SD Public Utilities

INTERIM RECEIVING WATERS MONITORING REPORT FOR THE POINT LOMA AND SOUTH BAY OCEAN OUTFALLS

2022

Environmental Monitoring and Technical Services
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CERTIFIED
Public Utilities Department
Continual Improvement, Prevention of Pollution, Regulatory Compliance
ISO 14001

The City of SAN DIEGO
Public Utilities Department
Environmental Monitoring & Technical Services Division

June 30, 2023

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

Attention: POTW Compliance Unit

Dear Mr. Gibson:

Enclosed is the 2022 Interim Receiving Waters Monitoring and Assessment Report for the Point Loma and South Bay Ocean Outfalls, as per requirements set forth in the following Orders/Permits:

(1) Order No. R9-2017-0007 (as amended by Order No. R9-2022-0078) for the City of San Diego's Point Loma Wastewater Treatment Plant (NPDES No. CA0107409).
(2) Order No. R9-2021-0011 for the City's South Bay Water Reclamation Plant (NPDES No. CA0109045).
(3) Order No. R9-2021-0001 for the United States Section of the International Boundary and Water Commission's South Bay International Wastewater Treatment Plant (NPDES No. CA0108928).

This combined report for the Point Loma and South Bay outfall regions contains data summaries, analyses, and assessments for all portions of the Ocean Monitoring Program conducted during 2022. Additional data in support of this report will be submitted separately to either the Regional Water Quality Control Board or the California Environmental Data Exchange Network (CEDEN) in accordance with the aforementioned permits.

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

If you have questions regarding this report, please call Dr. Ryan Kempster, the City's Senior Marine Biologist at (619) 758-2329.

Sincerely,

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

PV/rk

cc: U.S. Environmental Protection Agency, Region 9
International Boundary and Water Commission, U.S. Section

Interim Receiving Waters Monitoring Report for the Point Loma and South Bay Ocean Outfalls 2022

Point Loma Wastewater Treatment Plant
(Order No. R9-2017-0007; NPDES No. CA0107409)

South Bay Water Reclamation Plant
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South Bay International Wastewater Treatment Plant
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Prepared by:

City of San Diego Ocean Monitoring Program

Environmental Monitoring & Technical Services Division

Ryan Kempster, Managing Editor

June 2023

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Executive Summary

Executive Summary

The City of San Diego (City) conducts an extensive Ocean Monitoring Program to evaluate potential environmental effects associated with the discharge of treated wastewater to the Pacific Ocean via the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). Data collected are used to determine compliance with receiving water quality requirements, as specified in National Pollutant Discharge Elimination System (NPDES) permits, and associated orders; these permits and orders are issued by the San Diego Regional Water Quality Control Board (SDRWQCB) and the U.S. Environmental Protection Agency (USEPA) for the City's Point Loma Wastewater Treatment Plant (PLWTP), South Bay Water Reclamation Plant (SBWRP), and the South Bay International Wastewater Treatment Plant (SBIWTP), which is operated by the U.S. Section of the International Boundary and Water Commission (USIBWC). Treated effluent from both the SBWRP and SBIWTP commingle before discharge to the ocean via the SBOO, thus a single monitoring and reporting program, approved by the SDRWQCB and USEPA, is conducted to comply with these two permits.

The principal objectives of the combined ocean monitoring efforts for both the PLOO and SBOO are to: (1) measure and document compliance with NPDES permit requirements and California Ocean Plan (Ocean Plan) water quality objectives and standards; (2) track movement and dispersion of the wastewater plumes discharged via the outfalls; (3) assess any impact of wastewater discharge on the local marine ecosystem, including effects on coastal water quality, seafloor sediments, and marine life.

Although governed by three separate NPDES permits, this interim report summarizes the purpose, scope, methods, and findings of all receiving waters monitoring conducted for the PLOO and SBOO regions from January through December 2022. A full biennial monitoring and assessment report covering calendar years 2022 and 2023 will be produced and submitted to the San Diego Water Board and USEPA no later than July 1, 2024. Specific details of the primary ocean monitoring activities conducted during 2022 are presented in the following five chapters herein, while additional data are presented in Appendices A–D. All raw data for the 2022 sampling period will be submitted to either the SDRWQCB or the California Environmental Data Exchange Network (CEDEN) and may be accessed upon request. Chapter 1 provides a general introduction and overview of the combined PLOO and SBOO program. Chapter 2 presents data characterizing the results of water quality monitoring at 103 different shore or offshore stations located throughout the two regions. This includes measuring concentrations of fecal indicator bacteria in seawater samples and collecting various types of oceanographic data to evaluate dispersal of the PLOO and SBOO wastewater plumes and to assess compliance with Ocean Plan water contact standards. Assessments of benthic sediment quality (e.g., sediment chemistry, particle size distributions) and the ecological status of macrobenthic invertebrate communities at 49 core monitoring stations are presented in Chapter 3. Chapter 4 presents the results of trawling activities conducted at 13 different monitoring stations to assess the health and status of bottom dwelling (demersal) fish and megabenthic invertebrate communities. Contaminants in marine fishes collected from trawl and rig fishing stations are presented in Chapter 5.

Overall, the state of San Diego's coastal ocean waters remained in good condition in 2022 based on the preliminary findings and conclusions summarized in this report. Results for both the PLOO and SBOO regions were consistent with conditions documented in previous years, and there were few changes to local receiving waters, benthic sediments, and marine invertebrate and fish communities that could be attributed to wastewater discharge or other human activities. Coastal water quality conditions and compliance with Ocean Plan standards were excellent, and there was no evidence that wastewater plumes from the two outfalls were transported into nearshore recreational waters. There were also no clear outfall related patterns in sediment contaminant distributions or differences between invertebrate and fish assemblages at the different monitoring sites. Additionally, benthic habitats surrounding both outfalls, and throughout the entire San Diego region, remained in good overall condition similar to reference conditions for much of the Southern California Bight. Finally, the low levels of contaminant accumulation and general lack of physical anomalies, or other symptoms of disease or stress in local fishes was also indicative of a healthy marine environment off San Diego.

Chapter 1
General Introduction

Chapter 1. General Introduction

Program Requirements & Objectives

Ocean monitoring within the Point Loma and South Bay outfall regions is conducted by the City of San Diego (City) in accordance with requirements set forth in National Pollution Discharge Elimination System (NPDES) permits and associated orders for the following: the Point Loma Wastewater Treatment Plant (PLWTP), the South Bay Water Reclamation Plant (SBWRP), and the South Bay International Wastewater Treatment Plant (SBIWTP), which is owned and operated by the U.S. Section of the International Boundary and Water Commission (USIBWC) (see Table 1.1). These documents specify the terms and conditions that allow treated effluent to be discharged to the Pacific Ocean via the Point Loma Ocean Outfall (PLOO) and South Bay Ocean Outfall (SBOO). In addition, the Monitoring and Reporting Program (MRP), included within each of these orders, defines the requirements for monitoring ocean (receiving) waters surrounding the two outfalls. These requirements include sampling design, frequency of sampling, field operations and equipment, regulatory compliance criteria, types of laboratory tests and analyses, data management and analysis, statistical methods and procedures, environmental assessment, and reporting guidelines.

The combined ocean monitoring program for these regions is designed to assess the impact of treated wastewater discharged through the PLOO and SBOO on the coastal marine environment off San Diego. The main objectives of the program are to: (1) measure and document compliance with NPDES permit requirements and California Ocean Plan (Ocean Plan) water quality objectives and standards; (2) track movement and dispersion of the wastewater plumes discharged via the outfalls; (3) assess any impact of wastewater discharge on the local marine ecosystem, including effects on coastal water quality, seafloor sediments, and marine life. These data are used to evaluate and document any potential effects of treated wastewater discharge, or other anthropogenic inputs (e.g., storm water discharge, urban runoff), and natural influences (e.g., seasonality, climate change) on coastal water quality, seafloor sediment conditions, and local marine organisms.

Background

Point Loma Ocean Outfall

The City began operation of the PLWTP and original PLOO off Point Loma in 1963, at which time treated effluent was discharged approximately 3.9 km west of the Point Loma peninsula at a depth of around 60 m. The PLWTP operated as a primary treatment facility from 1963 to 1985, after which it was upgraded to advanced primary treatment between mid-1985 and July 1986. This improvement involved the addition of chemical coagulation to the treatment process, which resulted in an increase in removal of total suspended solids (TSS) to about 75%. Since then, the treatment process has continued to be improved with the addition of more sedimentation basins, expanded aerated grit removal, and refinements in chemical treatment, which together further reduced mass emissions from the plant. For example, TSS removals are now consistently greater than the 80%, as required by the NPDES permit.

The structure of the PLOO was significantly modified in the early 1990s when it was extended about 3.3 km farther offshore in order to prevent intrusion of the waste field into nearshore waters and to increase compliance with Ocean Plan standards for water-contact sports areas. Discharge from the original 60-m terminus was discontinued in November 1993 following completion of the outfall extension. Currently, the PLOO extends approximately 7.2 km west of the PLWTP to a depth of around 94 m, where the main outfall pipe splits into a Y-shaped (wye) 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. The average discharge of effluent through the PLOO in 2022 was ~139 million gallons per day (mgd).

South Bay Ocean Outfall

The SBOO is located just north of the international border between the United States and Mexico where it terminates approximately 5.6 km offshore and west of Imperial Beach at a depth of around 27 m. Unlike other southern California ocean outfalls that lie on the surface of the seafloor, the SBOO pipeline begins as a tunnel on land that extends from the SBWRP and SBIWTP facilities to the coastline, after which it continues beneath the seabed 4.3 km offshore. The outfall pipe connects to a vertical riser assembly that conveys effluent to a pipeline buried just beneath the surface of the seafloor. This subsurface pipeline then splits into a Y-shaped (wye) multiport diffuser system with the two diffuser legs each extending an additional 0.6 km to the north or south. The SBOO was originally designed to discharge wastewater through 165 diffuser ports and risers, which included one riser at the center of the wye and 82 risers spaced along each diffuser leg. Since discharge began, however, low flow rates have required closure of all ports along the northern diffuser leg and many along the southern diffuser leg in order for the outfall to operate effectively. Consequently, wastewater discharge is restricted primarily to the distal end of the southern diffuser leg and to a few intermediate points at or near the center of the wye. The average discharge of effluent through the SBOO in 2022 was about ~32 mgd, including 6.7 mgd of secondary and tertiary treated effluent from the SBWRP, and 25.3 mgd of secondary treated effluent from the SBIWTP.

