (e.g., see Svejkovsky 2009, City of San Diego 2008).

Historical Assessment of Oceanographic Conditions

Water column profiles of temperature, salinity, DO, pH, and transmissivity were analyzed for three nearfield stations (F29, F30, F31) sampled during the January (winter), April (spring), July (summer), and October (fall) quarterly surveys in 2008, after which they were compared to historical profiles for 1991–2007 (Figure 2.6). Water temperatures were fairly typical for the region throughout the year, with values generally within the historical range (i.e., mean ± one standard deviation) during each survey. Only DO exceeded historical conditions during the winter survey, with values well below the historical mean at depths of ≥60 m. During the spring survey, DO was below normal at most depths, while salinity was slightly higher than normal at depths below 60 m. These spring conditions suggest the presence of upwelled water that is typical of this season (Jackson 1986; see also discussion above). Values for most parameters were within historical ranges during the summer. The only exception was transmissivity, which had values above normal at mid-depths (i.e., between 25 and 60 m). In contrast, DO and pH values exceeded the upper end of the historical range at depths around 40 m during the fall survey, while transmissivity dropped below the historical range near 30 m at this time. These unusual conditions during the fall may be due to very strong Santa Ana winds that took place during the first two weeks of October (J. Svejkovsky, personal communication).

Summary and Conclusions

The Point Loma outfall region was characterized by relatively normal oceanographic conditions in 2008, which included localized upwelling and corresponding phytoplankton blooms in the spring. Upwelling events were indicated by cooler than normal water temperatures, especially at bottom depths, and higher than normal salinity in April. The presence of phytoplankton blooms was indicated by increased chlorophyll *a* concentrations during the spring, although these were not supported by remote sensing observations.

There was no apparent relationship between the outfall and values of ocean temperature, salinity, pH, transmissivity, chlorophyll *a*, and dissolved oxygen during 2008. Instead, oceanographic conditions appeared to follow normal seasonal patterns. For example, differences between surface and bottom waters (i.e., stratification) were first evident in the spring, were greatest during the summer, and then declined slightly in the fall. Since temperature is the main contributor to water column stratification in southern California, these differences between surface and bottom waters were important in preventing the waste field from surfacing. The restriction of elevated densities of fecal indicator bacteria to depths of 60 m or below also indicates that the wastewater plume remained

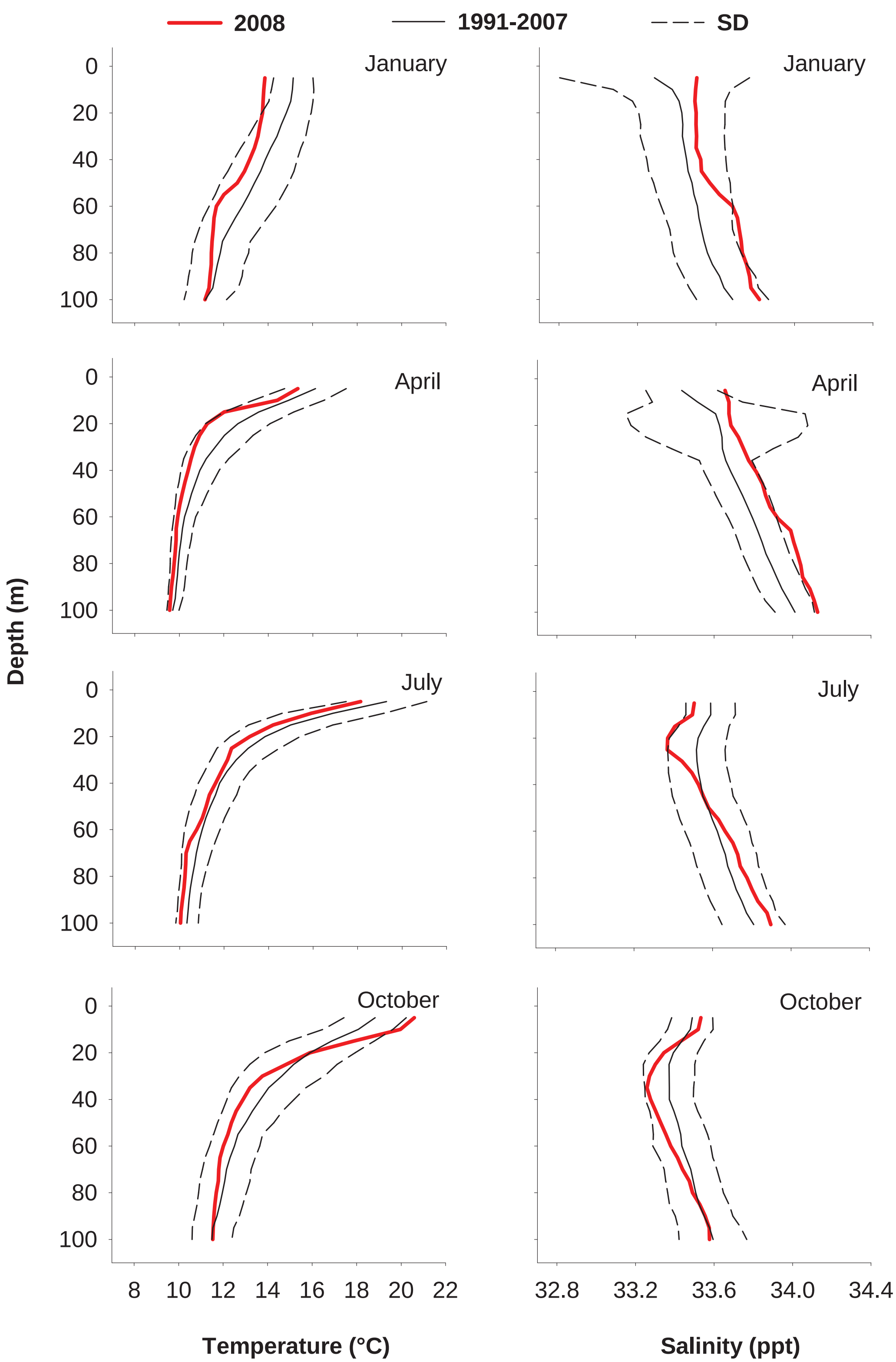


Figure 2.6
Water column temperature, salinity, dissolved oxygen, pH, and transmissivity profiles for 2008 compared to historical data for 1991–2007 at PLOO stations F29, F30, and F31. Data from 2008 are quarterly averages, whereas historical data represent 17-year means ± one standard deviation (SD); both are calculated for each month at 5-m depth intervals.

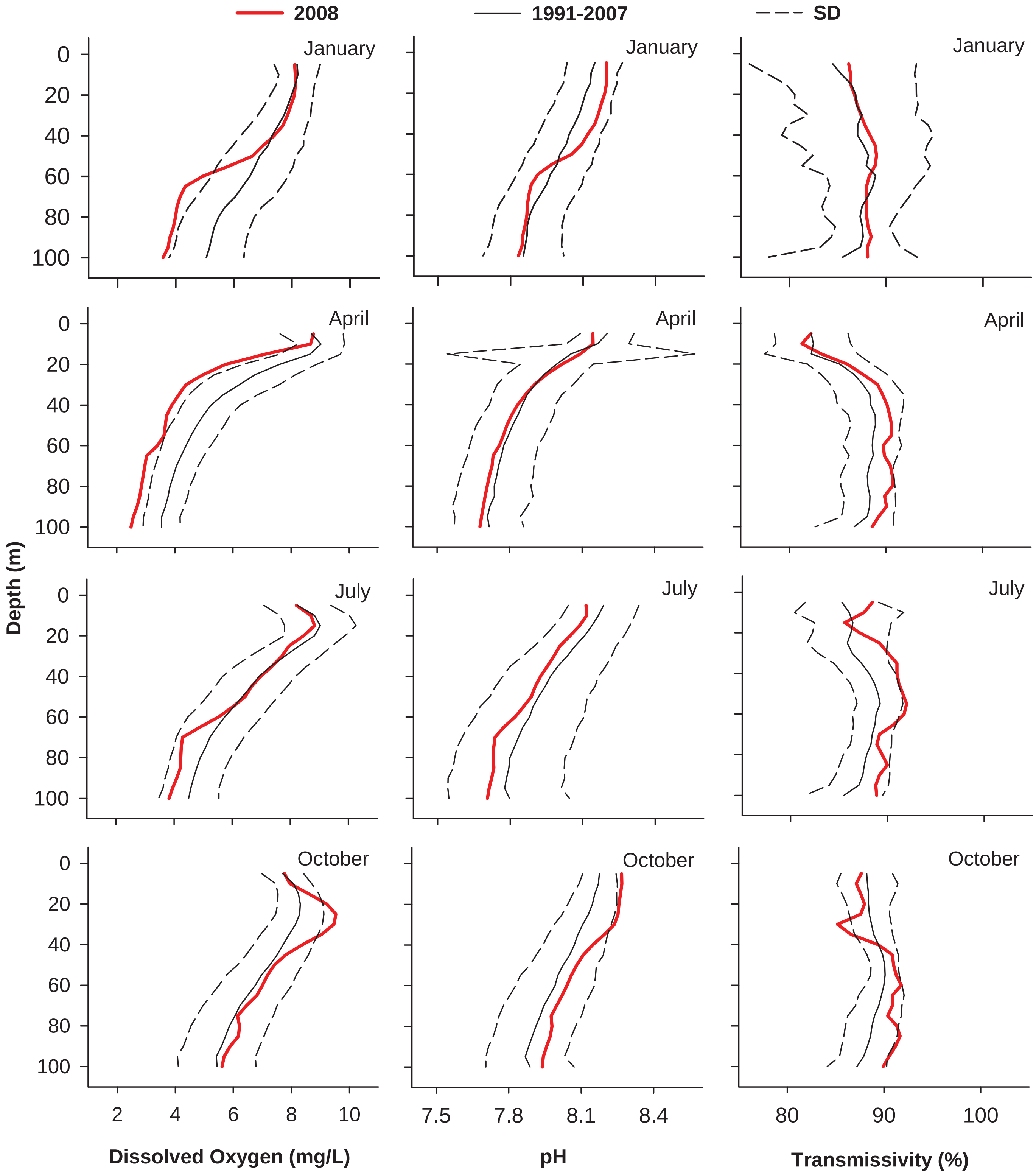


Figure 2.6 *continued*

trapped in relatively deep waters during the year (see Chapter 3). Moreover, the wastewater plume was not detectable in aerial imagery during 2008 (Svejkovsky 2009).

Oceanographic conditions for the SBOO region in 2008 remained notably consistent with long-term analysis of water column data collected between 1991 and 2007, which also did not reveal any changes in oceanographic parameters near the PLOO that could be attributed to wastewater discharge (see City of San Diego 2008). Instead, major changes in water temperatures and salinity off Point Loma region have generally corresponded to significant climate events that occurred within the California Current System (e.g., Peterson et al. 2006; Goericke et al. 2007, McClatchie et al. 2008). Additionally, transmissivity or water clarity has increased in the PLOO region over the past several years, and changes in pH and dissolved oxygen levels have not exhibited any apparent trends related to wastewater discharge.

Literature Cited

Bowden, K.F. (1975). Oceanic and Estuarine Mixing Processes. In: J.P. Riley and G. Skirrow (eds.). Chemical Oceanography, 2nd Edition. Academic Press, San Francisco. p 1–41.

City of San Diego. (2008). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Dailey, M.D., D.J. Reish, and J.W. Anderson, eds. (1993). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA.

Goericke, R., E. Venrick, T. Koslow, W.J. Sydeman, F.B. Schwing, S.J. Bograd, B. Peterson, R. Emmett, K.R. Lara Lara, G. Gaxiola-Castro, J.G. Valdez, K.D. Hyrenbach, R.W. Bradley, M. Weise, J. Harvey, C. Collins, and N. Lo. (2007). The state of the California Current, 2006–2007: Regional and local processes dominate. California Cooperative Oceanic Fisheries Investigations (CalCOFI) Reports, 48: 33–66.

Jackson, G.A. (1986). Physical Oceanography of the Southern California Bight. In: R. Eppley (ed.). Plankton Dynamics of the Southern California Bight. Springer Verlag, New York. p 13–52.

Largier, J., L. Rasmussen, M. Carter, and C. Scearce. (2004). Consent Decree – Phase One Study Final Report. Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to Determine Its Ability to Identify Source(s) of Recorded Bacterial Exceedances. Scripps Institution of Oceanography, University of California, San Diego, CA.

McClatchie, S., R. Goericke, J.A. Koslow, F.B. Schwing, S.J. Bograd, R. Charter, W. Watson, N. Lo, K. Hill, J. Gottschalck, M. l'Heureux, Y. Xue, W.T. Peterson, R. Emmett, C. Collins, G. Gaxiola-Castro, R. Durazo, M. Kahru, B.G. Mitchell, K.D. Hyrenbach, W.J. Sydeman, R.W. Bradley, P. Warzybok, and E. Bjorkstedt. (2008). The state of the California Current, 2007–2008: La Niña conditions and their effects on the ecosystem. California Cooperative Oceanic Fisheries Investigations (CalCOFI) Reports, 49: 39–76.

NOAA/NWS. (2009a). The National Oceanic and Atmospheric Association and the National Weather Service Archive of Local Climate Data for San Diego, CA. http://www.wrh.noaa.gov/sgx/climate/san-san.htm.

NOAA/NWS. (2009b). The National Oceanic and Atmospheric Association, Online Weather Data for San Diego, CA. http://www.weather.gov/climate/xmacis.php?wfo=sgx.

Peterson, B., R. Emmett, R. Goericke, E. Venrick, A. Mantyla, S.J. Bograd, F.B. Schwing, R. Hewitt, N. Lo, W. Watson, J. Barlow, M. Lowry, S. Ralston, K.A. Forney, B.E. Lavaniegos, W.J. Sydeman, D. Hyrenbach, R.W. Bradley, P. Warzybok, F. Chavez, K. Hunter, S. Benson, M. Weise, J. Harvey, G. Gaxiola-Castro, and R. Durazo. (2006). The state of the California Current, 2005–2006: Warm in the north, cool in the south. California Cooperative Oceanic Fisheries Investigations (CalCOFI) Reports, 47: 30–74.

Pickard, D.L. and W.J. Emery. (1990). Descriptive Physical Oceanorgraphy. 5th Edition. Pergamon Press, Oxford.

Skirrow, G. (1975). Chapter 9. The Dissolved Gases–Carbon Dioxide. In: Chemical Oceanography. J.P. Riley and G. Skirrow (eds.). Academic Press, London.

Svejkovsky, J. (2009). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/ Tijuana Region: Annual Summary Report, 1 January, 2008 – 31 December, 2008. Ocean Imaging, Solana Beach, CA.

[SWRCB] California State Water Resources Control Board. (2001). California Ocean Plan, Water Quality Control Plan, Ocean Waters of California. California Environmental Protection Agency. Sacramento, CA.

Terrill, E., K. Sung Yong, L. Hazard, and M. Otero. (2009). IBWC/Surfrider – Consent Decree Final Report. Coastal Observations and Monitoring in South Bay San Diego. Scripps Institution of Oceanography, University of California, San Diego, CA.

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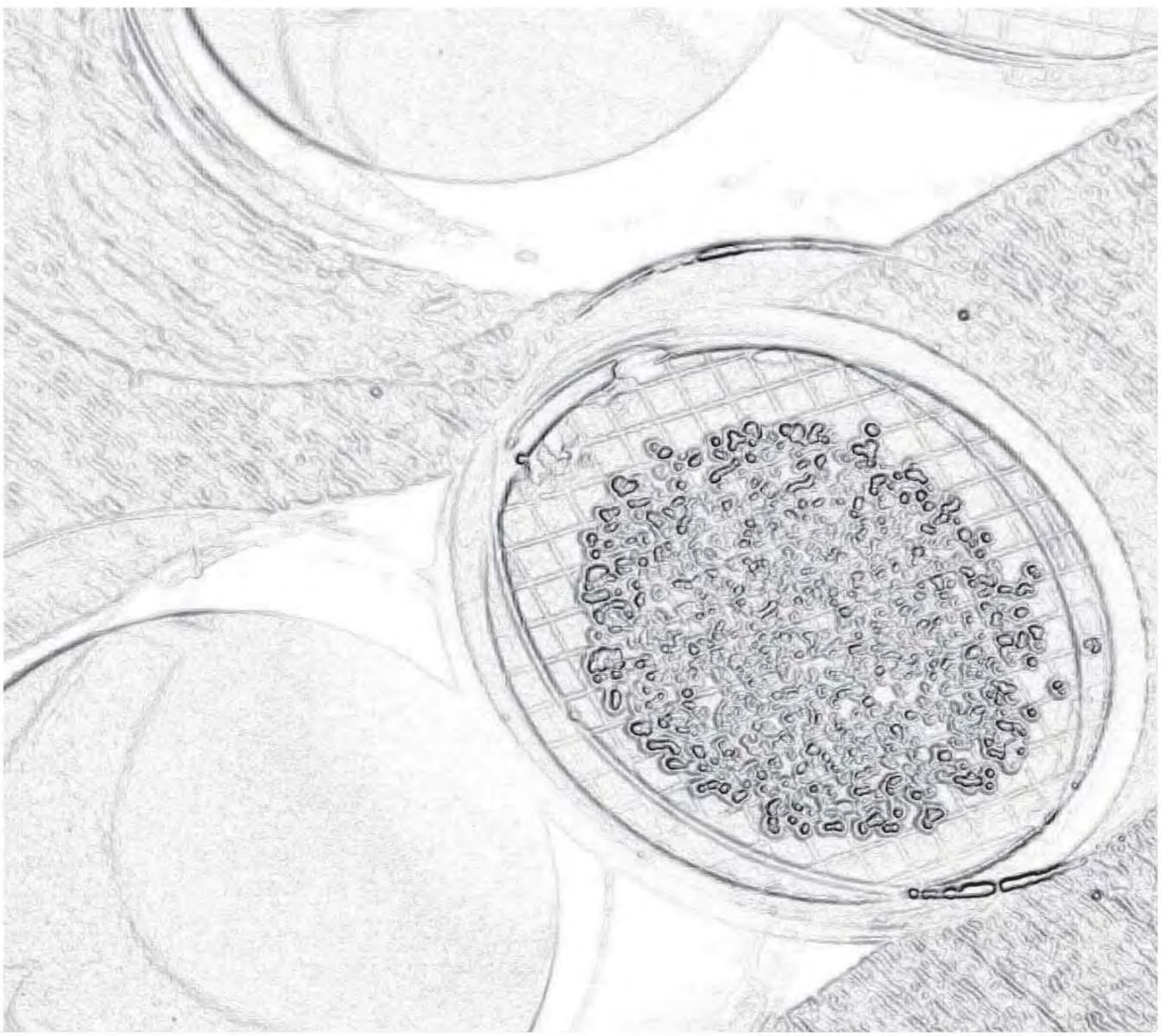
Chapter 3
Microbiology



Chapter 3. Microbiology

INTRODUCTION

The City of San Diego monitors water quality along the shoreline and in offshore ocean waters for the region surrounding the Point Loma Ocean Outfall (PLOO). This aspect of the City's ocean monitoring program is designed to assess general oceanographic conditions, evaluate patterns in movement and dispersal of the PLOO wastewater plume, and monitor compliance with water contact standards as defined in the 2001 California Ocean Plan (COP) according to NPDES permit specifications (see Chapter 1). Results of all sampling and analyses, including COP compliance summaries, are submitted to the San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Densities of fecal indicator bacteria (FIB), including total coliforms, fecal coliforms, and enterococcus, are measured and evaluated along with data on local oceanographic conditions (see Chapter 2) to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall. Analyses of these data may also help to identify other point or non-point sources of bacterial contamination (e.g., outflows from rivers or bays, surface runoff from local watersheds). This chapter summarizes and interprets patterns in seawater FIB concentrations collected for the Point Loma region during 2008.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 52 NPDES-mandated shore, kelp bed, or offshore monitoring sites during 2008 (Figure 3.1). Sampling was performed weekly at eight shore stations (i.e., stations D4, D5, and D7–D12) to monitor FIB concentrations in waters adjacent to public beaches and to evaluate compliance with the COP water contact standards (see Box 3.1). Eight stations located in nearshore waters within the Point Loma kelp forest were also monitored weekly to assess water quality conditions and COP compliance in areas used for recreational activities such as SCUBA diving, surfing, fishing, and kayaking. These include stations C4, C5, and C6 located near the inner edge of the kelp bed along the 9-m depth contour, and stations A1, A6, A7, C7, and C8 located near the outer edge of the kelp bed along the 18-m depth contour. An additional 36 stations (F01–F36) located further offshore in deeper waters were sampled quarterly during January, April, July, and October in order to monitor FIB levels and estimate the spatial extent of the wastewater plume at these times. Complete sampling of all 36 of these offshore stations usually occurs over a 3-day period. Three of these sites (stations F01–F03) are located along the 18-m depth contour, while 33 sites (11 per transect) are distributed along the 60-m (stations F04–F14),

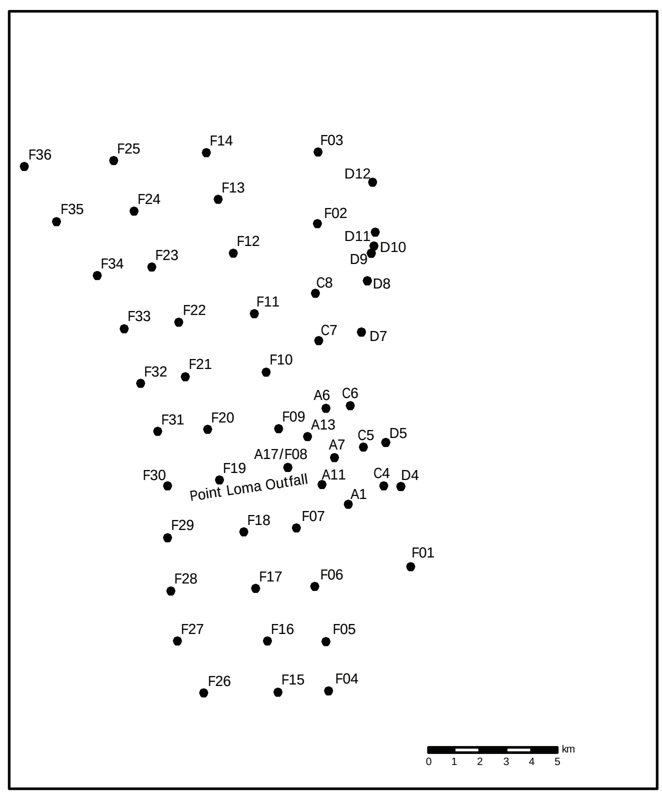


Figure 3.1
Water quality monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

Box 3.1

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

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

(b) *10,000 Total Coliform Standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(c) *60-day Fecal Coliform Standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

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

80-m (stations F15–F25), and 98-m (stations F26–F36) depth contours. Finally, three other stations (A11, A13, A17) located seaward of the kelp bed were sampled voluntarily as part of the weekly kelp bed sampling to monitor water quality near the original Point Loma outfall discharge location. Analyses for these three additional special study stations are not included herein, but have been reported elsewhere (see City of San Diego 2008a, 2009a).

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

Seawater samples for the kelp bed and offshore stations were collected at 3–5 discrete depths per site dependent upon station depth as indicated in Table 3.1 and analyzed for the above FIBs. These samples were collected using either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for each analysis were drawn into appropriate sample containers. All seawater samples were refrigerated onboard ship and transported to the CSDMML for subsequent processing and analysis. Visual observations of weather and sea conditions, and human or animal activity were also recorded at the time of sampling. Monitoring of the PLOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging of Solana Beach, California (e.g., Svejkovsky 2009) (see Chapter 2).

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to standard membrane filtration techniques (see APHA 1998). The CSDMML follows guidelines issued by the United States Environmental Protection Agency (U.S. EPA) Water Quality Office, Water Hygiene Division, and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1998).

Procedures for counting colonies of indicator bacteria, calculation and interpretation of results, data verification and reporting all follow guidelines established by the U.S. EPA (Bordner et al. 1978) and APHA (1998). According to these 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 in determining compliance with COP standards.

Table 3.1

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

Station transect	Sample depth (m) 1	3	9	12	18	25	60	80	98
Kelp bed									
9 m	x	x	x						
18 m	x			x	x				
Offshore									
18 m	x			x	x				
60 m	x					x	x		
80 m	x					x	x	x	
98 m	x					x	x	x	x

Quality assurance tests were performed routinely on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were processed according to method requirements to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in City of San Diego (2009b).

Bacteriological benchmarks defined in the 2001 COP and Assembly Bill 411 (AB 411) were used as reference points to distinguish elevated FIB values in receiving water samples discussed in this report. These benchmarks are: (a) >1000 CFU/100 mL for total coliforms; (b) >400 CFU/100 mL for fecal coliforms; (c) >104 CFU/100 mL for enterococcus. Data were summarized for analysis as counts of samples in which FIB concentrations exceed any of these benchmarks. Furthermore, any seawater sample with a total coliform concentration ≥1000 CFU/100 mL and a fecal:total (F:T) ratio ≥0.1 was considered representative of contaminated waters (see CDHS 2000). This condition is referred to as the Fecal:Total Ratio (FTR) criteria herein.

Results and Discussion

Shore Stations

As in 2007 (see City of San Diego 2008b), concentrations of indicator bacteria were generally very low along the shoreline in 2008 (Appendix B.1). Monthly FIB densities averaged 2–3265 CFU/100 mL for total coliforms, 2–98 CFU/100 mL for fecal coliforms, and 2–492 CFU/100 mL for enterococcus. As expected, the majority of samples with elevated FIBs (15 of 18 samples) and all of the samples that met the FTR criteria for contaminated seawater were collected during the wet season during or after rainfall events (Table 3.2), which occurred primarily in January, February, and December (Appendix B.2). The remaining three samples with elevated FIB densities occurred during periods with no rain. These included one sample collected at station D9 in August and two samples collected at station D8 during October and November. A possible source of contamination at station D8 is a tidally influenced storm drain in the

Table 3.2

The number of samples with elevated bacteria collected at PLOO shore stations during 2008. Elevated FIB=the total number of samples with elevated FIB densities; contaminated=the total number of samples that meet the fecal:total coliform ratio criteria indicative of contaminated seawater; Wet=January–March and November–December; Dry=April–October; n=total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed from north to south from top to bottom.

Station		Season Wet	Dry	Total
D12	Elevated FIB	1	—	1
	Contaminated	—	—	0
D11	Elevated FIB	2	—	2
	Contaminated	—	—	0
D10	Elevated FIB	3	—	3
	Contaminated	1	—	1
D9	Elevated FIB	3	1	4
	Contaminated	—	—	0
D8	Elevated FIB	5	1	6
	Contaminated	—	—	0
D7	Elevated FIB	1	—	1
	Contaminated	—	—	0
D5	Elevated FIB	1	—	1
	Contaminated	1	—	1
D4	Elevated FIB	—	—	0
	Contaminated	—	—	0
Total counts	Rain (in)	10.7	1.4	12.1
	Elevated FIB	16	2	18
	Contaminated	2	0	2
	n	200	288	488

Table 3.3
Summary of indicator bacteria densities (CFU/100 mL) at PLOO kelp bed stations in 2008. Data are expressed as means for all stations along each depth contour by month; n=total number of samples per month.

Assay	Contour	n	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	9 m	45	46	2	2	6	8	5	10	3	2	6	4	13
	18 m	75	9	8	4	4	3	50	3	6	8	25	4	16
Fecal	9 m	45	4	2	2	2	2	2	2	2	2	2	2	3
	18 m	75	3	3	2	2	2	3	2	2	2	2	2	3
Entero	9 m	45	4	2	2	2	2	2	2	2	2	2	2	8
	18 m	75	2	3	2	2	2	2	2	2	3	2	2	3

area (see Martin and Gruber 2005), which has previously been suggested as a likely cause of high FIB counts during dry periods (see City of San Diego 2005–2008b). Other sources that may contribute to bacterial contamination at this site and station D9 include beach wrack (e.g., kelp and seagrass) and shorebirds, all of which are often present during the collection of seawater samples along the shore.

Kelp Bed Stations

Concentrations of indicator bacteria were also very low at PLOO kelp bed stations in 2008. During the past year, average FIB densities in samples from stations along both the 9 and 18-m depth contours ranged from <2 to 50 CFU/100 mL for total coliforms, <2 to 4 CFU/100 mL for fecal coliforms, and <2 to 8 CFU/100 mL for enterococcus (Table 3.3). Of the 1440 seawater samples taken from kelp bed stations, only two samples (<1%) had elevated FIB concentrations, neither of which met the FTR criteria for contaminated seawater. One of these two samples was collected at station C5 in early December following a large rainfall event; it contained elevated levels of enterococcus (200 CFU/100 mL). The other sample was collected at station A6 in June with a total coliform count of 1800 CFU/100 mL. No samples collected at the kelp bed stations had elevated fecal coliform values during the year.

Offshore Stations

A summary of bacterial densities at the PLOO offshore stations during 2008 is presented in Table 3.4. Seawater samples collected from relatively shallow depths along the 18-m depth contour had total coliform, fecal coliform, and enterococcus concentrations averaging ≤31 CFU/100 mL. In contrast, average FIB densities in samples from deeper waters were as high as 2466 CFU/100 mL for total coliforms, 605 CFU/100 mL for fecal coliforms, and 91 CFU/100 mL for enterococcus. Of the 564 seawater samples collected at the offshore stations during the year, only 47 samples (~8%) contained elevated FIB densities of which 46 met the FTR criteria for contaminated waters (see Appendix B.3). Consequently, it appears likely that these elevated FIBs may serve as an appropriate surrogate for detecting the presence of the PLOO waste field. All of these samples were collected from depths of 60 m or greater (Figure 3.2). If these high counts were due to dispersion of the waste field, the results would indicate that the wastewater plume remained restricted to relatively deep waters throughout the year. In addition, the distribution of total coliform densities amongst the offshore stations suggests that wastewater dispersion varied between surveys (Figure 3.3). For example, the highest bacterial counts during January appeared to be concentrated adjacent to the discharge site at station F30, with a few additional elevated FIBs detected to the south at stations F29 and F26 along the 98-m depth contour. In contrast, these data indicate a mostly northward dispersion of the plume along the 80 and 98-m depth contours during the April, July, and October surveys.

California Ocean Plan Compliance

Compliance with the bacterial water contact standards specified in the 2001 COP (see Box 3.1) was very

Table 3.4
Summary of indicator bacteria densities (CFU/100 mL) at PLOO offshore stations in 2008. Data for each quarterly survey are expressed as means for all stations along each depth contour; n=total number of samples per survey.

Assay	Contour	n	Jan	Apr	Jul	Oct
Total	18 m	9	2	31	3	3
	60 m	33	109	163	15	19
	80 m	44	436	23	1403	912
	98 m	55	1106	1055	2466	475
Fecal	18 m	9	2	4	2	2
	60 m	33	5	29	4	4
	80 m	44	87	5	333	207
	98 m	55	204	392	605	93
Entero	18 m	9	2	4	2	2
	60 m	33	3	9	2	2
	80 m	44	28	3	43	21
	98 m	55	70	58	91	6

high in 2008 for all stations sampled along the shore and in the Point Loma kelp beds (see Appendices B.4 and B.5). For example, all samples collected from all of the kelp bed stations and seven of the eight shore stations were in compliance with each of the four COP standards. Only shore station D8 had any seawater samples where bacteria levels fell below 100% compliance. This station, located near a tidally influenced storm drain (see above), was 98% compliant with the 30-day total coliform standard and 100% compliant with the other three standards.

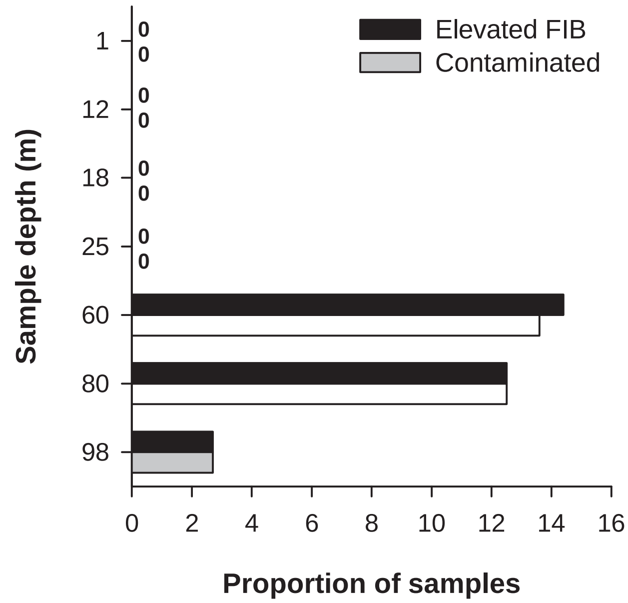


Figure 3.2
Summary of bacteria levels by depth for PLOO offshore stations in 2008. Data are expressed as the proportion of samples with elevated FIB densities (=elevated FIB) and the proportion of samples that met fecal:total coliform ratio criteria indicative of contaminated seawater (=contaminated).

Summary and Conclusions

There was no evidence that wastewater discharged to the ocean via the PLOO contaminated shoreline or near-shore recreational waters in 2008. Although elevated FIBs were occasionally detected along the shore and at a few nearshore stations throughout the year, concentrations of these bacteria tended to be relatively low overall. In general, elevated FIB densities were limited to instances when the source of contamination was likely associated with rainfall, heavy recreational use, or decaying plant material (i.e., kelp and surfgrass). For example, most of the elevated bacterial densities occurred during January, February, and December, which were some of the wettest months of the year. In addition, seawater samples from all of the kelp stations and all but one of the shore stations were 100% compliant with the four COP standards; the few exceedences at shore station D8 corresponded to rain events or other sources of contamination unrelated to the PLOO discharge.

Previous analyses of water quality data for the region have indicated that PLOO waste field typically remains well offshore and submerged in deep waters ever since the extension of the Point Loma outfall was completed in late 1993 (e.g., City of San Diego 2007). This pattern remained true for 2008 with evidence of the wastewater plume being restricted to depths of 60 m or below in offshore waters. Moreover, the wastewater plume was not detectable in aerial imagery during 2008 (Svejkovsky 2009). The depth (~98 m) of the discharge may be the dominant factor that inhibits the plume from reaching the surface. For example, wastewater released into these deep, cold and dense waters does not appear to mix with the top 25 m of the water column.

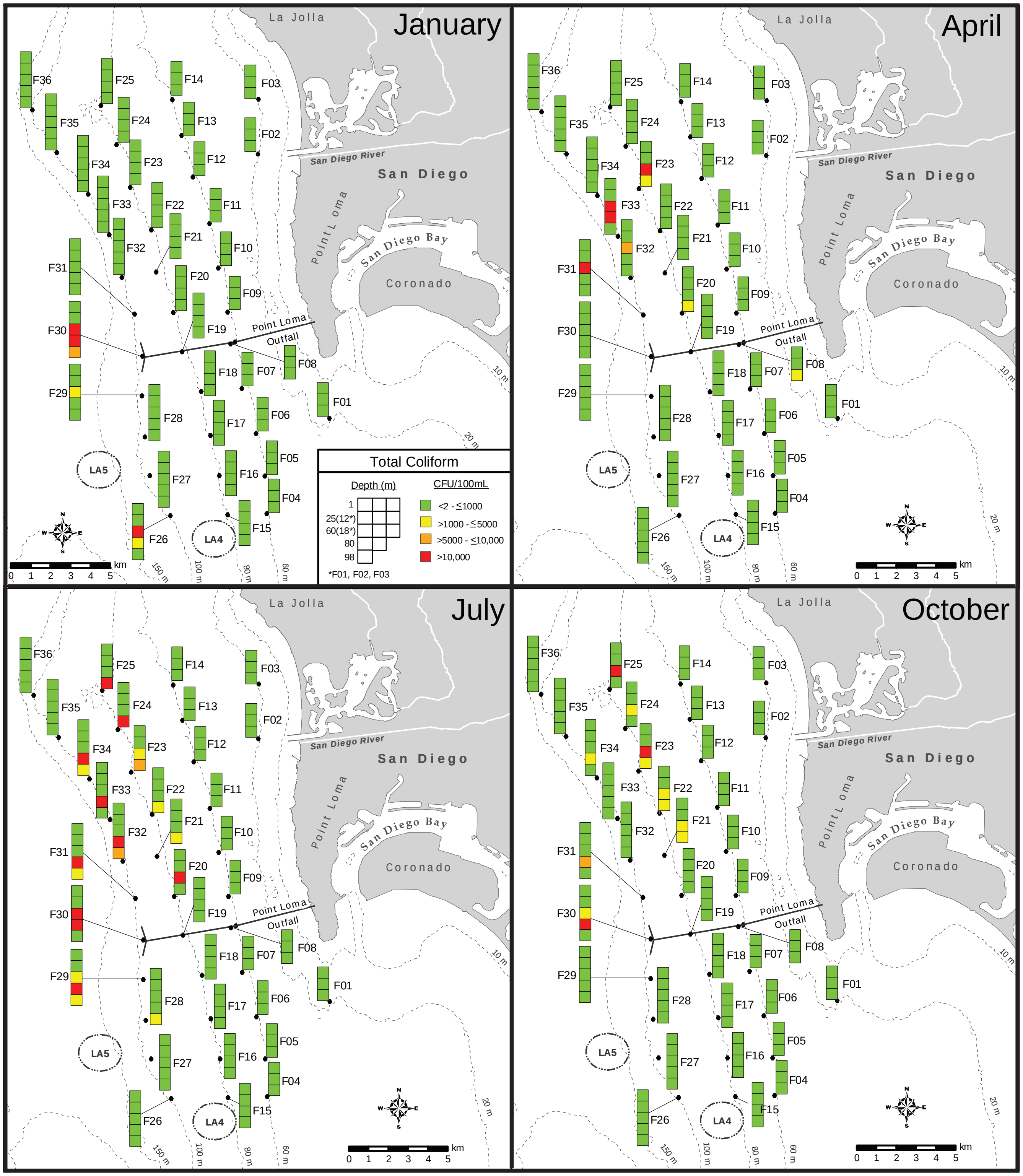


Figure 3.3
Total coliform concentrations for seawater samples collected during offshore surveys in 2008.

Literature Cited

[APHA] American Public Health Association (1998). Standard Methods for the Examination of Water and Wastewater, 18th edition. A.E. Greenberg, L.S. Clesceri, and A.D. Eaton (eds.). American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

Bordner, R., J. Winter, and P. Scarpino, eds. (1978). Microbiological Methods for Monitoring the Environment: Water and Wastes, EPA Research and Development, EPA-600/8-78-017.

[CDHS] California State Department of Health Services. (2000). Regulations for Public Beaches and Ocean Water-Contact Sports Areas. Appendix A: Assembly Bill 411, Statutes of 1997, Chapter 765. http://www.dhs.ca.gov/ps/ddwem/beaches/ab411_regulations.htm.

City of San Diego. (2005). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2004. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2006). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2005. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2006. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008a). Monthly Receiving Waters Monitoring Reports for the Point Loma Ocean Outfall, January–November 2008. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008b). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009a). Monthly Receiving Waters Monitoring Reports for the Point Loma Ocean Outfall, December 2008. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009b). EMTS Division Laboratory Quality Assurance Report, 2008. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Martin, A. and S. Gruber. (2005). Amplification of indicator bacteria in organic debris on southern California beaches. Technical paper 0507. Weston Solutions, Inc. Presented at StormCon 2005. Orlando, FL, USA. July 2005.

Svejkovsky, J. (2009). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/Tijuana Region: Annual Summary Report, 1 January, 2007 – 31 December, 2007. Ocean Imaging, Solana Beach, CA.

[SWRCB] California State Water Resources Control Board. (2001). California Ocean Plan, Water Quality Control Plan, Ocean Waters of California. California Environmental Protection Agency, Sacramento, CA.

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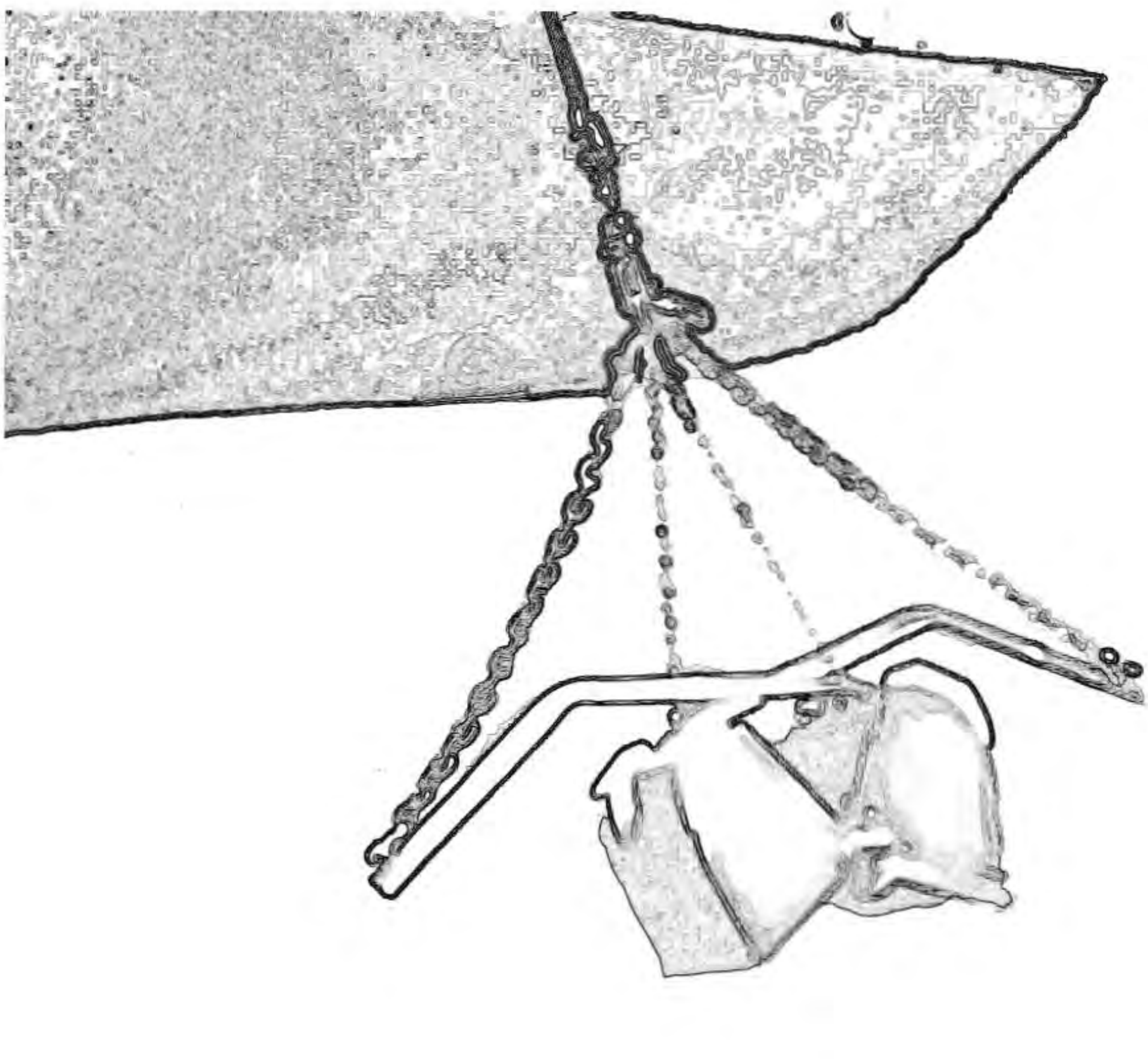
Chapter 4
Sediment Characteristics



Chapter 4. Sediment Characteristics

INTRODUCTION

Ocean sediment samples are collected and analyzed as part of the Point Loma Ocean Outfall (PLOO) monitoring program to characterize the surrounding physical environment and assess general sediment conditions. These conditions define the primary microhabitats for benthic invertebrates that live within or on the surface of sediments, and can therefore influence the distribution and presence of various species. The distributions of many demersal fishes are also often associated with specific sediment types that reflect the habitats of their preferred invertebrate prey (Cross and Allen 1993). Consequently, an understanding of differences in sediment conditions over time and space is 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. Natural factors that affect sediment conditions on the continental shelf include the strength and direction of bottom currents, exposure to wave action, seafloor topography, inputs associated with outflows from rivers and bays, beach erosion, runoff from other terrestrial sources, bioturbation by benthic macrofauna, and decomposition of calcareous organisms (e.g., Emery 1960). The analysis of parameters such as sediment grain size and the relative percentages of different sediment fractions (e.g., sand, silt, and clay) can provide useful information about current velocity, amount of wave action and overall habitat stability in an area. Further, understanding sediment particle size distributions facilitates interpretation of the interactions between benthic organisms and the environment. For example, differences in sediment composition (e.g., fine vs. coarse particles) and associated levels of organic loading at specific sites can affect the burrowing, tube building, and feeding abilities of infaunal invertebrates, thus affecting benthic community structure (Gray 1981, Snelgrove and Butman 1994). Geological history can also affect the chemical composition of local sediments. For example, erosion from coastal cliffs and shores, and flushing of terrestrial sediments and debris from bays, rivers, and streams can contribute to the deposition and accumulation of metals or other contaminants and also affect the overall organic content of sediments. Additionally, primary productivity by phytoplankton is a major source of organics to these sediments (Mann 1982, Parsons et al. 1990). Finally, particle size composition can affect concentrations of chemical constituents within sediments. For example, levels of organic compounds and trace metals within ocean sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Venkatesan 1993).