Receiving Waters Monitoring

The total area for the PLOO and SBOO monitoring program covers approximately 881 km² (~340 mi²) of coastal marine waters from Northern San Diego County into Northern Baja California. Core monitoring for the Point Loma region is conducted at 82 different stations, located from the shore to a depth of around 116 m. Core monitoring for the South Bay region is conducted at a total of 53 stations, ranging from the shore to depths of around 61 m (Figure 1.1). Each of the core monitoring stations is sampled for specific parameters as stated in their respective MRPs. A summary of the results for all quality assurance procedures performed during 2022, in support of these requirements, can be found in City of San Diego (2023). Data files, detailed methodologies, completed reports, and other pertinent information submitted to the San Diego Regional Water Quality Control Board (SDRWQCB) and the U.S. Environmental Protection Agency (USEPA), during the past year, are available on the City website (http://www.sandiego.gov/oceanmonitoring), via the California Environmental Data Exchange Network (CEDEN), and may also be provided upon request.

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 expanded with the construction and operation of the deeper outfall, as discussed previously. Data from the last year of regular monitoring near the original PLOO discharge site are presented in City of San Diego (1995b), while the results of a 3-year "recovery study" are summarized in City of San Diego (1998). Additionally, a more detailed assessment of spatial and temporal patterns surrounding the original discharge site is available in Zmarzly et al. (1994). From 1991 through 1993, the City also conducted "pre-discharge" monitoring for the new PLOO discharge site in order to collect baseline data prior to wastewater discharge into these deeper waters (City of San Diego 1995a,b). All permit mandated ocean monitoring for the South Bay region has also been performed by the City since wastewater discharge through the SBOO began in 1999; this included pre-discharge monitoring for 3½ years (July 1995–December 1998) in order to provide background information against which post-discharge conditions could be compared (City of San Diego 2000). Results of NPDES mandated monitoring for the extended PLOO from 1994 to 2019, and the SBOO from 1999 to 2019, are available in previous annual receiving waters monitoring reports (e.g., City of San Diego 2020). Finally, additional detailed assessments of the PLOO region have been completed as part of past modified NPDES permit renewal applications for the PLWTP submitted by the City and subsequent technical decisions issued by the USEPA (e.g., City of San Diego 2015a, USEPA 2017).

The City has also conducted annual region-wide surveys off the coast of San Diego since 1994, either as part of regular outfall monitoring requirements (e.g., City of San Diego 1999, 2020), or as part of larger multi-agency surveys of the entire Southern California Bight (SCB). The latter include the 1994 Southern California Bight Pilot Project (Allen et al. 1998, Bergen et al. 1998, 2001, Schiff and Gossett 1998) and subsequent Bight'98, Bight'03, Bight'08, Bight'13 and Bight'18 programs in 1998, 2003, 2008, 2013 and 2018 respectively (Allen et al. 2002, 2007, 2011, Noblet et al. 2002, Ranasinghe et al. 2003, 2007, 2012, Schiff et al. 2006, 2011, Dodder et al. 2016, Gillett et al. 2017, Walther et al. 2017, BSQPC 2018, SCCWRP 2018). These large-scale surveys are useful for characterizing the ecological health of diverse coastal areas to distinguish reference sites from those impacted by wastewater or storm water discharges, urban runoff, or other sources of contamination. In addition to the above activities, the City participates as a member of the Region Nine Kelp Survey Consortium to fund aerial surveys of all the major kelp beds in San Diego and Orange Counties (e.g., MBC Applied Environmental Sciences 2020).

Special Studies & Enhanced Monitoring

The City has actively participated in, or supported, numerous important special projects, or enhanced ocean monitoring studies, over the past 10 years or more. Many of these projects to date were identified as part of a scientific review of the City's Ocean Monitoring Program, conducted by the Scripps Institution of Oceanography (SIO) and other participating institutions (SIO 2004). This review evaluated the environmental monitoring needs of the region, and recommended special projects based on priorities identified. Examples of special projects currently underway, or being initiated include:

- **San Diego Kelp Forest Ecosystem Monitoring Project**: This project represents continuation of a long-term commitment by the City to support important research conducted on local kelp forests by SIO. This work is essential to assessing the health of San Diego's kelp forests and monitoring the effects of wastewater discharge on the local coastal ecosystem relative to other anthropogenic and natural influences (see City of San Diego 2022: Appendix A).

- **Real-Time Oceanographic Mooring Systems (RTOMS) for the PLOO and SBOO**: This project addresses recommendations that the City should improve monitoring of the fate and behavior of wastewater discharged to the ocean via the SBOO (Terrill et al. 2009) and PLOO (Rogowski et al. 2012a, 2012b, 2013). The project involves the deployment of RTOMS at the terminal ends of the

PLOO and SBOO to provide real time data on ocean conditions. The project began in late 2015 with initial deployment of the SBOO mooring in December 2016 and the PLOO mooring in March 2018. This project is being conducted in partnership with SIO, who presently operate a similar mooring system off Del Mar. The project is expected to significantly enhance the City's environmental monitoring capabilities in order to address current and emerging issues relevant to the health of San Diego's coastal waters, including plume dispersion, subsurface current patterns, ocean acidification, hypoxia, nutrient sources, and coastal upwelling. Additional details are available in the approved Plume Tracking Monitoring Plan for the project (City of San Diego 2018b) and City of San Diego 2022: Appendix E.

- **Sediment Toxicity Monitoring of the San Diego Ocean Outfall Regions**: This project started with a 3-year pilot study implemented as a new joint regulatory requirement for the Point Loma and South Bay outfall regions in 2015. Findings for the 2016–2018 pilot study (City of San Diego 2015b) were summarized in a final project report (City of San Diego 2019) that included recommendations for continued sampling through 2023. This final project report has been updated to include results from 2019 as City of San Diego 2020: Appendix C.

- **Remote Sensing of the San Diego/Tijuana Coastal Region**: This project represents a long-term effort, funded by the City and the USIBWC since 2002, to utilize satellite and aerial imagery to better understand regional water quality conditions off San Diego. The project is conducted by Ocean Imaging (Littleton, CO), and is focused on detecting and tracking the dispersion of wastewater plumes from local ocean outfalls and nearshore sediment plumes caused by stormwater runoff or outflows from local bays and rivers (Hess 2019, 2020). Additional information can be found in City of San Diego 2022: Appendix B.

- **San Diego Regional Benthic Condition Assessment Project**: This multi-phase study represents an ongoing, long-term project designed to assess the condition of continental shelf and slope habitats throughout the entire San Diego region. A preliminary summary of the deeper slope (>200 m) results for data collected between 2003–2013 was included in Appendix C.5 of City of San Diego (2015a), while several publications covering the remainder of the project are planned for completion in late 2021.

- **Euphotic Zone Study**: This multi-phase project aims to study the depth of the euphotic zone in the receiving waters to evaluate whether nutrients from the discharge plume reach the euphotic zone and thereby potentially stimulate phytoplankton productivity. Phase One of this study focuses on a review of existing data and scientific literature to estimate the depth of the euphotic zone in the PLOO region. Based on the findings of this review, and if warranted, the City of San Diego will prepare a Phase Two work plan to propose a study to fill any data gaps identified from Phase One, which may include receiving waters monitoring to address those data gaps. The Phase One report will be submitted by July 1st 2023.

Report Components & Organization

This report presents summaries of the results of all receiving waters monitoring activities conducted during January–December 2022 for both the Point Loma and South Bay outfall regions. A more comprehensive assessment, including detailed comparisons of long-term spatial and temporal changes and trends, will be prepared as part of the Biennial Receiving Waters Monitoring and Assessment Report for 2022–2023 to be submitted to the San Diego Water Board and USEPA by July 1, 2024. Included herein are results from all regular core stations that comprise the fixed-site monitoring grids surrounding the two outfalls (Figure 1.1), as well as results from the 2022 summer benthic survey of randomly selected sites that range from near the USA/Mexico border to northern San Diego County (Figure 1.2). The major components of the combined PLOO and SBOO monitoring program are covered in the following chapters and associated appendices of this report: Executive Summary; General Introduction (Chapter 1); Water Quality (Chapter 2, Appendix A); Benthic Conditions (Chapter 3, Appendix B); Demersal Fishes and Megabenthic Invertebrates (Chapter 4, Appendix C); Contaminants in Marine Fishes (Chapter 5, Appendix D).

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Chapter 1

Figures & Tables

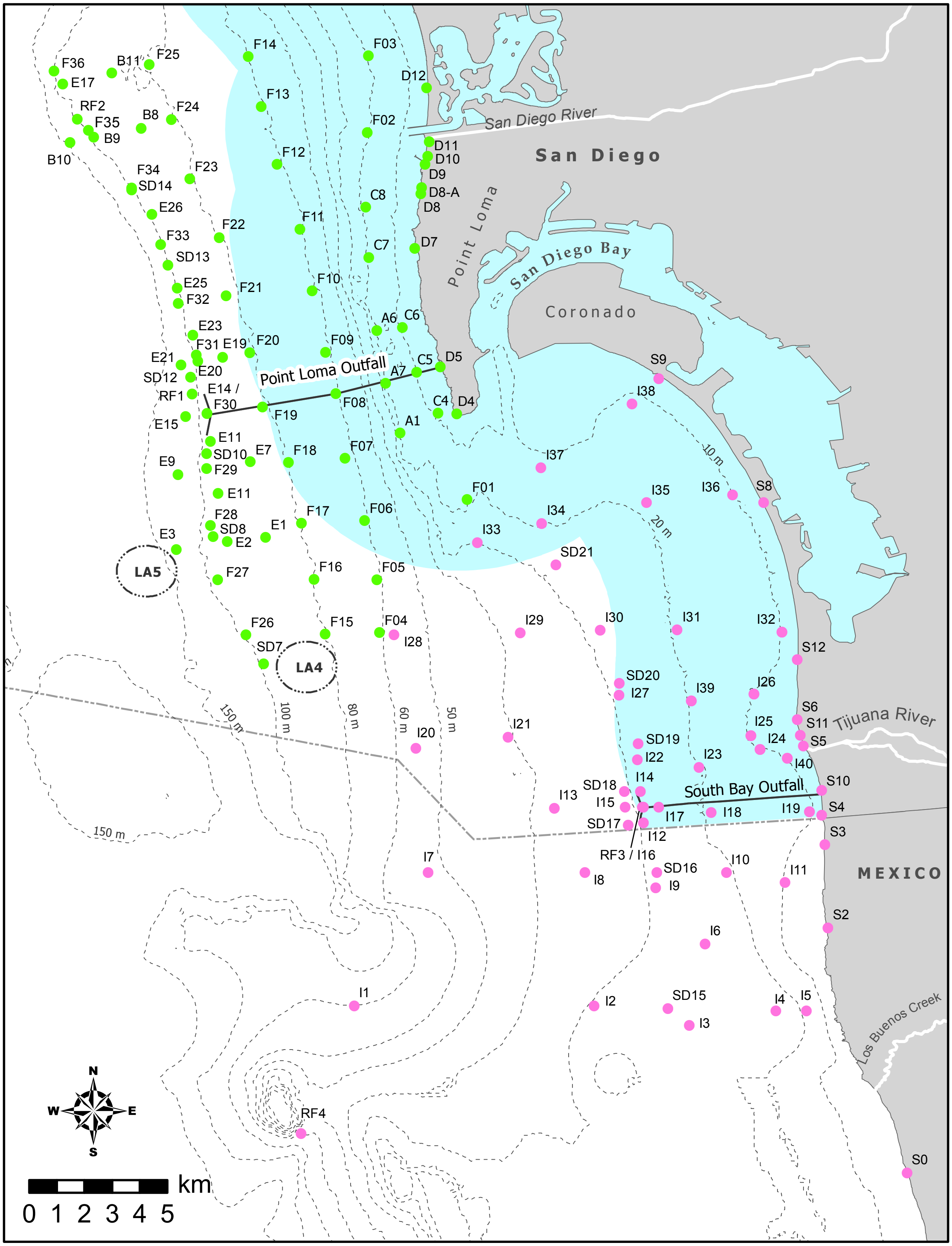

Figure 1.1

Core receiving waters monitoring stations for the PLOO (green) and SBOO (pink) as part of the City of San Diego's Ocean Monitoring Program. Light blue shading represents State of California jurisdictional waters.