Municipal wastewater outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of sediments through the discharge of treated effluent and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds discharged via ocean outfalls are trace metals, pesticides, and various organic compounds such as organic carbon, nitrogen, and sulfides (Anderson et al. 1993). Moreover, the presence of large outfall pipes and associated ballast materials (e.g., rock, sand) may alter the hydrodynamic regime in surrounding areas.

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2008 at monitoring sites surrounding the PLOO. The primary goals are to: (1) assess possible effects of wastewater discharge on benthic habitats by analyzing spatial and temporal variability of various sediment parameters, (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site, and (3) evaluate overall sediment quality in the region.

Materials and Methods

Field Sampling

Sediment samples were collected at 22 benthic stations in the PLOO region during 2008 (Figure 4.1). Stations in the PLOO region are located along the 88, 98, and 116-m depth contours, and include “E” stations located within 8 km of the outfall, and “B” stations located greater than 11 km north of the outfall. All 22 stations were sampled during the January survey while the July sampling was limited to 12 primary core stations to accommodate additional sampling for the Bight’08 regional project (see Chapter 1). The four stations considered to represent “nearfield” conditions herein (i.e., E11, E14, E15, E17) are located between about 100 and 750 m of the outfall wye or diffuser legs. 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 and visual observations of sediment composition (see Chapter 5). Sub-samples for various analyses were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (U.S. EPA 1987).

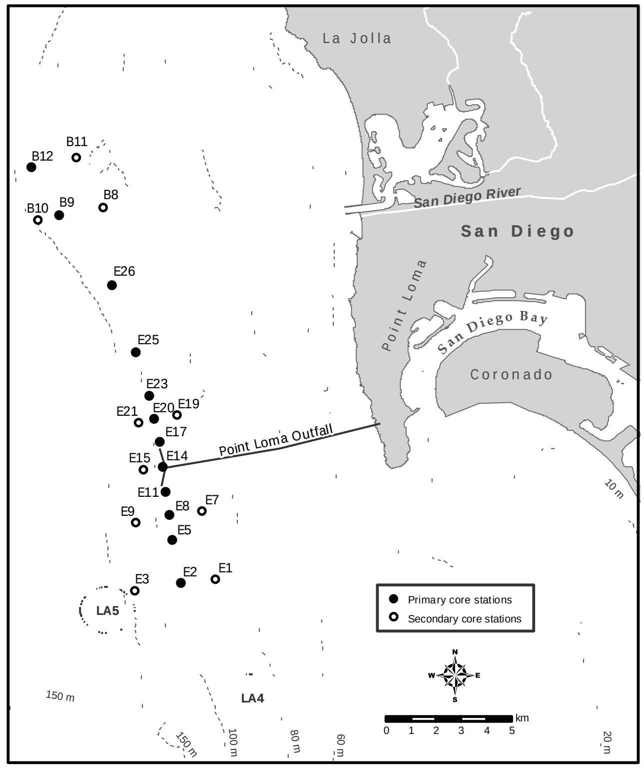


Figure 4.1
Benthic station locations sampled for the Point Loma Ocean Outfall Monitoring Program.

Laboratory Analyses

All sediment chemistry and particle size analyses were performed at the City of San Diego’s Wastewater Chemistry Services Laboratory. Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., 11 to -1 phi). Coarser particles (e.g., gravel, shell hash) were removed prior to laser analysis by screening the samples through a 2.0-mm mesh sieve; these data are expressed herein as the “coarse” fraction of the total sample sieved.

Output from the Horiba particle size analyzer was categorized into sand, silt, and clay fractions as follows: sand was defined as particles ranging between 2.0 and >0.0625 mm in diameter, silt as particles between 0.0625 and 0.0039 mm, and clay as particles <0.0039 mm. These data were standardized and combined with any sieved coarse fraction as described above (i.e., particles >2.0 mm) to obtain a complete distribution of the coarse, sand, silt, and clay fractions totaling 100%. The coarse fraction was included with the sand-silt-clay fractions in the calculation of various particle size parameters, which were determined using a normal probability scale (see Folk 1968). These parameters were then summarized and expressed as overall mean particle size (mm), phi size (mean, median, skewness, kurtosis), and the proportion of coarse materials, sand, silt, and clay. Additionally, the proportion of all fine particles (percent fines) was calculated as the sum of all silt and clay fractions for each sample.

Each sediment sample was analyzed for total organic carbon (TOC), total nitrogen (TN), total sulfides, biochemical oxygen demand (BOD), total volatile solids (TVS), trace metals, chlorinated pesticides (e.g., DDT), polychlorinated biphenyl compounds

(PCBs), and polycyclic aromatic hydrocarbons (PAHs) on a dry weight basis (see Appendix C.1). TOC, TN, and TVS were measured as percent weight (% wt) of the sediment sample; BOD, sulfides, and metals were measured in units of mg/kg and are expressed in this report as parts per million (ppm); pesticides and PCBs were measured in units of ng/kg and expressed as parts per trillion (ppt); PAHs were measured in units of μg/kg and expressed as parts per billion (ppb). The data for each parameter reported herein were generally limited to values above method detection limits (MDL). However, concentrations below MDLs were included as estimated values if the presence of the specific constituent was verified by mass-spectrometry (i.e., spectral peaks confirmed). A detailed description of the analytical protocols is available in City of San Diego (2009).

Data Analyses

Total DDT, total PCB, and total PAH were calculated for each sample as the sum of all constituents with reported values. Values for the individual constituents are listed in Appendix C.2. A value of zero was substituted for each non-detect (i.e., null value) data record when calculating means or other statistical descriptors. Summaries for each parameter included the detection rate (i.e., number of reported values/number of samples), annual mean by station, annual mean for all stations combined (areal mean), and maximum value during the year. Contaminant concentrations were further evaluated by comparing data from this study for 2008 to the Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines of Long et al. (1995) when available. The National Status and Trends Program of the National Oceanic and Atmospheric Administration (NOAA) originally calculated these thresholds to provide a mechanism for interpreting monitoring data. The ERLs are considered to represent chemical concentrations below which adverse biological effects are rarely observed. Values above the ERL but below the ERM represent values at which effects occasionally occur. Although concentrations above the ERM are considered to indicate likely biological effects, it is not always possible to validate such effects by subsequent toxicity testing (Schiff and Gossett 1998).

Results and Discussion

Particle Size Distribution

During 2008, ocean sediments collected off Point Loma were composed predominantly of coarse silt and very fine sands, with mean particle sizes ranging from about 0.04 to 0.09 mm (Table 4.1). There was little difference in intra-station particle size composition between the January and July surveys. The greatest difference occurred at station E2, where fines decreased from about 55% in January to 45% in July (Appendix C.3). Overall, fines averaged about 38% across the region during the year, ranging from a low of about 28% to a high of 56%. Several stations along the 98-m and 116-m depth contours from E21 south to E5 were composed of sediments that had lower percent fines than most stations to the north and to the south (Figure 4.2). Field observations of sediment samples from these stations (i.e., E5, E8, E11, E14, E15, E17, E21) indicated the presence of shell hash and/or coarse black sand (see Appendix C.3), which likely originated from the offshore deposition of dredged anoxic sediments from San Diego Bay and/or stabilizing materials used for the outfall pipe. Although no major changes in the percent fines composition of sediments have occurred since wastewater discharge began at the present discharge site at the end of 1993 (Figure 4.3), there has been a slight increase in mean particle size at station E14 located nearest the discharge site (see City of San Diego 2007). This increase is likely due to the presence of ballast material used during construction of the outfall extension.

The sorting coefficient reflects the range of grain sizes comprising sediments and is calculated as the standard deviation (SD) in phi size units (see Table 4.1). In general, areas composed of particles of similar size are considered to have well-sorted sediments (i.e., SD≤0.5 phi) and are indicative of areas subject to fast moving currents

Table 4.1

Summary of particle size parameters and organic loading indicators at PLOO benthic stations during 2008. Data are annual means per station (n=2) except where noted; SD=standard deviation; BOD=biochemical oxygen demand; TN=total nitrogen; TOC=total organic carbon; TVS=total volatile solids.

		Particle size						Organic indicators				
	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Coarse (%)	Sand (%)	Fines (%)	BOD (ppm)	Sulfides (ppm)	TN (%wt)	TOC (%wt)	TVS (%wt)
North reference stations												
B8*	88	0.043	4.5	1.5	0.0	44.0	56.0	287	3.40	0.077	0.85	2.92
B11*	88	0.053	4.2	2.0	3.8	49.9	46.3	376	1.63	0.078	3.51	4.14
B9	98	0.052	4.3	1.6	0.0	57.2	42.8	253	0.09	0.060	0.93	2.87
B12	98	0.069	3.9	1.8	0.9	66.5	32.7	268	0.17	0.054	3.99	3.23
B10*	116	0.071	3.8	1.6	0.0	71.6	28.4	314	2.52	0.056	2.32	2.77
Stations north of the outfall												
E19*	88	0.051	4.3	1.5	0.0	54.4	45.6	214	2.97	0.063	0.71	2.33
E20	98	0.060	4.1	1.4	0.0	63.1	36.9	193	3.95	0.053	0.62	2.08
E23	98	0.058	4.1	1.4	0.0	60.4	39.6	205	3.42	0.060	0.68	2.30
E25	98	0.060	4.1	1.5	0.0	62.6	37.3	180	0.31	0.056	0.72	2.24
E26	98	0.051	4.3	1.5	0.0	56.3	43.7	201	2.94	0.065	0.74	2.52
E21*	116	0.064	4.0	1.4	0.0	66.2	33.8	227	0.68	0.053	0.61	2.10
Nearfield stations												
E11	98	0.069	3.9	1.3	0.0	68.1	31.9	255	16.52	0.047	0.69	2.37
E14	98	0.070	3.8	1.4	1.0	69.1	29.8	322	8.24	0.043	0.66	1.91
E17	98	0.068	3.9	1.3	0.0	67.6	32.4	252	5.55	0.049	0.55	1.81
E15*	116	0.062	4.0	1.5	0.0	67.4	32.6	467	0.72	0.056	0.79	2.32
Stations south of the outfall												
E1*	88	0.055	4.2	1.7	1.4	55.0	43.6	254	1.91	0.039	0.45	2.34
E7*	88	0.056	4.2	1.5	0.0	58.2	41.8	249	0.31	0.054	0.59	2.08
E2	98	0.088	3.6	1.8	6.5	43.8	49.7	231	0.82	0.040	0.69	2.66
E5	98	0.064	4.0	1.4	0.0	65.2	34.8	148	0.53	0.043	0.64	1.80
E8	98	0.069	3.9	1.3	0.0	67.1	32.9	188	1.13	0.043	0.61	1.97
E3*	116	0.066	3.9	1.9	2.2	60.2	37.6	169	7.37	0.028	0.48	2.19
E9*	116	0.054	4.2	1.7	0.0	60.2	39.8	239	1.64	0.062	1.81	2.59
Detection rate (%)								100	88	100	100	100
2008 area mean		0.063	4.0	1.5	0.7	61.2	38.1	241	3.25	0.053	1.03	2.39
2008 area max		0.123	4.5	2.0	10.8	71.6	56.0	469	29.60	0.078	4.11	4.14

*Station sampled in January survey only (n=1) (see text).

or large disturbances (e.g., storm surge, rapid suspension/deposition of materials) (Folk 1968). In contrast, samples with particles of varied sizes are characteristic of poorly sorted sediments (i.e., SD≥1.0 phi). Sediments in the Point Loma region were poorly sorted in 2008 with sorting coefficients ranging from 1.3 to 2.0 phi (Table 4.1). These results are typical of the mid-shelf and reflect the multiple origins of sediments in the region (see Emery 1960). This also suggests that these sites are not subject to fast moving currents or large physical disturbances.

Indicators of Organic Loading

Sulfides, biochemical oxygen demand (BOD), total volatile solids (TVS), total organic carbon (TOC), and total nitrogen (TN) are quantified in sediments as measures of potential organic loading in the region from the PLOO discharge. Organic materials may

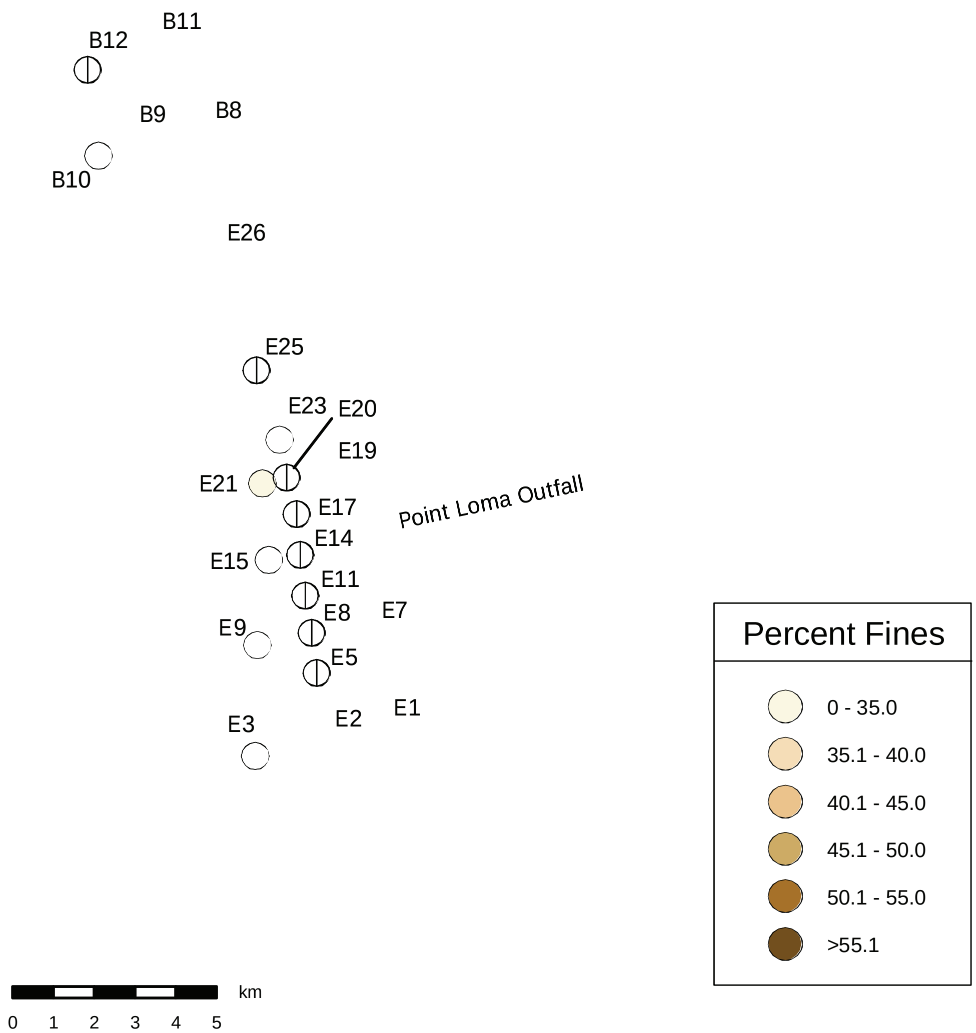


Figure 4.2
Distribution of fine material at PLOO benthic stations sampled during 2008. All stations were sampled in January; only primary core stations were sampled in July (see text); split circles show results of January (left) and July (right) surveys.

also become deposited in marine sediments via natural sources, including the result of primary productivity, breakdown of detrital materials, and outflows from rivers (Eganhouse and Venkatesan 1993). Such organic enrichment is of concern because it may disrupt ecological processes and impair habitat quality for macrobenthic marine organisms. For example, sulfides, which are the by-products of anaerobic bacterial breakdown of organic matter, may be toxic to benthic marine organisms if the sediments become excessively enriched (Gray 1981). Additionally, nitrogen is typically limiting in marine systems, and when enriched can lead to sudden phytoplankton "blooms" in coastal waters. After such blooms occur, a flux of organic material is again deposited in the sediment as the phytoplankton die and settle to the seafloor.

Generally, the distribution of organic indicators in PLOO sediments during 2008 was similar to that seen prior to discharge (see City of San Diego 1995). Biochemical oxygen demand, TOC, TN, and TVS

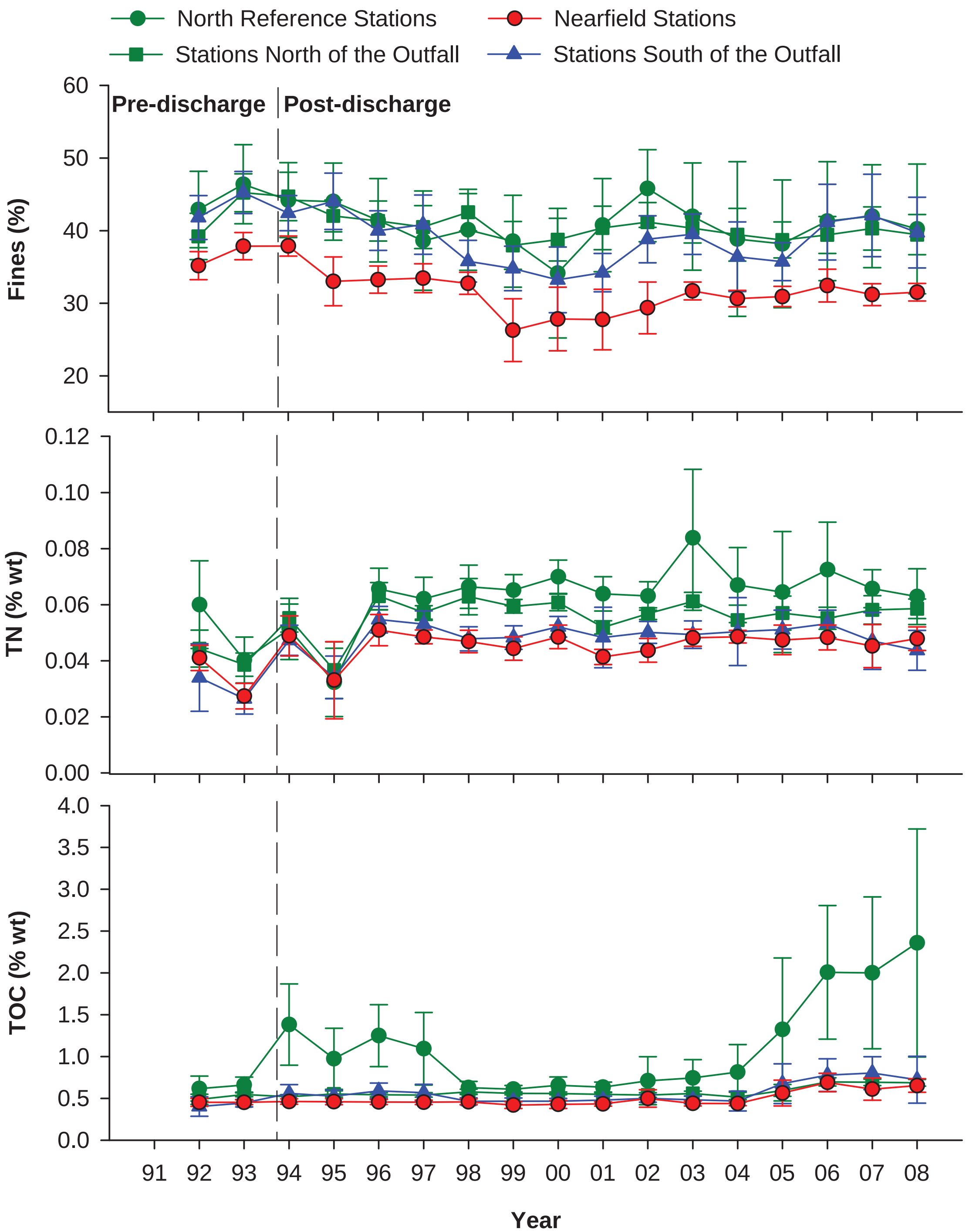


Figure 4.3

Summary of particle size and organic indicator data surrounding the PLOO from 1991–2008: Percent Fines (Fines); Total Nitrogen (TN); Total Organic Carbon (TOC); Sulfides; Biochemical Oxygen Demand (BOD); Total Volatile Solids (TVS). Data are expressed as means pooled over all stations in each station group (see Table 4.2; n≤14); % wt=percent weight. Error bars represent 95% confidence limits; reference line represents onset of discharge from PLOO.

were detected in 100% of samples, while sulfides were detected in 88% of samples (Table 4.1). With the exceptions of sulfides and BOD, the highest indicator concentrations did not occur at any of the four nearfield stations. For example, the highest concentrations of TOC, TN, and TVS occurred in sediments from stations B11 and B12, two of the northern reference stations (Appendix C.4). Only sulfides, and to a lesser extent BOD, have demonstrated noticeable changes near the outfall that

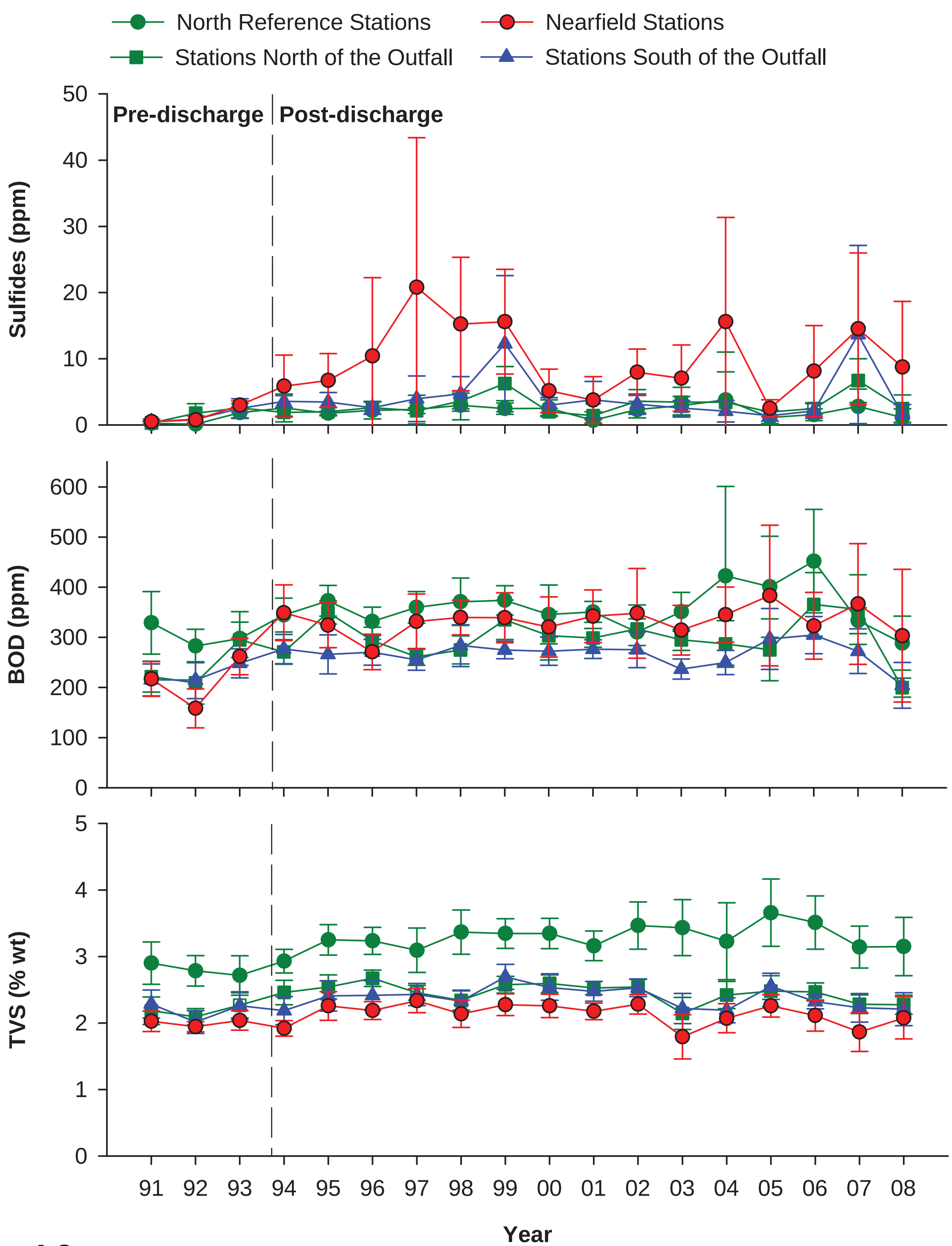


Figure 4.3 *continued*

appear to be associated with wastewater discharge (see Figure 4.3 and City of San Diego 2007).

Trace Metals

Aluminum, arsenic, barium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc were detected in 100% of the sediment samples collected in the Point Loma region during 2008 (Table 4.2). Another five metals (i.e., antimony, cadmium, selenium, silver, thallium) were also detected, but less frequently, at rates between 24–94%. Beryllium was not detected at all. Concentrations of each metal were highly variable, with no discernable patterns relative to the outfall. With the one exception of tin measured in sediments

Table 4.2

Concentrations of trace metals (ppm) detected at each PLOO benthic station during 2008. Data are annual means per station (n=2) except where noted; Values that exceed ERL or ERM threshold values are in bold; ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected. See Appendix C.1 for MDLs and the names of 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
North reference stations																		
B8*	11000	1.2	3.94	52.9	nd	0.13	23.4	7.3	17100	4.7	150.0	0.035	11.3	nd	**3.38**	1.1	2.3	36.4
B11*	11400	1.6	4.64	46.0	nd	0.20	26.4	5.1	21500	4.6	163.0	0.033	10.9	0.35	**1.27**	nd	1.6	41.4
B9	9060	0.7	4.03	80.1	nd	0.12	24.5	5.0	18400	3.6	113.1	0.031	8.9	nd	**1.48**	nd	1.6	38.0
B12	7775	0.7	5.21	25.8	nd	0.18	26.8	2.8	23000	4.4	76.3	0.017	7.1	nd	0.04	nd	1.4	38.6
B10*	6740	0.9	3.31	25.1	nd	0.14	20.2	3.1	15500	3.1	80.4	0.016	6.6	0.28	nd	nd	1.9	29.2
Stations north of the outfall																		
E19*	13100	0.9	3.27	52.1	nd	0.17	22.4	6.7	15500	4.1	151.0	0.034	10.9	nd	**2.17**	1.1	2.5	35.9
E20	9095	0.4	3.05	37.5	nd	0.14	16.7	6.0	11450	2.7	100.8	0.029	7.9	nd	**1.77**	0.3	1.6	28.0
E23	10050	0.6	3.10	41.1	nd	0.16	18.2	6.6	12650	3.3	111.0	0.032	8.8	nd	**2.36**	0.4	1.6	30.6
E25	9025	0.5	3.30	35.8	nd	0.14	16.7	5.5	11600	3.2	100.1	0.030	7.8	0.15	**1.82**	nd	1.5	27.6
E26	9640	0.5	3.19	41.2	nd	0.15	18.6	6.5	12950	3.7	113.6	0.037	8.9	nd	**2.41**	0.3	1.6	31.3
E21*	8050	0.9	2.68	30.3	nd	0.16	16.3	4.5	11000	2.9	98.7	0.026	7.8	0.12	**2.05**	nd	2.2	24.0
Nearfield stations																		
E11	7965	0.4	3.38	28.2	nd	0.13	14.4	4.5	10200	2.1	88.3	0.016	6.7	nd	**1.78**	0.3	1.9	25.4
E14	7290	0.4	2.86	29.0	nd	0.17	14.0	5.1	9545	2.1	83.2	0.022	6.6	0.12	0.77	0.6	1.5	24.3
E17	8575	0.3	3.48	32.1	nd	0.18	15.7	6.2	11000	2.6	92.4	0.027	7.3	nd	**1.15**	0.3	1.5	27.1
E15*	9330	0.7	2.87	32.1	nd	0.14	18.0	5.0	12300	3.1	106.0	0.027	8.2	0.25	**1.83**	nd	2.4	28.4
Stations south of the outfall																		
E1*	9750	0.4	3.15	41.5	nd	nd	15.6	5.9	12000	3.4	85.0	0.038	6.1	nd	**2.73**	nd	2.0	27.2
E7*	10700	1.0	2.85	39.7	nd	0.21	17.4	5.2	12500	3.2	118.0	0.031	8.3	0.30	**1.15**	0.7	2.2	29.2
E2	11050	0.5	2.85	52.3	nd	0.06	17.1	12.0	14850	3.9	102.5	0.045	7.1	0.15	**2.44**	nd	1.6	36.6
E5	10550	0.5	2.41	43.5	nd	0.09	17.1	7.8	12900	3.6	106.0	0.021	7.4	nd	**2.34**	0.2	1.4	32.9
E8	7975	0.5	2.82	32.4	nd	0.12	15.1	5.3	10550	2.7	90.5	0.022	6.6	nd	**1.78**	0.3	1.5	26.9
E3*	10600	0.7	2.45	54.5	nd	nd	14.8	12.7	13600	3.8	97.0	0.045	5.6	nd	**2.95**	nd	1.9	37.9
E9*	9240	0.8	2.66	31.3	nd	0.13	20.6	7.2	14200	4.3	101.0	0.059	7.7	nd	**1.32**	nd	2.2	38.4
Detection rate (%)	100	65	100	100	0	91	100	100	100	100	100	100	100	24	94	32	100	100
2008 area mean	9294	0.6	3.27	40.1	–	0.13	18.4	6.2	13629	3.3	103.1	0.030	7.8	0.06	**1.74**	0.2	1.7	31.3
2008 area max	13100	1.6	5.28	101.0	–	0.21	27.8	14.3	23500	5.4	163.0	0.059	11.3	0.35	**3.38**	1.1	3.0	41.4
ERL	na	na	8.2	na	na	1.20	81	34	na	46.7	na	0.15	20.9	na	1	na	na	150
ERM	na	na	70	na	na	9.6	370	270	na	218	na	0.71	51.6	na	3.7	na	na	410

*Station sampled in January survey only (n=1) (see text).

from station E11 in January, none of the highest metal concentrations occurred in sediments closest to the PLOO. Instead, most of the relatively high metal values were found in sediments from the north reference stations and/or stations south of the outfall. For example, maximum values for lead, nickel, silver, and thallium were detected in sediments collected from station B8 (Appendix C.5). In addition, arsenic, iron, and nickel were detected in concentrations that exceeded their pre-discharge maxima (i.e., 4.0, 20300, and 10.0 ppm respectively; see City of San Diego 2007) at stations located north of the outfall, including the "B" reference sites. Further, stations E2 and E3, located south of the outfall relatively close to the LA-5 dumpsite, had sediments with the highest concentrations of copper. The highest concentrations of mercury that were detected occurred in sediments from station E9, located about halfway between LA-5 and the outfall. Of all the metals detected, only silver exceeded any of the environmental threshold values during the year. For example, the ERL for this metal was exceeded in about 76% of the sediment samples collected throughout the region, although less frequently at the nearfield stations (i.e., ~43% of samples).

Pesticides

Chlorinated pesticides were detected in up to 97% of the samples collected from PLOO stations in 2008 (Table 4.3). Total DDT (primarily p,p-DDE) was the most prevalent pesticide, occurring in sediments from all but one station with an overall mean concentration of 97 ppt. All total DDT values were lower than the ERL of 1580 ppt for this pesticide and well below the pre-discharge maximum concentration of 7300 ppt (see City of San Diego 2007). Another pesticide detected during 2008 was hexachlorobenzene (HCB), which was found in 44% of samples at concentrations ranging from 86 to 1900 ppt. HCB occurred at a total of 13 different sites throughout the region, including two of the four nearfield stations (i.e., E14 and E17). While the maximum HCB value of 1900 ppt during the year was detected at station E17 in July, average concentrations for this pesticide at the nearfield sites were within the range of values reported elsewhere in the region. In addition, HCB was not detected at any of the nearfield stations during the earlier January survey (see Appendix C.6). A third pesticide, Dieldrin, was detected in a single sediment sample from station E5 during 2008 (i.e., 270 ppt in January), which represents the

Table 4.3

Concentrations of dieldrin, total DDT (tDDT), hexachlorobenzene (HCB), total PCB (tPCB), and total PAH (tPAH) at PLOO benthic stations in 2008. Data are annual means per station (n=2) except where noted; ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected.

	Dieldrin (ppt)	tDDT (ppt)	HCB (ppt)	tPCB (ppt)	tPAH (ppb)
North reference stations					
B8*	nd	600	910	45	17
B11*	nd	390	nd	nd	7
B9	nd	435	70	nd	4
B12	nd	328	nd	nd	7
B10*	nd	300	nd	nd	20
Stations north of the outfall					
E19*	nd	370	nd	311	11
E20	nd	300	115	nd	10
E23	nd	415	nd	nd	16
E25	nd	370	275	nd	4
E26	nd	313	535	nd	nd
E21*	nd	405	280	nd	nd
Nearfield stations					
E11	nd	200	nd	nd	nd
E14	nd	324	475	nd	nd
E17	nd	405	950	nd	3
E15*	nd	310	nd	110	89
Stations south of the outfall					
E1*	nd	nd	nd	nd	147
E7*	nd	290	86	nd	246
E2	nd	855	65	674	24
E5	135	220	60	nd	77
E8	nd	220	270	nd	4
E3*	nd	310	nd	9159	689
E9*	nd	310	670	9956	84
Detection rate (%)	3	97	44	21	56
2008 area mean	8	354	223	616	47
2008 area max	270	1340	1900	9956	689
ERL	na	1580	na	na	4022
ERM	na	46100	na	na	44792

*Station sampled in January survey only (n=1) (see text).

first time this pesticide has been detected at the PLOO stations since monitoring began in 1991. Analytical techniques that test for the presence of pesticides such as HCB and Dieldrin have improved significantly in recent years, which therefore may make pre- vs. post-discharge comparisons inappropriate for such compounds. Overall, the pesticide values detected in benthic sediments off Point Loma in 2008 continued to show no spatial patterns relative to the outfall discharge site.

PCBs and PAHs

Polychlorinated biphenyl compounds (PCBs) were detected in only 21% of all sediment samples during 2008, and these samples were collected from only six PLOO stations (i.e., stations B8, E2, E3, E9, E15, E19) (Table 4.3). The highest total PCB concentrations were found in sediments collected from two sites located nearest to the LA-5 dredge disposal site (i.e., stations E2 and E3), and from one station (E9) located between LA-5 and the PLOO discharge site. Sediments from each of these stations also had the greatest number of PCB congeners that were detected (e.g., up to 22/sample) (see Appendix C.2). PCBs have historically occurred at these and other stations located relatively near the LA-5 disposal site (City of San Diego 2007, Parnell et al. 2008).

In contrast to PCBs, low levels of various polycyclic aromatic hydrocarbons (PAHs) were detected at almost all of the stations during the year with a detection rate of 56% (Table 4.3). All concentrations of total PAH were below the ERL of 4022 ppt (Appendix C.6). The most prevalent PAHs detected were biphenyl, naphthalene, and pyrene (Appendix C.2). Each of these PAHs was detected in 18–29% of the samples. Overall, there was no apparent relationship between PAH concentrations and proximity to the outfall discharge site; instead, the highest concentrations occurred at stations south of the PLOO.

Summary and Conclusions

Ocean sediments at stations surrounding the PLOO in 2008 were comprised primarily of fine sands and coarse silt. Overall, these sediments were poorly sorted, consisting of particles of varied sizes, which suggest that sediments in the region were subject to low wave and current activity and/or physical disturbance. Several stations along the 98-m and 116-m depth contours from E21 south to E5 were composed of sediments that were coarser than most stations to the north and to the south. Field observations of these coarser sediment samples indicated the presence of shell hash and/or coarse black sand. Overall, differences in the particle size composition of sediments off Point Loma are likely affected by both anthropogenic and natural influences, including outfall construction materials, offshore disposal of dredged materials, multiple geological origins of specific sediment types, and recent deposits of detrital materials (e.g., Emery 1960, City of San Diego 2007, Parnell et al. 2008).

Concentrations of various contaminants, including most indicators of organic loading (e.g., BOD, TN, TVS), trace metals, pesticides (e.g., DDT), PCBs, and PAHs in sediments off Point Loma remained within the typical range of variability for San Diego and other areas of the southern California continental shelf (see Schiff and Gossett 1998, Noblet et al. 2003, Schiff et al. 2006). Most contaminants were detected rarely or in low concentrations during 2008. For example, PCBs, and the pesticides HCB and Dieldrin had detection rates ≤45% during the year. Although DDT and PAHs were detected in sediments at most stations, these compounds were present at concentrations below their ERLs. The only metal that exceeded ERL values for southern California was silver, which was present in relatively high concentrations throughout the PLOO region.

There were few clear spatial patterns in sediment contaminant concentrations relative to the PLOO discharge site in 2008, with the exception of slightly elevated sulfides and BOD near the outfall. Instead, the highest concentrations of several organic indicators, metals, DDT, PCBs, and PAHs were found in sediments from both the southern and/or northern-most stations. These included the highest values for copper, mercury, total PCBs, and total PAH in sediments near the LA-5 disposal site. In general, concentrations of sediment contaminants have been higher at these southern stations than elsewhere off San Diego, and are most likely due to misplaced deposits of dredged material that were originally destined for LA-5 (Parnell et al. 2008). Other previous studies have also attributed elevated levels of various contaminants such as PAHs, PCBs, trace metals, and DDT in this area to the deposits associated with LA-5 (see Anderson et al. 1993, City of San Diego 2003, Steinberger et al. 2003), many of which were also present in high concentrations in sediments originating from San Diego Bay (see City of San Diego 2003).

Overall, there is little evidence of organic and contaminant loading in sediments throughout the PLOO region after 15 years of wastewater discharge, with concentrations of most measured parameters occurring at levels within the typical range of variability seen throughout the Southern California Bight (e.g., see City of San Diego 2007). The only sustained effects have been restricted to a few sites located nearest the outfall discharge site, including station E14 near the center of the outfall wye, and stations E11 and E17 located near the ends of the southern and northern diffuser legs, respectively. These effects include a minor increase in sediment particle size through time, measurable increases in sulfide concentrations, and smaller increases in BOD (City of San Diego 2007). However, there is no evidence that the outfall discharge is affecting the quality of benthic sediments to the point that it will degrade the resident marine biota (e.g., see Chapter 5).

Literature Cited

Anderson, J.W., D.J. Reish, R.B. Spies, M.E. Brady, and E.W. Segelhorst. (1993). Human Impacts. In: M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 682–766.

City of San Diego. (1995). Outfall Extension Pre-Construction Monitoring Report (July 1991–October 1992). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003). An Ecological Assessment of San Diego Bay: A Component of the Bight'98 Regional Survey. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007). Appendix E. Benthic Sediments and Organisms. In: Application for Renewal of NPDES CA0107409 and 301(h) Modified Secondary Treatment Requirements Point Loma Ocean Outfall. Volume IV, Appendices A thru F. Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009). 2008 Annual Reports and Summary: Point Loma Wastewater Treatment Plant and Point Loma Ocean Outfall. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Cross, J.N. and L.G. Allen. (1993). Fishes. In: M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 459–540.

Eganhouse, R.P. and M.I. Venkatesan. (1993). Chemical Oceanography and Geochemistry. In: M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight:

A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 71–189.

Emery, K.O. (1960). The Sea off Southern California. John Wiley, New York, NY.

Folk, R.L. (1968). Petrology of Sedimentary Rocks. Hemphill, Austin, Texas.

Gray, J.S. (1981). The Ecology of Marine Sediments: An Introduction to the Structure and Function of Benthic Communities. Cambridge University Press, Cambridge, England.

Long, E.R., D.L. MacDonald, S.L. Smith, and F.D. Calder. (1995). Incidence of adverse biological effects within ranges of chemical concentration in marine and estuarine sediments. Environmental Management, 19(1): 81–97.

Mann, K.H. (1982). The Ecology of Coastal Marine Waters: A Systems Approach. University of California Press, Berkeley, CA.

Noblet, J.A., E.Y. Zeng, R. Baird, R.W. Gossett, R.J. Ozretich, and C.R. Phillips. (2003). Southern California Bight 1998 Regional Monitoring Program: VI. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Parnell, P.E., A.K. Groce, T.D. Stebbins, and P.K. Dayton. (2008). Discriminating sources of PCB contamination in fish on the coastal shelf off San Diego, California (USA). Marine Pollution Bulletin, 56: 1992–2002.

Parsons, T.R., M. Takahashi, and B. Hargrave (1990). Biological Oceanographic Processes 3rd Edition. Pergamon Press, Oxford.

Schiff, K.C. and R.W. Gossett. (1998). Southern California Bight 1994 Pilot Project: III. Sediment Chemistry. Southern California Coastal Water Research Project. Westminster, CA.