Table 1.1

NPDES permits and associated orders issued by the San Diego Water Board for the Point Loma Wastewater Treatment Plant (PLWTP), South Bay Water Reclamation Plant (SBWRP), and South Bay International Wastewater Treatment Plant (SBIWTP) discharges to the Pacific Ocean via the PLOO and SBOO.

Facility	Outfall	NPDES Permit No.	Order No.	Effective Dates
PLWTP	PLOO	CA0107409	R9-2017-0007[a]	October 1, 2017–September 30, 2022
SBWRP	SBOO	CA0109045	R9-2021-0011	July 1, 2021–June 30, 2026
SBIWTP	SBOO	CA0108928	R9-2021-0001	July 1, 2021–June 30, 2026

[a] Order R9-2017-0007 amended by Order R9-2022-0078 (permit administratively extended)

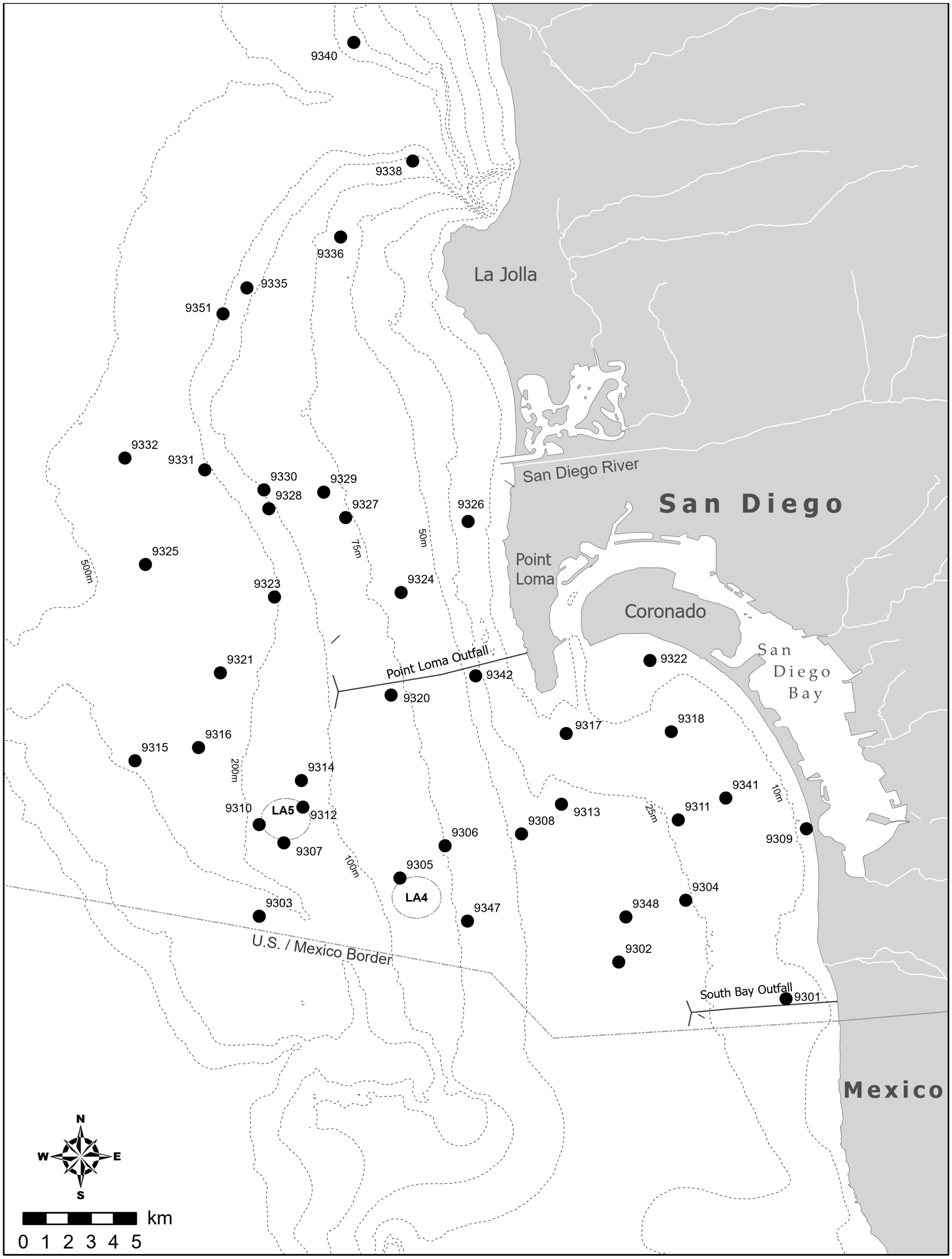

Figure 1.2
Regional randomly selected benthic survey stations sampled during summer 2022 as part of the City of San Diego's Ocean Monitoring Program.

Chapter 2
Water Quality

Chapter 2. Water Quality

Introduction

The City of San Diego conducts extensive monitoring along the shoreline and in offshore coastal waters surrounding the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively) to characterize regional water quality conditions and to identify possible impacts of wastewater discharge or other contaminant sources on the marine environment. In addition, the City's water quality monitoring efforts are designed to assess compliance with the water contact standards specified in the California Ocean Plan (Ocean Plan) to protect the beneficial uses of California's ocean waters (SWRCB 2019). This chapter presents summaries and preliminary analyses of the oceanographic and microbiological data collected during calendar year 2022 at a total of 103 water quality monitoring stations and two real-time oceanographic mooring systems (RTOMS) surrounding the PLOO and SBOO. Supplemental analyses supporting these results are presented in Appendix A. A more comprehensive assessment of these results will be presented in the 2022-2023 Biennial Assessment Report to be submitted by July 1, 2024.

Materials and Methods

Field Sampling

Shore Stations

Seawater samples were collected weekly at 19 shore stations to monitor concentrations of fecal indicator bacteria (FIB) in waters adjacent to public beaches (Figure 2.1). Sixteen of these stations are in California State waters and are therefore subject to Ocean Plan water contact standards (Table 2.1, Table 2.2, SWRCB 2019). These include eight PLOO stations (D4, D5, D7, D8/D8-A/D8-B, D9, D10, D11, D12) located from Mission Beach southward to the tip of Point Loma and eight SBOO stations (S4, S5, S6, S8, S9, S10, S11, S12) located between the USA/Mexico border and Coronado. Over the past several years, due to increasing instability in some cliffside areas of Point Loma, City staff have periodically been unable to safely access and sample some stations. As a result, the following modifications to sampling locations, which were fully approved by the Regional Board, have occurred: (1) Station D8 was replaced by alternate station D8-A during July 2016; (2) D8-A was subsequently replaced by station D8-B in March 2018; (3) D8-A sampling resumed in December 2020. The remaining three SBOO shore stations (S0, S2, S3) are located south of the international border and are not subject to Ocean Plan requirements.

Seawater samples were collected from the surf zone at each of the above stations in sterile 250-mL bottles, after which they were transported on blue ice to the City's Marine Microbiology Laboratory and analyzed to determine concentrations of three types of FIB (i.e., total coliform, fecal coliform, and *Enterococcus* bacteria). In addition, weather conditions and visual observations of water color, surf height, and human/animal activity were recorded at the time of collection. These observations have been previously reported in monthly receiving waters monitoring reports submitted to the San Diego Regional Water Quality Control Board (SDRWQCB) (see City of San Diego 2022–2023a,b), and are available online (City of San Diego 2023b).

Kelp and Offshore Stations

Fifteen stations located in relatively shallow waters within or near the Point Loma or Imperial Beach kelp forests (i.e., referred to as "kelp" stations herein) were monitored weekly to assess water quality conditions and Ocean Plan compliance in nearshore areas used for recreational activities, such as SCUBA diving, surfing, fishing, and kayaking (Figure 2.1). These included PLOO stations C4, C5 and C6 located along the 9-m depth contour near the inner edge of the Point Loma kelp forest; PLOO stations A1, A6, A7, C7 and C8 located along the 18-m depth contour near the outer edge of the kelp forest; SBOO stations I25, I26 and I39 located at depths of 9–18 m contiguous to the Imperial Beach kelp bed; SBOO stations I19, I24, I32 and I40 located in other nearshore waters along the 9-m depth contour in the South Bay region.

An additional 69 offshore stations were sampled quarterly to monitor water quality conditions and to estimate dispersion of the PLOO and SBOO wastewater plumes. These stations were monitored during February, May, August and November in 2022 with the 36 PLOO and 33 SBOO stations sampled over three to five days during each survey (Table 2.3, Table 2.4). Stations F1–F36 are arranged in a grid surrounding the PLOO along or adjacent to the 18, 60, 80 and 98-m depth contours, while stations I1–I40 are arranged in a grid surrounding the SBOO along the 9, 19, 28, 38 and 55-m depth contours (Figure 2.1). Of these, 15 of the PLOO stations (i.e., F01–F03, F06–F14, F18–F20) and 15 of the SBOO stations (i.e., I12, I14, I16–I18, I22–I23, I27, I31, I33–I38) are located within State jurisdictional waters (i.e., within 3 nautical miles of shore) and therefore subject to the Ocean Plan compliance standards.

Seawater samples for FIB analyses were collected from 3 to 5 discrete depths at the kelp and offshore stations as indicated in Tables 2.3 and 2.4. These samples were typically collected using a rosette sampler fitted with Niskin bottles surrounding a central conductivity, temperature, and depth instrument (CTD), although replacement samples due to misfires or other causes may have been collected from a separate follow-up cast using stand-alone Van Dorn bottles if necessary. All weekly kelp/nearshore samples and quarterly offshore SBOO samples were analyzed for all three types of FIB, while the quarterly offshore PLOO samples were only analyzed for *Enterococcus* per permit requirements. All FIB samples were refrigerated at sea and then transported on blue ice to the City's Marine Microbiology Lab for processing and analysis. Oceanographic data were collected simultaneously with the water samples at each station using the central CTD in the rosette sampler (see below). Visual observations of weather, sea conditions, and human/animal activity were also recorded at the time of sampling. These observations have been previously reported in monthly receiving waters monitoring reports submitted to the SDRWQCB, (see City of San Diego 2022–2023a,b), and are available online (City of San Diego 2023b).