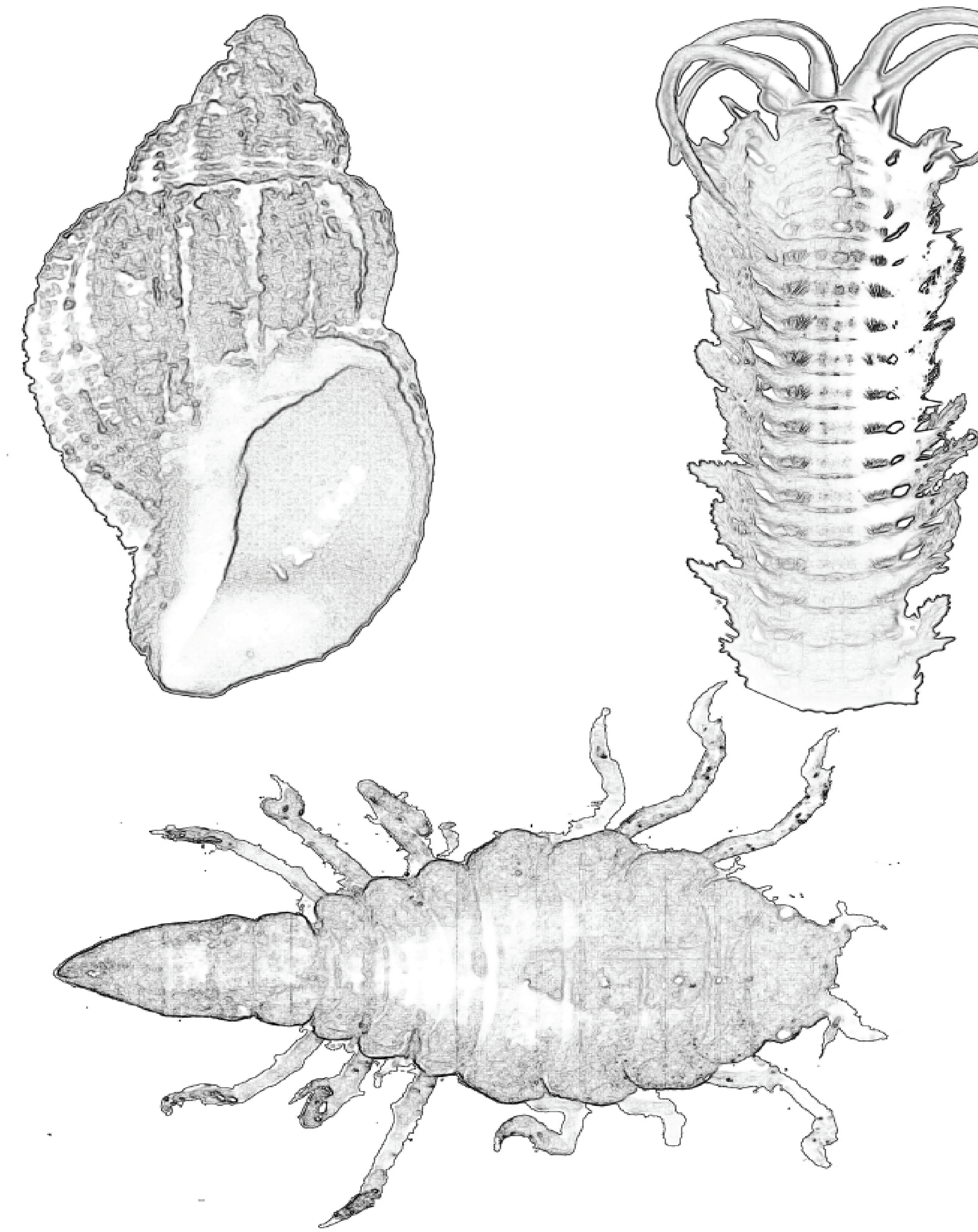
Schiff, K., K. Maruya, and K. Christenson. (2006). Southern California Bight 2003 Regional Monitoring Program: II. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Snelgrove, P.V.R. and C.A. Butman. (1994). Animal-sediment relationships revisited: cause versus effect. Oceanography and Marine Biology Annual Review, 32: 111–177.

Steinberger, A., E. Stein, and K. Schiff. (2003). Characteristics of dredged material disposal to the Southern California Bight between 1991 and 1997. In: Southern California Coastal Water Research Project Biennial Report 2001–2002. Long Beach, CA. p 50–60.

[USEPA] United States Environmental Protection Agency. (1987). Quality Assurance and Quality Control for 301(h) Monitoring Programs: Guidance on Field and Laboratory Methods. EPA Document 430/9-86-004. Office of Marine and Estuary Protection.

Chapter 5
Macrobenthic Communities



Chapter 5. Macrobenthic Communities

INTRODUCTION

Benthic macroinvertebrates along the coastal shelf of southern California represent a diverse faunal community that is important to the marine ecosystem (Fauchald and Jones 1979, Thompson et al. 1993a, Bergen et al. 2001). These animals serve vital functions in wide ranging capacities (Snelgrove et al. 1997). For example, some species decompose organic material as a crucial step in nutrient cycling; other species filter suspended particles from the water column, thus affecting water clarity. Many species of benthic macrofauna also are essential prey for fish and other organisms.

Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation. Certain macrofaunal species are sensitive to such changes and rarely occur in impacted areas, while others are opportunistic and can persist under altered conditions (Gray 1979). Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impact (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since many animals in these assemblages are relatively stationary and long-lived, they can integrate local environmental conditions (Hartley 1982, Bilyard 1987). Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs, which are often designed to document both existing conditions and trends over time.

Overall, the structure of benthic communities may be influenced by many factors including depth, sediment composition and quality (e.g., grain size distribution, contaminant concentrations), oceanographic conditions (e.g., temperature, salinity, dissolved oxygen, ocean currents), and biological factors (e.g., food availability, competition, predation). For example, benthic assemblages on the coastal shelf of southern California typically vary along sediment particle size and/or depth gradients (Bergen et al. 2001). Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have an understanding of background or reference conditions for an area. Such information is available for the monitoring area surrounding the Point Loma Ocean Outfall (PLOO) and the San Diego region in general (e.g., see City of San Diego 1999, 2008; Ranasinghe et al. 2003, 2007).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the PLOO during 2008. Descriptions and comparisons of the different macrofaunal assemblages that inhabit soft bottom habitats in the region and analysis of benthic community structure are included.

Materials and Methods

Collection and Processing of Samples

Benthic samples were collected at 22 benthic stations in the PLOO region during 2008 located along the 88, 98, or 116-m depth contours (Figure 5.1). These sites included 17 "E" stations located from approximately 5 km south to 8 km north of the outfall, and five "B" stations located about 11 km or further north of the outfall. All 22 stations were sampled during the January 2008 survey, while the following July 2008 sampling was limited to 12 "primary core" stations along the 98-m contour to accommodate additional sampling for the Bight'08 regional project (see Chapter 1). The four stations considered to represent "nearfield" conditions herein (i.e., E11, E14, E15, E17) are located between about 100 and 750 m of the outfall wye or diffuser legs.

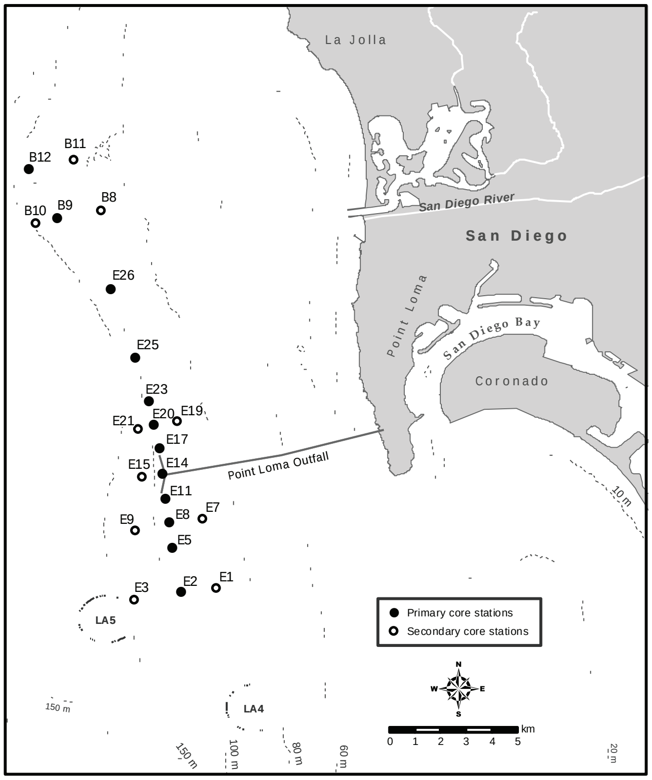


Figure 5.1
Benthic station locations, Point Loma Ocean Outfall Monitoring Program.

Samples for benthic community analyses were collected from two replicate 0.1-m^2 van Veen grabs per station during each survey. An additional grab was collected at each station for sediment quality analysis (see Chapter 4). The criteria to ensure consistency of grab samples established by the United States Environmental Protection Agency (U.S. EPA) were followed with regard to sample disturbance and depth of penetration (U.S. EPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All animals were sorted from the debris into major taxonomic groups by a subcontractor and then identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Data Analyses

The following community structure parameters were calculated for each station per 0.1-m^2 grab: species richness (number of species), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (see Swartz et al. 1986, Ferraro et al. 1994), benthic response index (BRI; see Smith et al. 2001), and infaunal trophic index (ITI; see Word 1980). Additionally, the total or cumulative number of species over all grabs was calculated for each station.

Multivariate analyses were performed using PRIMER software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). The macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. SIMPROF (similarity profile) analysis was used to confirm non-random structure of the dendrogram (Clarke et al. 2008). SIMPER (similarity percentages) analysis was used to identify individual species that typified each cluster group.

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis that there have been no changes in select community parameters due to operation of the PLOO (see Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986, 1992; Osenberg et al. 1994). The BACIP model compares differences between control (reference) and impact sites at times before (i.e., July 1991–October 1993) and after (i.e., January 1994–July 2008) an impact event (i.e., the onset of discharge). The analyses presented in this report are based on 2.5 years (10 quarterly surveys) of before impact data and 15 years (49 quarterly or semi-annual surveys) of after impact data. The E stations, located between about 0.1 and 8 km of the outfall, are considered most likely to be affected by wastewater discharge. Station E14 was selected as the impact site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and probably is the site most susceptible to impact. In contrast, the B stations are located farther from the outfall (>11 km) and are the obvious candidates for reference or control sites. However, benthic communities differed between the B and E stations prior to discharge (Smith and Riege 1994, City of San Diego 1995). Thus, two stations (E26 and B9) were selected to represent separate control sites in the BACIP tests. Station E26 is located 8 km north of the outfall and is considered the E station least likely to be impacted. Previous analyses suggested that station B9 was one of the most appropriate B stations for comparison with the E stations (Smith and Riege 1994, City of San Diego 1995). Six dependent variables were analyzed, including three community parameters (number of species, infaunal abundance, BRI) and abundances of three taxa that are considered sensitive to organic enrichment. These indicator taxa include ophiuroids in the genus *Amphiodia* (mostly *A. urtica*), and amphipods in the genera *Ampelisca* and *Rhepoxynius*. All BACIP analyses were interpreted using a Type I error rate of $\alpha=0.05$.

Results and Discussion

Community Parameters

Species richness

A total of 478 macrofaunal taxa (mostly species) were identified during the 2008 PLOO surveys. Of these, approximately 28% (n=132) represented rare taxa that were recorded only once. Mean values of species richness ranged from 61 species per 0.1 m^2 at B8 to 101 species per 0.1 m^2 at B11 (Table 5.1), which is consistent with previous values and patterns for these two northern reference sites (e.g., see City of San Diego 2008). Average values for the other 20 sites sampled during the year ranged between 70 and 90 species per grab. In addition, species richness in 8 of the 12 primary core stations showed a general decrease compared to 2007 (e.g., see City of San Diego 2008).

Macrofaunal abundance

A total of 17,270 macrofaunal individuals were counted in 2008 with mean abundance values ranging from 199 to 307 animals per 0.1 m^2 sample (Table 5.1). The largest number of animals occurred at station E19, which was the only station to average more than 300 animals per sample. The fewest animals (<212 per 0.1 m^2) were collected at stations B8 and E8, while the remaining sites had abundances ranging between 228 and 282 animals per grab. Overall, there was an 8% decrease in macrofaunal abundance at the 12 primary core stations between 2007 and 2008, with the largest difference occurring at station E14 (e.g., see City of San Diego 2008). This site averaged 410 and 237 individuals per grab in 2007 and 2008, respectively.

Species diversity, evenness, and dominance

Species diversity (H') averaged from 3.2 to 4.0 per station during 2008 (Table 5.1), which was generally similar to that seen in previous years (e.g., City of Diego 1995, 2008). The lowest diversity ($H'\leq3.4$) continued to occur at stations E1 and B8, while most of the remaining stations (n=17) had mean H' values between 3.8 and 4.0 during the year. There were no apparent patterns relative to distance from the outfall discharge site. Evenness (J') compliments diversity, with higher J' values (on a scale of 0–1) indicating that species are more evenly distributed (i.e., not dominated by a few highly abundant species). During 2008, J' values averaged between 0.77 and 0.91 per station, with spatial patterns similar to those for diversity.

Dominance was expressed as the Swartz dominance index, which is calculated as the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Therefore, lower index values (i.e., fewer species) indicate higher numerical dominance. Benthic assemblages in 2008 were characterized by relatively high numbers of evenly distributed species with index values averaging 30 species per station (Table 5.1). The highest dominance of 20 species was seen for the assemblage at station B8, while the lowest dominance (values ≥37) occurred at stations E2 and B11. Overall, these results are similar to historical values for the PLOO region (see City of San Diego 2007).

Table 5.1

Summary of macrobenthic community parameters for PLOO stations sampled during 2008. SR=species richness, no. species/0.1 m^2; Tot Spp=cumulative no. species for the year; Abun=abundance, no. individuals/0.1 m^2; H'=Shannon diversity index; J'=Evenness; Dom=Swartz dominance, (see text); BRI=benthic response index; ITI=infaunal trophic index. Nearfield stations in bold. Data are expressed as annual means (n=4 for primary core stations, n=2 for all others).

	Station	SR	Tot Spp	Abun	H'	J'	Dom	BRI	ITI
88-m contour	B11	101	159	274	4.0	0.87	39	10	76
	B8	61	89	212	3.2	0.78	20	8	86
	E19	81	104	307	3.6	0.83	25	13	80
	E7	81	113	262	3.6	0.82	28	10	85
	E1	76	111	282	3.4	0.77	24	10	87
*98-m contour**	B12	80	168	254	3.8	0.88	29	12	72
	B9	83	164	261	3.9	0.88	32	7	80
	E26	84	157	280	3.8	0.86	28	10	78
	E25	80	147	281	3.8	0.86	27	11	77
	E23	80	149	259	4.0	0.90	34	12	78
	E20	83	168	272	3.9	0.89	31	12	77
	E17	**81**	**165**	**262**	**3.9**	**0.88**	**29**	**19**	**72**
	E14	**70**	**139**	**237**	**3.7**	**0.88**	**25**	**23**	**67**
	E11	**77**	**142**	**228**	**3.9**	**0.90**	**32**	**15**	**77**
	E8	70	140	199	3.8	0.90	28	10	80
	E5	87	165	273	3.9	0.88	33	8	82
	E2	90	191	245	4.0	0.88	37	11	82
116-m contour	B10	80	115	243	3.9	0.90	32	15	73
	E21	78	109	230	3.9	0.89	31	10	79
	E15	**74**	**107**	**228**	**3.9**	**0.91**	**30**	**10**	**78**
	E9	85	118	245	3.9	0.87	33	13	78
	E3	83	122	254	3.8	0.87	32	12	77
All stations	Mean	80	138	254	3.8	0.87	30	12	78
	Std error	2	6	7	0.2	0.01	1	1	1
	Min	56	89	139	3.1	0.76	18	4	60
	Max	110	191	365	4.3	0.93	49	26	87

*primary core stations

Environmental disturbance indices

Benthic response index (BRI) values averaged from 7 to 23 at the various PLOO stations in 2008 (Table 5.1). This suggests that benthic communities in the region are relatively undisturbed as BRI values below 25 are considered indicative of reference conditions (Smith et al. 2001). The highest mean values (≥15) were measured at stations E11, E14, and E17 located nearest the discharge site, as well as at station B10 located about 11 km north of the outfall.

Mean infaunal trophic index (ITI) values ranged from 67 to 87 per station in 2008 (Table 5.1), which is similar to values reported in previous years. These relatively high values (i.e., ITI>60) have also been considered indicative of undisturbed sediments or reference environmental conditions (see Bascom et al. 1979).

Dominant Species

Macrofaunal communities in the Point Loma region were dominated by polychaete worms in 2008 (Table 5.2). For example, seven polychaete, two echinoderm, and one mollusc taxa were among the 10 most abundant macroinvertebrates sampled during the year (Table 5.3). Polychaetes were the most diverse of the major taxa, accounting for 53% of all species collected. Crustaceans accounted for 24% of the species, molluscs 13%, echinoderms 6%, and all other taxa combined for the remaining 4%. Polychaetes were also the most numerous animals, accounting for 52% of the total abundance. Crustaceans accounted for 19% of the animals, molluscs 14%, echinoderms 13%, and the remaining phyla 2%. Overall, the above distributions were very similar to those observed in 2007 (see City of San Diego 2008).

The two most abundant taxa were the ophiuroid *Amphiodia urtica* and the capitellid polychaete *Mediomastus* sp, averaging 22 and 17 individuals per 0.1 m^2, respectively. However, since juvenile ophiuroids usually cannot be identified to species and are recorded at the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae, respectively), this number underestimates actual populations of *A. urtica*. If values for total *A. urtica* abundance are adjusted to include these unidentified individuals, the estimated density of this species increases to 27 per grab sample, similar to that observed in 2007.

Many of the abundant species in 2008 were also dominant prior to discharge and ever since (e.g., City of San Diego 1995, 1999, 2006, 2008). For example, *A. urtica* has been among the most abundant and most commonly occurring species along the outer shelf off Point Loma since sampling began. In contrast, *Mediomastus* sp has

Table 5.2
Percent composition of species and total abundance by major macrofaunal taxa (phyla) for all PLOO stations sampled during 2008. Data are expressed as annual means (n=22 stations) for the region with ranges in parentheses.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	53 (41-62)	52 (20-76)
Arthropoda (Crustacea)	24 (13-30)	19 (7-32)
Mollusca	13 (4-22)	14 (3-33)
Echinodermata	6 (4-11)	13 (3-40)
Other Phyla	4 (1-7)	2 (0-5)

Table 5.3
Dominant macroinvertebrates at the PLOO benthic stations sampled during 2008. The 10 most abundant species are included. Abundance values are expressed as mean number of individuals per 0.1 m^2.

Species	Higher taxa	Abundance per sample	Abundance per occurence	Percent occurence
Amphiodia urtica	Echinodermata: Ophiuroidea	21.5	21.5	100
Mediomastus sp	Polychaeta: Capitellidae	17.1	17.1	100
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	10.6	10.6	100
Aricidea (*Acmira*) *catherinae*	Polychaeta: Paraonidae	6.7	6.7	100
Amphiodia sp	Echinodermata: Ophiuroidea	4.9	4.9	100
Tellina carpenteri	Mollusca: Bivalvia	4.3	4.3	100
Sternaspis fossor	Polychaeta: Sternapsidae	4.3	4.3	100
Aphelochaeta monilaris	Polychaeta: Cirratulidae	3.0	3.0	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	4.6	4.8	97
Lumbrineris cruzensis	Polychaeta: Lumbrineridae	4.2	4.3	97

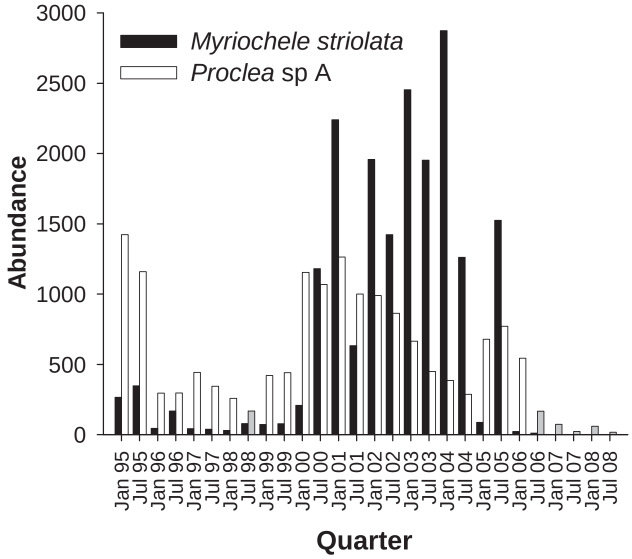


Figure 5.2

Total abundance of the polychaetes, *Myriochele striolata* and *Proclea* sp A for each survey at the PLOO benthic stations from 1995–2008.

Table 5.4

Results of BACIP t-tests for number of species (SR), infaunal abundance, benthic response index (BRI), and the abundance of several representative taxa around the PLOO (1991–2008). Impact site=near-ZID station E14; Control sites=farfield station E26 or reference station B9. Before impact period=July 1991 to October 1993 (n=10); After impact period=January 1994 to July 2008 (n=49). Critical t value=1.680 for α=0.05 (one-tailed t-tests, df=57). ns=not significant.

Variable	Control vs Impact	t	p
SR	E26 v E14	-3.01	0.002
	B9 v E14	-3.46	0.001
Abundance	E26 v E14	-1.42	ns
	B9 v E14	-2.68	0.005
BRI	E26 v E14	-15.25	<0.001
	B9 v E14	-10.34	<0.001
Ampelisca spp	E26 v E14	-1.62	ns
	B9 v E14	-1.28	ns
Amphiodia spp	E26 v E14	-6.63	<0.001
	B9 v E14	-4.65	<0.001
Rhepoxynius spp	E26 v E14	-0.75	ns
	B9 v E14	-0.65	ns

not been among the most abundant species in past years. Abundances of this polychaete remained relatively low in the region until about 2005, after which they have generally increased each year (see City of San Diego 1995, 1999, 2006, 2007, 2008). However, densities of other polychaetes such as the oweniid *Myriochele striolata* and the terebellid *Proclea* sp A that have been numerically dominant over time have been more cyclical (Figure 5.2). For instance, both of these species were among the most abundant polychaetes between 1999 and 2005, while their densities have decreased during recent years to levels similar to those observed in 1996–1998. Such variation can have significant effects on other descriptive statistics (e.g., dominance, diversity, and abundance) or environmental indices such as the BRI that use the abundance of indicator species in their equations.

BACIP Analyses

BACIP t-tests indicate that there has been a net change in the mean difference of species richness, BRI values, and *Amphiodia* spp abundance between impact site E14 and both control (reference) sites since the onset of wastewater discharge from the PLOO (Table 5.4). There also has been a net change in infaunal abundance between E14 and control site B9. The change in species richness may be due to the increased variability and higher numbers of species at the impact site between 1997 and 2007 (Figure 5.3A). Differences in *Amphiodia* populations reflect a decrease in the number of these ophiuroids collected at E14 and a general increase at the control stations until about 2001 (Figure 5.3E). *Amphiodia urtica* densities at station E14 in 2008 were similar to the low densities that have occurred since about 1999. While densities of this brittle star have declined in recent years at both control sites, they are more similar to pre-discharge values than densities near the outfall. Differences in the BRI generally are due to increased index values at station E14 since 1994 (Figure 5.3C). These higher BRI values at this site may be explained in part by the lower numbers of *Amphiodia*. The results for total infaunal abundances were more ambiguous (Figure 5.3B, Table 5.3). While the difference in mean abundances between station B9 and the impact site has changed since discharge began, no such pattern is apparent regarding the second control site (E26). Finally, no significant changes

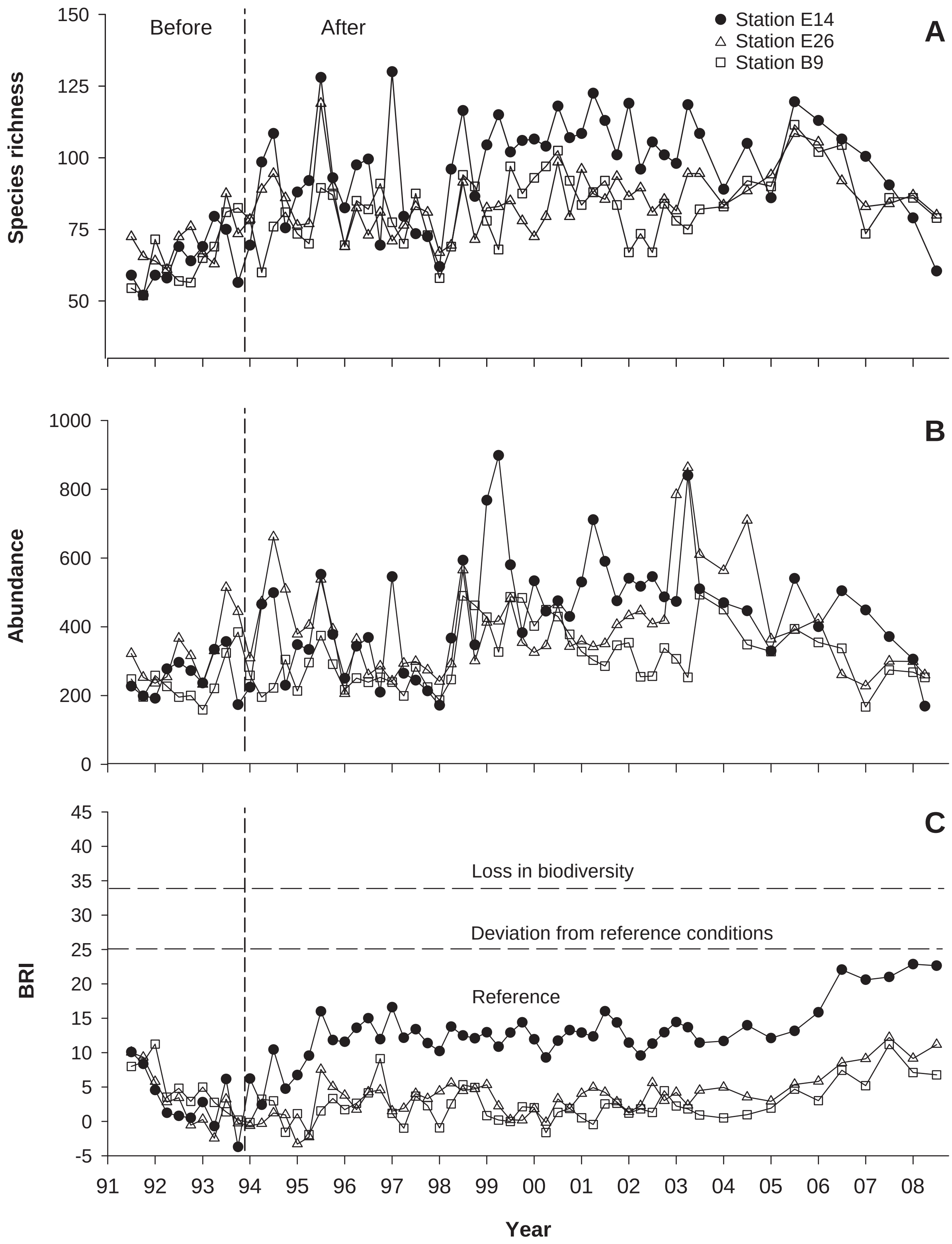


Figure 5.3

Comparison of several parameters at "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.4). Data for each station are expressed as means per 0.1 m^2 (n=2 per survey). (A) species richness; (B) infaunal abundance; (C) benthic response index (BRI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

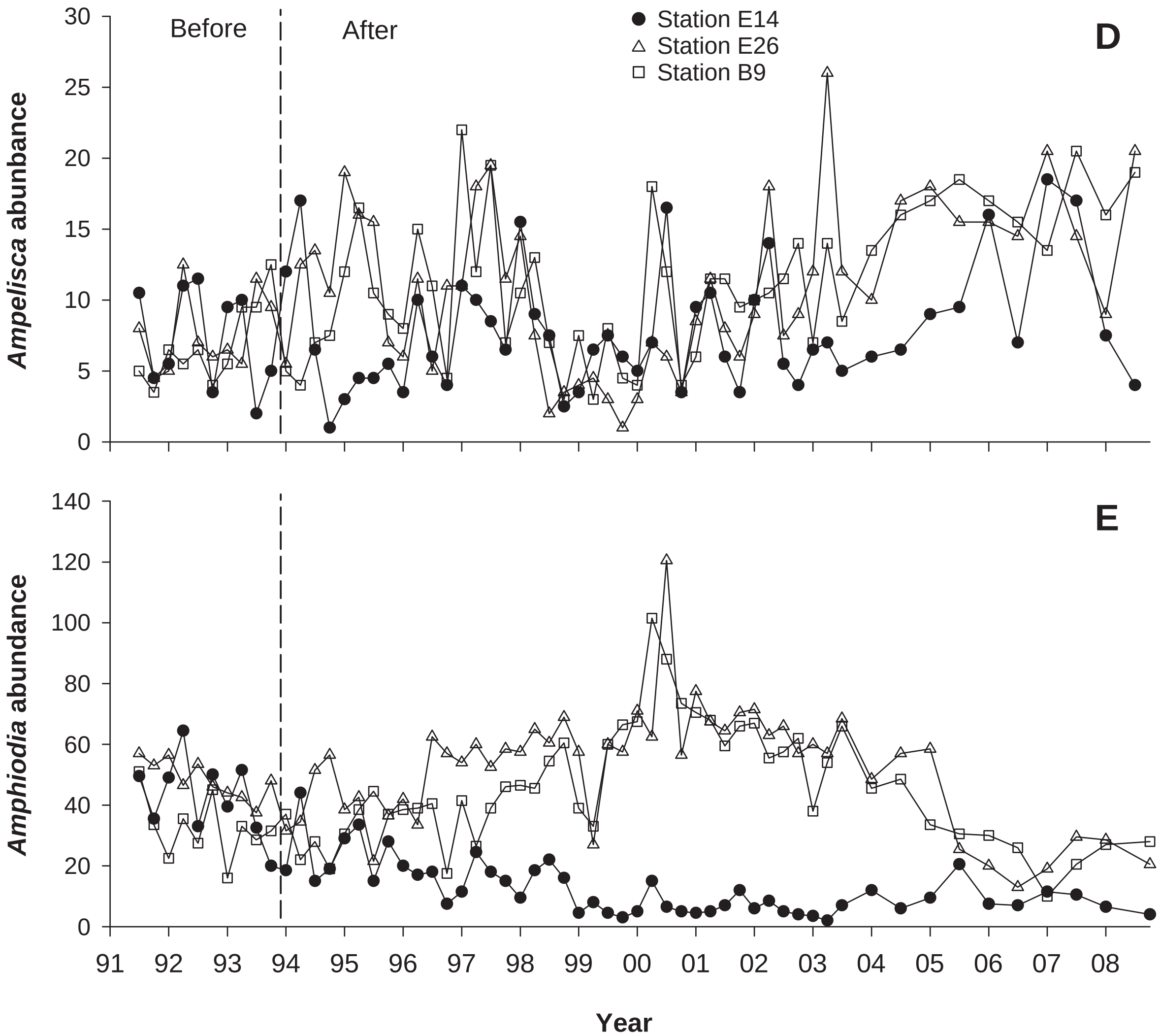


Figure 5.3 *continued*

in the difference in mean abundances of ampeliscid or phoxocephalid amphipods at the impact and control sites have occurred since discharge began (Figure 5.3D, Table 5.3).

Classification of Macrobenthic Assemblages

Results of the ordination and cluster analyses discriminated eight habitat-related macrobenthic assemblages (Figures 5.4 and 5.5). These assemblages (cluster groups A–H) varied in terms of species composition (i.e., specific taxa present) and the relative abundance of each species, and occurred at sites separated by different depths and/or sediment types (microhabitats). The SIMPROF procedure indicated statistically significant non-random structure among samples (π=3.29, $p<0.01$) and an MDS ordination of the station/survey entities supported the validity of the cluster groups (Figure 5.4B). SIMPER analysis was used to identify species that were characteristic, though not always the most abundant, of some assemblages; i.e., the three most characteristic species for each cluster group are indicated in Figure 5.4A. A complete list of all species comprising each group and their relative abundances can be found in Appendix D.1.

Cluster group A represented an assemblage restricted to both surveys from one northern reference site (station B12). Abundance averaged 254 individuals and species richness averaged 80 taxa per 0.1 m^2. The dominant species that characterized this assemblage included the gastropod *Micranellum crebricinctum* (formerly

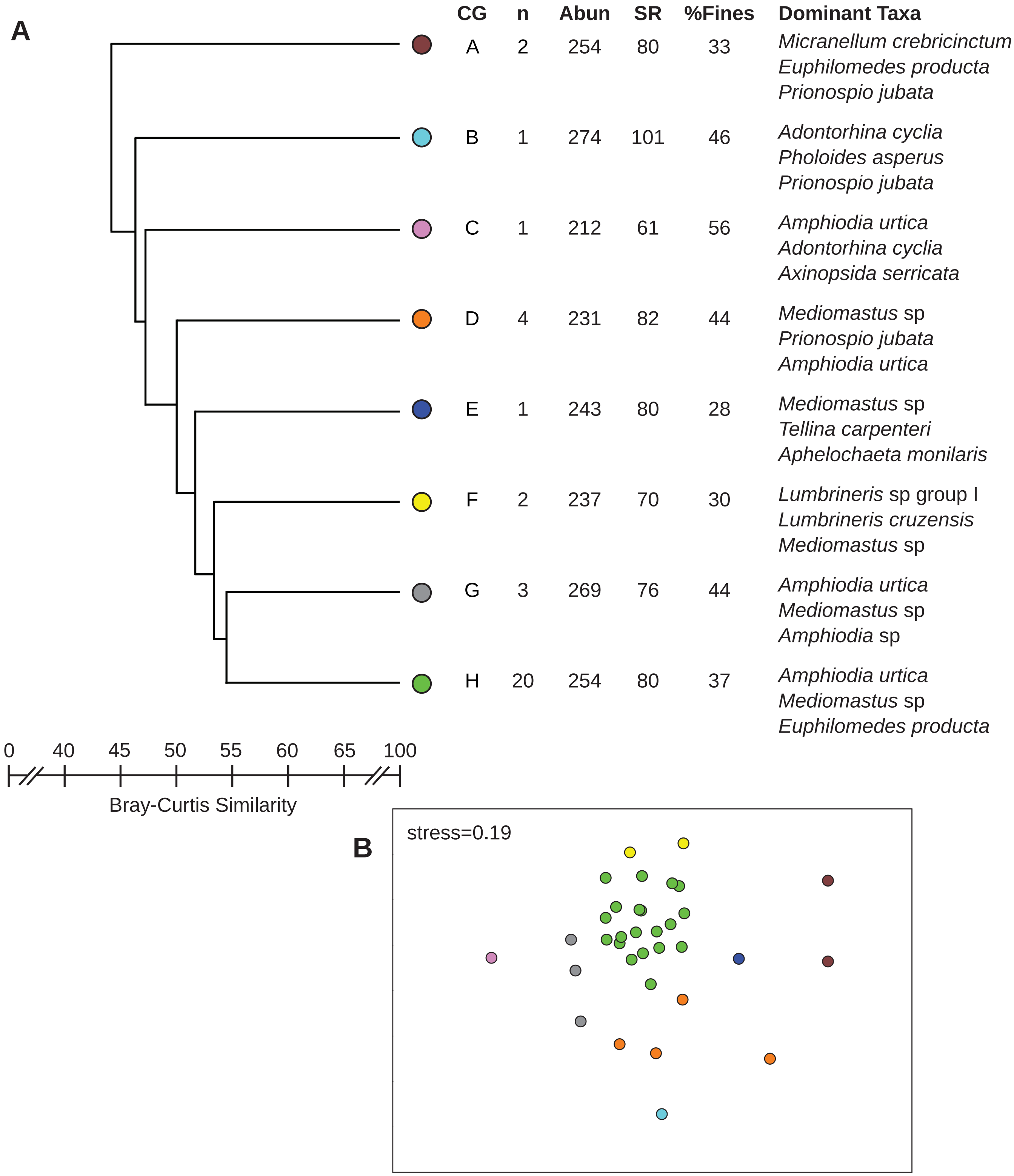


Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during winter and summer 2008. Data for infaunal abundance (Abun), species richness (SR), and percent fines are expressed as mean values per 0.1-m^2 grab over all stations in each group. (B) MDS ordination based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between faunal assemblages.

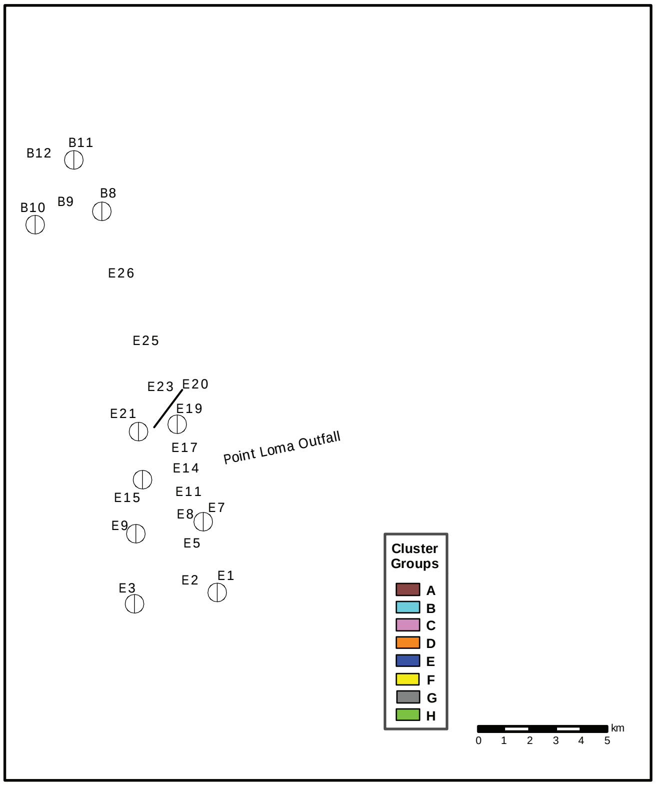


Figure 5.5
Distribution of macrobenthic assemblages off Point Loma delineated by ordination and classification analyses. Empty half cirlces represent secondary core stations not sampled in July 2008.

Caecum crebricinctum), the ostracod *Euphilomedes producta*, and the spionid polychaete *Prionospio jubata*. Sediments at this site averaged 33% fines over the two surveys.

Cluster group B comprised the assemblage that occurred at station B11 during the January survey (i.e., this station was not sampled during July 2008; see Materials and Methods). This station is located farthest north of the PLOO discharge site at a depth of 88 m. The B11 assemblage had the highest mean abundance (274 per 0.1 m^2) and species richness (101 taxa per 0.1 m^2) values compared to the other cluster groups. The bivalve *Adontorhina cyclia* was the dominant species characterizing this assemblage. The next two characteristic species were both polychaetes, and included the pholoid *Pholoides asperus* as well as *Prionospio jubata*. Sediments at this site were mixed, comprised of about 46% fines along with coarser materials such as shell hash and some small rocks.

Cluster group C represented the assemblage at station B8, another northern site located along the 88-m depth contour, which was also only sampled during the January survey similar to station B11 (see above). This assemblage averaged 212 organisms and 61 taxa per 0.1 m^2, the lowest for both parameters among all groups. The dominant species in this assemblage were the ophiuroid *Amphiodia urtica*, followed by the bivalves *Adontorhina cyclia* and *Axinopsida serricata*. The habitat was characterized by sediments containing 56% fine particles, the highest among all groups.

Cluster group D represented an assemblage characteristic of three of the southernmost sites located along the 98 and 116-m depth contours and nearest to the LA-5 dredged materials disposal site. This assemblage averaged 231 individuals and 82 taxa per 0.1 m^2. The three most characteristic species of this group were the capitellid polychaete *Mediomastus* sp, *Prionospio jubata*, and *Amphiodia urtica*. Sediments at these sites averaged 44% fines.

Cluster group E represented an assemblage from northern station B10 located along the 116-m contour, which was only sampled during January similar to stations B8 and B11 (i.e., cluster groups C and B, respectively) as described above. This assemblage averaged 243 individuals and 80 species per 0.1 m^2. The dominant species included *Mediomastus* sp, the bivalve *Tellina carpenteri*, and the cirratulid polychaete *Aphelochaeta monilaris*. The sediments associated with this group were mixed, composed of 28% fines with some shell hash.

Cluster group F represented a near-ZID assemblage sampled at station E14 during both the January and July surveys in 2008. Abundance averaged 237 individuals and species richness averaged 70 taxa per 0.1 m^2. The three most abundant species in this assemblage were all polychaetes, which included two lumbrinerids (*Lumbrineris* sp group I and *L. cruzensis*) along with *Mediomastus* sp. Sediments at this site were relatively coarse, comprised of black sand, shell hash, and an average of about 30% fines.

Cluster group G represented the assemblage at stations E1, E7, and E19 located along the 88-m contour, which were only sampled during January similar to those comprising groups B, C, and E (see above). This assemblage averaged 269 individuals and 76 taxa per 0.1 m^2. The brittle star *Amphiodia urtica* was the dominant species, while the next two most characteristic taxa for this assemblage were *Mediomastus* sp and juvenile *Amphiodia*. Sediments associated with this group averaged 44% fines.

Cluster group H represented the most widespread macrobenthic assemblage present in 2008, comprising animals from 59% of the samples and 11 stations. Average abundance for this group was 254 individuals per 0.1 m^2, while species richness averaged 80 taxa per sample. The dominant species characterizing group H were *Amphiodia urtica*, *Mediomastus* sp, and *Euphilomedes producta*. The sediments associated with this assemblage were characterized by some shell hash with 37% fines.

Summary and Conclusions

Benthic communities surrounding the PLOO continue to be dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began (see City of San Diego 1995, 1999, 2008). Polychaetes and ophiuroids are the most abundant and diverse infauna taxa in the region. Although many of the 2008 assemblages were dominated by similar species, the relative abundance of these species varied among sites. The brittle star *Amphiodia urtica* was the most abundant and widespread taxon, while the capitellid polychaete *Mediomastus* sp was the second most widespread benthic invertebrate, being dominant in five of the eight assemblages. Assemblages similar to those off Point Loma have been described for other areas in the Southern California Bight (SCB) by Barnard and Ziesenhenne (1961), Jones (1969), Fauchald and Jones (1979), Thompson et al. (1987, 1993a), Zmarzly et al. (1994), Diener and Fuller (1995), and Bergen et al. (1998, 2000, 2001).

Although variable, benthic communities off Point Loma generally have remained similar from year to year in terms of the number of species, number of individuals, and dominance (e.g., City of San Diego 1995, 1999, 2007). In addition, values for these parameters in 2008 were similar to those described for other sites throughout the SCB (e.g., Thompson et al. 1993b, Bergen et al. 1998, 2000, 2001; Ranasinghe et al. 2003, 2007). In spite of this overall stability, there has been some increase in the number of species and macrofaunal abundance during the post-discharge period (see City of San Diego 1995, 1999, 2007). In addition, the recent observed decreases in abundance at most stations in 2006 and 2008 were not accompanied by changes in dominance, a pattern inconsistent with predicted pollution effects. Further, benthic communities around the PLOO are not dominated by a few pollution tolerant species. For example, the opportunistic polychaete *Capitella capitata*, which is often associated with degraded soft bottom habitats, continues to occur in relatively low numbers off Point Loma. A total of 76 individual *C. capitata* were collected off Point Loma in 2008, with all occurring at stations located nearest the PLOO discharge site (i.e., E11, E14, E17). Densities of this polychaete at these three sites averaged 13 individuals per 0.1 m^2. In contrast, populations of *C. capitata* typically exceed densities of 500 individuals per 0.1 m^2 and constitute as much as 85% of the total abundance in polluted sediments (Swartz et al. 1986).

A few changes near the outfall suggest some effects are coincident with anthropogenic activities. BRI values are higher at stations nearest the outfall (E11, E14, E17) than at other sites in the region (see City of San Diego 2007). In addition, increases in BRI that occurred at station E14 after discharge began may be considered indicative of organic enrichment or some other type of disturbance. However, BRI values at this and all other sites still remain characteristic of undisturbed areas (see City of San Diego 1995, 2007; Smith et al. 2001). The increased variability in number of species and infaunal abundance at station E14 since discharge began may be indicative of community destabilization (see Warwick and Clarke 1993, Zmarzly et al. 1994). There has been some change in sediments at E14 since construction of the PLOO (see City of San Diego 2007). This suggests that changes in community structure near the PLOO could be related to localized physical disturbance associated with the structure of the outfall pipe as well as to organic enrichment associated with the discharge of effluent.

Populations of some indicator taxa have revealed changes over time that may correspond to organic enrichment near the outfall. For example, since 1997, there has been a significant change in the difference between ophiuroid (*Amphiodia* spp) populations that occur nearest the outfall (i.e., station E14) and those present at reference sites. This difference is mostly due to both a decrease in ophiuroid numbers near station E14 and a concomitant increase at reference areas during the post-discharge period. However, these differences have decreased over the past three years. Although long term changes in *Amphiodia* populations at E14 may likely be related to organic enrichment, altered sediment composition, or some other factor, abundances for the Point Loma region in general are still within the range of those occurring naturally in the SCB. In addition, natural population fluctuations of these and other resident species (e.g. *Myriochele striolata* and *Proclea* sp A) are common off San Diego (Zmarzly et al. 1994, Diener et al. 1995). Further complicating the picture, stable patterns in populations of pollution sensitive amphipods (i.e., *Ampelisca*, *Rhepoxynius*) and a limited presence of a pollution tolerant species (e.g., *Capitella capitata*) do not offer evidence of substantial outfall-related effects.

While it is difficult to detect specific effects of the PLOO on the offshore benthos region-wide, it is possible to see some changes occurring nearest the discharge site. Because of the minimal extent of these changes, it has not been possible to determine whether observed effects are due to habitat alteration related to the physical structure of the outfall pipe, organic enrichment, or a combination of factors. Such impacts have spatial and temporal dimensions that vary depending on a range of biological and physical factors. In addition, abundances of soft bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, 1992b; Otway 1995). The effects associated with the discharge of advanced primary treated sewage may be negligible or difficult to detect in areas subjected to strong currents that facilitate the dispersion of the wastewater plume (see Diener and Fuller 1995). Although some changes in macrobenthic assemblages have appeared near the outfall, assemblages in the Point Loma region are still similar to those observed prior to discharge and to natural indigenous communities characteristic of the southern California continental shelf.

Literature Cited

Barnard, J.L. and F.C. Ziesenhenne. (1961). Ophiuroidea communities of southern Californian coastal bottoms. Pacific Naturalist, 2: 131–152.

Bascom, W., A.J. Mearns, and J.Q. Word. (1979). Establishing boundaries between normal, changed, and degraded areas. In: Southern California Coastal Water Research Project Annual Report, 1978. Long Beach, CA. p 81–95.

Bergen, M., D.B. Cadien, A. Dalkey, D.E. Montagne, R.W. Smith, J.K. Stull, R.G. Velarde, and S.B. Weisberg. (2000). Assessment of benthic infaunal condition on the mainland shelf of southern California. Environmental Monitoring Assessment, 64: 421–434.

Bergen, M., S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, R.W. Smith, J.K. Stull, and R.G. Velarde. (1998). Southern California Bight 1994 Pilot Project: IV. Benthic Infauna. Southern California Coastal Water Research Project, Westminster, CA.

Bergen, M., S.B. Weisberg, R.W. Smith, D.B. Cadien, A. Dalkey, D.E. Montagne, J.K. Stull, R.G. Velarde, and J.A. Ranasinghe. (2001). Relationship between depth, sediment, latitude, and the structure of benthic infaunal assemblages on the mainland shelf of southern California. Marine Biology, 138: 637–647.

Bernstein, B.B. and J. Zalinski. (1983). An optimum sampling design and power tests for environmental biologists. Journal of Environmental Management, 16: 35–43.

Bilyard, G.R. (1987). The value of benthic infauna in marine pollution monitoring studies. Marine Pollution Bulletin, 18(11): 581–585.

City of San Diego. (1995). Outfall Extension Pre-Construction Monitoring Report. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1999). San Diego Regional Monitoring Report for 1994–1997. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2006). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2005. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007). Appendix E. Benthic Sediments and Organisms. In: Application for Renewal of NPDES CA0107409 and 301(h) Modified Secondary Treatment Requirements, Point Loma Ocean Outfall. Volume IV, Appendices A thru F. Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology, 18: 117–143.

Clarke, K.R. and R.N. Gorley. (2006). PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Clarke, K.R., P.J. Somerfield, and R.N. Gorley. (2008). Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. Journal of Experimental Marine Biology and Ecology, 366: 56–69.

Diener, D.R. and S.C. Fuller. (1995). Infaunal patterns in the vicinity of a small coastal wastewater outfall and the lack of infaunal community response to secondary treatment. Bulletin of the Southern California Academy of Science, 94: 5–20.

Diener, D.R., S.C. Fuller, A. Lissner, C.I. Haydock, D. Maurer, G. Robertson, and R. Gerlinger. (1995). Spatial and temporal patterns of the infaunal community near a major ocean outfall in southern California. Marine Pollution Bulletin, 30: 861–878.

Fauchald, K. and G.F. Jones. (1979). Variation in community structures on shelf, slope, and basin macrofaunal communities of the Southern California Bight. Report 19, Series 2. In: Southern California Outer Continental Shelf Environmental Baseline Study, 1976/1977 (Second Year) Benthic Program. Principal Investigators Reports, Vol. II. Science Applications, Inc. La Jolla, CA.

Ferraro, S.P., R.C. Swartz, F.A. Cole, and W.A. Deben. (1994). Optimum macrobenthic sampling protocol for detecting pollution impacts in the Southern California Bight. Environmental Monitoring and Assessment, 29: 127–153.

Gray, J.S. (1979). Pollution-induced changes in populations. Philosophical Transactions of the Royal Society of London (Series B.), 286: 545–561.

Hartley, J.P. (1982). Methods for monitoring offshore macrobenthos. Marine Pollution Bulletin, 12: 150–154.

Jones, G.F. (1969). The benthic macrofauna of the mainland shelf of southern California. Allan Hancock Monographs of Marine Biology, 4: 1–219.

Morrisey, D.J., L. Howitt, A.J. Underwood, and J.S. Stark. (1992a). Spatial variation in soft-sediment benthos. Marine Ecology Progress Series, 81: 197–204.

Morrisey, D.J., A.J. Underwood, L. Howitt, and J.S. Stark. (1992b). Temporal variation in soft-sediment benthos. Journal of Experimental Marine Biology and Ecology, 164: 233–245.

Osenberg, C.W., R.J. Schmitt, S.J. Holbrook, K.E. Abu-Saba, and A.R. Flegel. (1994). Detection of environmental impacts: Natural variability, effect size, and power analysis. Ecological Applications, 4: 16–30.

Otway, N.M. (1995). Assessing impacts of deepwater sewage disposal: a case study from New South Wales, Australia. Marine Pollution Bulletin, 31: 347–354.

Pearson, T.H. and R. Rosenberg. (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology Annual Review, 16: 229–311.

Ranasinghe, J.A., A.M. Barnett, K. Schiff, D.E. Montagne, C. Brantley, C. Beegan, D.B. Cadien, C. Cash, G.B. Deets, D.R. Diener, T.K. Mikel, R.W. Smith, R.G. Velarde, S.D. Watts, S.B. Weisberg. (2007). Southern California Bight 2003 Regional Monitoring Program: III. Benthic Macrofauna. Southern California Coastal Water Research Project. Costa Mesa, CA.

Ranasinghe, J.A., D.E. Montagne, R.W. Smith, T.K. Mikel, S.B. Weisberg, D. Cadien, R. Velarde, and A. Dalkey. (2003). Southern California Bight 1998 Regional Monitoring Program: VII. Benthic Macrofauna. Southern California Coastal Water Research Project. Westminster, CA.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull, and R.G. Velarde. (2001). Benthic response index for assessing infaunal communities on the southern California mainland shelf. Ecological Applications, 11(4): 1073–1087.

Smith, R.W. and L. Riege. (1994). Optimization and power analyses for the Point Loma monitoring design. Unpublished report to City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Snelgrove P.V.R., T.H. Blackburn, P.A. Hutchings, D.M. Alongi, J.F. Grassle, H. Hummel, G. King, I. Koike, P.J.D. Lambshead, N.B. Ramsing, V. Solis-Weiss. (1997). The importance of marine sediment biodiversity in ecosystem processes. Ambio, 26: 578–583.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. (1986). Environmental impact assessment: "Pseudoreplication" in time? Ecology, 67: 929–940.

Stewart-Oaten, A., J.R. Bence, and C.W. Osenberg. (1992). Assessing effects of unreplicated perturbations: no simple solutions. Ecology, 73: 1396–1404.

Swartz, R.C., F.A. Cole, and W.A. Deben. (1986). Ecological changes in the Southern California Bight near a large sewage outfall: benthic conditions in 1980 and 1983. Marine Ecology Progress Series, 31: 1–13.

Thompson, B.E., J. Dixon, S. Schroeter, and D.J. Reish. (1993a). Chapter 8. Benthic invertebrates. In: M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 369–458.

Thompson, B.E., J.D. Laughlin, and D.T. Tsukada. (1987). 1985 reference site survey. Technical Report No. 221, Southern California Coastal Water Research Project, Long Beach, CA.

Thompson, B.E., D. Tsukada, and D. O'Donohue. (1993b). 1990 reference site survey. Technical Report No. 269, Southern California Coastal Water Research Project, Long Beach CA.

[U.S. EPA] United States Environmental Protection Agency. (1987). Quality Assurance and Quality Control (QA/QC) for 301(h) Monitoring Programs: Guidance on Field and Laboratory Methods. EPA Document 430/9-86-004. Office of Marine and Estuarine Protection.

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. Australian Journal of Ecology, 18: 63–80.

Warwick, R.M. and K.R. Clarke. (1993). Increased variability as a symptom of stress in marine communities. Journal of Experimental Marine Biology and Ecology, 172: 215–226.

Word, J.Q. (1980). Classification of benthic invertebrates into infaunal trophic index feeding groups. In: W. Bascom (ed.). Biennial Report for the Years 1979–1980, Southern California Coastal Water Research Project, Long Beach, CA.

Zmarzly, D.L., T.D. Stebbins, D. Pasko, R.M. Duggan, and K.L. Barwick. (1994). Spatial patterns and temporal succession in soft-bottom macroinvertebrate assemblages surrounding an ocean outfall on the southern San Diego shelf: Relation to anthropogenic and natural events. Marine Biology, 118: 293–307.

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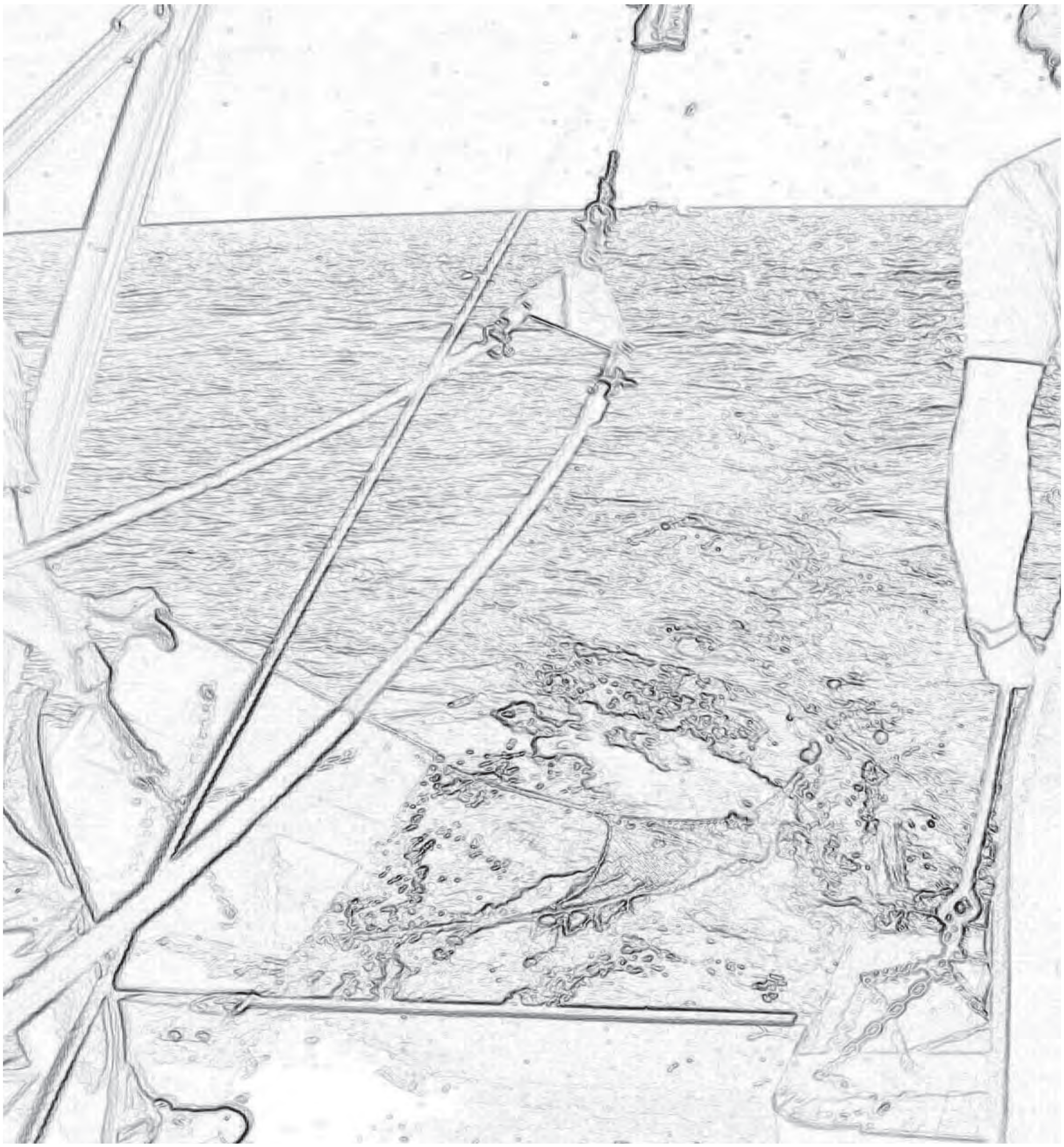
Chapter 6
Demersal Fishes
and Megabenthic Invertebrates



Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Marine fishes and invertebrates are conspicuous members of continental shelf habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Assemblages of bottom dwelling (demersal) fishes and relatively large (megabenthic), mobile invertebrates that live on the surface of the seafloor have been sampled extensively for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fish inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998, 2002, 2007). For the region surrounding the Point Loma Ocean Outfall (PLOO), the most common trawl-caught fishes include Pacific sanddab, longfin sanddab, Dover sole, hornyhead turbot, California tonguefish, plainfin midshipman, and yellowchin sculpin. Common trawl-caught invertebrates include various echinoderms (e.g., sea stars, sea urchins, sea cucumbers, and sand dollars), crustaceans (e.g., crabs and shrimp), molluscs (e.g., marine snails and octopuses), and other taxa.

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

The City of San Diego has been conducting trawl surveys in the area surrounding the present discharge site for the Point Loma Ocean Outfall (PLOO) since 1991. These surveys are designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of trawl-caught fish and invertebrate communities. This chapter presents analyses and interpretations of the demersal fish and megabenthic invertebrate data collected during 2008. A long-term analysis of changes in these communities from 1991 through 2008 is also presented.

Materials and Methods

Field Sampling

Trawl surveys were conducted at six fixed monitoring sites in the Point Loma region during 2008 (Figure 6.1). The six trawl stations, designated SD7, SD8, SD10, SD12, SD13, and SD14, are located along the 100-m depth contour, and encompass an area ranging from about 8 km north to 9 km south of the PLOO. A total of eight trawls were taken during two surveys in 2008. All six stations were sampled during the January (winter) survey, while sampling in July (summer) was limited to the two stations located nearest the outfall due to a resource exchange agreement to allow participation in the Bight'08 regional monitoring program (see Chapter 1). A single trawl was performed at each station during each survey using a 7.6-m Marinovich otter trawl fitted with a

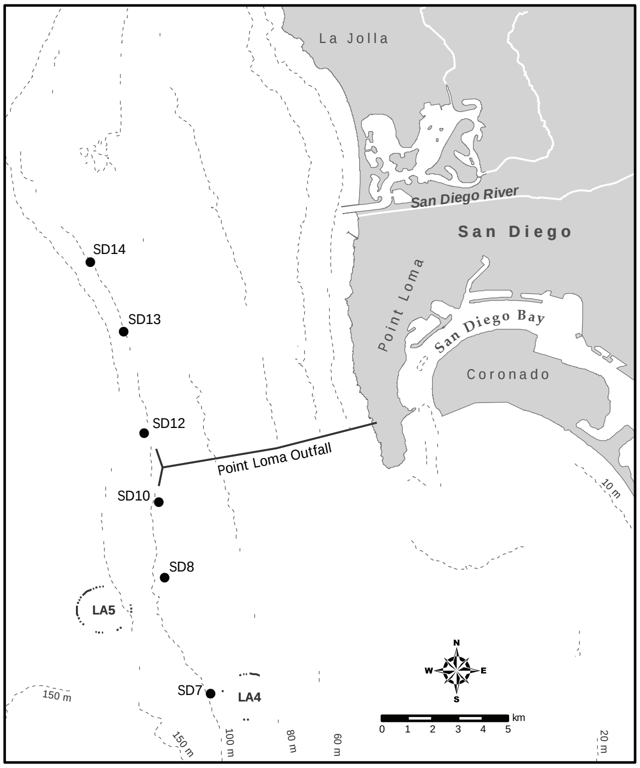


Figure 6.1
Otter trawl station locations, Point Loma Ocean Outfall Monitoring Program.

1.3-cm cod-end mesh net. The net was towed for 10 minutes bottom time at a speed of about 2.5 knots along a predetermined heading.

The total catch from each trawl was brought onboard ship for sorting and inspection. All fish and invertebrates captured were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned to the laboratory for further identification. For fishes, the total number of individuals and total biomass (kg, wet weight) were recorded for each species. Additionally, each individual fish was inspected for physical anomalies or indicators of disease (e.g., tumors, fin erosion, discoloration) as well as the presence of external parasites, and then measured to the nearest centimeter size class (standard lengths). For invertebrates, the total number of individuals per species was recorded.

Data Analyses

Populations of each fish and invertebrate species were summarized as percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence. In addition, species richness (number of species), total abundance, total biomass, and Shannon diversity index (H') were calculated for each station. For historical comparisons, the data were grouped as "nearfield" stations (SD10, SD12), "south farfield" stations (SD7, SD8), and "north farfield" stations (SD13, SD14). The two nearfield stations were those located closest to the outfall (i.e., within 1000 m of the north or south diffuser legs).

A long-term multivariate analysis of demersal fish communities in the region was performed using data collected from 1991 through 2008. However, in order to eliminate noise due to natural seasonal variation in populations, this analysis was limited to data for the July surveys only over these 18 years. PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (see Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking, and ordination by non-metric multidimensional scaling (MDS). The fish abundance data were square root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Because species composition was sparse at some stations, a "dummy" species with a value of one was added to all samples prior to computing similarities (see Clarke and Gorley 2006). SIMPER analysis was subsequently used to identify the individual species that distinguished each cluster group.

Results and Discussion

Fish Community

Thirty-four species of fish were collected in the area surrounding the PLOO in 2008 (Table 6.1, Appendix E.1). The total catch for the year was 1802 individuals, representing an average of about 225 fish per trawl. Pacific sanddabs were the dominant fish captured, occurring in every haul and accounting for 45% of the total number of fishes

Table 6.1

Demersal fish species collected in eight trawls in the PLOO region during 2008. PA=percent abundance; FO=frequency of occurrence; MAO=mean abundance per occurrence; MAH=mean abundance per haul.

Species	PA	FO	MAO	MAH	Species	PA	FO	MAO	MAH
Pacific sanddab	45	100	101	101	Blackbelly eelpout	<1	38	2	1
Yellowchin sculpin	11	88	29	25	Blackeye goby	<1	13	1	<1
Halfbanded rockfish	9	100	20	20	Blacktip poacher	<1	13	2	<1
Longspine combfish	6	100	14	14	Bluebanded ronquil	<1	25	2	<1
Plainfin midshipman	6	88	15	14	Bluespotted poacher	<1	13	1	<1
English sole	4	100	9	9	California lizardfish	<1	25	2	<1
Dover sole	4	100	9	9	California skate	<1	50	1	1
Shortspine combfish	3	100	7	7	California tonguefish	<1	38	2	1
Stripetail rockfish	3	63	10	6	Curlfin sole	<1	13	1	<1
Pink seaperch	1	75	4	3	Greenblotched rockfish	<1	63	1	1
Roughback sculpin	1	88	3	3	Longfin sanddab	<1	13	2	<1
California scorpionfish	1	63	3	2	Pink rockfish	<1	13	1	<1
Hornyhead turbot	1	75	3	2	Spotfin sculpin	<1	13	2	<1
Slender sole	1	50	4	2	Spotted cuskeel	<1	13	1	<1
Greenstriped rockfish	1	63	3	2	Spotted ratfish	<1	13	1	<1
Bigfin eelpout	<1	13	3	<1	Starry skate	<1	13	1	<1
Bigmouth sole	<1	38	3	1	White croaker	<1	13	2	<1

collected during the year. Halfbanded rockfish, longspine combfish, English sole, Dover sole, and shortspine combfish were also collected in every haul, but in much lower numbers. Other species collected frequently (≥75% of the trawls) included yellowchin sculpin, plainfin midshipman, pink seaperch, roughback sculpin, and hornyhead turbot. Pacific sanddabs averaged 101 fish per occurrence, while all other species averaged 29 or less with each contributing to no more than 11% of the total catch. The majority of species captured in the Point Loma region tended to be relatively small fish with an average length <20 cm (see Appendix E.1). Although larger species such as the California skate, starry skate, and spotted ratfish were also captured during the year, these skates and rays were relatively rare compared to species of bony fish.

During 2008, no more than 21 species of fish occurred in any one haul, and the corresponding diversity (H') values were all less than 2.2 (Table 6.2). Total abundance ranged from 100 to 438 fishes per haul; this variation tended to reflect differences in Pacific sanddab populations, which ranged between 43–247 fish per catch (Appendix E.2). Biomass varied widely from 4.7 to 13.5 kg per haul, with higher values coincident with either greater numbers of fishes or the large size of individual fish or fishes as expected. For example, the highest biomass measured during the year was 13.5 kg at station SD8 in January, which was due to both a large haul of Pacific sanddabs weighing 7 kg and two California skate with a combined weight of 2 kg (see Appendix E.3).

Large fluctuations in populations of a few dominant species have been the primary factor contributing to the high variation in fish community structure off Point Loma since 1991 (Figure 6.2, Figure 6.3). For example, species richness values for individual trawls performed within the PLOO region have ranged from 7 to 27 species, while total abundance per haul has varied from 44 to 2322 individuals/station/survey. These fluctuations in abundance have been greatest at stations SD10, SD12, SD13, and SD14 and generally reflect differences in populations of several dominant species. For example, the overall abundance has been low since January 2007 due to significantly fewer numbers of Pacific sanddabs, yellowchin sculpin, longspine combfish, Dover sole, and halfbanded rockfish captured during each survey at most stations.

Table 6.2

Summary of demersal fish community parameters for PLOO stations sampled during 2008. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight). ns=not sampled.

Station	Winter	Summer
Species Richness		
SD7	13	ns
SD8	19	ns
SD10	16	16
SD12	17	14
SD13	21	ns
SD14	18	ns
Survey Mean	17	15
Survey SD	3	1
Abundance		
SD7	156	ns
SD8	232	ns
SD10	200	196
SD12	100	188
SD13	292	ns
SD14	438	ns
Survey Mean	236	192
Survey SD	118	6
Diversity		
SD7	1.60	ns
SD8	1.96	ns
SD10	1.87	1.69
SD12	2.06	1.90
SD13	2.10	ns
SD14	1.57	ns
Survey Mean	1.86	1.79
Survey SD	0.23	0.15
Biomass		
SD7	6.4	ns
SD8	13.5	ns
SD10	5.1	4.8
SD12	4.7	5.2
SD13	10.1	ns
SD14	10.6	ns
Survey Mean	8.4	5.0
Survey SD	3.5	0.3

Moreover, patterns of change in the dominant species over time were generally similar among stations closest to the outfall and those at the northern sites. None of the observed changes appear to be associated with wastewater discharge.

Ordination and classification analyses of fish abundance data from 1991 through 2008 distinguished between nine main cluster groups or assemblages (cluster groups A–I; see Figure 6.4). These results indicate that the demersal fish community off Point Loma remains dominated by Pacific sanddabs, with differences in the relative abundance of this or other common species discriminating between the different cluster groups (see Table 6.3, Appendix E.2). During 2008, assemblages at stations SD10 and SD12 were similar to those that occurred during 2006 and 2007 at all of the stations except SD7 (see description of group H below). There do not appear to be any spatial or temporal patterns that can be attributed to the outfall or the onset of wastewater discharge. Instead, most differences in local fish assemblages appear to be more closely related to large-scale oceanographic events (e.g., El Niño conditions in 1998) or the unique characteristics of a specific station location. For example, fish assemblages at stations SD7 and SD8 located south of the outfall and not far from the LA-4 and LA-5 disposal sites, respectively, often grouped apart from the remaining trawl stations. The composition and main characteristics of each cluster group are described in the paragraphs that follow.

Cluster groups A–E comprised five unique assemblages, each represented by one or two station/survey entities (i.e., trawl catches), and accounting overall for <7% of the total number of trawls (Table 6.3). Although most of these groups were dominated by Pacific sanddabs, they were unique compared to the other assemblages (i.e., cluster groups F–I) in terms of lower total abundance, fewer species, and/or relatively high numbers of less common species (e.g, midshipman, rockfish). Cluster group A represented the assemblage from station SD10 sampled in 1997, which was characterized by the fewest species and fewest number of fish of all hauls (i.e., 7 species, 44 fish). Cluster groups B and C each consisted of assemblages from only two trawls; group B represented the catch from stations SD7 and SD8 sampled in 2001, while group C was comprised of trawls from station SD8 in 1994 and station SD14

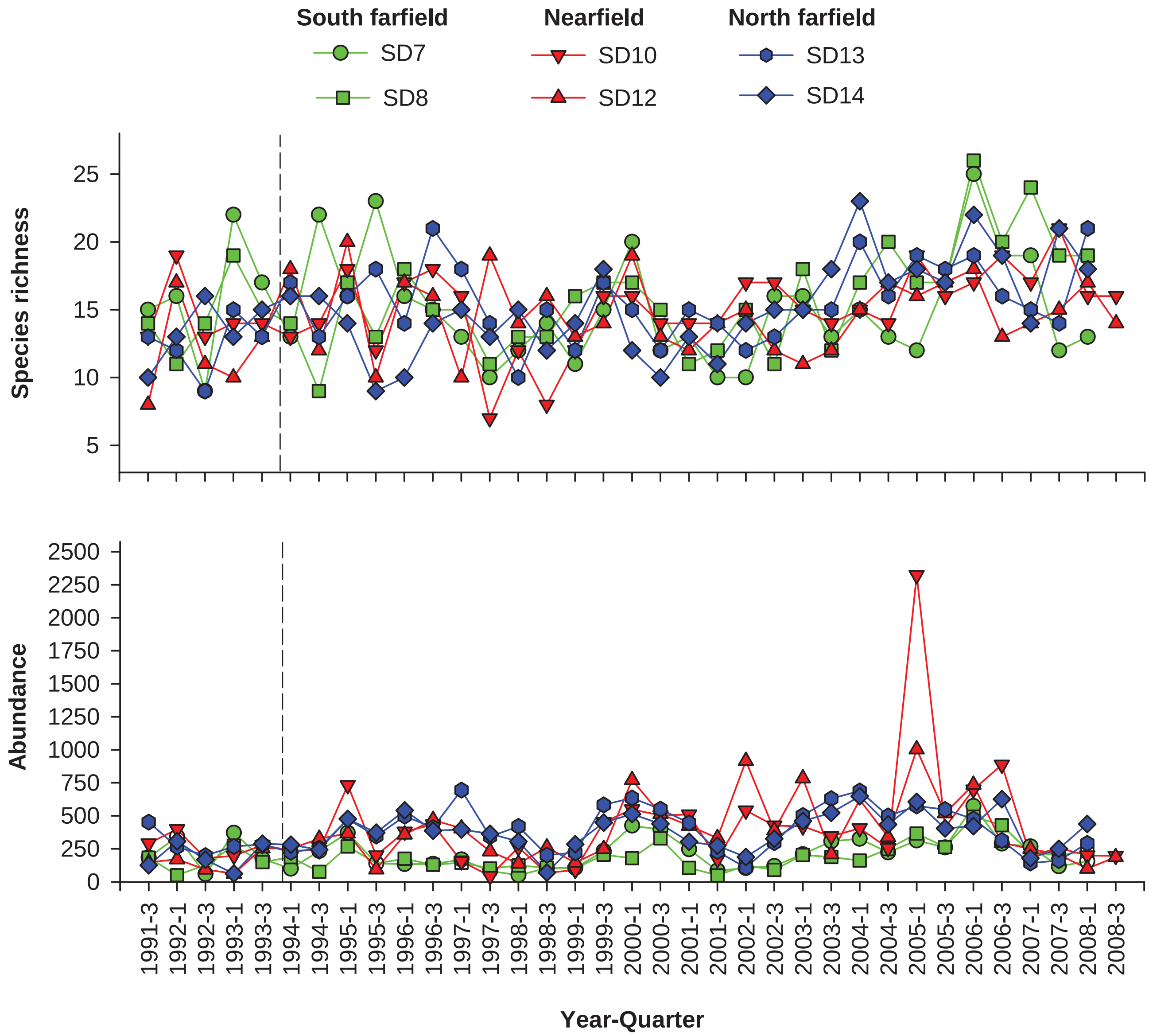


Figure 6.2

Species richness and abundance of demersal fish collected at each PLOO trawl station between 1991 and 2008. Data are total number of species and total number of individuals per haul, respectively. Dotted line represents initiation of wastewater discharge.

in 1998. These two assemblages were characterized by a few more species than group A (i.e., 11 species), and both also had low total abundances and relatively low numbers of Pacific sanddabs. Cluster group D represented the assemblage from station SD12 sampled in 1998. This assemblage was unique because it was dominated by a large population of plainfin midshipman. The second and third most abundant species comprising group D were Pacific sanddabs and Dover sole. Cluster group E represented the assemblage from station SD12 sampled in 1997, which had the highest number of species over all groups, and in addition to Pacific sanddabs was characterized by relatively high numbers of halfbanded rockfish and squarespot rockfish.

Cluster group F consisted of assemblages from a total of 18 trawls, all but three of which were from

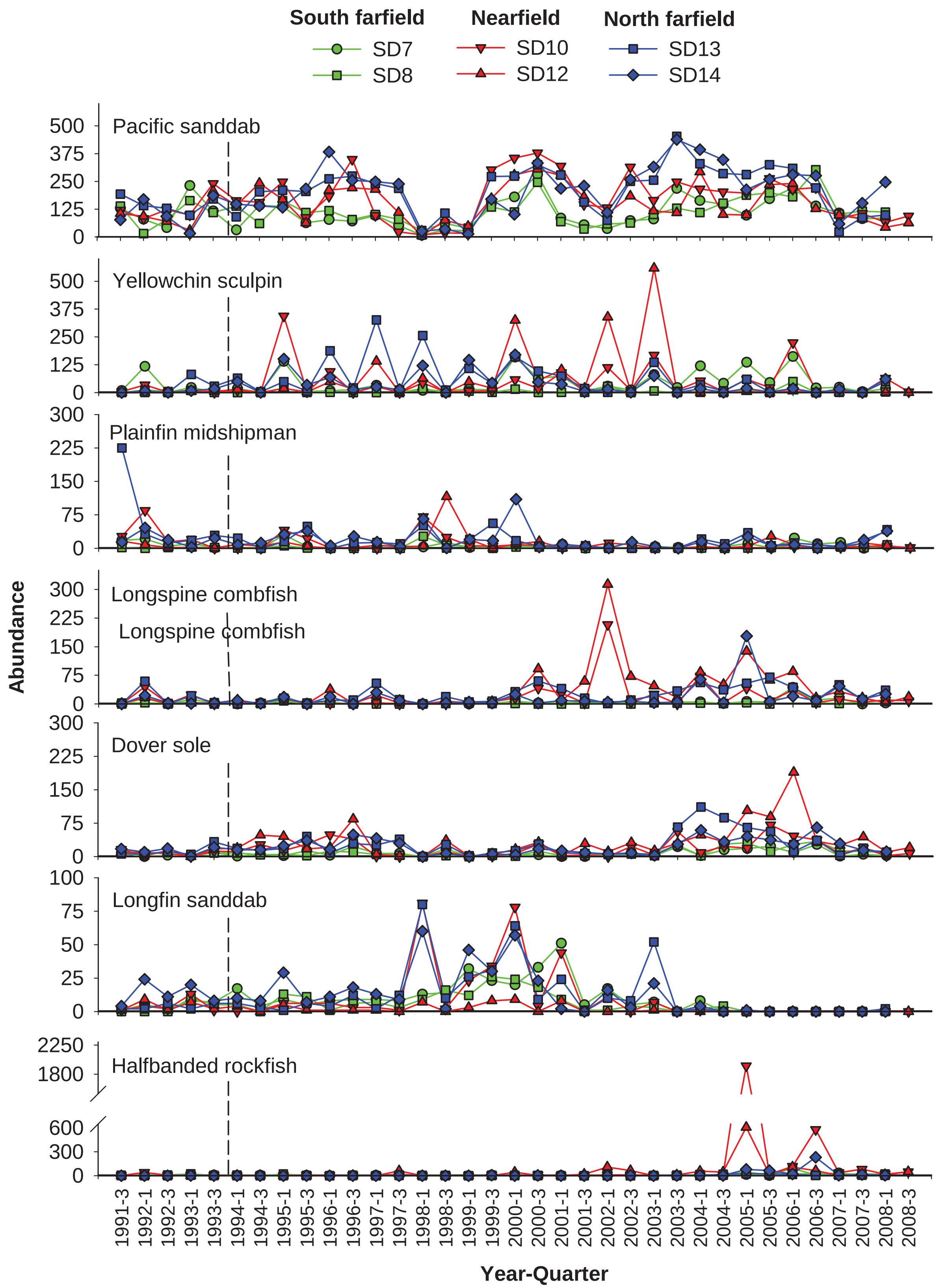


Figure 6.3
The seven most abundant fish species collected in the PLOO region from 1991 through 2008. Data are total number of individuals per haul. Dotted line represents initiation of wastewater discharge.

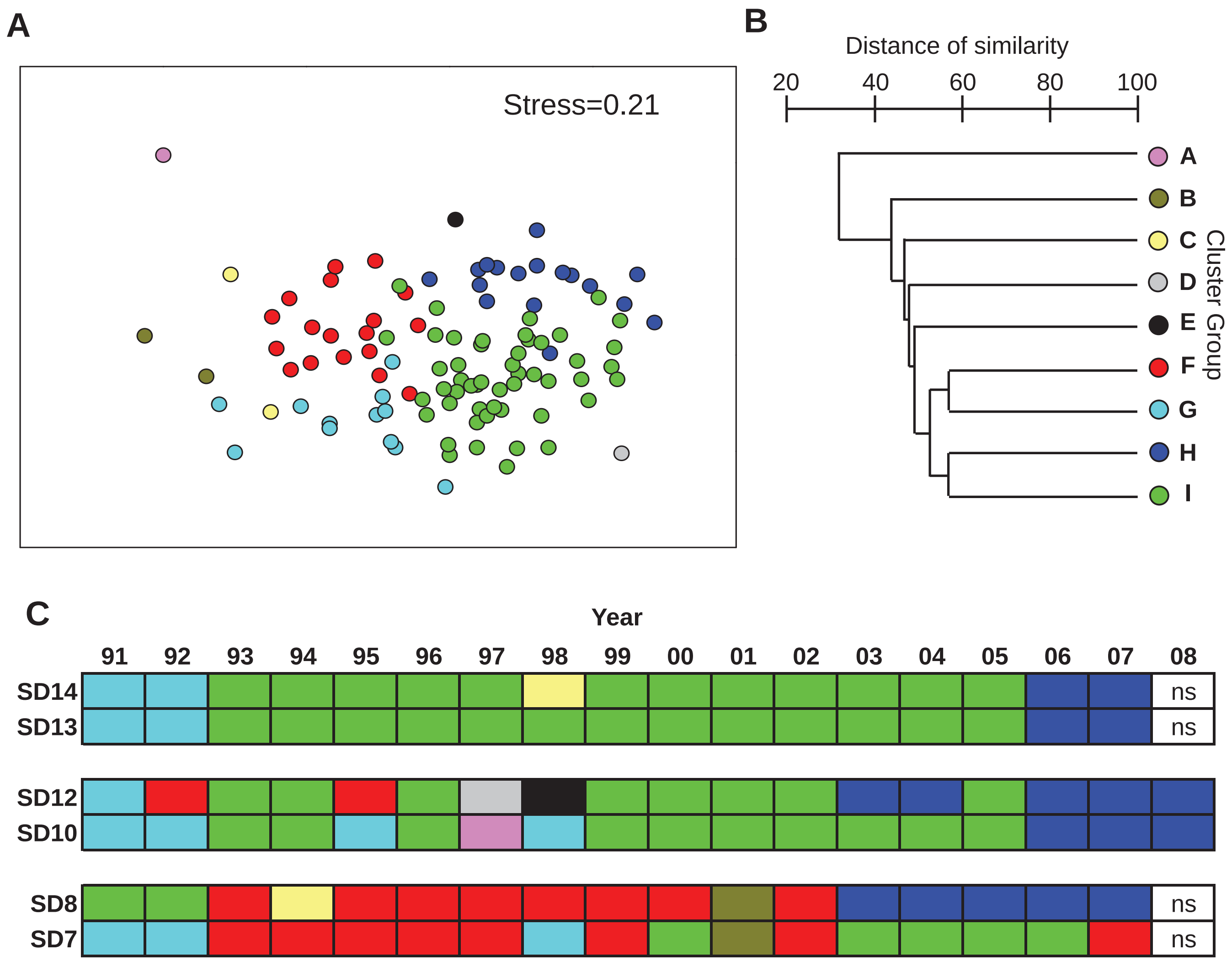


Figure 6.4
Results of classification analysis of demersal fish assemblages collected at PLOO stations SD7–SD14 between 1991 and 2008 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major cluster groups, and (C) a matrix showing distribution of cluster groups over time; ns=not sampled.

stations SD7 and SD8 between 1993 and 2002. Overall, this group was characterized by moderate numbers of fishes and different species. The Pacific sanddab was the dominant species in this group with an average of about 98 fish/haul, while the longfin sanddab and Dover sole were the next two most abundant species averaging ~8 fish/haul each. The relative abundances of the above two sanddab species, as well as halfbanded rockfish, shortspine combfish, California lizardfish, stripetail rockfish, plainfin midshipman, and squarespot rockfish distinguished this cluster group from all others (see Appendix E.4).

Cluster group G represented the assemblages from about 12% of all trawls. These included the trawl catches from station SD10 in 1995 and 1998, station SD7 in 1998, and almost all stations during 1991 and 1992. This group was characterized by relatively low species richness (~12 species/haul), moderate abundance (~185 fish/haul), and moderate numbers of Pacific sanddabs (~101 fish/haul). Also characteristic of this group were the plainfin midshipman and longfin sanddab, which averaged about 32 and 4 fish/haul, respectively. Other relatively abundant species included stripetail rockfish (~16 fish/haul) and Dover sole

Table 6.3

Description of cluster groups A–I defined in Figure 6.4. Data include number of hauls, mean species richness, mean total abundance, and mean abundance of the five most abundant species for each station group. Values that are underlined indicate species that were considered "characteristic" of that group according to SIMPER analyses (i.e., similarity/standard deviation ≥2.0).

	Cluster Groups								
	A	B	C	D	E	F	G	H	I
Number of hauls	1	2	2	1	1	18	12	17	50
Mean species richness	7	11	11	16	19	15	12	17	15
Mean abundance	44	68	74	261	231	149	185	310	360
Species	**Mean Abundance**								
Longfin sanddab	1.0	3.0	1.0			8.4	3.9	0.2	5.9
Pink seaperch	1.0	0.5	1.5	4.0	1.0	1.4	1.0	3.4	4.5
Gulf sanddab	1.0		1.0	5.0		0.2	0.3		0.7
Greenspotted rockfish	1.0				1.0	0.6	0.1		0.4
Spotfin sculpin	1.0		1.5			3.6		2.4	0.2
Halfbanded rockfish	16.0				60.0	2.3	0.5	69.5	7.2
Pacific sanddab	23.0	45.5	48.0	75.0	110.0	98.3	101.7	149.4	235.6
Dover sole		1.0	5.5	36.0	1.0	7.9	13.1	27.5	29.4
Yellowchin sculpin		5.0				3.8	2.9	0.6	17.0
Longspine combfish		2.5	2.0	7.0	2.0	0.6	1.2	11.0	14.1
Stripetail rockfish			7.5	1.0	5.0	2.7	16.5	2.3	13.0
Plainfin midshipman			1.5	116.0	4.0	1.6	32.3	3.9	9.3
Slender sole			0.5	2.0		1.0	0.5	6.8	5.4
Shortspine combfish					3.0	3.1	0.8	11.2	2.4
Greenblotched rockfish		0.5	1.5		8.0	0.7	0.3	0.5	1.3
California tonguefish		2.5			1.0	3.7	2.2	2.2	0.9
Bigmouth sole		2.5			1.0	1.2	0.4	0.6	0.8
California lizardfish		1.0				0.3	0.8	0.9	0.5
Roughback sculpin		1.5		2.0		0.3	0.3	0.2	0.4
Squarespot rockfish		0.5			23.0	0.1			
Vermilion rockfish					6.0				

(~13 fish/haul). The relative abundances of these four species distinguished this group from the others (Appendix E.4).