Oceanographic data were collected using a SeaBird SBE 25 Plus CTD. The CTD was lowered through the water column at each station to collect continuous measurements of water temperature, conductivity (used to calculate salinity), pressure (used to calculate depth), dissolved oxygen (DO), pH, transmissivity (a proxy for water clarity), chlorophyll *a* fluorescence (a proxy for phytoplankton), and colored dissolved organic matter (CDOM). Vertical profiles of each parameter were constructed for each station, per survey, by averaging the data values recorded within each 1-m depth bin.

This level of data reduction ensures that physical measurements used in subsequent analyses will correspond to discrete sampling depths required for bacterial monitoring (see above).

Real-time Oceanographic Mooring Systems

Two RTOMS were deployed at the terminal ends of the PLOO and SBOO (Figure 2.1). The PLOO RTOMS was anchored at a depth of approximately 100 m, just east of the northern diffuser leg, and the SBOO RTOMS was anchored at a depth of approximately 30 m, just west of the southern diffuser leg terminus. Each mooring was deployed for a period of approximately one year. The third PLOO deployment occurred from November 3, 2021 to November 22, 2022, and the fourth SBOO deployment occurred from November 3, 2021 to November 3, 2022. The SBOO buoy broke free from its anchor on November 3, 2022 during a storm and recovery of surface and mid-water column instruments and equipment was not possible. The fourth PLOO deployment began on December 8, 2022 and is on-going. Each RTOMS was outfitted with a series of instruments/sensors at fixed depths (Table 2.5). Critical parameters that were measured on a real-time basis, by both systems, included temperature, conductivity (salinity), total pH, DO, dissolved carbon dioxide (xCO_2), nitrogen (nitrate + nitrite), chlorophyll a, CDOM, biological oxygen demand (BOD), and current direction and velocity. Note that pH is reported in total scale from moored instruments with a more accurate calibration and measurement method for seawater, while pH has been reported in National Bureau of Standards (NBS) scale from CTD casts, and it is not recommended to convert between these scales (Marion et al. 2011). All parameters were recorded at 10-minute intervals, with the exception of nitrate + nitrite and xCO_2, which were recorded at 1-hour intervals. Equipment problems and sensor failures resulted in data gaps, and RTOMS data presented here include only data collected in real-time. For a summary of data issues and additional information on specific sensor issues and challenges experienced, see Appendix A.1. All raw RTOMS data for the 2022 sampling period are available on request and will be posted to the City's Open Data Portal in July of 2023.

Laboratory Analyses

The City's Marine Microbiology Laboratory follows guidelines issued by the U.S. Environmental Protection Agency (USEPA) Water Quality Office, and the California Department of Public Health (CDPH), and Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 2005, 2012, CDPH 2000, USEPA 2006). All bacterial analyses were initiated within eight hours of sample collection and conformed to standard membrane filtration techniques (APHA 2012).

FIB densities were determined and validated in accordance with USEPA and APHA guidelines (Bordner et al. 1978, APHA 2005, 2012, USEPA 2006). Plates with FIB counts above or below the ideal counting range were given greater than (>), greater than or equal to (≥), less than (<), or estimated (e) qualifiers. However, all qualifiers were dropped, and densities treated as discrete values when determining compliance with Ocean Plan standards.

Quality assurance tests were performed routinely on bacterial samples to ensure that analyses and sampling variability did not exceed acceptable limits. Laboratory and field duplicate bacteriological samples were processed according to method requirements to measure analyst precision and variability between samples, respectively. Results of these procedures were reported in a separate report (City of San Diego 2023a).

Data Analyses

Oceanographic Conditions

Water column parameters measured in 2022 were summarized as quarterly mean values, pooled over all stations, by the following depth layers: PLOO stations = 1–20 m, 21–60 m, 61–80 m, and 81–100 m; SBOO stations = 1–9 m, 10–19 m, 20–28 m, 29–38 m, and 39–55 m. Unless otherwise noted, analyses were performed using R (R Core Team, 2022) and various functions within the following packages: zoo, reshape2, Rmisc, ggplot2, gridExtra, mixOmics, fields, data.table, Hmisc, oce, RODBC, tidyverse (Zeileis and Grothendieck 2005, Wickham 2007, Hope 2013, Wickham et al. 2016, Auguie 2017, Rohart et al. 2017, Nychka et al. 2017, Dowle and Srinivasan 2019, Harrell et al. 2018, Kelley and Richards 2018, Ripley and Lapsley 2017, Wickham et al. 2019).

Bacteriological Compliance

Compliance with the running geometric mean standards for fecal coliforms and *Enterococcus* was assessed using running 30-day and 42-day windows, respectively. Compliance with the median standard for total coliforms was assessed over a running 30-day window. Compliance with the statistical threshold value (STV) metrics for total coliforms and *Enterococcus* was calculated at monthly intervals. Compliance calculations were limited to shore, kelp and offshore stations located within State waters, excluding resamples. In all instances, compliance was rounded to the nearest whole number (e.g. 99.5% equates to 100%). For the purpose of visualization, to assess temporal and spatial trends, and to assess compliance with the HF183 sampling standards (Table 2.2), elevated FIB was determined by the number of analyses in which FIB concentrations exceeded the threshold established by the 2019 Ocean Plan's water quality bacterial objectives for single sample maximum (SSM) or STV benchmark levels (Table 2.1, SWRCB 2019). Due to the nature of the STV metric, elevated FIB does not necessarily indicate out-of-compliance for individual analyses of *Enterococcus* and total coliform densities. Compliance with the HF183 sampling metrics was calculated as the proportion of analyses showing elevated FIB within the rolling window specified in Table 2.2, assessed daily over the report period. Compliance calculations were limited to shore, kelp and offshore stations located within State waters and various functions within the following packages: reshape2, RODBC, Hmisc, tidyverse (Wickham 2007, Ripley and Lapsley 2017, Harrell et al. 2018, Wickham 2019).

Wastewater Plume Detection and Out-of-Range Calculations

Presence or absence of the wastewater plume at the PLOO and SBOO offshore stations was estimated by evaluation of a combination of oceanographic parameters (i.e., detection criteria). The reporting and analysis of these data are not part of the 2022 interim report and will be reported as part of the 2022-2023 Biennial report, published in June 2024.

Real-time Oceanographic Mooring Systems

Prior to conducting analyses, all data were subject to a comprehensive suite of quality assurance/quality control (QA/QC) procedures following Quality Assurance of Real-Time Oceanographic Data (QARTOD) methodologies (US IOOS 2017, 2023). Results of QARTOD tests are included in Appendix A.2, A.3, see City of San Diego 2023a for details. After review, all flagged data identified as suspect or bad, either manually or from automated tests, were excluded from further analyses and are not presented in this report. A detailed log of data flagged manually by parameter, site, depth, and date range is available upon request. When possible, additional QA/QC procedures involved analyzing quarterly

CTD casts to validate data from RTOMS sensors, and seawater samples to validate and perform drift corrections to nitrate + nitrate results. For details on validation CTD casts and water sample data, see City of San Diego 2023a.

Analyses were performed in R (R Development Core Team 2022) using functions within various packages (i.e., data.table, dplyr, ggplot2, gtools, lubridate, pracma, purrr, reshape2, Rmisc, tidyverse, and mixOmics) (Dowle and Srinivasan 2019, Wickham and Francois 2021, Wickham et al. 2016, Warnes et al. 2018, Grolemund and Wickham 2011, Borchers 2021, Wickham and Henry 2023, Wickham 2007, Hope 2013, Wickham et al. 2019, Rohart et al. 2017). Annual time series of raw and daily-averaged data were plotted at each depth and site for all parameters that passed review, with the exception of ADCP data (described below). In addition, summary statistics were completed at each depth and site with the following seasonal periods that align with quarterly water quality sampling: winter (January–March); spring (April–June); summer (July–September); fall (October–December). Large data gaps were identified as seasons with <40% data recovery, based on expected number of samples for sensor-specific sampling intervals, and were excluded from summary analyses.

Ocean current data collected by downward-facing surface-mounted RTOMS ADCP instruments (Teledyne RD Instruments 300 kHz Workhorse Broadband) were checked for quality by eliminating those measurements that did not meet echo intensity criteria (i.e., minimum average intensity >100 counts and minimum correlation among the four beams of >70%). Following this initial screening, tidal frequency data were removed using the PL33 filter (Alessi et al. 1984) and compass direction was corrected to true north (+12.8 degrees). For all RTOMS deployments, ADCP data were summarized by season and select depth bins, as described above.

Results

All CTD and bacterial water quality data and associated visual observations for calendar year 2022 have been previously reported in monthly receiving waters monitoring reports submitted to the San Diego Water Board and the USEPA (see City of San Diego 2022–2023a, b).

Oceanographic Conditions

Ocean temperature, salinity, DO, pH, transmissivity, and chlorophyll *a* data collected by CTD during 2022 in the PLOO and SBOO monitoring regions are summarized by depth layer for the entire year in Tables 2.6 and 2.7, and by depth layer for each survey in Appendices A.4 and A.5. These same parameters are plotted by depth and survey in Appendices A.6 and A.7. Ocean temperature, salinity, DO, total pH, chlorophyll *a*, CDOM, turbidity, nitrate + nitrite, BOD, and xCO_2 data collected by PLOO and SBOO RTOMS during 2022 are summarized by depth and season in Appendices A.8 and A.9. Ocean current velocity and magnitude are summarized by depth layer and season in Appendices A.10 and A.11. All RTOMS parameters except current velocity are plotted over time in Appendix A.12.

Bacteriological Compliance

The distribution of microbial concentrations for each bacteriological metric during each sampling period are summarized visually with their respective 2019 Ocean Plan water contact standard thresholds for PLOO and SBOO in Figures 2.2 and 2.3. Compliance rates for STV water contact standards are summarized in Table 2.8, and compliance rates for HF183 water contact standards are summarized in Table 2.9. Compliance with 2015 Ocean Plan water contact standards (Appendix A.13) is summarized for PLOO only in Appendix A.14.

Plume Dispersion and Effects

CDOM, plotted by depth and survey, is included in Appendix A.6 and A.7. Potential plume detection results will be summarized in the 2022-23 Biennial Report, to be published June 2024.

Summary

During 2022, oceanographic conditions off San Diego were generally within historical ranges reported for the PLOO and SBOO monitoring regions. Conditions typically indicative of coastal upwelling were most evident during the spring months, while maximum stratification or layering of the water column occurred during mid-summer, after which the waters became more mixed in the winter. Decreases in water clarity or transmissivity tended to be associated with terrestrial runoff or outflows from rivers and bays, the re-suspension of nearshore bottom sediments due to waves or storm activity, and to the presence of strong and sustained phytoplankton blooms, particularly in the spring.