Cluster group H comprised the assemblages from the only two stations sampled during July 2008 survey (i.e., SD10, SD12), as well as from all stations except SD7 in 2006 and 2007, SD12 during 2003–2004, and SD8 between 2003 and 2005. This group was characterized by relatively high numbers of Pacific sanddabs (~149 fish/haul), halfbanded rockfish (69 fish/haul), and Dover sole (~27 fish/haul). The higher abundances of these species helped distinguish this group from all of the others (Appendix E.4).

Cluster group I may represent "normal" or "background" conditions in the PLOO region, representing assemblages from almost half (i.e., 48%) of all trawls included in the analysis. Most of these assemblages were sampled at stations around or north of the PLOO between 1993 and 2005 (i.e., stations SD10–SD14). The main exceptions occurred during and after the 1998 El Niño (i.e., 1997–1999). This group was characterized by the highest average numbers of Pacific sanddabs (~235 fish/haul) and the second highest average numbers of Dover sole (~29 fish/haul). The next three most abundant species in this group were yellowchin sculpin (17 fish/haul),

Table 6.4

Species of megabenthic invertebrates collected in eight trawls in the PLOO region during 2008. PA=percent abundance; FO=frequency of occurrence; MAO=mean abundance per occurrence; MAH=mean abundance per haul.

Species	PA	FO	MAO	MAH	Species	PA	FO	MAO	MAH
Lytechinus pictus	97	100	2181	2181	*Rossia pacifica*	<1	25	1	<1
Acanthoptilum sp	2	75	68	51	*Philine alba*	<1	25	2	<1
Luidia foliolata	<1	75	6	4	*Metridium farcimen*	<1	25	1	<1
Parastichopus californicus	<1	63	5	3	*Antiplanes catalinae*	<1	25	1	<1
Ophiura luetkenii	<1	63	6	4	*Pleurobranchaea californica*	<1	13	1	<1
Octopus rubescens	<1	63	1	1	*Paguristes bakeri*	<1	13	2	<1
Strongylocentrotus fragilis	<1	63	2	2	*Neosimnia barbarensis*	<1	13	2	<1
Thesea sp B	<1	38	1	1	*Megasurcula carpenteriana*	<1	13	1	<1
Spatangus californicus	<1	38	2	1	*Cancellaria crawfordiana*	<1	13	1	<1
Platymera gaudichaudii	<1	38	1	<1	*Armina californica*	<1	13	1	<1
Astropecten verrilli	<1	38	4	2	*Arctonoe pulchra*	<1	13	1	<1
Sicyonia ingentis	<1	25	5	1					

longspine combfish (~14 fish/haul), and stripetail rockfish (13 fish/haul). The higher numbers of these five species, plus moderate numbers of longfin sanddab, plainfin midshipman and halfbanded rockfish, distinguished group I from the other assemblages.

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the PLOO region during 2008. There were no incidences of fin rot, discoloration, skin lesions, tumors, or any other indicators of disease among fishes collected during the year. Evidence of parasitism was also very low for trawl-caught fishes off Point Loma. Although the copepod *Phrixocephalus cincinnatus* infected <2% of the Pacific sanddabs collected during the year, this eye parasite was found on fish collected during each survey, and at least once from each station. In addition, a single slender sole with an eye parasite was reported from station SD12 during the winter survey.

Invertebrate Community

A total of 18,021 megabenthic invertebrates (~2253 per trawl) representing 23 taxa were collected during 2008 (Table 6.4, Appendix E.5). As in previous years, the sea urchin *Lytechinus pictus* was the most abundant and most frequently captured species, occurring in all trawls and accounting for 97% of the total invertebrate abundance. Other common species that occurred in more than half of the hauls included the sea pen *Acanthoptilum* sp, the sea star *Luidia foliolata*, the sea cucumber *Parastichopus californicus*, the brittle star *Ophiura luetkenii*, the octopus *Octopus rubescens*, and the sea urchin *Strongylocentrotus fragilis*.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.5). Species richness ranged from 5 to 13 species per haul, diversity (H') values ranged from 0.02 to 1.02 per haul, and total abundance ranged from 55 to 6012 individuals per haul. Patterns in total invertebrate abundance tended to mirror variation in *L. pictus* populations (Appendix E.6). For example, stations SD7, SD8, and SD10 had much higher invertebrate abundances than the other four stations due to relatively large catches of *L. pictus* (i.e., ≥2500/haul). The low diversity values (≤1.02) for the region were due to the numerical dominance of this sea urchin. Dominance of *L. pictus* is typical for these types of habitats throughout the SCB (e.g., Allen et al. 1998).

Invertebrate species richness and abundances have varied over time (Figure 6.5). For example, species richness has ranged from 3 to 29 species per year since 1991, although patterns of change have been similar among stations. In contrast, changes in total abundance have differed greatly

Table 6.5
Summary of megabenthic invertebrate community parameters for PLOO stations sampled during 2008. Data are included for species richness (number of species), abundance (number of individuals), and diversity (H'). ns=not sampled.

Station	Winter	Summer
Species Richness		
SD7	6	ns
SD8	10	ns
SD10	9	11
SD12	5	13
SD13	6	ns
SD14	11	ns
Survey Mean	8	12
Survey SD	2	1
Abundance		
SD7	2516	ns
SD8	2524	ns
SD10	6012	4867
SD12	55	471
SD13	974	ns
SD14	602	ns
Survey Mean	2114	2669
Survey SD	2161	3108
Diversity		
SD7	0.05	ns
SD8	0.07	ns
SD10	0.02	0.05
SD12	0.43	1.02
SD13	0.37	ns
SD14	0.57	ns
Survey Mean	0.25	0.54
Survey SD	0.23	0.69

among the trawl stations. The average annual invertebrate catches have been consistently low at stations SD13 and SD14, while the remaining stations have demonstrated large fluctuations in abundance. These fluctuations typically reflect changes in *L. pictus* populations, as well as populations of *Acanthoptilum* sp, *S. fragilis*, the shrimp *Sicyonia ingentis*, and the sea star *Astropectin verrilli* (Figure 6.6). Additionally, abundances of *L. pictus* and *A. verrilli* are typically much lower at the two northern sites, which likely reflect differences in sediment composition (e.g., fine sands vs. mixed coarse/fine sediments, see Chapter 4). None of the observed variability in the trawl-caught invertebrate community appeared related to the discharge of wastewater from the PLOO.

Summary and Conclusions

Pacific sanddabs continued to dominate fish assemblages surrounding the Point Loma Ocean Outfall during 2008 as they have for many years. This species occurred at all stations and accounted for 45% of the total fish catch. Other characteristic, but less abundant species of fish included halfbanded rockfish, longspine combfish, English sole, Dover sole, shortspine combfish, yellowchin sculpin, plainfin midshipman, pink seaperch, roughback sculpin, and hornyhead turbot. Most of these common fishes were relatively small, averaging less than 20 cm in length. Although the composition and structure of the fish assemblages varied among stations, most differences were due to fluctuations in Pacific sanddab populations.

Assemblages of megabenthic invertebrates in the region were similarly dominated by a single species, the sea urchin *Lytechinus pictus*. Variations in overall community structure of the trawl-caught invertebrates generally reflect changes in the abundance of this urchin, as well as several other dominant species. These other species include the sea pen *Acanthoptilum* sp, the sea star *Luidia foliolata*, the sea cucumber *Parastichopus californicus*, the brittle star *Ophiura luetkenii*, the octopus *Octopus rubescens*, and the sea urchin *Strongylocentrotus fragilis*.

Overall, results of the 2008 trawl surveys provide no evidence that wastewater discharged through the PLOO has affected either demersal fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of trawl-caught fishes and invertebrates were similar at stations located near the outfall and farther away. These results are supported by the findings of another recent assessment of these communities off San Diego

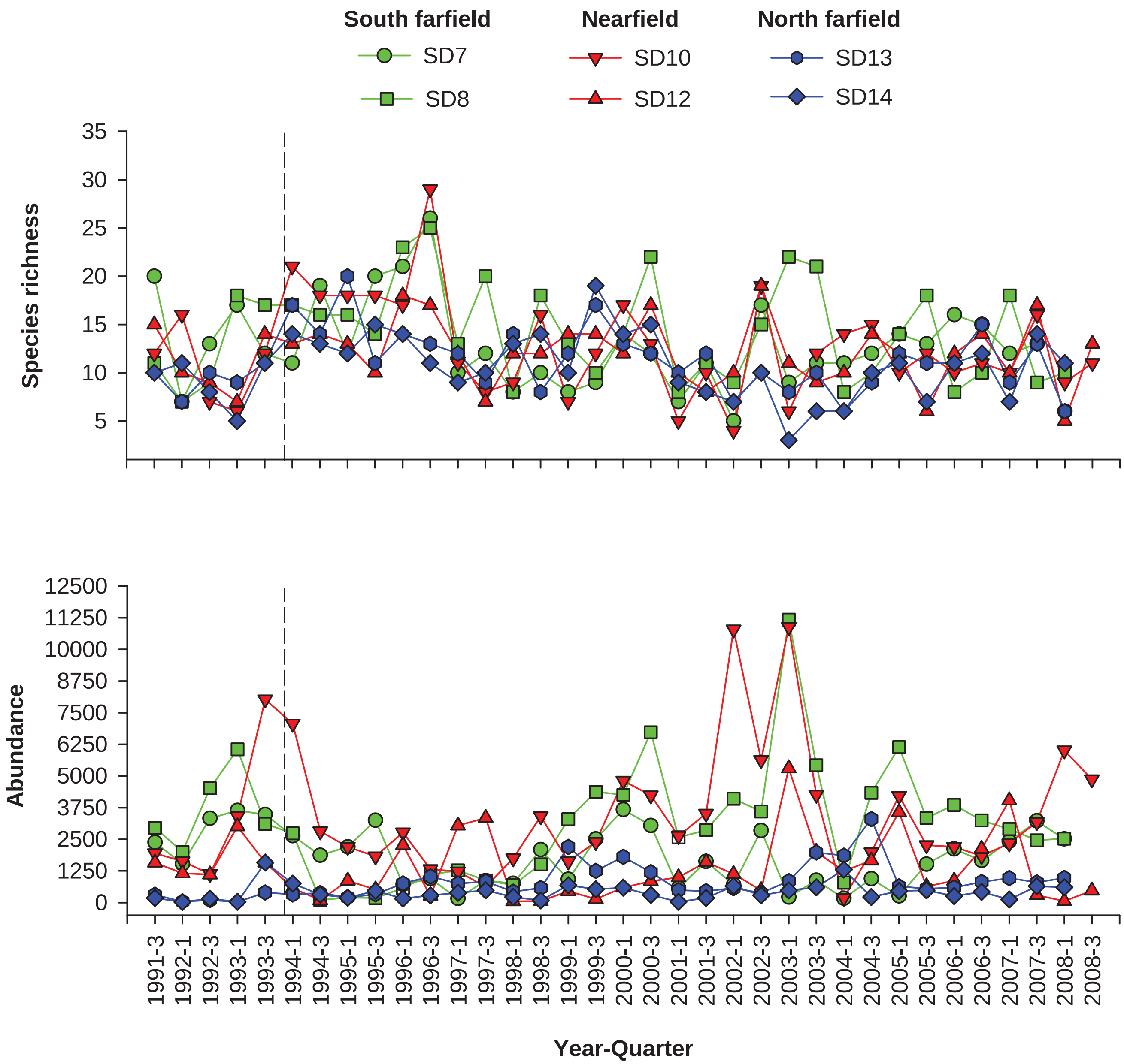


Figure 6.5

Species richness and abundance of megabenthic invertebrates collected at each PLOO trawl station between 1991 and 2008. Data are total number of species and total number of individuals per haul, respectively. Dotted line represents initiation of wastewater discharge.

(City of San Diego 2007). Significant changes in these communities appear most likely to be due to natural factors such as changes in ocean water temperatures associated with large-scale oceanographic events (e.g., El Niño or La Niña) or to the mobile nature of many of resident species. Finally, the absence of disease or other physical abnormalities in local fishes suggests that their populations continue to be healthy off Point Loma.

Literature Cited

Allen, M.J. (1982). Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D. dissertation. University of California, San Diego. La Jolla, CA.

Allen, M.J. (2005). The check list of trawl-caught fishes for Southern California from depths of

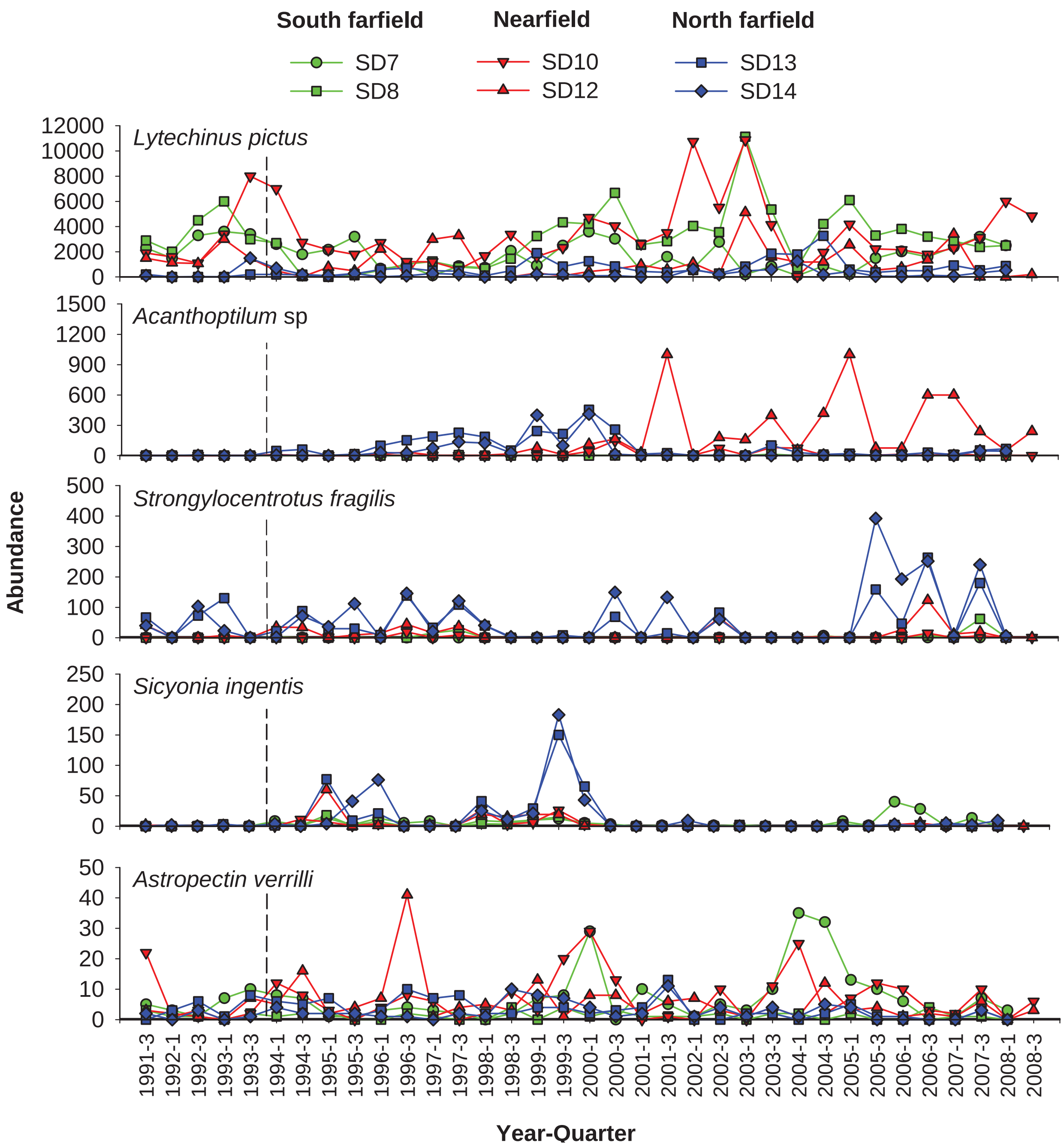


Figure 6.6

The five most abundant megabenthic species collected in the PLOO region from 1991 through 2008. Data are total number of individuals per haul. Dotted line represents initiation of wastewater discharge.

2–1000 m. Southern California Research Project, Westminister, CA.

Allen, M.J., S.L. Moore, K.C. Schiff, S.B. Weisberg, D. Diener, J.K. Stull, A. Groce, J. Mubarak, C.L. Tang, and R. Gartman. (1998). Southern California Bight 1994 Pilot Project: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L.

Moore, D.W. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. (2002). Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., T. Mikel, D. Cadien, J.E. Kalman, E.T. Jarvis, K.C. Schiff, D.W. Diehl, S.L. Moore, S. Walther, G. Deets, C. Cash, S. Watts, D.J. Pondella II, V. Raco-Rands, C. Thomas, R. Gartman, L. Sabin, W. Power, A.K. Groce, and J.L. Armstrong. (2007). Southern California Bight 2003 Regional Monitoring Program: IV. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Costa Mesa, CA.

City of San Diego. (2007). Appendix E. Benthic Sediments and Organisms. In: Application for Renewal of NPDES CA0107409 and 301(h) Modified Secondary Treatment Requirements, Point Loma Ocean Outfall. Volume IV, Appendices A thru F. Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology, 18: 117–143.

Clarke, K.R. and R.N. Gorley. (2006). Primer v6: User Manual/Tutorial. PRIMER-E: Plymouth.

Cross, J.N., J.N. Roney, and G.S. Kleppel. (1985). Fish food habitats along a pollution gradient. California Fish and Game, 71: 28–39.

Cross, J.N. and L.G. Allen. (1993). Chapter 9. Fishes. In: M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 459–540.

Eschmeyer, W.N. and E.S. Herald. (1998). A Field Guide to Pacific Coast Fishes of North America. Houghton and Mifflin Company, New York.

Helvey, M. and R.W. Smith. (1985). Influence of habitat structure on the fish assemblages associated with two cooling-water intake structures in southern California. Bulletin of Marine Science, 37: 189–199.

Karinen, J.B., B.L. Wing, and R.R. Straty. (1985). Records and sightings of fish and invertebrates in the eastern Gulf of Alaska and oceanic phenomena related to the 1983 El Niño event. In: W.S. Wooster and D.L. Fluharty (eds.). El Niño North: El Niño Effects in the Eastern Subarctic Pacific Ocean. Washington Sea Grant Program. p 253–267.

Murawski, S.A. (1993). Climate change and marine fish distribution: forecasting from historical analogy. Transactions of the American Fisheries Society, 122: 647–658.

[SCAMIT] The Southern California Association of Marine Invertebrate Taxonomists. (2008). A taxonomic listing of soft bottom macro- and megabenthic invertebrates from infaunal and epibenthic monitoring programs in the Southern California Bight; Edition 5. SCAMIT. San Pedro, CA.

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. Australian Journal of Ecology, 18: 63–80.

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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 Point Loma Ocean Outfall (PLOO) monitoring program to assess the accumulation of contaminants in their tissues. Bioaccumulation of contaminants in fish occurs through the biological uptake and retention of chemical contaminants derived via various exposure pathways (U.S. EPA 2000). The main exposure routes for demersal fishes include uptake of dissolved chemicals in seawater and the ingestion and assimilation of pollutants contained in different food sources (Rand 1995). Because of their proximity to seafloor sediments, these fish may also accumulate contaminants through ingestion of suspended particulates or sediments that contain pollutants. For this reason, the levels of many contaminants in the tissues of demersal 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 Point Loma ocean monitoring program consists of two components: (1) liver tissues are analyzed for trawl-caught fishes; (2) muscle tissues are analyzed for fishes collected by hook and line (rig fishing). Species of fish collected by trawling activities (see Chapter 6) are representative of the general demersal fish community, and certain species are targeted based on their prevalence in the community and therefore ecological significance. The chemical analysis of liver tissues in these fish is especially important for assessing population effects since this is the organ where contaminants typically concentrate (i.e., bioaccumulate). In contrast, fishes targeted for capture by rig fishing represent species that are characteristic of a typical sport fisher's catch, and are therefore considered of recreational and commercial importance and more directly relevant to human health issues. Consequently, muscle tissue is analyzed from these fishes because it is the tissue most often consumed by humans, and therefore the results may have implications related to public health concerns and policy.

This chapter presents the results of all tissue analyses that were performed on fishes collected in the PLOO region during 2008. All liver and muscle samples were analyzed for contaminants as specified in the NPDES discharge permits that govern the PLOO monitoring program (see Chapter 1). Most of these contaminants are also sampled for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program. NOAA initiated this program to detect and monitor changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of environmental concern (Lauenstein and Cantillo 1993).

Materials and Methods

Field Collection

Fishes were collected during October of 2008 from four trawl zones (see below) and two rig fishing stations (Figure 7.1). Pacific sanddabs (*Citharichthys sordidus*) and English sole (*Parophrys vetulus*) were collected for analysis of liver tissues from the trawling zones, while several species of rockfish (*Sebastes* spp) were collected for analysis of muscle tissues at the two rig fishing stations (see Table 7.1). The rockfish species analyzed included copper rockfish (*S. caurinus*), greenblotched rockfish (*S. rosenblatti*), and vermilion rockfish (*S. miniatus*), although the mixed rockfish samples may have included additional species of *Sebastes*.

Each trawl zone represents an area centered on a specific site or sites. Zone 1 includes the two 1-km areas surrounding nearfield stations SD10 and SD12, which are located just south and north of the PLOO, respectively. Zone 2 includes the two 1-km areas surrounding the two northern farfield stations, SD13 and SD14. Zone 3 represents the 1-km area surrounding station SD8, which is located south of the outfall near the LA-5 dredged materials disposal site. Zone 4 is the 1-km area surrounding station SD7, which is located several kilometers south of the outfall and near the old (non-active) LA-4 disposal site. All trawl-caught fishes

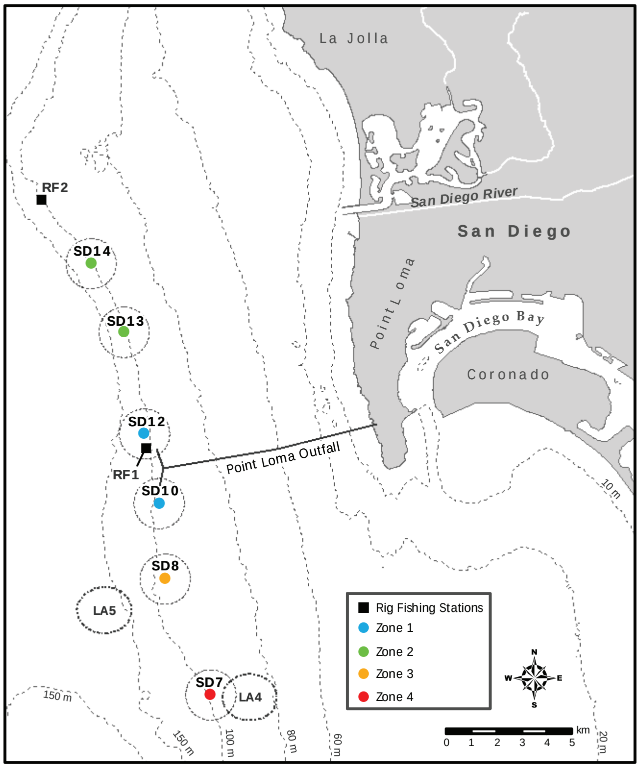

Figure 7.1
Otter trawl stations/zones and rig fishing stations for the Point Loma Ocean Outfall Monitoring Program. See text for description of zones.

were collected following City of San Diego guidelines (see Chapter 6 for a description of collection methods). Efforts to collect the targeted 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 station location using standard rod and reel procedures; fishing effort was limited to 5 hours at each of these stations.

In order to facilitate the collection of sufficient tissue for subsequent chemical analysis, only fish ≥13 cm in standard length were retained. These fish were sorted into no more than three composite samples per station, each containing a minimum of three individuals. Composite samples were typically made up of a single species; the only exceptions were samples that consisted of mixed species of rockfish. All fish collected 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 held in the freezer at -80°C until dissection and tissue processing.

Table 7.1
Species of fish collected from each PLOO trawl zone or rig fishing station (RF1–RF2) during October 2008. Comp=composite; Pacific sanddab=PS; English sole=ES; copper rockfish=CRF; vermilion rockfish=VRF; greenblotched rockfish=GBRF; mixed rockfish=MRF.

Station/Zone	Comp 1	Comp 2	Comp 3
Zone 1	PS	PS	ES
Zone 2	PS	PS	PS
Zone 3	PS	PS	PS
Zone 4	PS	PS	PS
RF1	CRF	MRF	GBRF
RF2	VRF	VRF	MRF

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 (2004) for additional details. Prior to dissection, each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus. The standard length (cm) and weight (g) of each fish were recorded (Appendix F.1). Dissections were carried out on Teflon® pads that were cleaned between samples. The tissues (liver or muscle) from each dissected fish were then 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 for analysis within 10 days of dissection.

The chemical constituents analyzed for each tissue sample were measured on a wet weight basis, and included trace metals, chlorinated pesticides, and polychlorinated biphenyl compounds (PCBs) (see Appendix F.2). Metals were measured in units of mg/kg and are expressed herein as parts per million (ppm), while pesticides and PCBs were measured as µg/kg and expressed as parts per billion (ppb). Totals for PCBs, PAHs, and the pesticides DDT, BHC (=lindane and derivatives), and chlordane were calculated as the sum of the detected constituents (i.e., total PCB=sum of all congeners detected); detected values for each individual constituent are listed in Appendix F.3. This report includes estimated values for some

Table 7.2

Summary of metals, pesticides, total PCBs, and lipids in liver tissues of fishes collected at PLOO trawl zones during 2008. Data include the number of detected values (n), as well as minimum (Min), maximum (Max), and mean detected concentrations for each species.The number of samples per species is indicated in parentheses; nd=not detected.

	English sole (1)		Pacific sanddab (11)					
Parameter	**n**	**Min/Max**	**n**	**Min**	**Max**	**Mean**	**% Detected**	**Max**
Metals (*ppm*)								
Aluminum	nd	—	7	3	22	16	58	22
Antimony	nd	—	10	0.2	0.6	0.4	83	0.6
Arsenic	1	6.79	11	1.19	3.40	2.50	100	6.79
Barium	1	0.12	11	0.17	0.48	0.29	100	0.48
Beryllium	nd	—	1	0.104	0.104	0.104	8	0.104
Cadmium	1	0.71	11	2.58	11.80	6.17	100	11.80
Chromium	1	0.2	11	0.2	0.4	0.3	100	0.4
Copper	1	4.8	11	5.0	9.6	6.9	100	9.6
Iron	1	115	11	45	157	88	100	157
Lead	1	2.6	7	0.2	0.3	0.3	67	2.6
Manganese	1	1.0	11	0.7	1.2	0.9	100	1.2
Mercury	1	0.06	11	0.04	0.22	0.10	100	0.22
Nickel	1	0.2	6	0.2	0.4	0.3	58	0.4
Selenium	1	2.15	11	0.48	1.10	0.77	100	2.15
Silver	1	0.15	3	0.06	0.20	0.11	33	0.20
Thallium	nd	—	6	0.6	0.7	0.6	50	0.7
Tin	1	2.7	11	4.1	4.9	4.5	100	4.9
Zinc	1	65.40	11	24.50	39.20	31.37	100	65.40
Pesticides (*ppb*)								
HCB	nd	—	10	4.5	6.6	5.5	83	6.6
Total Chlordane	nd	—	2	10	14	12	17	14
Total DDT	1	82.0	11	115.0	830.3	455.9	100	830.3
Total PCB (*ppb*)	1	69.4	11	64.3	606.0	254.0	100	606.0
Lipids (*% wt*)	1	10.1	11	37.0	45.2	42.4	100	45.2

parameters determined to be present in a sample with high confidence (i.e., peaks confirmed by mass-spectrometry), but that otherwise occurred at levels below the method detection limit (MDL). A detailed description of the protocols for chemical analyses is available in City of San Diego (2009).

Results and Discussion

Contaminants in Trawl-Caught Fishes

Metals

Eleven metals occurred in 100% of the liver samples analyzed from trawl-caught fishes in 2008, including arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc (Table 7.2). Another seven metals (i.e., aluminum, antimony, beryllium, lead, nickel, silver, thallium) were also detected, but less frequently at rates between 8–83%. Concentrations of most metals were <15 ppm. Exceptions occurred for aluminum, iron, and zinc, which all had concentrations >20 ppm in at least one sample. Of all the metals detected, iron was present in the highest concentrations in both species of fish that were analyzed (i.e., Pacific sanddabs and English sole). Comparisons of the frequently detected metals from sanddab samples collected from zone 1 located nearest the discharge site to those located farther away (i.e., zones 2–4) suggest

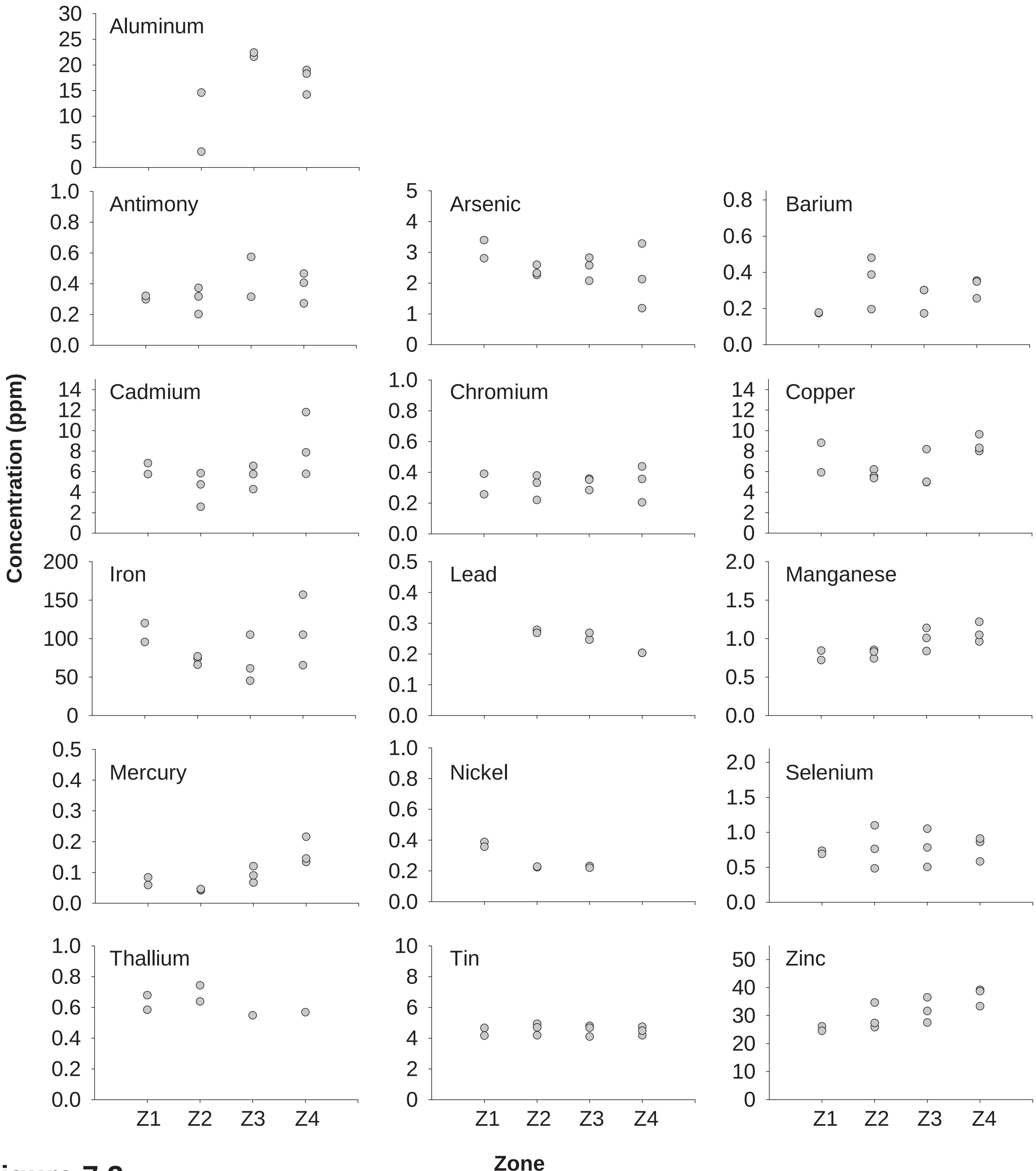

Figure 7.2
Concentrations of frequently detected metals in liver tissues of Pacific sanddabs collected from each PLOO trawl zone (Z1–Z4) during 2008. Only two Pacific sanddabs samples were collected from zone 1; otherwise missing values=non-detects.

no clear relationship between contaminant loads in fish tissues and proximity to the outfall (Figure 7.2). Only nickel concentrations appeared to be higher in sanddab samples collected near the outfall than at the other monitoring sites. However, all tissue samples had very low nickel concentrations compared to those reported previously for the PLOO region (see City of San Diego 2007a).

Pesticides

Only three chlorinated pesticides were detected in trawl-caught fishes during 2008 (Table 7.2), each at concentrations substantially less than historical highs (see City of San Diego 2007a). Individual components of total chlordane and total DDT are listed in Appendix F.2, while detected values are included in Appendix F.3. DDT was detected in all tissue samples with concentrations ranging between 82 and 830 ppb. Hexachlorobenzene (HCB) was also detected frequently (83% of samples), but at much lower concentrations (i.e., <7 ppb). Chlordane, which consisted solely of trans-nonachlor, was also found in relatively low concentrations (≤14 ppb), and in only two sanddab samples. As with metals, there was no clear relationship between concentrations of these pesticides and proximity to the outfall (Figure 7.3).

PCBs

Polychlorinated biphenyl compounds occurred in every liver tissue sample analyzed during the year. All PCB congeners that were detected are summarized in Appendix F.3. Overall, total PCB concentrations were highly variable in fish livers, ranging from 64 to 606 ppb (Table 7.2). These values were an order of magnitude less than reported previously for the region (e.g., see City of San Diego 2007a), and there was no clear relationship between PCB accumulation in fish livers and proximity to the outfall (Figure 7.3). Instead, the highest PCB concentration was detected in a sanddab sample from zone 3, a location where PCB concentrations have historically been higher in several species of fish (e.g., see City of San Diego 2003, 2007a); these elevated PCBs have been found to be most likely associated with sediment deposition targeted for the LA-5 dredge materials dumpsite (Parnell et al. 2008).

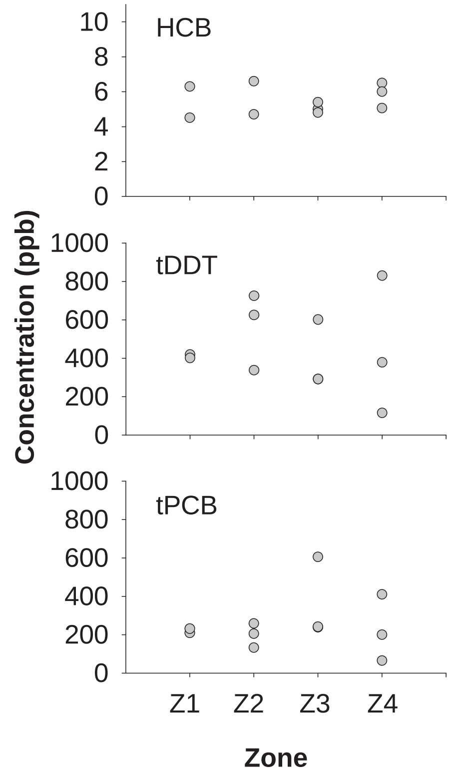

Figure 7.3
Concentrations of hexachlorobenzene (HCB), total DDT (tDDT), and total PCB (tPCB) in liver tissues of Pacific sanddabs collected from each PLOO trawl zone (Z1–Z4) during 2008. Only two Pacific sanddabs samples were collected from zone 1; otherwise missing values=non-detects.

Contaminants in Fishes Collected by Rig Fishing

Arsenic, barium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc occurred in 100% of the muscle tissue samples collected from various species of rockfish at the two rig fishing stations in 2008 (Table 7.3). In addition to these 10 metals, aluminum, antimony, beryllium, cadmium, silver, and thallium were also detected, but less frequently at detection rates of 17–83%. The metals present in the highest concentrations were aluminum (up to 3.11 ppm), arsenic (up to 5.75 ppm), iron (up to 6.76 ppm), and zinc (up to 5.72 ppm).

The pesticide DDT was detected in 100% of the muscle samples, while hexachlorobenzene (HCB) and PCB were detected in 50 and 67% of the samples, respectively (Table 7.4). Each of these contaminants was detected in relatively low concentrations (i.e., <15 ppb).

To address human health concerns, contaminant concentrations found in the muscle tissues of fishes collected as part of the PLOO monitoring program were compared to state, national, and international limits and standards (see Table 7.3,7.4). These include: 1) the California Office of Environmental Health Hazard Assessment (OEHHA), which has developed fish contaminant goals for chlordane, DDT, methylmercury, PCBs, and selenium (Klasing and Brodberg 2008); 2) the United States Food and Drug Administration (U.S. FDA), which has set limits on the amount of mercury, total DDT, and chlordane in seafood that is to be sold for human

Table 7.3

Summary of metals in muscle tissues of fishes collected at PLOO rig fishing stations during 2008. Data include the number of detected values (n), as well as minimum (Min), maximum (Max), and mean detected concentrations for each species. Concentrations are expressed as parts per million (ppm); the number of samples per species is indicated in parentheses; nd=not detected. Data are compared to OEHHA fish contaminant goals (OEHHA), U.S. FDA action limits (AL), and median international standards (IS) for parameters where these exist. Bold values meet or exceed these standards. See Appendix F.2 for names of each metal represented by periodic table symbol.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Mn	Hg	Se	Ag	Tl	Sn	Zn
Copper rockfish (1)																
n	nd	1	1	1	nd	nd	1	1	1	1	1	1	nd	nd	1	1
Min/Max	—	0.2	**1.42**	0.08	—	—	0.1	0.6	3	0.1	0.18	**0.57**	—	—	1.8	4.93
Greenblotched rockfish (1)																
n	nd	1	1	1	1	1	1	1	1	1	1	1	nd	nd	1	1
Min/Max	—	0.3	**5.75**	0.13	0.042	0.08	0.2	0.8	5	0.2	**0.28**	**0.34**	—	—	2.0	4.46
Mixed rockfish (2)																
n	1	1	2	2	nd	nd	2	2	2	2	2	2	nd	2	2	2
Min	2	0.2	**1.42**	0.09	—	—	0.2	1.1	5	0.1	0.13	**0.39**	—	0.4	1.7	3.01
Max	2	0.2	**2.44**	0.11	—	—	0.2	1.1	5	0.2	**0.29**	**0.50**	—	0.6	2.0	5.72
Mean	2	0.2	**1.93**	0.10	—	—	0.2	1.1	5	0.1	0.21	**0.45**	—	0.5	1.8	4.36
Vermilion rockfish (2)																
n	2	2	2	2	nd	nd	2	2	2	2	2	2	2	2	2	2
Min	3	0.2	1.04	0.09	—	—	0.1	0.7	6	0.2	0.12	0.27	0.05	0.7	2.0	3.32
Max	3	0.2	**1.74**	0.10	—	—	0.2	0.9	7	0.3	0.13	**0.31**	0.05	0.8	2.1	3.83
Mean	3	0.2	1.39	0.10	—	—	0.2	0.8	7	0.3	0.12	0.29	0.05	0.8	2.1	3.57
All species:																
% Detected	50	83	100	100	17	17	100	100	100	100	100	100	33	67	100	100
Max	3	0.3	**5.75**	0.13	0.042	0.08	0.2	1.1	7	0.3	**0.29**	**0.57**	0.05	0.8	2.1	5.72
OEHHA											0.22	7.4				
AL*											1.0					
IS*			1.4			1	1	20			0.5	0.3			175	70

*From Mearns et al. 1991. U.S. FDA action limits for mercury and all international standards are for shellfish, but are often applied to fish.

consumption (see Mearns et al. 1991); 3) international standards for acceptable concentrations of various metals and DDT (see Mearns et al. 1991). Of the contaminants detected in muscle tissues of fishes collected off Point Loma during 2008, the metals arsenic and selenium occurred in concentrations slightly higher than median international standards, while mercury (as a proxy for methylmercury) exceeded the OEHHA fish contaminant goal. Exceedences for arsenic and selenium occurred in every species of fish, while the exceedance for mercury occurred only in greenblotched and vermilion rockfish samples.

In addition to addressing public health issues, spatial patterns were analyzed for HCB, DDT, and total PCB concentrations, as well as for all metals that occurred frequently in fish muscle tissues (Figure 7.4). Overall, concentrations of HCB, DDT, PCB, and various metals in the muscles of fishes captured at the two rig fishing stations were fairly similar, which suggests that there was no relationship to the outfall discharge site. However, comparisons of contaminant loads in fishes from these stations should be considered with caution since different species were collected at the two sites, and the bioaccumulation of contaminants may differ between species because

Table 7.4

Summary of chlorinated pesticides, total PCB, and lipids in muscle tissues of fishes collected at PLOO rig fishing stations during 2008. Data include the number of detected values (n), as well as minimum (Min), maximum (Max), and mean detected concentrations for each species. HCB=hexachlorobenzene; tDDT=total DDT; tPCB=total PCB. The number of samples per species is indicated in parentheses. Data are compared to OEHHA fish contaminant goals (OEHHA), U.S. FDA action limits (AL), and median international standards (IS) for parameters where these exist. Bold values meet or exceed these standards.

	HCB (ppb)	tDDT (ppb)	tPCB (ppb)	Lipids (% wt)
Copper rockfish (1)				
n	nd	1	1	1
Min/Max	—	6.3	1.5	0.5
Greenblotched rockfish (1)				
n	1	1	1	1
Min/Max	15.0	9.7	1.3	0.3
Mixed rockfish (2)				
n	1	2	1	2
Min	0.4	0.9	0.5	0.2
Max	0.4	7.5	0.5	0.5
Mean	0.4	4.2	0.5	0.3
Vermilion rockfish (2)				
n	1	2	1	2
Min	0.4	5.0	1.3	0.1
Max	0.4	8.2	1.3	0.7
Mean	0.4	6.6	1.3	0.4
All species:				
% Detected	50	100	67	100
Max	15.0	9.7	1.5	0.7
OEHHA		21	3.6	
AL*		5000		
IS*		5000		

* From Mearns et al. 1991. U.S. FDA action limits and all international standards are for shellfish, but are often applied to fish.

of differences in physiology, diet, and exposure to contaminant sources associated with migration habits and/or other large scale movements. This potential problem may be minimal in the Point Loma region as all fish specimens sampled in 2008 belong to the same family (Scorpaenidae), have similar life histories (i.e., bottom dwelling tertiary carnivores), and are therefore likely to have similar mechanisms of exposure to and uptake of contaminants (e.g., direct contact with sediments, similar food sources). However, species such as those reported herein are known to traverse large areas (M. Love, pers. comm.), and therefore may be exposed to contaminants present instead in other locations.