Water quality conditions were mostly consistent with data reported previously for both regions. Compliance with both the SSM and geometric mean standards was higher in the PLOO region, and at kelp and offshore stations compared to stations along the shore. Under current California Ocean Plan 2019 water contact standards, compliance, especially in the case of total coliforms, is reduced compared to previous years evaluated under California Ocean Plan 2015 water contact standards. These data coincide with unusually high transboundary flows from the Tijuana River reported for this period (IBWC, 2022). Reduced compliance in both outfall regions tends to occur during the wet season and is significantly influenced by terrestrial outflows, such as the Tijuana River. Finally, there was no evidence that wastewater discharged into the ocean via either outfall reached nearshore recreational waters.

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Chapter 2

Figures & Tables

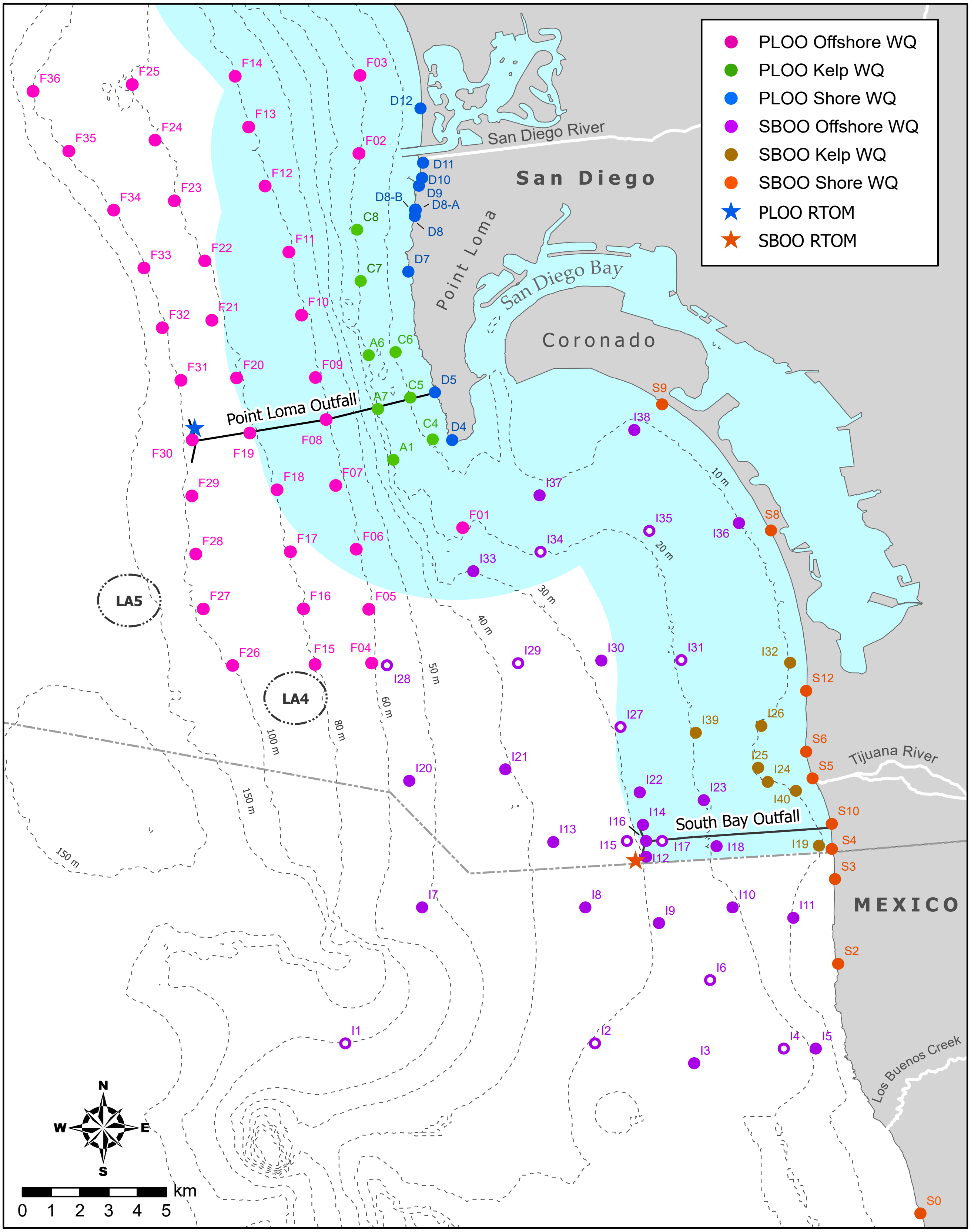

Figure 2.1
Water quality (WQ) monitoring station locations sampled around the PLOO and SBOO as part of the City of San Diego's Ocean Monitoring Program. Light blue shading represents State of California jurisdictional waters. Open circles are sampled by CTD only.

Table 2.1

Water quality objectives for water contact areas, California Ocean Plan (SWRCB 2019).

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

(a) Fecal Coliforms:

1) A 30-day geometric mean of fecal coliform density shall not exceed 200 CFU/100 mL, calculated based on the five most recent samples from each site

2) A single sample maximum of fecal coliform density shall not exceed 400 CFU/100 mL.

(b) Enterococcus:

1) A 42-day geometric mean of Enterococcus density shall not exceed 30 CFU/100 mL, calculated weekly

2) A statistical threshold value of Enterococcus density shall not exceed 110 CFU/100 mL in more than 10% of samples per calendar month.

(c) Total Coliforms:

1) The median of total coliform density shall not exceed 70 CFU/100 mL*.

2) A statistical threshold value of total coliform density shall not exceed 230 CFU/100 mL in more than 10% of samples.

B. Physical Characteristics

(a) Floating particulates and oil and grease shall not be visible.

(b) The discharge of waste shall not cause aesthetically undesirable discoloration of the ocean surface.

(c) Natural light shall not be significantly reduced at any point outside of the initial dilution zone as the result of the discharge of waste.

C. Chemical Characteristics

(a) The dissolved oxygen concentration shall not at any time be depressed more than 10% from what occurs naturally, as a result of the discharge of oxygen demanding waste materials.

(b) The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.

D. A time period is not specified for the total coliforms running median calculation. For the purposes of this report, the median was calculated over a 30-day running window.

Table 2.2

Receiving Water Bacterial Compliance (NPDES Permit No. CA0109045, Order No. R9-2021-0011; NPDES Permit No. CA0108928, Order No. R9-2021-0001).

Receiving water monitoring for human marker HF183 and effluent monitoring for fecal indicator bacteria may be required if any of the following conditions are true, and if the source of contamination is unknown.

A. The overall compliance rate with the receiving water limitations for bacterial characteristics is below 90% within a rolling one-year period.

B. A single monitoring location exceeds the bacteria receiving water limitations more than 50% of the time within a rolling one-year period for offshore monitoring locations.

C. A single monitoring location exceeds the bacteria receiving water limitations more than 50% of the time within a rolling quarterly period for kelp/nearshore monitoring locations.

Table 2.3

Depths from which seawater samples are collected for bacteriological analysis from kelp and offshore stations.

Station Contour	PLOO 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

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

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

Table 2.4

Sample dates for quarterly oceanographic surveys conducted during 2022. All stations in each station group were sampled on a single day (see Figure 2.1 for stations and locations).

PLOO Sampling Dates					SBOO Sampling Dates				
Station Group	Feb	May	Aug	Nov	Station Group	Feb	May	Aug	Nov
Kelp WQ	7	16	15	14	Kelp WQ	31*	2	8	1*
18 & 60-m WQ	9	19	17	17	North WQ	4	5	10	29
80-m WQ	10	20	18	18	Mid WQ	3	4	9	30
98-m WQ	8	18	16	15	South WQ	1	3	11	28

*SBOO Kelp WQ sampling was conducted January 31 with February sampling dates and December 1 with November sampling dates.

Table 2.5
Sensor configuration and model type for RTOMS by site and depth during 2022.

Sensor Depth		
PLOO	**SBOO**	**Parameters Measured (Sensor Types)**
1 m (surface)	1 m (surface)	Temperature, conductivity, pH (total), DO (Sea-Bird SeapHOx)
		Ocean currents (RDI 300kHz ADCP)
		Partial pressure of carbon dioxide (Pro-Oceanus pCO_2 System)
		Chlorophyll *a*, CDOM, turbidity (Sea-Bird ECO triplet)
		Nitrate + nitrite (Sea-Bird SUNA V2)
10 m	10 m	Temperature, conductivity (Sea-Bird MicroCAT)
	18 m	Temperature, conductivity, DO (Sea-Bird MicroCAT ODO)
		Chlorophyll *a*, CDOM, turbidity (Sea-Bird ECO triplet)
20 m		Temperature, conductivity (Sea-Bird MicroCAT)
	26 m (cage)	Temperature, conductivity, pH, DO (Sea-Bird SeapHOx)
		Chlorophyll *a*, CDOM, turbidity (Sea-Bird ECO triplet)
		Nitrate + nitrite (Sea-Bird SUNA V2)
		BOD (Chelsea UviLux)
30 m (cage-1)		Temperature, conductivity, pH, DO (Sea-Bird SeapHOx)
		Chlorophyll *a*, CDOM, turbidity (Sea-Bird ECO triplet)
		Nitrate + nitrite (Sea-Bird SUNA V2)
		BOD (Chelsea UviLux)
45 m		Temperature, conductivity (Sea-Bird MicroCAT)
60 m		Temperature, conductivity (Sea-Bird MicroCAT)
75 m (cage-2)		Temperature, conductivity, pH, DO (Sea-Bird SeapHOx)
		Chlorophyll a, CDOM, turbidity (Sea-Bird ECO triplet)
		Nitrate + nitrite (Sea-Bird SUNA V2)
90 m		Temperature, conductivity, DO (Sea-Bird MicroCAT ODO)
90 m (cage-2)		Temperature, conductivity, pH, DO (Sea-Bird Deep SeapHOx)
		Chlorophyll *a*, CDOM, turbidity (Sea-Bird ECO triplet)
		Nitrate + nitrite (Sea-Bird SUNA V2)
		BOD (Chelsea UviLux)

Table 2.6

Summary of temperature, salinity, DO, pH, transmissivity, and chlorophyll *a* for various depth layers as well as the entire water column for all PLOO stations during 2022. See Appendix A.4 for sample sizes.

		Depth (m)				
Parameter		**1–20**	**21–60**	**61–80**	**81–98**	**1–98**
Temperature (°C)	min	10.4	9.9	9.6	9.6	9.6
	max	23.8	17.4	12.4	11.6	23.8
	mean	15.8	12.3	11.0	10.6	13.0
Salinity (ppt)	min	33.30	33.34	33.45	33.58	33.30
	max	33.91	33.98	34.07	34.18	34.18
	mean	33.54	33.55	33.69	33.84	33.60
DO (mg/L)	min	3.2	3.1	2.9	2.5	2.5
	max	10.1	9.0	5.6	4.8	10.1
	mean	7.5	5.5	4.3	3.8	5.8
pH	min	7.7	7.6	7.6	7.7	7.6
	max	8.3	8.2	7.9	7.8	8.3
	mean	8.1	7.9	7.8	7.7	7.9
Transmissivity (%)	min	48	75	60	44	44
	max	92	93	93	93	93
	mean	86	90	90	90	89
Chlorophyll *a* (µg/L)	min	0.3	0.3	0.2	0.2	0.2
	max	20.8	13.6	2.5	1.7	20.8
	mean	1.9	1.6	0.7	0.7	1.5

Table 2.7

Summary of temperature, salinity, DO, pH, transmissivity, and chlorophyll *a* for various depth layers as well as the entire water column for all SBOO stations during 2022. See Appendix A.5 for sample sizes.

		Depth (m)					
Parameter		**1–9**	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
Temperature (°C)	min	12.8	10.9	10.6	10.4	10.3	10.3
	max	22.7	20.9	15.5	14.8	14.2	22.7
	mean	15.8	14.3	13.2	12.7	12.0	14.3
Salinity (ppt)	min	33.27	33.23	33.38	33.36	33.37	33.23
	max	33.72	33.76	33.83	33.90	33.95	33.95
	mean	33.51	33.50	33.51	33.53	33.58	33.51
DO (mg/L)	min	4.8	3.4	3.3	3.1	3.0	3.0
	max	10.2	10.3	8.9	8.0	7.1	10.3
	mean	8.2	7.4	6.2	5.7	5.1	7.1
pH	min	7.8	7.7	7.7	7.7	7.6	7.6
	max	8.3	8.3	8.2	8.2	8.1	8.3
	mean	8.2	8.1	8.0	7.9	7.9	8.1
Transmissivity (%)	min	54	44	47	59	40	40
	max	91	91	92	92	92	92
	mean	82	84	86	88	89	84
Chlorophyll *a* (µg/L)	min	0.3	0.3	0.7	0.9	0.3	0.3
	max	21.5	13.2	12.8	6.2	9.1	21.5
	mean	2.4	2.3	2.0	1.6	1.1	2.1

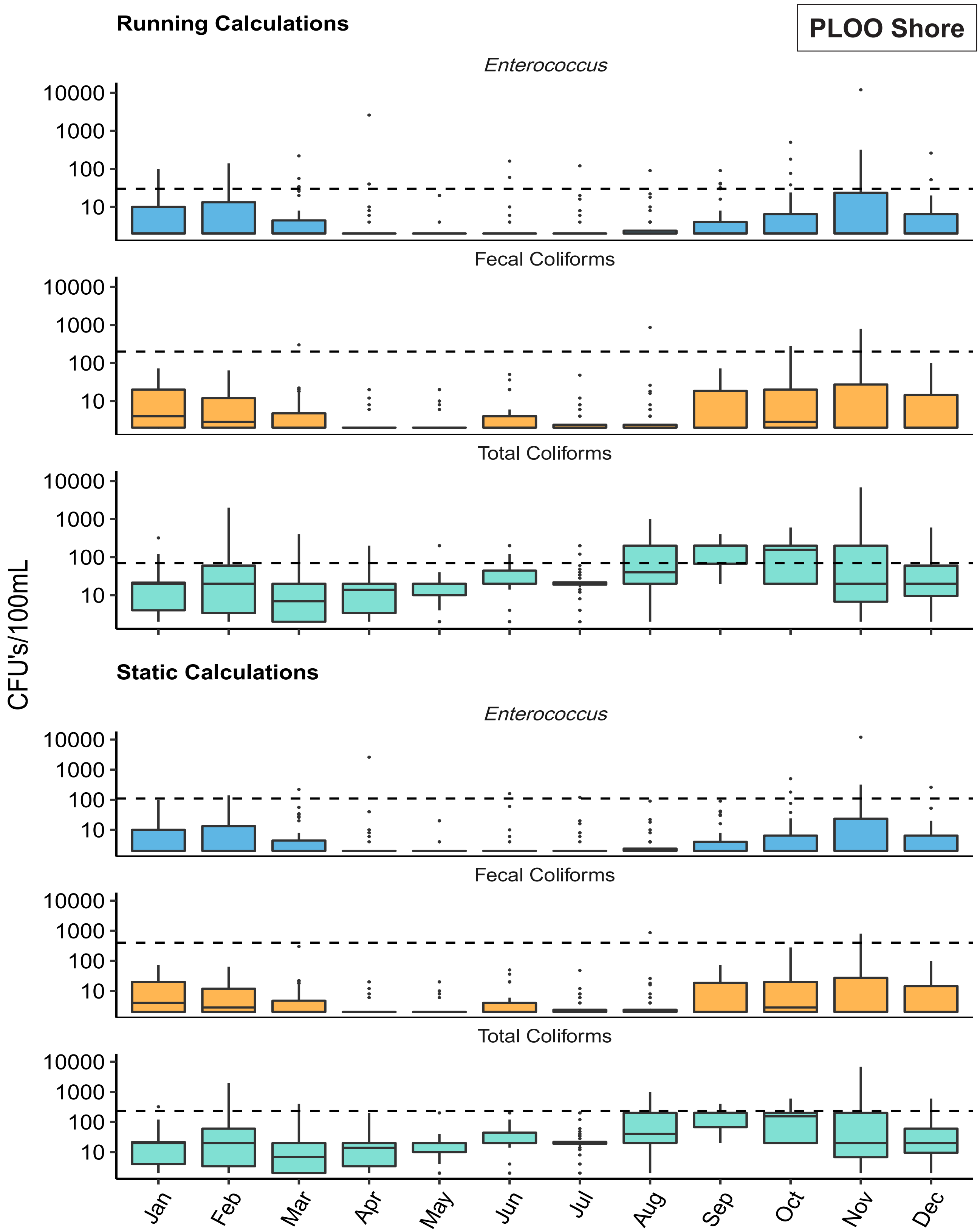

Figure 2.2
Bacteriological data for PLOO shore, kelp, and offshore stations located within state jurisdictional waters sampled in 2022, binned by month. Boxes represent the interquartile range. Dashed line represents the water contact standard compliance threshold*. Boxes = median, upper and lower quantiles; whiskers = 1.5x interquartile range, dots = outliers. *STV compliance is calculated separately and shown in Table 2.8