Summary and Conclusions

Several trace metals, the pesticides DDT, HCB, and chlordane, and a combination of PCB congeners were detected in liver tissue samples collected from two different species of flatfish (i.e., Pacific sanddabs, English sole) in the PLOO region during 2008. Many of the same contaminants were also detected in muscle tissues of several species of rockfish (*Sebastes* spp) sampled during the year, although often less frequently and/or in lower concentrations. Tissue contaminant values ranged widely in fishes collected within and among stations. However, all contaminant concentrations were within the range of values reported previously for the Southern California Bight (SCB) (e.g., Mearns et al. 1991, Allen et al. 1998). In addition, concentrations of these contaminants were generally similar to those reported previously by the City of San Diego for the Point Loma region (e.g., City of San Diego 2003, 2007a), as well as for other long-term monitoring sites for the South Bay Ocean Outfall monitoring area (e.g., City of San Diego 2007b). Further, while some muscle tissue samples from sport fish collected off Point Loma had arsenic and selenium concentrations above the median international standard for shellfish, and some had mercury levels that exceeded OEHHA fish contaminant goals, concentrations of mercury and DDT were still below FDA human consumption limits.

The frequent occurrence of metals and chlorinated hydrocarbons in the tissues of fish captured off Point Loma may be due to multiple factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals occur naturally in the environment, although little information is available on background levels in fish tissues. In addition, Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants

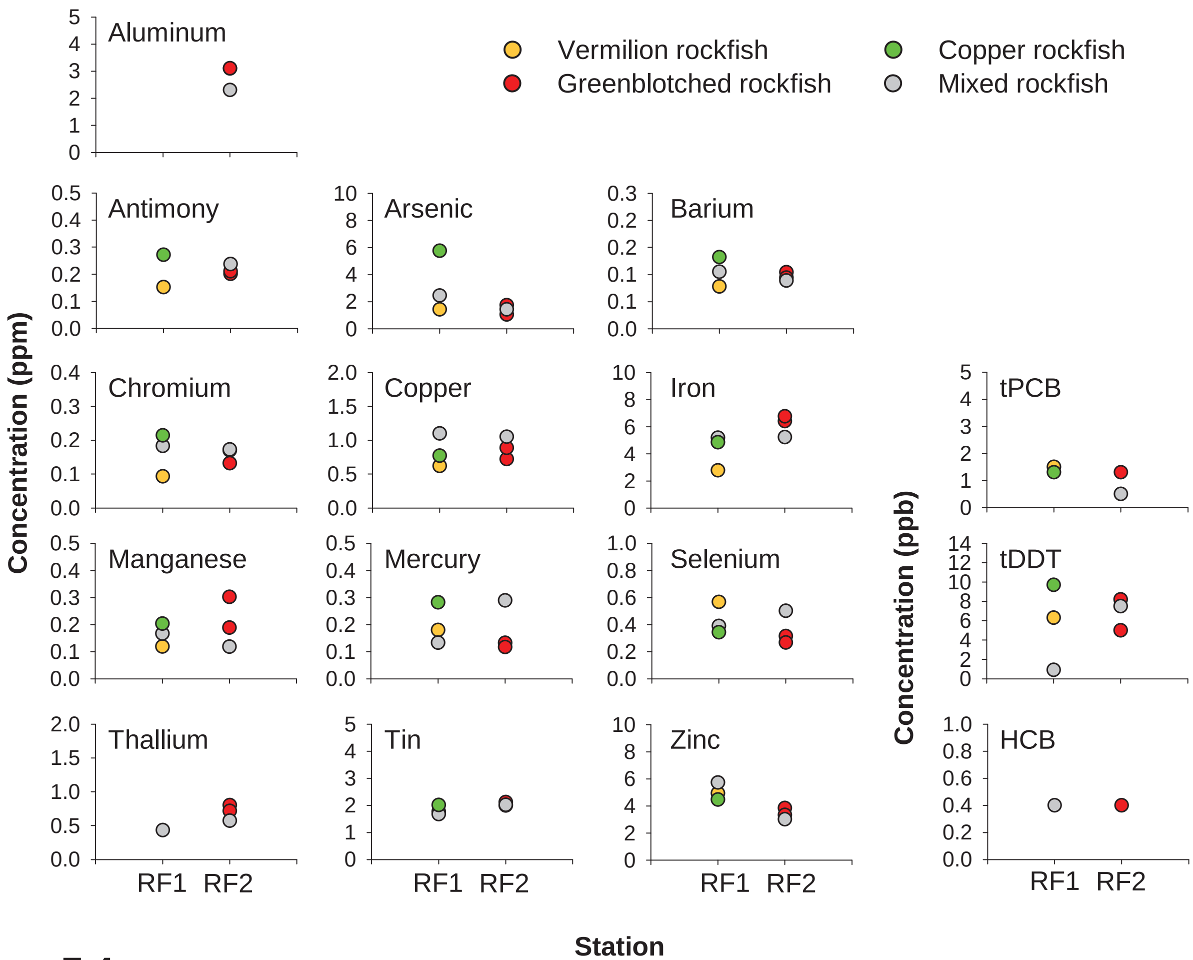

Figure 7.4
Concentrations of frequently detected metals, total PCB (tPCB), total DDT (tDDT), and hexachlorobenzene (HCB) in muscle tissues of fishes collected from each PLOO rig fishing station during 2008. All missing values=non-detects.

to be considered reference sites. This conclusion has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998, 2002).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. Exposure to contaminants can vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). Fishes may also be exposed to contaminants in an area that is highly contaminated and then move into an area that is not. In addition, intra-specific differences in feeding habits, age, reproductive status, and gender can affect the amount of contaminants a fish will retain in its tissues (e.g., Connell 1987, Evans et al. 1993).

Overall, there was no evidence that fishes collected in 2008 were contaminated by the discharge of wastewater from the PLOO. Concentrations of most contaminants were similar across zones/stations, and no clear relationship with proximity to the outfall was evident. These results are supported by the findings of two recent assessments of bioaccumulation in fishes off San Diego (City of San Diego 2007a, Parnell et al. 2008). Finally, there was no other indication of adverse fish health in the region, such as the presence of fin rot, other indicators of disease, or any physical anomalies (see Chapter 6).

Literature Cited

Allen, M.J., S.L. Moore, K.C. Schiff, D. Diener, S.B. Weisburg, J.K. Stull, A. Groce, E. Zeng, J. Mubarak, C.L. Tang, R. Gartman, and C.I. Haydock. (1998). Assessment of demersal fish and megabenthic invertebrate assemblages on the mainland shelf of Southern California in 1994. Southern California Coastal Water Research Project, Westminster, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. (2002). Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

Brown, D.A., R.W. Gossett, G.P. Hershelman, C.G. Word, A.M. Westcott, and J.N. Cross. (1986). Municipal wastewater contamination in the Southern California Bight: Part I–Metal and Organic Contaminants in Sediments and Organisms. Marine Environmental Research, 18: 291–310.

City of San Diego. (2003). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2002. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2004). Quality Assurance Manual, 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007a). Appendix F. Bioaccumulation Assessment. In: Application for Renewal of NPDES CA0107409 and 301(h) Modified Secondary Treatment Requirements, Point Loma Ocean Outfall. Volume IV, Appendices A thru F. Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007b). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 2006. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009). 2008 Annual Reports and Summary: Point Loma Wastewater Treatment Plant and Point Loma Ocean Outfall. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Connell, D.W. (1987). Age to PCB concentration relationship with the striped bass (*Morone saxatilis*) in the Hudson River and Long Island Sound. Chemosphere, 16: 1469–1474.

Evans, D.W., D.K. Dodoo, and P.J. Hanson. (1993). Trace element concentrations in fish livers: Implications of variations with fish size in pollution monitoring. Marine Pollution Bulletin, 26: 329–334.

Klasing, S. and R. Brodberg (2008). Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Sacramento, CA.

Lauenstein, G.G. and A.Y. Cantillo, eds. (1993). Sampling and Analytical Methods of the NOAA National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984–1992: Vol. I–IV. Technical Memorandum. NOS ORCA 71. NOAA/NOS/ORCA, Silver Spring, MD.

Mearns, A.J., M. Matta, G. Shigenaka, D. MacDonald, M. Buchman, H. Harris, J. Golas, and G. Lauenstein. (1991). Contaminant Trends in the Southern California Bight: Inventory and Assessment. NOAA Technical Memorandum NOS ORCA 62. Seattle, WA.

Otway, N. (1991). Bioaccumulation studies on fish: choice of species, sampling designs, problems and implications for environmental management.

In: A.G. Miskiewicz (ed.). Proceedings of a Bioaccumulation Workshop: Assessment of the Distribution, Impacts, and Bioaccumulation of Contaminants in Aquatic Environments. Australian Marine Science Association, Inc./Water Board.

Parnell, P.E., A.K. Groce, T.D. Stebbins, and P.K. Dayton. (2008). Discriminating sources of PCB contamination in fish on the coastal shelf off San Diego, California (USA). Marine Pollution Bulletin 56: 1992–2002.

Rand, G.M. ed. (1995). Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment. 2nd ed. Taylor and Francis, Washington, D.C.

Schiff, K. and M.J. Allen. (1997). Bioaccumulation of chlorinated hydrocarbons in livers of flatfishes from the Southern California Bight. In: S.B. Weisberg, C. Francisco, and D. Hallock (eds.). Southern California Coastal Water Research Project Annual Report 1995–1996. Southern California Coastal Water Research Project, Westminster, CA.

[U.S. EPA] United States Environmental Protection Agency. (2000). Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs. EPA-823-R-00-001. U.S. Environmental Protection Agency. February 2000.

Glossary

GLOSSARY

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

Adsorption
The adhesion of dissolved substances to the surface of sediment or on the surface of an organism (e.g., a flatfish).

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

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

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

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

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

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

Biota
The living organisms within a habitat or region.

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

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

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

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

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

Crustacea
A group (subphylum) of marine invertebrates characterized by jointed legs and an exoskeleton (e.g., crabs, shrimp, and lobster).

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

These parameters are used to assess the physical ocean environment.

Demersal
Organisms living on or near the bottom of the ocean and capable of active swimming.

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

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

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

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

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

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

FIB
Fecal indicator bacteria (FIB) are the bacteria (total coliform, fecal coliform, and enterococcus) measured and evaluated to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall.

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

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

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

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

Invertebrate
An animal without a backbone (e.g., sea star, crab, and worm).

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

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

Macrobenthic invertebrate
Epifaunal or infaunal benthic invertebrates that are visible with the naked eye. This group typically includes those animals larger than meiofauna and

smaller than megafauna. These animals are collected in grab samples from soft-bottom marine habitats and retained on a 1-mm mesh screen.

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

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

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

Motile
Self-propelled or actively moving.

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

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

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

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

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

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

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

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

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

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

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

Polychaeta
A taxonomic group (class) of invertebrates characterized as having worm-like features,

segments, and bristles or tiny hairs. Examples include bristle worms and tube worms.

Pycnocline
A depth zone in the ocean where sea water density changes rapidly with depth and typically is associated with a decline in temperature and increase in salinity.

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

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

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

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

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

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

Shell hash
Sediments composed of shell fragments.

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

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

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

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

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

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

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

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

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

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

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

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

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

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Appendices

Appendix A

Supporting Data

2008 PLOO Stations

Oceanographic Conditions

Appendix A.1

Summary of temperature, salinity, density, dissolved oxygen, pH, transmissivity, and chlorophyll *a* at all PLOO stations during 2008. Values are expressed as averages over the entire water column for each survey; data are organized by depth contour, with stations listed north to south.

		Temperature (°C)				Salinity (ppt)			
Contour	**Station**	**Jan**	**Apr**	**Jul**	**Oct**	**Jan**	**Apr**	**Jul**	**Oct**
9-m	C6	13.5	13.0	19.1	19.7	33.37	33.92	33.68	33.45
	C5	13.4	13.3	18.4	19.4	33.39	33.92	33.69	33.53
	C4	13.5	12.6	18.1	18.4	33.42	33.89	33.69	33.44
18-m	F03	13.2	13.7	15.2	16.6	33.44	33.80	33.62	33.37
	F02	13.2	12.6	15.1	15.2	33.22	33.84	33.63	33.35
	C8	13.4	11.6	17.7	18.0	33.44	33.91	33.63	33.46
	C7	13.3	11.9	17.0	18.3	33.43	33.97	33.64	33.46
	A6	13.2	11.6	18.0	19.0	33.45	33.94	33.69	33.49
	A7	13.1	12.1	17.2	18.1	33.49	33.92	33.68	33.47
	A1	13.2	11.7	16.2	18.5	33.49	33.89	33.71	33.47
	F01	13.3	12.5	14.6	14.3	33.43	33.86	33.64	33.33
60-m	F14	12.9	10.9	12.7	14.6	33.52	33.91	33.64	33.35
	F13	12.9	10.8	12.6	14.4	33.52	33.91	33.64	33.35
	F12	13.0	10.7	12.7	14.2	33.51	33.90	33.61	33.34
	F11	13.1	10.7	12.7	13.9	33.50	33.89	33.61	33.34
	F10	13.2	10.6	12.8	14.2	33.52	33.88	33.60	33.36
	F09	13.2	10.9	12.6	14.0	33.52	33.88	33.61	33.37
	F08	13.2	10.8	12.4	13.9	33.52	33.89	33.62	33.38
	F07	13.2	10.9	13.4	13.8	33.49	33.87	33.60	33.36
	F06	12.5	11.3	12.7	13.7	33.60	33.87	33.59	33.40
	F05	12.5	11.0	12.9	13.5	33.59	33.86	33.61	33.37
	F04	12.5	10.9	13.3	13.7	33.59	33.84	33.60	33.37
80-m	F15	12.2	11.2	12.2	13.6	33.62	33.85	33.57	33.39
	F16	12.2	11.2	12.4	13.6	33.62	33.85	33.60	33.40
	F17	12.2	11.1	12.4	13.4	33.62	33.86	33.59	33.42
	F18	12.2	11.1	12.4	13.3	33.64	33.87	33.59	33.41
	F19	12.9	10.7	12.3	13.6	33.56	33.88	33.60	33.39
	F20	12.8	10.7	12.5	13.9	33.57	33.89	33.62	33.39
	F21	12.7	10.9	12.6	13.9	33.57	33.89	33.61	33.39
	F22	12.6	10.6	12.6	13.9	33.58	33.91	33.62	33.38
	F23	12.6	10.5	12.2	14.2	33.59	33.98	33.67	33.38
	F24	12.6	10.7	12.2	14.3	33.59	33.97	33.68	33.39
	F25	12.4	10.7	12.2	14.4	33.60	33.99	33.69	33.39
98-m	F36	12.1	10.7	11.4	14.0	33.67	34.00	33.73	33.39
	F35	12.1	10.4	11.5	13.9	33.66	34.00	33.73	33.40
	F34	12.3	10.6	11.4	13.7	33.63	33.97	33.73	33.40
	F33	12.3	10.5	11.7	13.5	33.63	33.91	33.66	33.40
	F32	12.5	10.6	11.7	13.6	33.61	33.91	33.64	33.42
	F31	12.7	10.6	11.7	13.7	33.60	33.90	33.64	33.42
	F30	12.7	10.6	11.9	13.8	33.58	33.89	33.64	33.41
	F29	12.1	10.9	11.8	13.4	33.68	33.86	33.57	33.42
	F28	12.2	11.1	11.8	13.4	33.67	33.84	33.58	33.42
	F27	12.2	10.9	11.7	13.2	33.68	33.84	33.58	33.42
	F26	12.1	10.9	11.8	13.3	33.68	33.86	33.59	33.41

Appendix A.1 *continued*

Contour	Station	Density (δ/θ) Jan	Apr	Jul	Oct	Contour	Station	Dissolved Oxygen (mg/L) Jan	Apr	Jul	Oct
9-m	C6	25.04	25.54	23.98	23.66	**9-m**	C6	7.6	6.8	7.8	7.3
	C5	25.06	25.48	24.16	23.80		C5	7.4	7.0	7.9	7.0
	C4	25.07	25.60	24.23	23.97		C4	7.6	7.3	7.9	6.4
18-m	F03	25.15	25.31	24.83	24.34	**18-m**	F03	7.9	8.4	8.5	8.4
	F02	24.97	25.56	24.85	24.64		F02	7.8	7.1	8.1	7.9
	C8	25.11	25.80	24.29	24.06		C8	7.7	5.8	8.8	7.4
	C7	25.12	25.79	24.44	24.01		C7	7.4	5.8	8.0	6.0
	A6	25.16	25.83	24.26	23.85		A6	7.3	5.5	7.6	7.1
	A7	25.20	25.73	24.43	24.05		A7	7.0	6.3	7.6	7.1
	A1	25.18	25.78	24.68	23.96		A1	7.2	5.6	7.5	7.1
	F01	25.11	25.59	24.98	24.82		F01	7.8	6.9	7.7	7.7
60-m	F14	25.27	25.93	25.36	24.75	**60-m**	F14	7.0	4.4	7.0	8.0
	F13	25.26	25.96	25.38	24.79		F13	7.1	4.2	6.9	7.9
	F12	25.24	25.96	25.36	24.84		F12	7.2	4.2	7.1	7.8
	F11	25.22	25.95	25.34	24.91		F11	7.4	4.2	7.2	7.6
	F10	25.21	25.98	25.32	24.84		F10	7.4	3.6	7.3	7.9
	F09	25.21	25.91	25.37	24.89		F09	7.3	4.0	6.9	7.6
	F08	25.20	25.94	25.41	24.93		F08	7.5	3.9	6.8	7.6
	F07	25.18	25.91	25.19	24.93		F07	7.6	4.2	7.4	7.6
	F06	25.40	25.81	25.34	24.97		F06	6.3	5.0	7.0	7.4
	F05	25.39	25.88	25.32	25.00		F05	6.4	4.6	7.0	7.7
	F04	25.40	25.88	25.21	24.95		F04	6.3	4.7	7.4	7.8
80-m	F15	25.47	25.82	25.43	25.00	**80-m**	F15	5.9	4.9	6.6	7.5
	F16	25.47	25.83	25.39	24.99		F16	5.9	4.9	6.5	7.6
	F17	25.48	25.85	25.40	25.07		F17	5.9	4.9	6.5	7.3
	F18	25.50	25.86	25.39	25.06		F18	5.8	4.8	6.6	7.3
	F19	25.29	25.94	25.43	24.99		F19	6.7	4.2	6.6	7.6
	F20	25.32	25.95	25.39	24.93		F20	6.7	4.2	6.5	7.6
	F21	25.34	25.91	25.35	24.94		F21	6.6	4.4	6.8	7.5
	F22	25.37	25.98	25.38	24.91		F22	6.4	4.0	6.8	7.6
	F23	25.37	26.05	25.49	24.85		F23	6.2	3.8	6.5	7.6
	F24	25.37	26.00	25.49	24.83		F24	6.2	4.0	6.4	7.6
	F25	25.41	26.02	25.49	24.83		F25	6.0	4.3	6.4	7.8
98-m	F36	25.54	26.04	25.69	24.91	**98-m**	F36	5.4	4.0	5.8	7.8
	F35	25.52	26.09	25.68	24.93		F35	5.5	3.8	5.9	7.6
	F34	25.46	26.03	25.69	24.97		F34	5.7	3.9	5.8	7.4
	F33	25.46	26.00	25.58	25.02		F33	5.7	3.9	6.1	7.6
	F32	25.40	25.99	25.57	25.00		F32	6.1	4.0	6.2	7.4
	F31	25.37	25.98	25.57	24.99		F31	6.3	4.0	6.1	7.5
	F30	25.34	25.97	25.53	24.97		F30	6.2	4.1	6.1	7.5
	F29	25.54	25.88	25.50	25.05		F29	5.5	4.6	6.3	7.3
	F28	25.50	25.84	25.51	25.05		F28	5.6	4.9	6.4	7.3
	F27	25.51	25.87	25.52	25.09		F27	5.5	4.7	6.3	7.2
	F26	25.54	25.88	25.51	25.08		F26	5.3	4.8	6.3	7.2

Appendix A.1 *continued*

Contour	Station	pH Jan	pH Apr	pH Jul	pH Oct	Contour	Station	Transmissivity (%) Jan	Transmissivity (%) Apr	Transmissivity (%) Jul	Transmissivity (%) Oct
9-m	C6	8.1	8.2	8.2	8.1	**9-m**	C6	74	63	81	82
	C5	8.1	8.1	8.2	8.1		C5	77	55	81	80
	C4	8.1	8.1	8.2	8.1		C4	77	65	79	83
18-m	F03	8.1	8.2	8.1	8.2	**18-m**	F03	77	70	78	84
	F02	8.1	8.1	8.1	8.2		F02	74	67	79	77
	C8	8.1	8.0	8.2	8.1		C8	77	73	83	87
	C7	8.1	8.0	8.1	8.0		C7	78	73	83	83
	A6	8.1	8.0	8.1	8.1		A6	80	76	83	88
	A7	8.0	8.0	8.1	8.1		A7	81	73	82	87
	A1	8.0	8.0	8.1	8.1		A1	81	73	83	88
	F01	8.1	8.1	8.0	8.1		F01	79	77	80	87
60-m	F14	8.1	7.9	7.9	8.2	**60-m**	F14	81	86	86	87
	F13	8.1	7.9	7.9	8.2		F13	82	87	86	87
	F12	8.1	7.9	7.9	8.1		F12	82	87	85	87
	F11	8.1	7.9	7.9	8.1		F11	82	87	86	87
	F10	8.1	7.8	8.0	8.1		F10	84	85	87	88
	F09	8.1	7.8	7.9	8.1		F09	84	84	87	88
	F08	8.1	7.8	7.9	8.1		F08	84	85	88	88
	F07	8.1	7.8	8.0	8.1		F07	83	83	86	89
	F06	8.0	7.9	7.9	8.1		F06	84	83	87	90
	F05	8.0	8.0	7.9	8.1		F05	85	85	86	90
	F04	8.0	8.0	8.0	8.1		F04	86	87	87	90
80-m	F15	8.0	7.9	7.9	8.1	**80-m**	F15	87	86	89	90
	F16	8.0	7.9	7.9	8.1		F16	87	86	89	89
	F17	8.0	7.9	7.9	8.1		F17	87	86	89	89
	F18	8.0	7.9	7.9	8.1		F18	88	85	89	89
	F19	8.1	7.9	7.9	8.1		F19	87	88	90	90
	F20	8.1	7.8	7.9	8.1		F20	87	88	89	90
	F21	8.1	7.8	7.9	8.1		F21	88	88	89	90
	F22	8.1	7.8	7.9	8.1		F22	88	88	89	90
	F23	8.0	7.9	7.9	8.1		F23	87	89	88	88
	F24	8.0	7.8	7.9	8.2		F24	87	89	88	88
	F25	8.0	7.9	7.9	8.2		F25	88	87	88	89
98-m	F36	8.0	7.8	7.9	8.1	**98-m**	F36	88	88	90	90
	F35	8.0	7.8	7.9	8.1		F35	88	88	90	90
	F34	8.0	7.8	7.9	8.1		F34	88	89	89	90
	F33	8.0	7.8	7.9	8.1		F33	88	88	90	90
	F32	8.0	7.8	7.9	8.1		F32	88	89	90	90
	F31	8.0	7.8	7.9	8.1		F31	88	89	90	89
	F30	8.0	7.8	7.9	8.1		F30	88	89	90	89
	F29	8.0	7.9	7.9	8.1		F29	88	87	90	90
	F28	8.0	7.9	7.9	8.1		F28	88	87	90	90
	F27	8.0	7.9	7.9	8.1		F27	88	88	90	90
	F26	8.0	7.9	7.9	8.1		F26	88	87	90	90

Appendix A.1 *continued*

Contour	Station	Chlorophyll *a* (µg/L) Jan	Apr	Jul	Oct
9-m	C6	1.83	8.96	3.31	3.50
	C5	1.25	10.56	3.23	1.78
	C4	1.67	14.89	3.12	1.83
18-m	F03	3.8	16.4	10.8	2.3
	F02	4.5	13.6	8.8	2.8
	C8	4.4	20.3	3.2	1.7
	C7	3.8	10.9	4.0	2.4
	A6	2.7	11.2	3.7	1.9
	A7	3.4	11.0	5.0	2.1
	A1	4.0	20.8	5.0	1.7
	F01	3.1	8.2	9.5	2.9
60-m	F14	2.8	2.4	4.4	2.6
	F13	2.9	2.2	4.8	2.7
	F12	3.0	2.4	5.8	2.6
	F11	3.1	2.3	5.0	2.7
	F10	2.9	3.2	4.6	2.3
	F09	2.7	4.0	3.6	2.3
	F08	3.0	4.0	3.3	2.3
	F07	3.2	5.4	4.7	2.8
	F06	3.1	6.1	3.5	1.3
	F05	2.9	4.4	4.1	2.8
	F04	2.6	3.6	4.1	2.9
80-m	F15	2.2	3.1	3.1	2.6
	F16	2.2	3.6	2.2	2.7
	F17	2.4	4.1	2.0	2.0
	F18	2.2	4.4	2.2	2.1
	F19	2.8	2.9	2.8	2.2
	F20	2.7	3.1	2.4	2.1
	F21	2.6	3.0	2.4	2.1
	F22	2.4	2.6	2.7	2.1
	F23	2.3	1.8	3.1	2.9
	F24	2.3	2.0	2.7	2.6
	F25	2.1	4.2	2.7	2.7
98-m	F36	2.1	2.7	2.1	2.6
	F35	2.2	2.8	1.9	2.1
	F34	2.0	2.3	1.8	2.0
	F33	2.4	3.0	1.7	2.4
	F32	2.3	3.0	1.8	2.2
	F31	2.2	2.7	1.9	2.4
	F30	2.1	2.6	2.0	2.5
	F29	1.8	2.9	1.5	2.2
	F28	1.8	2.8	1.4	2.2
	F27	1.8	2.8	1.4	2.1
	F26	1.5	2.7	1.7	2.3

Appendix B

Supporting Data

2008 PLOO Stations

Microbiology

Appendix B.1

Summary of rainfall and bacteria levels at shore stations in the PLOO region during 2008. Rainfall data are from Lindbergh Field, San Diego, CA. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) densities are expressed as mean CFU/100 mL per month and for the entire year. Stations are listed from south to north from left to right.

Month	Rain (in)		D4	D5	D7	D8	D9	D10	D11	D12	All stations
Jan	3.3	*Total*	20	128	50	204	144	232	68	32	110
		Fecal	6	6	10	13	26	20	10	6	12
		Entero	2	11	46	127	70	71	27	2	45
Feb	1.2	*Total*	11	17	16	140	81	113	3265	23	458
		Fecal	6	6	6	15	16	43	55	6	19
		Entero	2	4	10	135	51	56	80	10	44
Mar	0.3	*Total*	3	10	9	25	16	32	24	13	17
		Fecal	2	2	3	4	2	14	10	7	6
		Entero	2	2	2	3	2	4	6	4	3
Apr	0.0	*Total*	7	9	6	129	10	26	52	16	32
		Fecal	2	2	2	8	2	2	13	2	4
		Entero	2	2	2	8	2	5	16	2	5
May	0.2	*Total*	6	49	13	21	57	29	48	49	34
		Fecal	4	2	2	2	2	10	18	6	6
		Entero	2	2	2	2	5	14	19	2	6
Jun	Trace	*Total*	8	56	13	128	19	32	53	49	45
		Fecal	6	3	2	4	3	9	14	2	5
		Entero	3	5	2	4	2	4	4	2	3
Jul	0.0	*Total*	20	20	88	64	21	34	37	10	37
		Fecal	2	6	26	9	10	19	9	6	11
		Entero	6	2	6	4	3	7	13	2	6
Aug	0.0	*Total*	13	16	180	17	181	22	20	9	57
		Fecal	2	2	38	3	90	9	13	3	20
		Entero	5	2	2	3	54	4	21	4	12
Sep	0.0	*Total*	19	56	96	36	17	25	37	2	36
		Fecal	7	18	20	21	7	15	14	2	13
		Entero	5	15	8	7	2	10	9	2	7
Oct	1.2	*Total*	17	50	87	1173	17	33	18	11	176
		Fecal	2	3	6	41	11	13	17	3	12
		Entero	2	2	7	92	6	11	7	7	17
Nov	2.5	*Total*	16	364	13	1016	24	56	85	19	199
		Fecal	2	12	2	27	6	12	19	9	11
		Entero	17	18	2	21	3	12	36	10	15
Dec	3.4	*Total*	19	424	85	575	201	776	1304	150	442
		Fecal	4	39	11	38	30	98	52	59	41
		Entero	11	39	5	106	130	453	492	84	165
		n	61	61	61	61	61	61	61	61	
Annual means		**Total**	13	100	55	294	66	118	418	32	
		Fecal	4	9	11	15	17	22	20	9	
		Entero	5	9	8	43	28	54	61	11	

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Appendix B.2

Summary of samples with elevated (bold) total coliform (>1000 CFU/100 mL), fecal coliform (>400 CFU/100 mL), and/or enterococcus (>104 CFU/100 mL) densities collected at PLOO shore stations during 2008. Bold F:T values are samples collected in 2008 which meet the FTR criteria for contamination (Total ≥1000 CFU/100 mL and F:T ≥0.10). Values are expressed as CFU/100 mL; Total=total coliform; Fecal=fecal coliform; Entero=enterococcus; F:T=fecal to total coliform ratio.

Station	Date	Total	Fecal	Entero	F:T
D7	05-Jan-2008	200	40	**220**	0.20
D8	05-Jan-2008	800	40	**560**	0.05
D9	05-Jan-2008	600	100	**340**	0.17
D10	05-Jan-2008	800	60	**320**	0.08
D11	16-Feb-2008	**>16,000**	140	**260**	0.01
D8	22-Feb-2008	440	36	**640**	0.08
D9	22-Feb-2008	180	56	**220**	0.31
D10	22-Feb-2008	160	68	**160**	0.43
D9	20-Aug-2008	820	**440**	**260**	0.54
D8	19-Oct-2008	**5600**	14	**320**	0.00
D8	12-Nov-2008	**3800**	26	4	0.01
D8	18-Dec-2008	**1400**	60	**380**	0.04
D9	18-Dec-2008	800	100	**620**	0.13
D10	18-Dec-2008	**3400**	400	**2200**	**0.12**
D11	18-Dec-2008	**6200**	200	**2400**	0.03
D12	18-Dec-2008	600	260	**360**	0.43
D5	24-Dec-2008	**1600**	160	98	**0.10**
D8	30-Dec-2008	**1200**	28	76	0.02

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Appendix B.3

Summary of samples with elevated (bold) total coliform (>1000 CFU/100 mL), fecal coliform (>400 CFU/100 mL), and/or enterococcus (>104 CFU/100 mL) densities collected at PLOO offshore stations during 2008. Bold F:T values are samples collected in 2008 which meet the FTR criteria for contamination (Total ≥1000 CFU/100 mL and F:T ≥0.10). Values are expressed as CFU/100 mL; Total=total coliform; Fecal=fecal coliform; Entero=enterococcus; F:T=fecal to total coliform ratio.

Station	Date	Sample Depth (m)	Total	Fecal	Entero	F:T
F08	09-Jan-2008	60	1000	180	54	**0.18**
F30	09-Jan-2008	60	**>16,000**	**9000**	**1300**	**0.56**
F30	09-Jan-2008	80	**>16,000**	**7400**	**1000**	**0.46**
F30	09-Jan-2008	98	**10,000**	**3000**	**400**	**0.30**
F26	11-Jan-2008	60	**11,000**	**800**	**170**	0.07
F26	11-Jan-2008	80	**3000**	**1000**	**180**	**0.33**
F29	11-Jan-2008	60	**1700**	240	20	**0.14**
F20	01-Apr-2008	80	**1500**	200	92	**0.13**
F23	16-Apr-2008	60	**15,000**	**3200**	**880**	**0.21**
F23	16-Apr-2008	80	**1200**	160	**120**	**0.13**
F36	16-Apr-2008	60	1000	240	**220**	**0.24**
F08	17-Apr-2008	60	**3000**	54	2	0.02
F31	17-Apr-2008	60	**>16,000**	**4200**	**680**	**0.26**
F32	17-Apr-2008	60	**10,000**	**1000**	**460**	**0.10**
F33	17-Apr-2008	60	**>16,000**	**1400**	**1200**	0.09
F33	17-Apr-2008	80	**16,000**	**4000**	**1100**	**0.25**
F21	01-Jul-2008	80	**2000**	**560**	60	**0.28**
F23	08-Jul-2008	60	**1400**	**420**	52	**0.30**
F23	08-Jul-2008	80	**7400**	**860**	**110**	**0.12**
F24	08-Jul-2008	80	**>16,000**	**4200**	**140**	**0.26**
F25	08-Jul-2008	80	**>16,000**	**3200**	**150**	**0.20**
F34	08-Jul-2008	80	**13,000**	**1400**	**120**	**0.11**
F34	08-Jul-2008	98	**2200**	**440**	52	**0.20**
F20	09-Jul-2008	60	**>16,000**	**4400**	**1000**	**0.28**
F21	09-Jul-2008	60	**1500**	180	14	**0.12**
F22	09-Jul-2008	80	**2400**	**800**	**260**	**0.33**
F30	09-Jul-2008	60	**>16,000**	**6600**	**1100**	**0.41**
F30	09-Jul-2008	80	**>16,000**	**9000**	**1400**	**0.56**
F31	09-Jul-2008	80	**14,000**	**1800**	**420**	**0.13**
F31	09-Jul-2008	98	**3600**	**900**	90	**0.25**
F32	09-Jul-2008	80	**>16,000**	**2800**	**260**	**0.18**
F32	09-Jul-2008	98	**6200**	**1000**	**160**	**0.16**
F33	09-Jul-2008	80	**>16,000**	**3800**	**340**	**0.24**
F28	10-Jul-2008	98	**5000**	**1100**	**110**	**0.22**
F29	10-Jul-2008	60	**4000**	**840**	**150**	**0.21**
F29	10-Jul-2008	80	**17,000**	**2200**	**600**	**0.13**
F29	10-Jul-2008	98	**3000**	**800**	68	**0.27**
F23	06-Oct-2008	60	**14,000**	**3000**	**260**	**0.21**
F23	06-Oct-2008	80	**3600**	**620**	80	**0.17**
F24	06-Oct-2008	60	**3200**	**680**	52	**0.21**
F25	06-Oct-2008	60	**11,000**	**2000**	**200**	**0.18**
F34	06-Oct-2008	80	**1600**	400	56	**0.25**

Appendix B.3 *continued*

Station	Date	Sample Depth (m)	Total	Fecal	Entero	F:T
F21	07-Oct-2008	80	**1800**	**520**	18	**0.29**
F22	07-Oct-2008	60	**2200**	**1100**	**110**	**0.50**
F22	07-Oct-2008	80	**1600**	400	60	**0.25**
F30	07-Oct-2008	60	**1200**	240	10	**0.20**
F30	07-Oct-2008	80	**12,000**	**2600**	70	**0.22**
F31	07-Oct-2008	60	1000	160	10	**0.16**
F31	07-Oct-2008	80	**10,000**	**1600**	66	**0.16**

Appendix B.4

Summary of compliance with California Ocean Plan water contact standards for PLOO shore stations during 2008. The values reflect the number of days that each station exceeded the 30-day Total Coliform, 10,000 Total Coliform, 60-day Fecal Coliform, and 30-day Fecal Geometric Mean Standards (see Chapter 3, Box 3.1). Shore stations are listed from south to north from left to right.

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
30-Day Total Coliform Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	6	0	0	0	0
December	31	0	0	0	2	0	0	0	0
Percent compliance		100%	100%	100%	98%	100%	100%	100%	100%
10,000 Total Coliform Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%

Appendix B.4 *continued*

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
60-Day Fecal Coliform Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%
30-Day Fecal Geometric Mean Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%

Appendix B.5

Summary of compliance with California Ocean Plan water contact standards for PLOO kelp bed stations during 2008. The values reflect the number of days that each station exceeded the 30-day Total Coliform, 10,000 Total Coliform, 60-day Fecal Coliform, and 30-day Fecal Geometric Mean Standards (see Chapter 3, Box 3.1). Kelp stations are listed left to right from south to north by depth contour.

		9 m stations			18 m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
30-Day Total Coliform Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%
10,000 Total Coliform Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%

Appendix B.5 *continued*

Month	# days	9 m stations C4	C5	C6	18 m stations A1	A7	A6	C7	C8
60-Day Fecal Coliform Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%
30-day Fecal Geometric Mean Standard									
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		100%	100%	100%	100%	100%	100%	100%	100%

Appendix C

Supporting Data

2008 PLOO Stations

Sediment Characteristics

Appendix C.1

Constituents and method detection limits (MDL) for sediment samples analyzed for the PLOO monitoring program during 2008.

Parameter	MDL	Parameter	MDL
Sulfides-Total (ppm)	0.14	Total Solids (% wt)	0.24
Total Nitrogen (% wt)	0.005	Total Volatile Solids (% wt)	0.11
Total Organic Carbon (% wt)	0.01	Biochemical Oxygen Demand (ppm)	2
Metals (ppm)			
Aluminum (Al)	2	Lead (Pb)	0.8
Antimony (Sb)	0.3	Manganese (Mn)	0.08
Arsenic (As)	0.33	Mercury (Hg)	0.003
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 (Tl)	0.5
Copper (Cu)	0.2	Tin (Sn)	0.3
Iron (Fe)	9	Zinc (Zn)	0.2
Pesticides (ppt)			
Aldrin	700	Cis Nonachlor	700
Alpha Endosulfan	700	Gamma (trans) Chlordane	700
Beta Endosulfan	700	Heptachlor	700
Dieldrin	700	Heptachlor epoxide	700
Endosulfan Sulfate	700	Methoxychlor	700
Endrin	700	Oxychlordane	700
Endrin aldehyde	700	Trans Nonachlor	700
Hexachlorobenzene (HCB)	400	o,p-DDD	400
Mirex	700	o,p-DDE	700
BHC, Alpha isomer	400	o,p-DDT	700
BHC, Beta isomer	400	p,-p-DDMU	*
BHC, Delta isomer	400	p,p-DDD	700
BHC, Gamma isomer	400	p,p-DDE	400
Alpha (cis) Chlordane	700	p,p-DDT	700

* No MDL available for this parameter

Appendix C.1 *continued*

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

Appendix C.2

Summary of the constituents that make up total DDT, total PCB, and total PAH in each sediment sample collected as part of PLOO monitoring program during 2008. nd=not detected; ns=not sampled.

Station	Class	Constituent	January	July	Units
B8	DDT	p,p-DDD	140	ns	ppt
B8	DDT	p,p-DDE	460	ns	ppt
B8	PCB	PCB 153/168	45	ns	ppt
B8	PAH	Naphthalene	17	ns	ppb
B9	DDT	p,p-DDD	200	nd	ppt
B9	DDT	p,p-DDE	460	210	ppt
B9	PAH	Biphenyl	8	nd	ppb
B10	DDT	p,p-DDE	300	ns	ppt
B10	PAH	Naphthalene	20	ns	ppb
B11	DDT	p,p-DDE	390	ns	ppt
B11	PAH	Biphenyl	7	ns	ppb
B12	DDT	p,p-DDE	445	210	ppt
B12	PAH	Naphthalene	13	nd	ppb
E1	PAH	Anthracene	20	ns	ppb
E1	PAH	Fluoranthene	35	ns	ppb
E1	PAH	Naphthalene	19	ns	ppb
E1	PAH	Phenanthrene	28	ns	ppb
E1	PAH	Pyrene	44	ns	ppb
E2	DDT	p,p-DDD	210	nd	ppt
E2	DDT	p,p-DDE	560	370	ppt
E2	DDT	p,p-DDT	nd	570	ppt
E2	PCB	PCB 105	88	nd	ppt
E2	PCB	PCB 110	220	nd	ppt
E2	PCB	PCB 138	nd	330	ppt
E2	PCB	PCB 149	nd	160	ppt
E2	PCB	PCB 149	300	nd	ppt
E2	PCB	PCB 153/168	180	nd	ppt
E2	PCB	PCB 180	69	nd	ppt
E2	PAH	Biphenyl	7	nd	ppb
E2	PAH	Pyrene	nd	42	ppb

Appendix C.2 *continued*

Station	Class	Constituent	January	July	Units
E3	DDT	p,p-DDE	310	ns	ppt
E3	PCB	PCB 105	200	ns	ppt
E3	PCB	PCB 110	600	ns	ppt
E3	PCB	PCB 118	510	ns	ppt
E3	PCB	PCB 123	25	ns	ppt
E3	PCB	PCB 128	120	ns	ppt
E3	PCB	PCB 138	600	ns	ppt
E3	PCB	PCB 149	690	ns	ppt
E3	PCB	PCB 151	280	ns	ppt
E3	PCB	PCB 153/168	380	ns	ppt
E3	PCB	PCB 156	64	ns	ppt
E3	PCB	PCB 170	250	ns	ppt
E3	PCB	PCB 177	360	ns	ppt
E3	PCB	PCB 180	840	ns	ppt
E3	PCB	PCB 183	280	ns	ppt
E3	PCB	PCB 187	750	ns	ppt
E3	PCB	PCB 194	640	ns	ppt
E3	PCB	PCB 201	970	ns	ppt
E3	PCB	PCB 206	730	ns	ppt
E3	PCB	PCB 49	200	ns	ppt
E3	PCB	PCB 52	190	ns	ppt
E3	PCB	PCB 70	190	ns	ppt
E3	PCB	PCB 99	290	ns	ppt
E3	PAH	1-methylphenanthrene	15	ns	ppb
E3	PAH	2-methylnaphthalene	2	ns	ppb
E3	PAH	3,4-benzo(B)fluoranthene	169	ns	ppb
E3	PAH	Benzo[A]anthracene	136	ns	ppb
E3	PAH	Benzo[K]fluoranthene	153	ns	ppb
E3	PAH	Chrysene	110	ns	ppb
E3	PAH	Fluoranthene	23	ns	ppb
E3	PAH	Naphthalene	16	ns	ppb
E3	PAH	Pyrene	66	ns	ppb
E5	DDT	p,p-DDE	150	nd	ppt
E5	DDT	p,p-DDT	nd	290	ppt
E5	PAH	Benzo[A]anthracene	47	nd	ppb
E5	PAH	Chrysene	76	nd	ppb
E5	PAH	Naphthalene	11	nd	ppb
E5	PAH	Pyrene	22	nd	ppb

Appendix C.2 *continued*

Station	Class	Constituent	January	July	Units
E7	DDT	p,p-DDE	290	ns	ppt
E7	PAH	1-methylnaphthalene	19	ns	ppb
E7	PAH	2-methylnaphthalene	22	ns	ppb
E7	PAH	Acenaphthene	6	ns	ppb
E7	PAH	Benzo[A]anthracene	33	ns	ppb
E7	PAH	Biphenyl	16	ns	ppb
E7	PAH	Chrysene	43	ns	ppb
E7	PAH	Fluoranthene	20	ns	ppb
E7	PAH	Naphthalene	59	ns	ppb
E7	PAH	Pyrene	28	ns	ppb
E8	DDT	p,p-DDE	270	nd	ppt
E8	DDT	p,p-DDE	170	nd	ppt
E8	PAH	Biphenyl	7	nd	ppb
E9	DDT	p,p-DDE	310	ns	ppt
E9	PCB	PCB 101	800	ns	ppt
E9	PCB	PCB 105	150	ns	ppt
E9	PCB	PCB 110	470	ns	ppt
E9	PCB	PCB 118	320	ns	ppt
E9	PCB	PCB 138	370	ns	ppt
E9	PCB	PCB 149	360	ns	ppt
E9	PCB	PCB 151	120	ns	ppt
E9	PCB	PCB 153/168	210	ns	ppt
E9	PCB	PCB 156	47	ns	ppt
E9	PCB	PCB 169	440	ns	ppt
E9	PCB	PCB 170	290	ns	ppt
E9	PCB	PCB 177	420	ns	ppt
E9	PCB	PCB 180	1100	ns	ppt
E9	PCB	PCB 183	350	ns	ppt
E9	PCB	PCB 187	1000	ns	ppt
E9	PCB	PCB 194	960	ns	ppt
E9	PCB	PCB 201	1500	ns	ppt
E9	PCB	PCB 206	1000	ns	ppt
E9	PCB	PCB 52	49	ns	ppt
E9	PAH	2-methylnaphthalene	5	ns	ppb
E9	PAH	Benzo[A]anthracene	37	ns	ppb
E9	PAH	Phenanthrene	15	ns	ppb
E9	PAH	Pyrene	28	ns	ppb

Appendix C.2 *continued*

Station	Class	Constituent	January	July	Units
E11	DDT	p,p-DDE	220	180	ppt
E14	DDT	p,p-DDE	230	330	ppt
E14	DDT	p,p-DDT	nd	87	ppt
E15	DDT	p,p-DDE	310	ns	ppt
E15	PCB	PCB 149	73	ns	ppt
E15	PCB	PCB 153/168	37	ns	ppt
E15	PAH	1-methylnaphthalene	11	ns	ppb
E15	PAH	1-methylphenanthrene	19	ns	ppb
E15	PAH	2-methylnaphthalene	10	ns	ppb
E15	PAH	Biphenyl	13	ns	ppb
E15	PAH	Naphthalene	35	ns	ppb
E17	DDT	p,p-DDE	240	300	ppt
E17	DDT	p,p-DDT	nd	270	ppt
E17	PAH	Biphenyl	6	nd	ppb
E19	DDT	p,p-DDE	370	ns	ppt
E19	PCB	PCB 149	200	ns	ppt
E19	PCB	PCB 153/168	63	ns	ppt
E19	PCB	PCB 180	48	ns	ppt
E19	PAH	Fluoranthene	11	ns	ppb
E20	DDT	p,p-DDE	340	260	ppt
E20	PAH	Biphenyl	9	nd	ppb
E20	PAH	Naphthalene	12	nd	ppb
E21	DDT	p,p-DDE	405	ns	ppt
E23	DDT	p,p-DDE	370	260	ppt
E23	DDT	p,p-DDT	nd	200	ppt
E23	PAH	Biphenyl	9	nd	ppb
E23	PAH	Naphthalene	23	nd	ppb
E25	DDT	p,p-DDE	330	280	ppt
E25	DDT	p,p-DDT	nd	130	ppt
E25	PAH	Biphenyl	8	nd	ppb
E26	DDT	p,p-DDE	320	210	ppt
E26	DDT	p,p-DDT	nd	95	ppt

Appendix C.3

PLOO sediment statistics for the January 2008 survey.

	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Fines (%)	Visual Observations
North reference stations													
B8	88	0.043	4.5	1.5	4.2	0.4	0.9	0.0	44.0	52.6	3.4	56.0	
B11	88	0.053	4.2	2.0	3.8	0.3	0.9	3.8	49.9	42.5	3.8	46.3	Mud, pea gravel, shell hash, rocks
B9	98	0.052	4.3	1.6	3.7	0.5	1.0	0.0	57.5	39.6	2.9	42.5	Mud, pea gravel
B12	98	0.065	3.9	1.8	3.2	0.5	0.9	0.0	65.5	31.8	2.7	34.5	Shell hash
B10	116	0.071	3.8	1.6	3.3	0.5	1.3	0.0	71.6	26.1	2.3	28.4	Shell hash
Stations north of the outfall													
E19	88	0.051	4.3	1.5	3.9	0.4	1.1	0.0	54.4	42.9	2.7	45.6	
E20	98	0.060	4.1	1.4	3.6	0.5	1.2	0.0	63.3	34.3	2.4	36.7	
E23	98	0.060	4.1	1.4	3.7	0.4	1.2	0.0	61.4	36.1	2.5	38.6	Shell hash
E25	98	0.064	4.0	1.4	3.6	0.5	1.2	0.0	64.2	33.3	2.4	35.8	Shell hash
E26	98	0.051	4.3	1.5	3.8	0.5	1.0	0.0	56.2	40.8	3.0	43.8	Shell hash
E21	116	0.064	4.0	1.4	3.5	0.5	1.3	0.0	66.2	31.7	2.1	33.8	
Nearfield stations													
E11	98	0.069	3.9	1.3	3.5	0.5	1.4	0.0	68.0	29.9	2.1	32.0	
E14	98	0.067	3.9	1.4	3.5	0.5	1.3	0.0	69.5	28.5	1.9	30.4	Black sand, shell hash
E17	98	0.067	3.9	1.4	3.5	0.5	1.3	0.0	67.3	30.9	1.8	32.7	
E15	116	0.062	4.0	1.5	3.4	0.6	1.3	0.0	67.4	29.5	3.1	32.6	
Stations south of the outfall													
E1	88	0.055	4.2	1.7	3.8	0.4	0.9	1.4	55.0	40.3	3.3	43.6	Coarse sand, shell hash, pea gravel
E7	88	0.056	4.2	1.5	3.8	0.4	1.1	0.0	58.2	39.6	2.2	41.8	
E2	98	0.123	3.0	1.8	4.0	-0.8	0.9	10.8	34.6	54.5	0.0	54.5	Coarse sand, shell hash, pea gravel
E5	98	0.068	3.9	1.4	3.5	0.5	1.2	0.0	66.6	31.4	2.0	33.4	
E8	98	0.066	3.9	1.4	3.6	0.4	1.2	0.0	66.3	31.5	2.1	33.6	
E3	116	0.066	3.9	1.9	3.2	0.5	0.9	2.2	60.2	34.2	3.4	37.6	Coarse sand, shell hash, pea gravel
E9	116	0.054	4.2	1.7	3.6	0.5	1.0	0.0	60.2	36.1	3.7	39.8	Coarse black sand, shell hash

Appendix C.3 *continued*

PLOO sediment statistics for the July 2008 survey. ns=not sampled.

	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Fines (%)	Visual Observations
North reference stations													
B8	88	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
B11	88	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
B9	98	0.052	4.3	1.7	3.7	0.5	0.9	0.0	56.9	39.9	3.2	43.1	Mud, pea gravel
B12	98	0.072	3.8	1.8	3.1	0.5	1.1	1.7	67.4	27.9	2.9	30.9	Shell hash, pea gravel
B10	116	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Stations north of the outfall													
E19	88	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E20	98	0.060	4.1	1.4	3.6	0.5	1.2	0.0	62.9	34.8	2.3	37.1	Shell hash
E23	98	0.055	4.2	1.5	3.7	0.5	1.2	0.0	59.4	37.9	2.6	40.6	Shell hash
E25	98	0.057	4.1	1.5	3.7	0.4	1.1	0.0	61.1	35.9	3.0	38.9	Shell hash
E26	98	0.052	4.3	1.5	3.8	0.4	1.0	0.0	56.4	40.8	2.8	43.6	Shell hash
E21	116	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Nearfield stations													
E11	98	0.068	3.9	1.3	3.6	0.4	1.3	0.0	68.1	29.9	1.9	31.8	Shell hash
E14	98	0.073	3.8	1.4	3.5	0.4	1.4	2.1	68.8	26.6	2.5	29.1	Coarse black sand, shell hash
E17	98	0.069	3.8	1.3	3.5	0.5	1.4	0.0	67.9	30.0	2.1	32.1	Shell hash, organic material
E15	116	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Stations south of the outfall													
E1	88	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E7	88	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E2	98	0.053	4.2	1.8	3.8	0.4	0.9	2.1	53.0	40.9	4.0	44.9	Coarse sand, pea gravel, shell hash
E5	98	0.061	4.0	1.5	3.6	0.4	1.1	0.0	63.9	33.4	2.6	36.1	Coarse black sand, shell hash
E8	98	0.071	3.8	1.3	3.5	0.5	1.4	0.0	67.9	30.1	1.9	32.1	Shell hash
E3	116	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E9	116	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Appendix C.4

Summary of organic loading indicators at PLOO benthic stations for the January (A) and July (B) 2008 surveys. nd=not detected; ns=not sampled.

A	BOD (ppm)	Sulfides (ppm)	TN (% wt)	TOC (% wt)	TVS (% wt)
North reference stations					
B8	287	3.40	0.077	0.85	2.92
B11	376	1.63	0.078	3.51	4.14
B9	312	0.18	0.059	0.86	2.83
B12	296	0.34	0.060	4.11	3.24
B10	314	2.52	0.056	2.32	2.77
Stations north of the outfall					
E19	214	2.97	0.063	0.71	2.33
E20	209	0.37	0.053	0.64	1.92
E23	231	5.78	0.060	0.68	2.20
E25	208	nd	0.056	0.68	2.16
E26	221	5.89	0.066	0.76	2.67
E21	227	0.68	0.053	0.61	2.10
Nearfield stations					
E11	391	29.60	0.045	0.72	2.01
E14	469	14.90	0.045	0.68	1.98
E17	299	0.50	0.050	0.57	1.81
E15	467	0.72	0.056	0.79	2.32
Stations south of the outfall					
E1	254	1.91	0.039	0.45	2.34
E7	249	0.31	0.054	0.59	2.08
E2	296	0.71	0.032	0.62	2.57
E5	202	0.21	0.041	0.65	1.72
E8	246	1.28	0.042	0.61	2.09
E3	169	7.37	0.028	0.48	2.19
E9	239	1.64	0.062	1.81	2.59

B	BOD (ppm)	Sulfides (ppm)	TN (% wt)	TOC (% wt)	TVS (% wt)
North reference stations					
B8	ns	ns	ns	ns	ns
B11	ns	ns	ns	ns	ns
B9	194	nd	0.061	0.99	2.91
B12	240	nd	0.049	3.86	3.23
B10	ns	ns	ns	ns	ns
Stations north of the outfall					
E19	ns	ns	ns	ns	ns
E20	177	7.54	0.053	0.60	2.25
E23	178	1.07	0.061	0.69	2.41
E25	151	0.63	0.056	0.76	2.32
E26	181	nd	0.064	0.72	2.38
E21	ns	ns	ns	ns	ns
Nearfield stations					
E11	118	3.44	0.049	0.65	2.74
E14	175	1.58	0.042	0.63	1.85
E17	204	10.60	0.048	0.53	1.82
E15	ns	ns	ns	ns	ns
Stations south of the outfall					
E1	ns	ns	ns	ns	ns
E7	ns	ns	ns	ns	ns
E2	166	0.92	0.049	0.76	2.75
E5	93	0.86	0.045	0.62	1.89
E8	129	0.98	0.044	0.61	1.85
E3	ns	ns	ns	ns	ns
E9	ns	ns	ns	ns	ns

Appendix C.5

Concentrations of trace metals (ppm) for the January 2008 PLOO survey. ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected. Values that exceed ERL or ERM threshold values are in bold.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
North reference stations																		
B8	11000	1.2	3.94	52.9	nd	0.13	23.4	7.3	17100	4.7	150.0	0.035	11.3	nd	**3.38**	1.1	2.3	36.4
B11	11400	1.6	4.64	46.0	nd	0.20	26.4	5.1	21500	4.7	163.0	0.033	10.9	0.35	**1.27**	nd	1.6	41.4
B9	9030	1.3	3.30	101.0	nd	0.12	24.7	4.1	18000	3.5	128.0	0.029	9.7	nd	**1.79**	nd	2.2	35.3
B12	7590	1.3	5.28	25.0	nd	0.19	27.8	1.3	23500	3.4	86.0	0.017	7.6	nd	nd	nd	2.0	36.2
B10	6740	0.9	3.31	25.1	nd	0.14	20.2	3.1	15500	3.1	80.4	0.017	6.6	0.28	nd	nd	1.9	29.2
Stations north of the outfall																		
E19	13100	0.9	3.27	52.1	nd	0.17	22.4	6.7	15500	4.1	151.0	0.034	10.9	nd	**2.17**	1.1	2.5	35.9
E20	9250	0.8	3.26	34.1	nd	0.11	16.5	4.3	11600	2.3	108.0	0.022	8.0	nd	**2.04**	0.5	2.2	25.8
E23	9900	1.2	3.00	40.2	nd	0.19	18.6	5.9	13000	3.1	121.0	0.025	9.2	nd	**3.01**	0.8	2.0	28.3
E25	8400	1.1	3.31	34.7	nd	0.17	16.8	4.6	11700	3.1	106.0	0.024	8.1	0.29	**1.97**	nd	2.0	25.4
E26	9300	0.9	3.01	42.4	nd	0.19	19.7	5.7	14000	3.6	129.0	0.030	9.7	nd	**3.31**	0.6	2.1	30.5
E21	8050	0.9	2.68	30.3	nd	0.16	16.3	4.6	11000	2.9	98.7	0.026	7.8	0.12	**2.05**	nd	2.2	24.0
Nearfield stations																		
E11	8880	0.8	3.43	28.4	nd	0.14	15.5	3.5	11000	1.8	104.0	0.017	7.4	nd	**2.85**	0.7	3.0	25.2
E14	7960	0.8	3.03	29.7	nd	0.19	15.0	4.6	10500	2.1	98.8	0.018	7.2	nd	0.67	1.1	2.2	25.8
E17	8640	0.5	3.48	30.6	nd	0.15	15.7	6.0	11300	2.4	99.1	0.018	7.5	nd	0.91	0.7	2.0	25.9
E15	9330	0.7	2.87	32.1	nd	0.14	18.0	5.1	12300	3.1	106.0	0.027	8.2	0.25	**1.83**	nd	2.4	28.4
Stations south of the outfall																		
E1	9750	0.4	3.15	41.5	nd	nd	15.6	5.9	12000	3.4	85.0	0.038	6.1	nd	**2.73**	nd	2.0	27.2
E7	10700	1.0	2.85	39.7	nd	0.21	17.4	5.2	12500	3.2	118.0	0.031	8.3	0.30	**1.15**	0.7	2.2	29.2
E2	12100	1.0	2.30	54.0	nd	nd	16.6	9.7	15900	2.6	105.0	0.044	6.7	0.30	**3.24**	nd	2.0	34.1
E5	10500	0.9	1.84	37.8	nd	0.08	16.7	4.4	12000	2.4	112.0	0.019	7.3	nd	**2.90**	0.4	1.6	27.9
E8	9020	0.9	2.63	32.3	nd	0.11	15.7	4.2	11100	2.5	105.0	0.021	6.9	nd	**2.76**	0.7	2.2	27.0
E3	10600	0.7	2.45	54.5	nd	nd	14.8	12.7	13600	3.8	97.0	0.045	5.6	nd	**2.95**	nd	1.9	37.9
E9	9240	0.8	2.66	31.3	nd	0.13	20.6	7.2	14200	4.3	101.0	0.059	7.7	nd	**1.32**	nd	2.2	38.4
ERL	na	na	8.2	na	na	1.20	81	34	na	46.7	na	0.15	20.9	na	1	na	na	150
ERM	na	na	70	na	na	9.6	370	270	na	218	na	0.71	51.6	na	3.7	na	na	410

Appendix C.5 *continued*

Concentrations of trace metals (ppm) for the July 2008 PLOO survey. ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected; ns=not sampled. Values that exceed ERL or ERM threshold values are in bold.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
North reference stations																		
B8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
B11	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
B9	9090	nd	4.75	59.2	nd	0.13	24.3	5.9	18800	3.7	98.2	0.034	8.1	nd	**1.18**	nd	1.0	40.8
B12	7960	nd	5.13	26.7	nd	0.17	25.8	4.3	22500	5.4	66.5	0.017	6.7	nd	0.09	nd	0.9	41.1
B10	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Stations north of the outfall																		
E19	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E20	8940	nd	2.83	41.0	nd	0.17	16.9	7.7	11300	3.2	93.6	0.037	7.9	nd	**1.50**	nd	1.1	30.3
E23	10200	nd	3.20	42.0	nd	0.14	17.8	7.3	12300	3.5	101.0	0.039	8.4	nd	**1.71**	nd	1.1	32.9
E25	9650	nd	3.28	36.9	nd	0.11	16.6	6.4	11500	3.3	94.3	0.036	7.6	nd	**1.67**	nd	1.1	29.9
E26	9980	nd	3.37	40.0	nd	0.11	17.5	7.2	11900	3.8	98.2	0.044	8.2	nd	**1.51**	nd	1.1	32.1
E21	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Nearfield stations																		
E11	7050	nd	3.32	28.0	nd	0.13	13.4	5.6	9400	2.4	72.5	0.016	6.0	nd	0.72	nd	0.8	25.7
E14	6620	nd	2.68	28.4	nd	0.15	13.1	5.5	8590	2.1	67.7	0.026	6.0	0.24	0.84	nd	0.8	22.8
E17	8510	nd	3.47	33.7	nd	0.20	15.7	6.4	10700	2.9	85.8	0.036	7.1	nd	**1.40**	nd	1.1	28.3
E15	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Stations south of the outfall																		
E1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E7	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E2	10000	nd	3.40	50.6	nd	0.12	17.6	14.3	13800	5.3	100.0	0.046	7.5	nd	**1.64**	nd	1.2	39.1
E5	10600	nd	2.97	49.3	nd	0.10	17.6	11.1	13800	5.0	100.0	0.023	7.5	nd	**1.78**	nd	1.2	38.0
E8	6930	nd	3.01	32.5	nd	0.13	14.5	6.5	10000	2.9	76.1	0.023	6.4	nd	0.80	nd	0.8	26.8
E3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E9	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
ERL	na	na	8.2	na	na	1.20	81	34	na	46.7	na	0.15	20.9	na	1	na	na	150
ERM	na	na	70	na	na	9.6	370	270	na	218	na	0.71	51.6	na	3.7	na	na	410

Appendix C.6

Concentrations of pesticides, total PCB, and total PAH detected at each PLOO benthic station during the January (A) and July (B) 2008 surveys. ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected; ns=not sampled.

A	Dieldrin (ppt)	tDDT (ppt)	HCB (ppt)	tPCB (ppt)	tPAH (ppb)
North reference stations					
B8	nd	600	910	45	17
B11	nd	390	nd	nd	7
B9	nd	660	nd	nd	8
B12	nd	445	nd	nd	13
B10	nd	300	nd	nd	20
Stations north of the outfall					
E19	nd	370	nd	311	11
E20	nd	340	nd	nd	20
E23	nd	370	nd	nd	32
E25	nd	330	320	nd	8
E26	nd	320	970	nd	nd
E21	nd	405	280	nd	nd
Nearfield stations					
E11	nd	220	nd	nd	nd
E14	nd	230	nd	nd	nd
E17	nd	240	nd	nd	6
E15	nd	310	nd	110	89
Stations south of the outfall					
E1	nd	nd	nd	nd	147
E7	nd	290	86	nd	246
E2	nd	1340	nd	857	7
E5	270	290	nd	nd	155
E8	nd	270	540	nd	7
E3	nd	310	nd	9159	689
E9	nd	310	670	9956	84
ERL	na	1580	na	na	4022
ERM	na	46100	na	na	44792

B	Dieldrin (ppt)	tDDT (ppt)	HCB (ppt)	tPCB (ppt)	tPAH (ppb)
North reference stations					
B8	ns	ns	ns	ns	ns
B11	ns	ns	ns	ns	ns
B9	nd	210	140	nd	nd
B12	nd	210	nd	nd	nd
B10	ns	ns	ns	ns	ns
Stations north of the outfall					
E19	ns	ns	ns	ns	ns
E20	nd	260	230	nd	nd
E23	nd	460	nd	nd	nd
E25	nd	410	230	nd	nd
E26	nd	305	99	nd	nd
E21	ns	ns	ns	ns	ns
Nearfield stations					
E11	nd	180	nd	nd	nd
E14	nd	417	950	nd	nd
E17	nd	570	1900	nd	nd
E15	ns	ns	ns	ns	ns
Stations south of the outfall					
E1	ns	ns	ns	ns	ns
E7	ns	ns	ns	ns	ns
E2	nd	370	130	490	42
E5	nd	150	120	nd	nd
E8	nd	170	nd	nd	nd
E3	ns	ns	ns	ns	ns
E9	ns	ns	ns	ns	ns
ERL	na	1580	na	na	4022
ERM	na	46100	na	na	44792

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Appendix D

Supporting Data

2008 PLOO Stations

Macrobenthic Communities

Appendix D.1

All taxa composing cluster groups A–H from the 2008 surveys of PLOO benthic stations. Data are expressed as mean abundance per sample (no./0.1 m^2) and represent the most abundant taxa in each group. Values for the three most abundant species in each cluster group are in bold; (n)=number of station/survey entities per cluster group.

		Cluster Group							
Species/Taxa	**Taxa**	**A (2)**	**B (1)**	**C (1)**	**D (4)**	**E (1)**	**F (2)**	**G (3)**	**H (20)**
Acanthoptilum sp	Cnidaria				0.1				0.4
Acila castrensis	Mollusca	0.3							<0.1
Acoetes pacifica	Polychaeta	0.3							<0.1
Acrocirrus cf *frontifilis*	Polychaeta		0.5						
Acteocina cerealis	Mollusca	0.3		0.5	0.5	1.5	5.5	1.3	3.3
Acteocina sp	Mollusca								0.1
Acteon traskii	Mollusca				0.1		0.3		<0.1
Adontorhina cyclia	Mollusca	1.8	**20.0**	**24.5**	0.1	5.0	0.3	3.2	6.0
Aglaophamus verrilli	Polychaeta	0.3	0.5	1.5	0.6			1.3	0.3
Alvania rosana	Mollusca	0.8	1.5						0.2
Amaeana occidentalis	Polychaeta				0.5	0.5		0.5	0.1
Amage anops	Polychaeta		0.5						
Americhelidium shoemakeri	Crustacea	0.3					0.8		0.2
Americhelidium sp SD4	Crustacea	0.3							0.1
Ampelisca agassizi	Crustacea							0.2	0.1
Ampelisca brevisimulata	Crustacea	0.3	1.0	1.5	0.6		0.8	0.7	1.2
Ampelisca careyi	Crustacea	2.8	1.0		2.0	1.5	2.3	1.5	2.7
Ampelisca cf *brevisimulata*	Crustacea							0.2	0.3
Ampelisca cristata cristata	Crustacea				0.1		1.0	0.5	0.7
Ampelisca hancocki	Crustacea	0.3	1.0	0.5	1.1	0.5	0.3	1.2	1.7
Ampelisca indentata	Crustacea				0.4				
Ampelisca milleri	Crustacea		1.5		0.1			0.5	
Ampelisca pacifica	Crustacea	1.3	0.5	2.5	2.6	1.5	1.3	4.3	4.3
Ampelisca pugetica	Crustacea	2.8	1.0	1.5	1.4	2.0		0.7	1.9
Ampelisca romigi	Crustacea	0.3			0.4				0.1
Ampelisca sp	Crustacea				0.6		0.3	0.5	0.3
Ampharete finmarchica	Polychaeta				0.1			1.0	0.4
Ampharete labrops	Polychaeta				0.1				
Ampharete sp	Polychaeta		0.5					0.3	0.2
Ampharetidae	Polychaeta	0.3			0.4			0.2	0.2
Ampharetidae sp SD1	Polychaeta	0.3	0.5		0.1				0.1
Amphichondrius granulatus	Echinodermata		0.5	1.0	2.6	1.0			0.4
Amphicteis mucronata	Polychaeta								<0.1
Amphicteis scaphobranchiata	Polychaeta		0.5		0.9	0.5	0.3	0.3	0.4
Amphicteis sp	Polychaeta								0.1
Amphiodia digitata	Echinodermata	7.0	2.0	0.5	2.3	3.0	0.5		0.1
Amphiodia sp	Echinodermata	3.5	1.5	8.5	5.4	4.0	1.5	**15.2**	3.7
Amphiodia urtica	Echinodermata	1.8	10.0	**51.0**	**16.6**	2.0	3.3	**60.7**	**20.4**
Amphioplus sp	Echinodermata								0.1
Amphioplus strongyloplax	Echinodermata								0.1
Amphipholis squamata	Echinodermata		1.5		0.1				
Amphiporus sp	Nemertea								<0.1
Amphissa undata	Mollusca	0.3			0.1				
Amphiura arcystata	Echinodermata				0.4			0.2	0.1
Amphiuridae	Echinodermata	2.5	1.5	2.0	2.5	1.0	1.5	4.7	1.8

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group							
		A	B	C	D	E	F	G	H
Amygdalum politum	Mollusca					0.5			
Anarthruridae	Crustacea								<0.1
Anobothrus gracilis	Polychaeta	0.3			0.8	1.0	0.8	1.0	0.8
Anonyx lilljeborgi	Crustacea	0.3	0.5			1.0	0.3		0.3
Anopla	Nemertea								<0.1
Aoroides sp	Crustacea								<0.1
Aoroides sp A	Crustacea	0.5	0.5						
Aphelochaeta glandaria complex	Polychaeta	6.3	0.5		2.8	0.5	1.0	0.7	3.4
Aphelochaeta monilaris	Polychaeta	1.3	2.5	0.5	1.5	**11.5**	0.8	3.8	3.3
Aphelochaeta sp	Polychaeta		0.5		0.5	0.5	0.5	0.5	0.4
Aphelochaeta sp LA1	Polychaeta	0.5	4.0		3.5	2.5	0.8	1.0	0.4
Aphelochaeta tigrina	Polychaeta	1.0	1.5		1.1	0.5		0.2	0.2
Aphrodita sp	Polychaeta		0.5						<0.1
Apionsoma misakianum	Sipuncula		5.0						
Apistobranchus ornatus	Polychaeta								<0.1
Arabella sp	Polychaeta				0.1				
Arachnanthus sp A	Cnidaria				0.1				0.1
Araphura breviaria	Crustacea	0.3			0.1	0.5		0.2	0.8
Araphura cuspirostris	Crustacea				0.3				
Araphura sp	Crustacea							0.2	
Araphura sp SD1	Crustacea	0.3							0.5
Argissa hamatipes	Crustacea				0.1				
Aricidea (*Acmira*) *catherinae*	Polychaeta	8.3	1.0	0.5	3.9	5.5	8.5	4.2	8.0
Aricidea (*Acmira*) *lopezi*	Polychaeta							0.5	0.4
Aricidea (*Acmira*) *simplex*	Polychaeta	0.5	3.5	0.5	3.1	0.5	1.0	1.5	2.0
Aricidea (*Acmira*) sp	Polychaeta						0.3		0.1
Aricidea (*Aedicira*) *pacifica*	Polychaeta								<0.1
Aricidea (*Allia*) *antennata*	Polychaeta	0.8			0.3				0.2
Aricidea (*Allia*) *hartleyi*	Polychaeta				0.3				0.1
Aricidea (*Allia*) sp A	Polychaeta	0.5			1.1	1.5	2.3	1.8	2.8
Aricidea (*Aricidea*) *pseudoarticulata*	Polychaeta								<0.1
Aricidea (*Aricidea*) *wassi*	Polychaeta	1.0			0.5				0.1
Armandia brevis	Polychaeta		1.0				0.3		
Artacama coniferi	Polychaeta	0.3		0.5					0.1
Artacamella hancocki	Polychaeta				0.4				0.1
Aruga holmesi	Crustacea		0.5		0.1			0.2	<0.1
Aruga oculata	Crustacea				0.1		0.3	0.7	0.2
Asabellides lineata	Polychaeta	0.3	0.5						0.1
Ascidiacea	Chordata				0.3				
Asteroidea	Echinodermata								<0.1
Astropecten verrilli	Echinodermata	0.3							
Axinopsida serricata	Mollusca	2.0	11.5	**21.0**	0.6	6.0	12.0	13.5	9.5
Balanoglossus sp	Chordata								<0.1
Bathyleberis cf *garthi*	Crustacea	0.3							0.1
Bathymedon pumilus	Crustacea		0.5		0.1		0.3	0.7	0.7
Mollusca	Mollusca								0.1
Brada pluribranchiata	Polychaeta			0.5				0.3	0.1
Brada villosa	Polychaeta	0.3							
Brisaster sp	Echinodermata			0.5					

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Byblis millsi	Crustacea	1.8	0.5		0.4			0.8	0.4
Byblis sp	Crustacea				0.1				0.1
Caecognathia crenulatifrons	Crustacea	4.0		2.0	1.3	1.0	1.8	2.0	2.1
Campylaspis canaliculata	Crustacea		0.5				0.3		<0.1
Campylaspis rubromaculata	Crustacea				0.1				
Capitella capitata complex	Polychaeta						10.8		0.9
Capitellidae	Polychaeta								<0.1
Caprella mendax	Crustacea				0.1				
Cardiomya pectinata	Mollusca				0.1			0.2	
Carinoma mutabilis	Nemertea		0.5		0.1			0.3	<0.1
Cephalaspidea	Mollusca								<0.1
Cephalophoxoides homilis	Crustacea		0.5		0.3				0.1
Cerebratulus sp	Nemertea								<0.1
Chaetozone hartmanae	Polychaeta	3.3	2.5	1.0	2.9	7.5	5.3	1.8	5.7
Chaetozone hedgpethi	Polychaeta				0.1				0.1
Chaetozone sp	Polychaeta	1.0	0.5		0.5	0.5			0.2
Chaetozone sp SD1	Polychaeta	1.8							0.1
Chaetozone sp SD3	Polychaeta	1.8			0.4				
Chaetozone sp SD4	Polychaeta	3.8							
Chaetozone sp SD5	Polychaeta	0.3							
Chauliopleona dentata	Crustacea							0.5	0.1
Chiridota sp	Echinodermata			0.5	0.4	1.0	0.3	0.8	0.4
Chloeia pinnata	Polychaeta	2.5			0.8	1.0	4.5		1.2
Chone albocincta	Polychaeta							0.5	0.1
Chone ecaudata	Polychaeta				0.1				
Chone paramollis	Polychaeta								0.1
Chone sp	Polychaeta							0.2	<0.1
Chone sp B	Polychaeta				0.3				
Chone trilineata	Polychaeta	1.3	0.5		0.6	0.5	2.5	0.7	0.6
Chone veleronis	Polychaeta							0.2	
Cirratulidae	Polychaeta	0.8	1.0		0.5		0.3	0.3	0.4
Cirrophorus furcatus	Polychaeta				0.1				
Clymenura gracilis	Polychaeta	0.3	3.0	2.5	4.3		0.8	3.2	1.3
Compressidens stearnsii	Mollusca	0.8			0.1	1.0			0.4
Compsomyax subdiaphana	Mollusca							0.2	
Conidae	Mollusca		0.5						
Corbula porcella	Mollusca						0.3		
Corophiida	Crustacea								0.1
Corymorpha bigelowi	Cnidaria	0.3							
Cossura candida	Polychaeta			0.5	1.1		1.0	0.3	0.5
Cossura sp	Polychaeta			0.5	0.4				0.2
Cryptonemertes actinophila	Nemertea				0.1				
Cuspidaria parapodema	Mollusca				0.1			0.2	0.1
Cyclopecten catalinensis	Mollusca								<0.1
Cylichna diegensis	Mollusca		0.5	2.0			0.8	0.8	0.5
Decamastus gracilis	Polychaeta	7.8	0.5		4.6	10.5	5.3	0.3	3.5
Deflexilodes norvegicus	Crustacea	0.3		0.5	0.4	1.5	0.3		1.4
Deilocerus decorus	Crustacea	0.3	0.5						
Dentalium vallicolens	Mollusca								<0.1

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Desdimelita desdichada	Crustacea				0.1				
Diaphana californica	Mollusca				0.1				
Diastylis crenellata	Crustacea	0.5	1.5		0.6		1.5	0.2	1.4
Dipolydora socialis	Polychaeta		1.5		0.1				0.3
Dougaloplus amphacanthus	Echinodermata	1.0	0.5		0.8	2.5			0.1
Dougaloplus sp	Echinodermata				0.1	0.5			0.1
Dougaloplus sp A	Echinodermata	0.3	4.5		0.1				
Drilonereis falcata	Polychaeta				0.6		0.3		0.1
Drilonereis longa	Polychaeta		0.5		0.8			0.3	<0.1
Drilonereis sp	Polychaeta	1.3	1.0		1.6	1.0	0.3		0.2
Drilonereis sp A	Polychaeta				0.6				
Eclysippe trilobata	Polychaeta	0.3			0.1	0.5	1.0		0.7
Edwardsia sp G	Cnidaria		0.5				0.3		<0.1
Edwardsiidae	Cnidaria								0.1
Ennucula tenuis	Mollusca	0.8	3.0	5.0	2.0	1.0	2.3	5.7	2.3
Enteropneusta	Chordata								<0.1
Eranno bicirrata	Polychaeta				0.1				0.2
Eranno lagunae	Polychaeta			0.5	0.3	0.5			0.1
Eteone leptotes	Polychaeta								<0.1
Eteone pigmentata	Polychaeta								<0.1
Euchone arenae	Polychaeta				0.1				0.1
Euchone hancocki	Polychaeta				0.1				
Euchone incolor	Polychaeta	0.3			0.1		0.5	0.2	0.6
Euclymeninae	Polychaeta	0.3	1.0		0.6		0.3	0.7	1.0
Euclymeninae sp A	Polychaeta		2.5	0.5	1.5	2.0	0.8	2.0	1.0
Eudorella pacifica	Crustacea								0.3
Eudorellopsis longirostris	Crustacea	0.3							
Eulalia californiensis	Polychaeta		1.5						
Eulalia levicornuta complex	Polychaeta				0.1				<0.1
Eulima raymondi	Mollusca				0.1				
Eulimidae	Mollusca					0.5			
Eunice americana	Polychaeta					1.0		0.2	<0.1
Euphilomedes carcharodonta	Crustacea	3.0	1.0		1.3	0.5	8.5	1.3	5.7
Euphilomedes producta	Crustacea	**13.3**	3.0	2.5	3.0	5.5	8.0	0.3	**9.2**
Eurydice caudata	Crustacea				0.1				
Eusyllis blomstrandi	Polychaeta	0.5	0.5						
Exogone dwisula	Polychaeta				0.1				
Exogone lourei	Polychaeta		1.5		1.6				
Exosphaeroma rhomburum	Crustacea								<0.1
Eyakia robusta	Crustacea	0.8	2.5	3.0	1.5			0.5	1.2
Falcidens longus	Mollusca	0.3		1.0					0.1
Fauveliopsis sp SD1	Polychaeta	13.0			0.1	3.5			
Flabelligeridae	Polychaeta						0.3		
Foxiphalus obtusidens	Crustacea							0.2	0.1
Foxiphalus similis	Crustacea	1.3			0.9				0.2
Galathowenia pygidialis	Polychaeta								0.1
Gammaropsis ociosa	Crustacea	0.3	2.5		0.3		0.3		
Gammaropsis thompsoni	Crustacea				0.3				
Gastropteron pacificum	Mollusca						0.3		

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Glycera americana	Polychaeta				0.1		0.5	0.2	<0.1
Glycera nana	Polychaeta	1.5	2.5	2.0	4.5	3.5	8.8	4.2	2.0
Glycera tesselata	Polychaeta		1.0						
Glycinde armigera	Polychaeta	0.5	1.5		2.1	2.5	0.3	1.0	0.9
Goniada brunnea	Polychaeta	0.3					0.3		0.3
Goniada maculata	Polychaeta	0.5	1.0		0.8	1.0	0.8		0.3
Gymnonereis crosslandi	Polychaeta			0.5	0.1				
Halianthella sp A	Cnidaria					0.5		0.3	0.1
Halicoides synopiae	Crustacea				0.1			0.5	0.2
Haliophasma geminatum	Crustacea	1.5	1.0		1.3		1.3		0.4
Hartmanodes hartmanae	Crustacea							0.2	
Hemilamprops californicus	Crustacea								0.1
Heteronemertea	Nemertea								<0.1
Heteronemertea sp SD2	Nemertea				0.3				0.1
Heterophoxus ellisi	Crustacea				0.5				0.1
Heterophoxus oculatus	Crustacea	0.3	1.5	2.5	0.6		1.0	2.8	1.2
Heterophoxus sp	Crustacea								0.1
Heterospio catalinensis	Polychaeta					0.5			
Hippomedon sp	Crustacea	0.3							
Hippomedon sp A	Crustacea	3.3							0.7
Huxleyia munita	Mollusca	7.0			0.5	2.0		1.3	0.2
Idoteidae	Crustacea								<0.1
Inusitatomysis insolita	Crustacea								0.1
Janiralata occidentalis	Crustacea								<0.1
Jasmineira sp B	Polychaeta				0.1				0.2
Kurtzia arteaga	Mollusca	0.5							
Kurtzina beta	Mollusca	1.5	0.5	2.0	0.4	1.0		1.2	0.7
Lanassa sp	Polychaeta								<0.1
Lanassa venusta venusta	Polychaeta		0.5		0.1				0.5
Lanice conchilega	Polychaeta		0.5						
Laonice cirrata	Polychaeta	1.0	1.0		0.5		0.5	0.2	0.3
Laonice nuchala	Polychaeta		2.5	0.5	0.9				<0.1
Lasaeidae	Mollusca							0.2	
Leitoscoloplos pugettensis	Polychaeta							0.2	
Leptochelia dubia	Crustacea	1.5	0.5		1.9	2.5	0.5	0.5	2.6
Leptochiton rugatus	Mollusca		0.5						
Leptostylis abditis	Crustacea				0.1				
Leptosynapta sp	Echinodermata	2.0		0.5	1.5	3.0	0.3	0.2	0.5
Levinsenia gracilis	Polychaeta				0.9			0.3	0.8
Levinsenia sp B	Polychaeta		0.5		2.4			0.3	0.5
Limatula saturna	Mollusca	0.3							
Lineidae	Nemertea		0.5	0.5	0.6		0.5	0.8	0.6
Lineus bilineatus	Nemertea	0.3					1.5		0.3
Lirobittium larum	Mollusca	9.5							
Listriella goleta	Crustacea				0.4		0.3	0.5	<0.1
Listriella melanica	Crustacea	0.3							
Listriella sp SD1	Crustacea						0.3		
Lucinoma annulatum	Mollusca			0.5	0.1	0.5	1.3	1.2	0.6
Lumbrineridae	Polychaeta								0.1

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Lumbrineridae Group III	Polychaeta				0.5		0.3		0.1
Lumbrineris cruzensis	Polychaeta	1.3	0.5	3.0	5.4	0.5	**8.5**	3.8	4.3
Lumbrineris latreilli	Polychaeta		0.5				0.5		0.1
Lumbrineris lingulata	Polychaeta	1.0			1.1			0.2	
Lumbrineris sp	Polychaeta								0.2
Lumbrineris sp Group I	Polychaeta		1.5	1.5	10.1	3.0	**13.5**	9.2	5.7
Lumbrineris sp Group II	Polychaeta	0.8	1.0		0.5				0.1
Lysippe sp A	Polychaeta	0.5	1.0		3.3	5.0	1.3	0.5	1.7
Lysippe sp B	Polychaeta		1.0		0.5	0.5	0.3	0.5	0.3
Lytechinus pictus	Echinodermata	0.5	0.5	0.5	0.3			0.3	0.4
Macoma sp	Mollusca	0.3		0.5	0.1				0.4
Macoma yoldiformis	Mollusca						0.3		
Maera similis	Crustacea					1.0			
Magelona berkeleyi	Polychaeta	1.0							
Magelona sp B	Polychaeta	0.3							
Maldane sarsi	Polychaeta	0.3	1.0	1.5	1.0	1.5	1.3	2.2	0.8
Maldanidae	Polychaeta	0.3	1.0		0.3		0.8	0.8	0.6
Malmgreniella baschi	Polychaeta				0.3				0.1
Malmgreniella macginitiei	Polychaeta				0.3		0.3		<0.1
Malmgreniella sanpedroensis	Polychaeta					0.5		0.2	<0.1
Malmgreniella scriptoria	Polychaeta								<0.1
Malmgreniella sp	Polychaeta	0.3							<0.1
Malmgreniella sp A	Polychaeta	0.5		0.5	0.5	1.5		0.5	0.4
Mayerella banksia	Crustacea							0.2	
Mediomastus sp	Polychaeta	13.0	4.5	5.0	**23.6**	**18.5**	**22.3**	**18.7**	**16.6**
Megalomma sp	Polychaeta								<0.1
Megalomma splendida	Polychaeta					0.5			<0.1
Megasurcula carpenteriana	Mollusca								<0.1
Melanella rosa	Mollusca						0.3		
Melinna oculata	Polychaeta							0.2	0.1
Melphisana bola complex	Crustacea								0.1
Metaphoxus frequens	Crustacea						0.3		0.1
Metasychis disparidentatus	Polychaeta						0.3		
Micranellum crebricinctum	Mollusca	**16.0**							
Microjassa sp	Crustacea					0.5			
Micrura sp	Nemertea								0.1
Molgula napiformis	Chordata					1.0			0.1
Molgula pugetiensis	Chordata				0.1			0.2	<0.1
Molgula regularis	Chordata		0.5						
Molgula sp	Chordata								0.2
Molpadia intermedia	Echinodermata	0.3						0.2	
Mollusca	Mollusca					0.5			0.1
Monoculodes emarginatus	Crustacea	0.3	1.5		0.8	1.0	0.3	0.5	0.7
Monticellina cryptica	Polychaeta	1.3	2.5	0.5	2.0		0.3	1.8	1.2
Monticellina siblina	Polychaeta	0.5	1.0		1.1	10.0	0.3		0.4
Monticellina sp	Polychaeta				0.3	2.0		0.2	0.1
Monticellina tesselata	Polychaeta	0.3		0.5	0.3	0.5			0.1
Mooreonuphis exigua	Polychaeta	0.3			0.1				
Mooreonuphis nebulosa	Polychaeta	0.3	1.5		0.5				