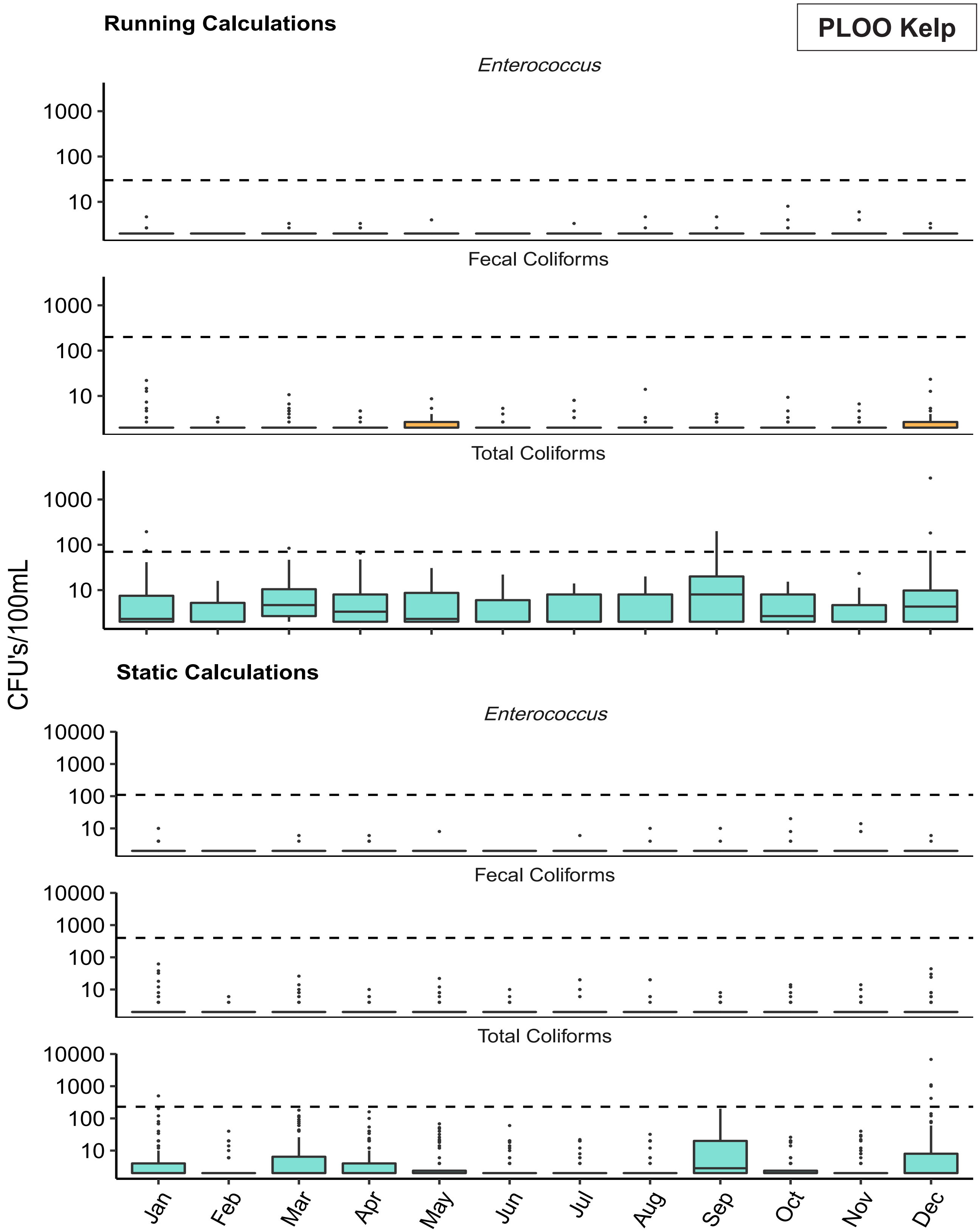

Figure 2.2 *continued*

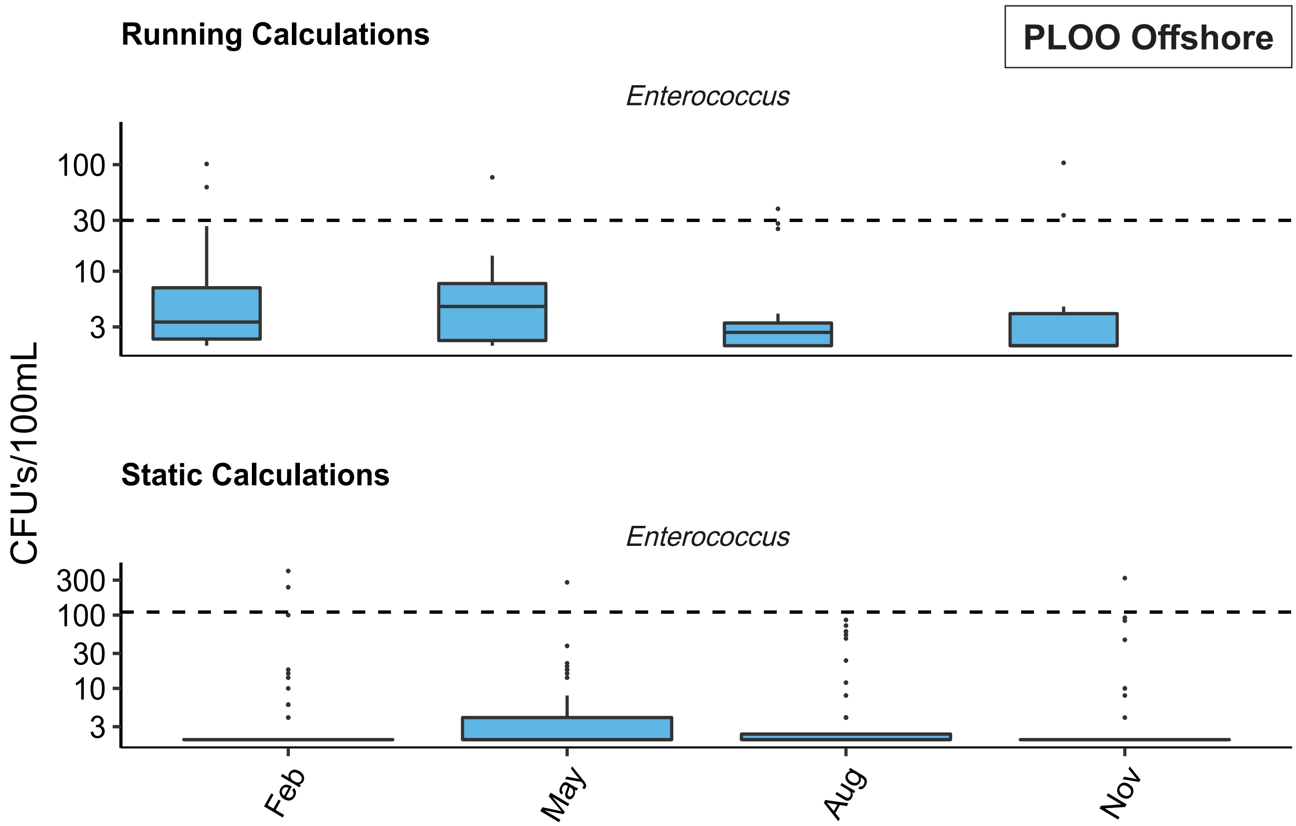

Figure 2.2 *continued*

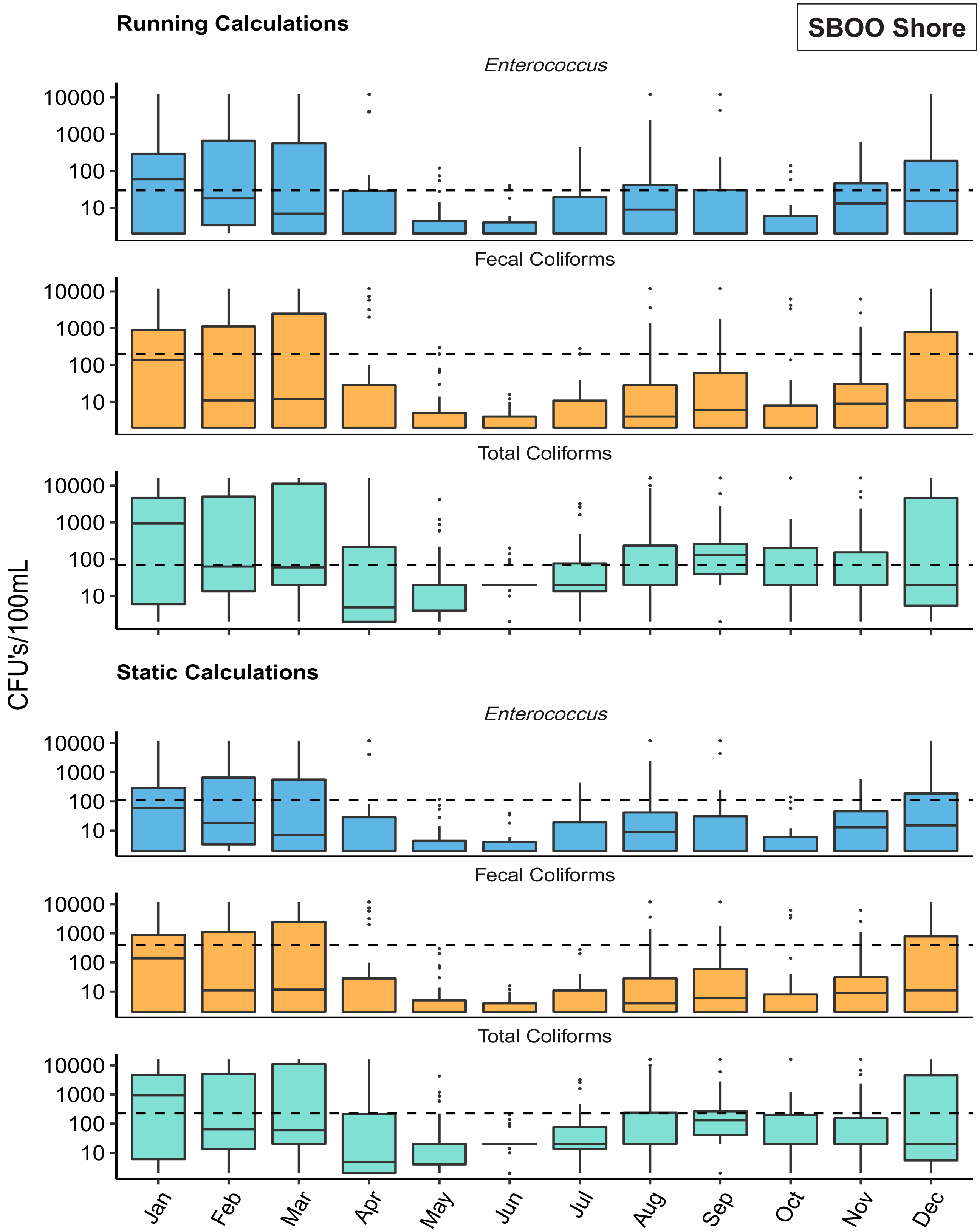

Figure 2.3
Bacteriological data for SBOO shore, kelp, and offshore stations located within state jurisdictional waters sampled in 2022, binned by month. Boxes represent the interquartile range. Dashed line represents the water contact standard compliance threshold*. Boxes = median, upper and lower quantiles; whiskers = 1.5x interquartile range, dots = outliers. *STV compliance is calculated separately and shown in Table 2.8