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Mooreonuphis segmentispadix	Polychaeta	0.5							
Mooreonuphis sp	Polychaeta	1.8			0.1				<0.1
Mooresamytha bioculata	Polychaeta								<0.1
Myriochele gracilis	Polychaeta	0.5	0.5		0.3	2.5		0.8	0.6
Myriochele striolata	Polychaeta								<0.1
Myriowenia californiensis	Polychaeta	0.3							
Mysidella americana	Crustacea								0.1
Myxicola sp	Polychaeta			0.5					<0.1
Naticidae	Mollusca								<0.1
Nebalia pugettensis complex	Crustacea						0.3		0.1
Nematoda	Nematoda				0.3				<0.1
Nemocardium centifilosum	Mollusca		0.5		0.3				0.1
Nephtys caecoides	Polychaeta				0.1				0.3
Nephtys cornuta	Polychaeta								0.1
Nephtys ferruginea	Polychaeta	1.3	0.5		0.5	3.5	1.3	0.7	1.1
Nereis sp A	Polychaeta				0.3				0.1
Nicippe tumida	Crustacea				0.1	0.5		0.5	0.5
Ninoe tridentata	Polychaeta							0.2	
Nothria occidentalis	Polychaeta		0.5						
Notocirrus californiensis	Polychaeta				0.3				0.1
Notomastus magnus	Polychaeta			0.5					
Notomastus sp	Polychaeta					0.5			0.1
Notomastus sp A	Polychaeta	1.0	1.0		3.3	0.5	5.0	0.5	0.4
Nuculana hamata	Mollusca	0.3	2.0				0.3	0.3	<0.1
Nuculana sp	Mollusca							0.2	
Nuculana sp A	Mollusca	1.0	3.5	1.0	0.3	1.5	6.0	1.3	1.1
Odostomia sp	Mollusca	1.5		0.5	0.1		0.5	0.2	0.5
Oerstedia dorsalis	Nemertea				0.3				
Onuphidae	Polychaeta								<0.1
Onuphis sp	Polychaeta								<0.1
Onuphis sp A	Polychaeta	0.3				1.0	0.3		0.2
Ophelina acuminata	Polychaeta			0.5				0.2	
Ophiura luetkenii	Echinodermata	0.5		0.5	0.3			0.7	0.2
Ophiuroidea	Echinodermata	0.3			0.1				0.1
Orchomenella decipiens	Crustacea								0.1
Pachynus barnardi	Crustacea								<0.1
Paguridae	Crustacea					0.5			
Paguristes turgidus	Crustacea					0.5			
Palaeonemertea	Nemertea								0.1
Pandora bilirata	Mollusca			0.5				0.3	0.1
Paradiopatra parva	Polychaeta	1.3	0.5	1.5	0.5	2.0	1.8	2.7	1.3
Paradoneis sp	Polychaeta								0.1
Paramage scutata	Polychaeta			0.5	0.1		0.3	0.5	0.1
Paranaitis polynoides	Polychaeta								<0.1
Paranaitis sp SD1	Polychaeta				0.1				
Paranemertes californica	Nemertea		0.5		0.1			0.2	0.4
Paraonidae	Polychaeta		0.5		0.1				0.3
Paraprionospio alata	Polychaeta	0.3	1.0		0.8	5.0	0.5	0.8	0.9
Pardaliscella symmetrica	Crustacea					0.5			

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Parvilucina tenuisculpta	Mollusca	2.0	1.0			3.5	4.5	1.3	1.8
Pectinaria californiensis	Polychaeta			0.5	0.8	0.5	1.3	1.5	1.7
Pentamera populifera	Echinodermata		0.5						
Periploma sp	Mollusca		0.5						
Petaloclymene pacifica	Polychaeta				0.3			0.2	0.3
Petaloproctus neoborealis	Polychaeta		6.0						
Phascolion sp A	Sipuncula	0.3	1.5	0.5	0.4	2.5	1.3	0.8	0.4
Pherusa negligens	Polychaeta		0.5		0.1				<0.1
Pherusa neopapillata	Polychaeta		5.0		0.1	0.5	0.3		0.1
Phisidia sanctaemariae	Polychaeta				0.5		0.5	0.5	0.7
Pholoe glabra	Polychaeta	1.5	0.5	0.5	0.9	1.0	0.8	1.2	1.1
Pholoides asperus	Polychaeta		**20.0**		0.3				
Phoronis sp	Phorona	0.3			0.3	1.0		0.3	0.1
Phoronis sp SD1	Phorona				0.1				0.1
Photis bifurcata	Crustacea		1.0				0.5		0.1
Photis californica	Crustacea	0.3	2.5		0.5				<0.1
Photis lacia	Crustacea	0.8	0.5		0.4		0.5		0.3
Photis macrotica	Crustacea				0.3				
Photis parvidons	Crustacea	0.3							
Photis sp	Crustacea	1.3	1.0		0.6	1.0	0.3	0.3	0.5
Phyllochaetopterus limicolus	Polychaeta	0.3							
Phyllodoce cuspidata	Polychaeta								0.1
Phyllodoce groenlandica	Polychaeta				0.1			0.2	0.1
Phyllodoce hartmanae	Polychaeta						0.3		
Phyllodoce longipes	Polychaeta							0.2	
Phyllodoce pettiboneae	Polychaeta								<0.1
Pinnixa occidentalis complex	Crustacea	0.3		1.0	0.5				<0.1
Pinnixa sp	Crustacea				0.1				
Pinnixa tubicola	Crustacea								<0.1
Pionosyllis articulata	Polychaeta		0.5						0.1
Piromis sp A	Polychaeta	0.3	0.5		0.5				
Pista brevibranchiata	Polychaeta				0.3				
Pista estevanica	Polychaeta	0.8	1.0		1.0	1.0	0.3		0.2
Pista sp	Polychaeta							0.2	
Pista wui	Polychaeta						0.3	0.2	<0.1
Podarkeopsis glabrus	Polychaeta		0.5		0.1				0.1
Polycirrus sp	Polychaeta		1.0	0.5	0.6			0.3	0.4
Polycirrus sp A	Polychaeta	0.3	1.0		0.8	0.5	0.5	0.5	1.1
Polycirrus sp I	Polychaeta							0.2	
Polygireulima rutila	Mollusca					0.5			
Polynoidae	Polychaeta				0.1				
Polyplacophora	Mollusca		0.5						
Polyschides quadrifissatus	Mollusca		0.5	2.0	0.8		1.3	1.0	1.5
Postasterope barnesi	Crustacea								<0.1
Prachynella lodo	Crustacea		0.5						0.1
Praxillella gracilis	Polychaeta								0.1
Praxillella pacifica	Polychaeta		0.5	1.0	1.5	1.0	0.8	1.3	2.2
Prionospio (*Minuspio*) *lighti*	Polychaeta				0.3			0.5	0.1
Prionospio (*Prionospio*) *dubia*	Polychaeta	4.0	4.0	0.5	7.0	3.0	1.3	3.0	2.6

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Prionospio (*Prionospio*) *jubata*	Polychaeta	**19.5**	**17.5**	2.0	**18.5**	11.0	7.8	9.2	8.7
Prionospio (*Prionospio*) sp	Polychaeta								<0.1
Procampylaspis caenosa	Crustacea	0.3	0.5						0.1
Proclea sp A	Polychaeta		1.0		1.1			4.5	1.0
Protocirrineris sp	Polychaeta				0.1	0.5			
Protocirrineris sp B	Polychaeta			0.5					
Protomedeia articulata complex	Crustacea			1.5			0.3	1.0	1.4
Pseudomma californica	Crustacea								<0.1
Rhachotropis sp A	Crustacea		0.5	0.5	0.5			0.7	0.3
Rhepoxynius bicuspidatus	Crustacea	0.5	1.5	6.5	0.5		2.5	5.0	4.6
Rhepoxynius lucubrans	Crustacea								<0.1
Rhepoxynius menziesi	Crustacea				0.1		2.0	0.2	0.9
Rhodine bitorquata	Polychaeta				0.6	1.0	0.3	0.5	0.3
Rictaxis punctocaelatus	Mollusca	1.0			0.8	1.0			0.1
Rochefortia compressa	Mollusca							0.3	<0.1
Rochefortia mortoni	Mollusca				0.1				
Rochefortia tumida	Mollusca		4.0	1.5	0.1			2.2	0.2
Rutiderma lomae	Crustacea								<0.1
Sabellidae	Polychaeta								<0.1
Sabellides manriquei	Polychaeta								<0.1
Scalibregma californicum	Polychaeta				0.1				0.1
Mollusca	Mollusca			0.5					<0.1
Schmittius politus	Crustacea		0.5						
Scleroconcha trituberculata	Crustacea				0.1				<0.1
Scolanthus sp A	Cnidaria							0.3	<0.1
Scoletoma tetraura complex	Polychaeta		1.0	0.5	1.4			0.2	0.5
Scoloplos armiger complex	Polychaeta	2.0			1.4	2.5	2.0	1.2	3.5
Scoloura phillipsi	Crustacea	0.3							
Sigalion spinosus	Polychaeta	0.3				1.0			0.8
Siphonolabrum californiensis	Crustacea			0.5			0.3	0.2	0.2
Sipuncula	Sipuncula		2.0						
Solamen columbianum	Mollusca		1.0	0.5	0.1		0.5		<0.1
Solariella peramabilis	Mollusca	0.5				1.0	0.5		0.1
Solemya reidi	Mollusca						1.5		
Sosane occidentalis	Polychaeta	0.3			0.1				0.1
Spatangus californicus	Echinodermata		0.5		0.1				<0.1
Sphaerodorum papillifer	Polychaeta								<0.1
Spio filicornis	Polychaeta	0.5	2.0			0.5	0.5	1.0	0.4
Spiophanes berkeleyorum	Polychaeta	1.0	1.0		0.1	1.0	1.5	0.7	4.9
Spiophanes bombyx	Polychaeta				0.1				
Spiophanes duplex	Polychaeta		0.5		0.3	1.5	0.5	1.2	1.1
Spiophanes kimballi	Polychaeta	0.8			0.3		0.5	0.2	0.5
Stereobalanus sp	Chordata		2.0	2.5	0.8				0.1
Sternaspis fossor	Polychaeta	0.8	1.5	3.5	2.0	5.5	3.3	3.7	5.4
Sthenelais tertiaglabra	Polychaeta	0.5	0.5	0.5		0.5	0.5	0.2	0.2
Sthenelanella uniformis	Polychaeta	0.3	1.0		1.1		0.3		0.2
Stolidobranchiata	Chordata								0.1
Streblosoma sp	Polychaeta							0.2	<0.1
Streptosyllis sp SD1	Polychaeta				0.1				

Appendix D.1 *continued*

Species/Taxa	Taxa	Cluster Group A	B	C	D	E	F	G	H
Strongylocentrotus fragilis	Echinodermata		0.5						
Stylatula sp	Cnidaria				0.1				
Tanaella propinquus	Crustacea			1.0	0.9			0.8	1.2
Tanaidacea	Crustacea	0.3						0.2	0.1
Tanaopsis cadieni	Crustacea	0.3			0.4			1.2	0.3
Tellina cadieni	Mollusca			0.5				0.2	0.2
Tellina carpenteri	Mollusca	5.0	8.0	4.0	2.8	**13.0**	5.8	2.8	4.1
Tellina sp	Mollusca								<0.1
Tenonia priops	Polychaeta			0.5					<0.1
Terebellidae	Polychaeta				0.3				0.1
Terebellides californica	Polychaeta	0.5	1.5	1.0	2.0	2.0	0.3	4.0	3.9
Terebellides reishi	Polychaeta				0.3				0.2
Terebellides sp	Polychaeta		0.5		0.5			1.2	0.2
Terebellides sp Type D	Polychaeta				0.1				0.1
Tetrastemma nigrifrons	Nemertea				0.1				
Thracia trapezoides	Mollusca		0.5					0.2	0.1
Thracioidea	Mollusca		0.5						
Thyasira flexuosa	Mollusca							0.3	0.1
Travisia brevis	Polychaeta	0.3	1.5	3.0	0.5			3.8	1.2
Trigonulina novemcostatus	Mollusca	0.3							
Tubulanidae	Nemertea							0.2	
Tubulanus cingulatus	Nemertea							0.2	<0.1
Tubulanus polymorphus	Nemertea				0.5				0.2
Tubulanus sp A	Nemertea								<0.1
Turbonilla sp A	Mollusca	0.3					0.5		<0.1
Turbonilla sp SD1	Mollusca					0.5			0.1
Turbonilla sp SD2	Mollusca				0.1			0.2	0.1
Turbonilla sp SD5	Mollusca						0.3	0.2	0.1
Turbonilla sp SD6	Mollusca	0.3							
Typhlotanais crassus	Crustacea								<0.1
Typhlotanais sp	Crustacea								<0.1
Typhlotanais williamsi	Crustacea							0.2	0.1
Typosyllis heterochaeta	Polychaeta	0.3	1.0		0.6	0.5		0.5	0.1
Urothoe elegans complex	Crustacea	4.5	1.0		0.9				0.3
Virgularia agassizii	Cnidaria							0.2	
Volvulella californica	Mollusca								<0.1
Volvulella cylindrica	Mollusca								0.1
Volvulella panamica	Mollusca			2.5			0.3	0.2	0.2
Westwoodilla tone	Crustacea	0.8	1.0	0.5	0.9	0.5	0.8	0.3	0.8
Xenoleberis californica	Crustacea			0.5			0.3		0.1
Zygeupolia rubens	Nemertea			1.0					

Appendix E

Supporting Data

2008 PLOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix E.1

Summary of demersal fish species captured during 2008 at PLOO stations. Data are number of fish (n), biomass (Bm, kg, wet weight), minimum (Min), maximum (Max), and mean length (cm, standard length). Taxonomic arrangement and scientific names are of Eschmeyer and Herald (1998) and Allen (2005).

				Length		
Taxon/Species	**Common name**	**n**	**Bm**	**Min**	**Max**	**Mean**
RAJIFORMES						
Rajidae						
Raja inornata	California skate	5	3.7	28	54	45
Raja stellulata	Starry skate	1	0.1	21	21	21
CHIMAERIFORMES						
Chimaeridae						
Hydrolagus colliei	Spotted ratfish	1	0.1	30	30	30
AULOPIFORMES						
Synodontidae						
Synodus lucioceps	California lizardfish	3	0.2	14	20	16
OPHIDIIFORMES						
Ophidiidae						
Chilara taylori	Spotted cuskeel	1	0.1	16	16	16
BATRACHOIDIFORMES						
Batrachoididae						
Porichthys notatus	Plainfin midshipman	108	2.7	7	18	12
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	17	6.4	15	29	22
Sebastes elongatus	Greenstriped rockfish	13	0.5	4	13	6
Sebastes eos	Pink rockfish	1	0.1	7	7	7
Sebastes rosenblatti	Greenblotched rockfish	7	0.5	6	8	7
Sebastes saxicola	Stripetail rockfish	51	1.0	7	11	8
Sebastes semicinctus	Halfbanded rockfish	161	3.3	8	15	10
Hexagrammidae						
Zaniolepis frenata	Shortspine combfish	57	1.1	7	16	13
Zaniolepis latipinnis	Longspine combfish	112	2.2	6	15	12
Cottidae						
Chitonotus pugetensis	Roughback sculpin	23	0.7	7	10	8
Icelinus quadriseriatus	Yellowchin sculpin	203	1.3	4	9	7
Icelinus tenuis	Spotfin sculpin	2	0.1	9	10	10
Agonidae						
Xeneretmus latifrons	Blacktip poacher	2	0.1	14	14	14
Xeneretmus triacanthus	Bluespotted poacher	1	0.1	15	15	15
PERCIFORMES						
Sciaenidae						
Genyonemus lineatus	White croaker	2	0.2	17	20	19
Embiotocidae						
Zalembius rosaceus	Pink seaperch	24	0.8	6	14	10
Bathymasteridae						
Rathbunella hypoplecta	Bluebanded ronquil	3	0.2	10	16	13
Zoarcidae						
Lycodopsis pacifica	Blackbelly eelpout	5	0.3	16	22	20
Lycodes cortezianus	Bigfin eelpout	3	0.1	17	23	21

Appendix E.1 *continued*

Taxon/Species	Common name	n	Bm	Length Min	Length Max	Length Mean
Gobiidae						
Rhinogobiops nicholsii	Blackeye goby	1	0.1	4	4	4
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys sordidus	Pacific sanddab	809	22.4	4	27	11
Citharichthys xanthostigma	Longfin sanddab	2	0.2	14	16	15
Hippoglossina stomata	Bigmouth sole	8	0.6	14	21	16
Pleuronectidae						
Eopsetta exilis	Slender sole	16	0.5	10	15	12
Microstomus pacificus	Dover sole	68	2.6	7	18	13
Parophrys vetulus	English sole	69	6.4	11	28	18
Pleuronichthys coenosus	Curlfin sole	1	0.1	15	15	15
Pleuronichthys verticalis	Hornyhead turbot	17	1.3	10	17	14
Cynoglossidae						
Symphurus atricauda	California tonguefish	5	0.3	14	16	15

Appendix E.2

Summary of total abundance by species and station for demersal fish at the Point Loma Ocean Outfall trawl stations during 2008.

	January 2008						
Name	SD7	SD8	SD10	SD12	SD13	SD14	Species abundance by survey
Pacific sanddab	85	112	66	43	99	247	652
Yellowchin sculpin	18	3	65	2	50	61	199
Plainfin midshipman	6	8	5	6	42	39	106
Longspine combfish	2	9	10	3	36	26	86
English sole	23	14	10	1	7	9	64
Halfbanded rockfish	2	20	19	12	5	5	63
Stripetail rockfish	5	6	7		13	20	51
Dover sole	2	10	2	10	6	11	41
Shortspine combfish	4	27	3	2	1	2	39
Roughback sculpin	3	2		1	5	8	19
California scorpionfish		2	3	5	6	1	17
Hornyhead turbot	2	2	1	1	8	3	17
Pink seaperch		2	3		3	1	9
Bigmouth sole		6	1	1			8
Slender sole				6	1		7
Greenblotched rockfish			2	2	1	1	6
Blackbelly eelpout				3	1	1	5
California tonguefish	3			1	1		5
Greenstriped rockfish		1	2		2		5
California skate	1	2	1				4
California lizardfish					2	1	3
Blacktip poacher		2					2
Bluebanded ronquil		2					2
Longfin sanddab					2		2
Spotfin sculpin		2					2
Bluespotted poacher						1	1
Curlfin sole						1	1
Spotted ratfish					1		1
Starry skate				1			1
Winter total	156	232	200	100	292	438	1418

Appendix E.2 *continued*

Name	July 2008		Species abundance by survey
	SD10	SD12	
Pacific sanddab	94	63	157
Halfbanded rockfish	49	49	98
Dover sole	7	20	27
Longspine combfish	8	18	26
Shortspine combfish	6	12	18
Pink seaperch	11	4	15
Slender sole	3	6	9
Greenstriped rockfish	1	7	8
English sole	4	1	5
Roughback sculpin	2	2	4
Yellowchin sculpin	4		4
Bigfin eelpout		3	3
Plainfin midshipman	2		2
White croaker	2		2
Blackeye goby		1	1
Bluebanded ronquil	1		1
California skate		1	1
Greenblotched rockfish		1	1
Pink rockfish	1		1
Spotted cuskeel	1		1
Summer total	196	188	384

Appendix E.3

Summary of biomass (kg) by species and station for demersal fish at the Point Loma Ocean Outfall trawl stations during 2008.

	January 2008						
Name	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Biomass by survey**
Pacific sanddab	3.2	7.0	1.5	0.5	2.3	5.6	20.1
California scorpionfish		0.6	1.0	1.8	2.5	0.5	6.4
English sole	2.0	1.5	0.6	0.2	1.0	0.6	5.9
California skate	0.1	2.0	0.5				2.6
Plainfin midshipman	0.1	0.1	0.1	0.2	1.1	1.0	2.6
Dover sole	0.1	0.3	0.1	0.4	0.3	0.4	1.6
Longspine combfish	0.1	0.2	0.1	0.1	0.5	0.5	1.5
Hornyhead turbot	0.2	0.1	0.1	0.1	0.5	0.3	1.3
Halfbanded rockfish	0.1	0.3	0.2	0.4	0.1	0.1	1.2
Yellowchin sculpin	0.1	0.1	0.2	0.1	0.3	0.4	1.2
Stripetail rockfish	0.1	0.1	0.1		0.3	0.4	1.0
Shortspine combfish	0.1	0.3	0.1	0.1	0.1	0.1	0.8
Bigmouth sole		0.3	0.2	0.1			0.6
Roughback sculpin	0.1	0.1		0.1	0.1	0.1	0.5
Greenblotched rockfish			0.1	0.1	0.1	0.1	0.4
Pink seaperch		0.1	0.1		0.1	0.1	0.4
Blackbelly eelpout				0.1	0.1	0.1	0.3
California tonguefish	0.1			0.1	0.1		0.3
Greenstriped rockfish		0.1	0.1		0.1		0.3
Slender sole				0.2	0.1		0.3
California lizardfish					0.1	0.1	0.2
Longfin sanddab					0.2		0.2
Blacktip poacher		0.1					0.1
Bluebanded ronquil		0.1					0.1
Bluespotted poacher						0.1	0.1
Curlfin sole						0.1	0.1
Spotfin sculpin		0.1					0.1
Spotted ratfish					0.1		0.1
Starry skate				0.1			0.1
Winter total	6.4	13.5	5.1	4.7	10.1	10.6	50.4

Appendix E.3 *continued*

Name	July 2008		Biomass by survey
	SD10	SD12	
Pacific sanddab	1.4	0.9	2.3
Halfbanded rockfish	1.1	1.0	2.1
California skate		1.1	1.1
Dover sole	0.2	0.8	1.0
Longspine combfish	0.3	0.4	0.7
English sole	0.4	0.1	0.5
Pink seaperch	0.3	0.1	0.4
Shortspine combfish	0.1	0.2	0.3
Greenstriped rockfish	0.1	0.1	0.2
Roughback sculpin	0.1	0.1	0.2
Slender sole	0.1	0.1	0.2
White croaker	0.2		0.2
Bigfin eelpout		0.1	0.1
Blackeye goby		0.1	0.1
Bluebanded ronquil	0.1		0.1
Greenblotched rockfish		0.1	0.1
Pink rockfish	0.1		0.1
Plainfin midshipman	0.1		0.1
Spotted cuskeel	0.1		0.1
Yellowchin sculpin	0.1		0.1
Summer total	4.8	5.2	10.0

Appendix E.4

Summary of top three species that discriminate between each cluster group according to SIMPER analyses (i.e., dissimilarity ≥1.5). Values are average dissimilarity between groups for that species; YS=yellowchin sculpin, PM=plainfin midshipman, CL=California lizardfish, LS=longfin sanddab, DS=Dover sole, PS=Pacific sanddab, GS=gulf sanddab, SR=stripedtail rockfish, HR=halfbanded rockfish, SC=shortspine rockfish, SqR=squarespot rockfish, BE=bigfin eelpout.

	A			B			C			D			E			F			G			H		
B	HR	YS	PS																					
	11.6	6.0	5.4																					
C	HR	LS	PS	YS	SR	DS/LS																		
	11.6	6.7	6.2	5.0	4.4	3.8																		
D	PM	LS	HR	PM	LS	GS	PM	LS	BE															
	18.2	10.2	6.8	16.3	8.0	3.4	14.5	5.6	3.0															
E	PS	SqR	HR	HR	SqR	PS	HR	SqR	PS	PM	HR	LS												
	9.6	8.1	6.3	11.7	6.5	5.7	11.7	7.2	5.4	9.6	8.5	5.5												
F	PS	HR	LS	PS	LS	SC	PS	CL	SR	PM	LS	CL	HR	SqR	CL									
	10.3	6.4	5.9	5.4	3.7	2.9	5.0	3.8	3.7	12.8	4.3	3.3	8.5	6.0	3.3									
G	PM	PS	HR	PM	PS	SR	PM	PS	SR	PM	LS	PS	HR	SqR	PM	PM	PS	SR						
	10.3	9.7	7.9	9.0	6.1	5.4	6.6	6.0	5.0	8.6	3.3	3.0	9.3	6.2	3.5	6.0	4.3	4.0						
H	PS	LS	HR	HR	PS	LS	HR	PS	SC	PM	HR	PS/SC	SqR	HR	LS	HR	PS		HR	PS	PM			
	11.2	8.1	5.2	8.2	7.4	6.2	8.2	7.0	4.6	10.0	6.2	3.4	5.0	4.7	4.3	5.8	3.9		6.6	4.3	4.2			
I	PS	LS	YS	PS	LS	SR	PS	YS	LS	PM	PS	YS	HR	SqR	PS	PS	LS	YS	PS	PM	SR	HR	PS	YS
	16.9	8.1	5.6	12.3	6.2	3.6	12.0	5.0	4.0	9.2	6.9	3.7	6.5	5.2	5.0	7.2	3.2	3.2	7.5	3.8	3.3	4.8	4.3	3.4

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Appendix E.5

List of megabenthic invertebrate taxa captured during 2008 at PLOO stations. Data are number of individuals (n). Taxonomic arrangement from SCAMIT 2008.

Taxon/Species					n
CNIDARIA					
	ANTHOZOA				
		Alcyonacea			
			Plexauridae		
				Thesea sp B	4
		Pennatulacea			
			Virgulariidae		
				Acanthoptilum sp	407
		Actiniaria			
			Metridiidae		
				Metridium farcimen	2
MOLLUSCA					
	GASTROPODA				
		Hypsogastropoda			
			Ovulidae		
				Neosimnia barbarensis	2
			Turridae		
				Megasurcula carpenteriana	1
				Antiplanes catalinae	2
			Cancellariidae		
				Cancellaria crawfordiana	1
		Opisthobranchia			
			Philinidae		
				Philine alba	3
			Pleurobranchidae		
				Pleurobranchaea californica	1
			Arminidae		
				Armina californica	1
	CEPHALOPODA				
		Sepiolida			
			Sepiolidae		
				Rossia pacifica	2
		Octopoda			
			Octopodidae		
				Octopus rubescens	6
ANNELIDA					
	POLYCHAETA				
		Aciculata			
			Polynoidae		
				Arctonoe pulchra	1
ARTHROPODA					
	MALACOSTRACA				
		Decapoda			
			Sicyoniidae		
				Sicyonia ingentis	10
			Diogenidae		
				Paguristes bakeri	2

Appendix E.5 *continued*

Taxon/Species				n
			Calappidae	
			Platymera gaudichaudii	3
ECHINODERMATA				
	ASTEROIDEA			
		Paxillosida		
			Luidiidae	
			Luidia foliolata	34
			Astropectinidae	
			Astropecten verrilli	12
	OPHIUROIDEA			
		Ophiurida		
			Ophiuridae	
			Ophiura luetkenii	32
	ECHINOIDEA			
		Temnopleuroida		
			Toxopneustidae	
			Lytechinus pictus	17449
		Echinoida		
			Strongylocentrotidae	
			Strongylocentrotus fragilis	12
		Spatangoida		
			Spatangidae	
			Spatangus californicus	7
	HOLOTHURIODEA			
		Aspidochirotida		
			Stichopodidae	
			Parastichopus californicus	27

Appendix E.6

Summary of total abundance by species and station for megabenthic invertebrates at the Point Loma Ocean Outfall trawl stations during 2008.

Name	January 2008						Species abundance by survey
	SD7	SD8	SD10	SD12	SD13	SD14	
Lytechinus pictus	2500	2500	6000	2	887	525	12414
Acanthoptilum sp		1	3	50	68	45	167
Luidia foliolata		6	1		10	7	24
Parastichopus californicus	6	8	2		5	2	23
Strongylocentrotus fragilis	2	2	1			6	11
Sicyonia ingentis					1	9	10
Ophiura luetkenii	4		2		3		9
Spatangus californicus		1				4	5
Astropecten verrilli	3						3
Octopus rubescens			1	1		1	3
Philine alba	1	2					3
Metridium farcimen		1				1	2
Paguristes bakeri		2					2
Thesea sp B		1	1				2
Antiplanes catalinae			1				1
Arctonoe pulchra						1	1
Cancellaria crawfordiana				1			1
Megasurcula carpenteriana				1			1
Platymera gaudichaudii						1	1
Winter total	2516	2524	6012	55	974	602	12683

Appendix E.6 *continued*

Name	July 2008 SD10	July 2008 SD12	Species abundance by survey
Lytechinus pictus	4838	197	5035
Acanthoptilum sp		240	240
Ophiura luetkenii	5	18	23
Luidia foliolata	7	3	10
Astropecten verrilli	6	3	9
Parastichopus californicus	3	1	4
Octopus rubescens	2	1	3
Neosimnia barbarensis		2	2
Platymera gaudichaudii	1	1	2
Rossia pacifica	1	1	2
Spatangus californicus	2		2
Thesea sp B		2	2
Strongylocentrotus fragilis	1		1
Antiplanes catalinae		1	1
Armina californica		1	1
Pleurobranchaea californica	1		1
Summer total	4867	471	5338

Appendix F

Supporting Data

2008 PLOO Stations

Bioaccumulation of Contaminants in Fish Tissues

Appendix F.1

Lengths and weights of fishes used for each composite sample (Comp) for the PLOO monitoring program during October 2008. Data are summarized as number of individuals (n), minimum (min), maximum (max), and mean values.

				Length (cm, size class)			Weight (g)		
Station	Comp	Species	n	min	max	mean	min	max	mean
RF1	1	Copper rockfish	3	26	39	34	476	1800	1192
RF1	2	Mixed rockfish	3	20	30	25	168	711	391
RF1	3	Greenblotched rockfish	3	24	36	30	439	1016	669
RF2	1	Vermilion rockfish	3	31	39	35	1000	1800	1400
RF2	2	Vermilion rockfish	3	31	34	33	756	1100	955
RF2	3	Mixed rockfish	3	24	28	26	410	621	483
ZONE1	1	Pacific sanddab	6	14	16	16	44	60	53
ZONE1	2	Pacific sanddab	8	12	18	15	29	82	58
ZONE1	3	English sole	8	15	21	19	56	157	109
ZONE2	1	Pacific sanddab	9	15	18	16	46	77	58
ZONE2	2	Pacific sanddab	7	15	19	16	46	98	65
ZONE2	3	Pacific sanddab	8	15	20	17	49	116	69
ZONE3	1	Pacific sanddab	5	15	24	17	45	231	89
ZONE3	2	Pacific sanddab	8	15	18	16	41	105	67
ZONE3	3	Pacific sanddab	5	14	21	18	38	157	87
ZONE4	1	Pacific sanddab	5	17	22	18	64	165	94
ZONE4	2	Pacific sanddab	3	15	23	19	69	264	157
ZONE4	3	Pacific sanddab	3	18	22	20	87	196	136

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Appendix F.2

Constituents and method detection limits for fish tissue samples analyzed for the PLOO monitoring program during October 2008.

Parameter	MDL Liver	MDL Muscle	Parameter	MDL Liver	MDL Muscle
Metals (ppm)					
Aluminum (Al)	3	3	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)	0.03	0.03
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)	0.1	0.1	Tin (Sn)	0.2	0.2
Iron (Fe)	2	2	Zinc (Zn)	0.15	0.15
Chlorinated Pesticides (ppb)					
Aldrin	*	6.67	Hexachlorobenzene	13.3	1.33
Alpha (cis) Chlordane	13.3	2	Mirex	13.3	1.33
Alpha Endosulfan	167	33	o,p-DDD	13.3	1.33
BHC, Alpha isomer	33.3	2	o,p-DDE	13.3	1.33
BHC, Beta isomer	13.3	2	o,p-DDT	13.3	1.33
BHC, Delta isomer	20	2	Oxychlordane	66.7	6.67
BHC, Gamma isomer	167	3.33	p,p-DDD	13.3	1.33
Cis Nonachlor	20	3.33	p,p-DDE	13.3	1.33
Dieldrin	13.3	1.33	p,p-DDMU	13.3	1.33
Endrin	13.3	1.33	p,p-DDT	13.3	1.33
Gamma (trans) Chlordane	20	2	Toxaphene	3333	333
Heptachlor	33.3	3.33	Trans Nonachlor	13.3	2
Heptachlor epoxide	100	6.67			

* no MDL available for this parameter

Appendix F.2 *continued*

Parameter	MDL Liver	MDL Muscle	Parameter	MDL Liver	MDL Muscle
Polychlorinated Biphenyl Congeners (PCBs) (ppb)					
PCB 18	33.3	1.33	PCB 126	13.3	1.33
PCB 28	13.3	1.33	PCB 128	13.3	1.33
PCB 37	13.3	1.33	PCB 138	13.3	1.33
PCB 44	13.3	1.33	PCB 149	13.3	1.33
PCB 49	13.3	1.33	PCB 151	13.3	1.33
PCB 52	13.3	1.33	PCB 153/168	13.3	1.33
PCB 66	13.3	1.33	PCB 156	13.3	1.33
PCB 70	13.3	1.33	PCB 157	13.3	1.33
PCB 74	13.3	1.33	PCB 158	13.3	1.33
PCB 77	13.3	1.33	PCB 167	13.3	1.33
PCB 81	13.3	1.33	PCB 169	13.3	1.33
PCB 87	13.3	1.33	PCB 170	13.3	1.33
PCB 99	13.3	1.33	PCB 177	13.3	1.33
PCB 101	13.3	1.33	PCB 180	13.3	1.33
PCB 105	13.3	1.33	PCB 183	13.3	1.33
PCB 110	13.3	1.33	PCB 187	13.3	1.33
PCB 114	13.3	1.33	PCB 189	13.3	1.33
PCB 118	13.3	1.33	PCB 194	13.3	1.33
PCB 119	13.3	1.33	PCB 201	13.3	1.33
PCB 123	13.3	1.33	PCB 206	13.3	1.33
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)					
1-methylnaphthalene	27.9	26.4	Benzo[G,H,I]perylene	27.2	59.5
1-methylphenanthrene	17.4	23.3	Benzo[K]fluoranthene	32	37.3
2,3,5-trimethylnaphthalene	21.7	21.6	Biphenyl	38	19.9
2,6-dimethylnaphthalene	21.7	19.5	Chrysene	18.1	23
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[e]pyrene	41.8	40.6	Pyrene	9.1	16.6

Appendix F.3

Summary of constituents that make up total DDT, total chlordane, and total PCB in each sample collected as part of the PLOO monitoring program during October 2008.

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	RF1	1	Copper rockfish	Muscle	DDT	p,p-DDE	6.3	ppb
2008-4	RF1	1	Copper rockfish	Muscle	PCB	PCB 101	0.3	ppb
2008-4	RF1	1	Copper rockfish	Muscle	PCB	PCB 138	0.5	ppb
2008-4	RF1	1	Copper rockfish	Muscle	PCB	PCB 153/168	0.5	ppb
2008-4	RF1	1	Copper rockfish	Muscle	PCB	PCB 180	0.2	ppb
2008-4	RF1	2	Mixed rockfish	Muscle	DDT	p,p-DDE	0.9	ppb
2008-4	RF1	3	Greenblotched rockfish	Muscle	DDT	p,p-DDE	9.7	ppb
2008-4	RF1	3	Greenblotched rockfish	Muscle	PCB	PCB 153/168	0.9	ppb
2008-4	RF1	3	Greenblotched rockfish	Muscle	PCB	PCB 180	0.4	ppb
2008-4	RF2	1	Vermilion rockfish	Muscle	DDT	p,p-DDE	8.2	ppb
2008-4	RF2	1	Vermilion rockfish	Muscle	PCB	PCB 101	0.5	ppb
2008-4	RF2	1	Vermilion rockfish	Muscle	PCB	PCB 138	0.5	ppb
2008-4	RF2	1	Vermilion rockfish	Muscle	PCB	PCB 180	0.3	ppb
2008-4	RF2	2	Vermilion rockfish	Muscle	DDT	p,p-DDE	5.0	ppb
2008-4	RF2	3	Mixed rockfish	Muscle	DDT	p,p-DDE	7.5	ppb
2008-4	RF2	3	Mixed rockfish	Muscle	PCB	PCB 138	0.5	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	DDT	p,p-DDD	5.2	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	DDT	p,p-DDE	390.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	DDT	p,p-DDMU	18.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	DDT	p,p-DDT	6.1	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 101	9.1	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 105	4.6	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 110	7.1	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 118	18.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 128	5.1	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 138	31.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 149	5.6	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 151	3.7	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 153/168	39.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 170	5.9	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 177	3.1	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 180	20.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 183	4.6	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 187	16.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 194	5.0	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 201	5.6	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 206	2.4	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 49	1.6	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 52	2.7	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 66	2.4	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 70	2.1	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 74	1.6	ppb
2008-4	ZONE1	1	Pacific sanddab	Liver	PCB	PCB 99	12.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	Chlordane	Trans Nonachlor	9.7	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	DDT	p,p-DDE	380.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	DDT	p,p-DDMU	15.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	DDT	p,p-DDT	6.7	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 101	8.2	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 105	6.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 110	8.3	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 118	20.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 128	5.2	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 138	34.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 149	5.3	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 151	3.4	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 153/168	49.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 170	8.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 177	3.6	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 180	21.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 183	5.6	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 187	17.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 194	4.9	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 201	5.3	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 206	2.8	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 49	1.7	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 52	2.8	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 66	2.6	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 70	2.0	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 74	1.8	ppb
2008-4	ZONE1	2	Pacific sanddab	Liver	PCB	PCB 99	13.0	ppb
2008-4	ZONE1	3	English sole	Liver	DDT	p,p-DDE	82.0	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 101	4.9	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 118	7.1	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 138	8.6	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 149	5.8	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 153/168	15.0	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 180	7.6	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 183	2.3	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 187	8.8	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 194	3.2	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 66	1.7	ppb
2008-4	ZONE1	3	English sole	Liver	PCB	PCB 99	4.4	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	DDT	p,p-DDD	9.1	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	DDT	p,p-DDE	680.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	DDT	p,p-DDMU	24.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	DDT	p,p-DDT	12.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 101	9.9	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 118	22.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 128	4.6	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 138	32.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 153/168	45.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 158	2.1	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 170	7.3	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 177	4.1	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 180	20.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 183	4.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 187	17.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 201	7.5	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 49	2.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 52	4.4	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 66	2.8	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 70	3.4	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 74	2.0	ppb
2008-4	ZONE2	1	Pacific sanddab	Liver	PCB	PCB 99	14.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	DDT	o,p-DDE	4.7	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	DDT	p,p-DDE	320.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	DDT	p,p-DDMU	13.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 101	7.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 105	3.5	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 110	5.7	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 128	4.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 138	20.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 149	3.9	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 151	3.1	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 153/168	29.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 170	4.1	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 180	12.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 183	3.1	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 187	11.0	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 194	3.3	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 201	7.1	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 52	2.3	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 66	2.1	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 70	1.4	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 74	1.3	ppb
2008-4	ZONE2	2	Pacific sanddab	Liver	PCB	PCB 99	7.9	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	DDT	o,p-DDE	6.6	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	DDT	p,p-DDD	6.7	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	DDT	p,p-DDE	580.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	DDT	p,p-DDMU	22.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	DDT	p,p-DDT	10.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 101	12.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 105	6.6	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 110	9.1	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 118	24.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 128	7.2	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 138	39.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 149	6.2	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 151	4.8	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 153/168	51.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 170	7.8	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 180	21.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 183	5.6	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 187	21.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 194	5.6	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 201	7.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 206	3.3	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 52	4.0	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 66	3.4	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 70	2.3	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 74	2.3	ppb
2008-4	ZONE2	3	Pacific sanddab	Liver	PCB	PCB 99	15.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	DDT	p,p-DDE	280.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	DDT	p,p-DDMU	11.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 101	12.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 105	6.8	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 110	15.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 118	25.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 128	7.8	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 149	10.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 151	6.7	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 153/168	61.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 170	7.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 180	20.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 183	5.3	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 187	20.0	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 194	4.4	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 201	6.3	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 49	2.8	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 52	4.5	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 66	2.7	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 70	3.1	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 74	1.9	ppb
2008-4	ZONE3	1	Pacific sanddab	Liver	PCB	PCB 99	16.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	DDT	p,p-DDE	580.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	DDT	p,p-DDMU	21.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 101	32.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 105	14.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 110	30.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 118	56.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 128	16.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 138	77.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 149	24.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 151	13.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 153/168	120.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 156	6.5	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 167	4.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 170	14.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 177	11.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 180	41.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 183	10.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 187	48.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 194	9.1	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 201	12.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 206	4.5	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 49	8.3	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 52	10.0	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 66	7.6	ppb
2008-4	ZONE3	2	Pacific sanddab	Liver	PCB	PCB 99	38.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	DDT	p,p-DDE	280.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	DDT	p,p-DDMU	11.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 101	11.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 105	5.7	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 110	11.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 118	20.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 128	5.6	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 138	34.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 149	6.6	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 151	5.2	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 153/168	48.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 158	2.2	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 170	6.6	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 177	3.6	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 180	21.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 183	6.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 187	18.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 194	5.4	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 201	6.0	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 49	2.3	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 52	3.9	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 66	2.3	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 70	2.2	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 74	1.6	ppb
2008-4	ZONE3	3	Pacific sanddab	Liver	PCB	PCB 99	13.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	Chlordane	Trans Nonachlor	14.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	DDT	o,p-DDE	9.7	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	DDT	p,p-DDD	11.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	DDT	p,p-DDE	780.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	ZONE4	1	Pacific sanddab	Liver	DDT	p,p-DDMU	21.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	DDT	p,p-DDT	8.6	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 101	21.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 105	10.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 110	15.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 118	35.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 128	8.3	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 138	51.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 149	12.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 151	7.6	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 153/168	78.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 158	3.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 167	2.6	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 170	11.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 177	6.1	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 180	33.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 183	9.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 187	28.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 201	31.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 49	4.9	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 52	8.0	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 66	4.9	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 70	3.4	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 74	2.7	ppb
2008-4	ZONE4	1	Pacific sanddab	Liver	PCB	PCB 99	25.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	DDT	p,p-DDE	360.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	DDT	p,p-DDMU	18.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 101	12.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 105	4.8	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 110	8.3	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 118	15.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 128	4.7	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 138	26.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 149	8.2	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 151	4.3	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 153/168	41.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 170	5.6	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 177	3.7	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 180	18.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 183	5.2	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 187	15.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 194	4.5	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 201	6.1	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 66	3.0	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 70	2.2	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 74	1.3	ppb
2008-4	ZONE4	2	Pacific sanddab	Liver	PCB	PCB 99	11.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Parameter	Value	Units
2008-4	ZONE4	3	Pacific sanddab	Liver	DDT	p,p-DDE	115.0	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 101	5.8	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 110	3.4	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 118	7.3	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 138	8.3	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 149	3.5	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 151	2.4	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 153/168	14.5	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 180	5.8	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 183	1.6	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 187	5.3	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 52	2.1	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 70	0.7	ppb
2008-4	ZONE4	3	Pacific sanddab	Liver	PCB	PCB 99	3.5	ppb

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