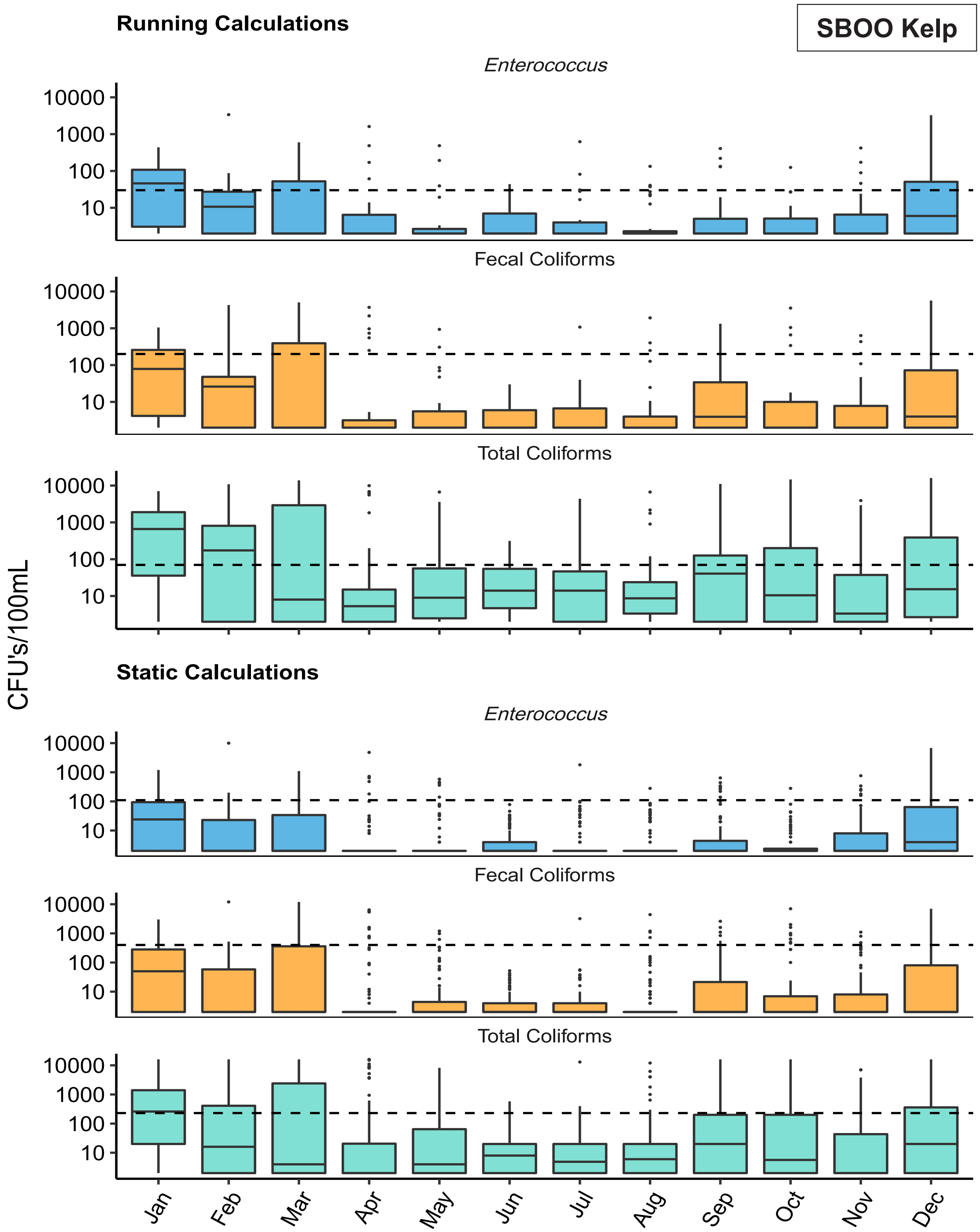

Figure 2.3 *continued*

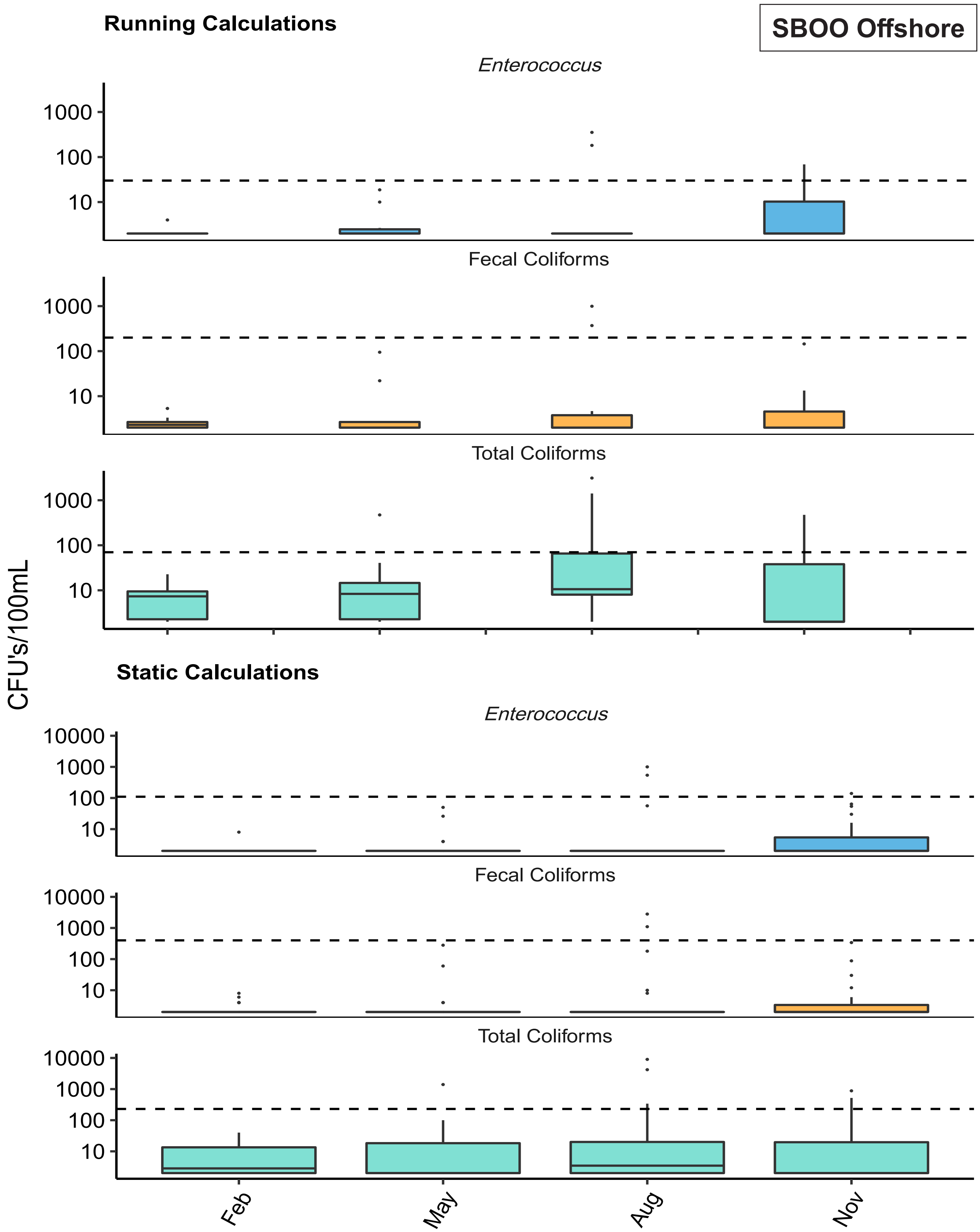

Figure 2.3 *continued*

Table 2.8

Compliance rates for Statistical Threshold Value water contact standards for PLOO and SBOO monitoring stations located within state jurisdictional waters sampled during 2022. Offshore stations are sampled quarterly; — = not sampled.

Enterococcus

Year	Project		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	**PLOO**	*Shore*	100	88	88	88	100	88	88	100	100	75	38	88
		Kelp	100	100	100	100	100	100	100	100	100	100	100	100
		Offshr	—	83	—	—	92	—	—	100	—	—	92	—
	SBOO	*Shore*	38	25	38	62	88	100	75	50	50	88	50	25
		Kelp	43	86	43	86	71	100	100	100	71	100	71	0
		Offshr	—	100	—	—	100	—	—	80	—	—	90	—

Total Coliforms

Year	Project		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	**PLOO**	*Shore*	88	88	88	100	100	100	100	88	88	75	25	62
		Kelp	100	100	100	100	100	100	100	100	100	100	100	88
	SBOO	*Shore*	25	25	25	38	38	100	50	50	38	38	38	25
		Kelp	0	0	14	57	14	57	83	43	14	0	43	14
		Offshr	—	100	—	—	90	—	—	80	—	—	90	—

Table 2.9

Compliance rates for HF183 water contact standards for PLOO and SBOO monitoring stations located within state jurisdictional waters sampled during 2022. Offshore stations are sampled quarterly; Samples taken in the PLOO monitoring region are not analyzed for fecal coliforms or total coliforms.

		Fecal Coliforms	Total Coliforms	*Enterococcus*
PLOO				
Overall		100	100	100
Kelp		100	100	100
Offshore		—	—	100
SBOO				
Overall		98	0	100
Kelp	I19	100	70	100
	I24	100	95	100
	I25	100	95	100
	I40	100	72	100
Offshore		100	100	100

Chapter 3
Benthic Conditions

Chapter 3. Benthic Conditions

Introduction

The City of San Diego (City) conducts extensive monitoring of benthic sediments and communities of small benthic invertebrates (macrofauna) that live within, or on the surface of, soft-bottom seafloor habitats surrounding the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). This monitoring helps to characterize regional benthic conditions and identify potential effects of wastewater discharge, or other anthropogenic inputs, on the marine benthic environment. This chapter presents summaries and preliminary analyses of the sediment quality, sediment toxicity, and macrofaunal community data collected during calendar year 2022 at PLOO, SBOO, and San Diego regional benthic monitoring stations. A more comprehensive assessment of these results will be presented in the 2022-2023 Biennial Assessment Report to be submitted by July 1, 2024.

Materials And Methods

Collection and Processing of Samples

Samples were collected at a total of 89 benthic stations to monitor ocean sediments and macrofaunal communities during 2022 (Figure 3.1). These included 22 stations arranged in a grid surrounding the PLOO, along or adjacent to the 88, 98, or 116-m depth contours, and 27 stations arranged in a grid surrounding the SBOO, along or adjacent to the 19, 28, 38, or 55-m depth contours. These stations were sampled during the winter (January) and summer (July). The four stations located within 1000 m of the zone of initial dilution (ZID) for each outfall are considered to represent near-ZID conditions. These include PLOO stations E11, E14, E15, and E17, and SBOO stations I12, I14, I15, and I16. The remaining 40 "regional" stations were selected using a probability-based random stratified sampling design as described in Bergen (1996), Stevens (1997), and Stevens and Olsen (2004). Regional stations were sampled during the summer at depths ranging from 8 to 453 m, including 10 sites along the inner shelf (8–30 m), 15 sites along the mid-shelf (30–120 m), 9 sites along the outer shelf (120–200 m), and 6 sites on the upper slope (200–453 m).

Samples were collected using a double 0.1-m^2 Van Veen grab, with one grab per cast used for sediment quality analysis, one grab per cast used for benthic community analysis, and subsequent grabs used for sediment toxicity testing where required. Visual observations of weather, sea conditions, and human/animal activity were also recorded at the time of sampling. Criteria established by the U.S. Environmental Protection Agency (USEPA) to ensure consistency of these types of samples were followed with regard to sample disturbance and depth of penetration (USEPA 1987). Sub-samples for particle size and sediment chemistry analyses were taken from the top 2 cm of the sediment surface and handled according to standard guidelines (USEPA 1987, SCCWRP 2018).

For sediment toxicity samples, a plastic (e.g., high-density polyethylene [HDPE], polycarbonate, Teflon) or stainless-steel scoop was used to collect sediment from the top 2 cm of the undisturbed surface material in the grab. Contact with sediment within 1 cm of the sides of the grab was avoided to minimize cross-contamination. In most cases, multiple grabs were required to obtain enough sediment for toxicity testing (i.e., up to 6 L sediment). If more than one grab was required, sediment from each grab was added to a Teflon bag and homogenized thoroughly using either a clean Teflon or plastic spoon, or by kneading the sample within the bag. Once collected, the toxicity samples were stored in the dark at 4°C in the laboratory for no longer than four weeks prior to testing.

Samples for infauna analysis were transferred to a wash table aboard ship, rinsed with seawater, and then sieved through a 1.0-mm mesh screen to remove as much sediment as possible. The macroinvertebrates retained on the screen were transferred to sample jars, relaxed for 30 minutes in a magnesium sulfate solution, and then fixed with buffered formalin. The preserved samples were then transferred back to the City's Marine Biology Laboratory. After a minimum of 72 hours, but no more than 10 days, in formalin, each sample was thoroughly rinsed with fresh water and transferred to 70% ethanol for final preservation.

Laboratory Analyses

Sediment Particle Size

All particle size analyses were performed at the City's Environmental Chemistry Services Laboratory. Particle size analysis was performed using either a Horiba LA-950V2 Laser Particle Size Analyzer or a set of nested sieves. The Horiba measures particles ranging in size from 0.5 to 2000 µm. Coarser sediments were removed and quantified prior to laser analysis by screening samples through a 2000 µm mesh sieve. These data were later combined with the Horiba results to obtain a complete distribution of particle sizes totaling 100%, and then classified into 11 sub-fractions and four main size fractions based on the Wentworth scale (Folk 1980) (see Appendix B.1). When a sample contained substantial amounts of coarse sand, gravel, shell hash, or other large materials that could damage the Horiba analyzer or where the general distribution of sediments would be poorly represented by laser analysis, a set of nested sieves with mesh sizes of 2000, 1000, 500, 250, 125, 75, and 63 µm was used to divide the samples into eight sub-fractions. See Appendix B.2 for visual observations from each PLOO and SBOO core station, and Appendix B.3 from each regional station.

Sediment Chemistry

All sediment chemistry analyses were performed at the City's Environmental Chemistry Services Laboratory. Detailed analytical protocols are available upon request. Briefly, sediment sub-samples were analyzed on a dry weight basis to determine concentrations of various indicators of organic loading (i.e., biochemical oxygen demand, total organic carbon, total nitrogen, total sulfides, total volatile solids), 18 trace metals, 9 chlorinated pesticides, 42 polychlorinated biphenyl compound congeners (PCBs), 24 polycyclic aromatic hydrocarbons (PAHs), and 13 polybrominated diphenyl ethers (PBDEs) (see Appendix B.4).

Sediment Toxicity Testing

A detailed description of the sediment toxicity testing protocols can be found in City of San Diego (2022b). Briefly, all sediment toxicity testing was conducted by the City of San Diego Toxicology Laboratory (CSDTL) using the marine amphipod *Eohaustorius estuarius*. The 10-day amphipod tests were conducted in accordance with EPA 600/R-94/0925 (USEPA 1994) and the procedures previously approved for the Southern California Bight 2018 Regional Monitoring Program (Bight'18 Toxicology Committee 2018). Juvenile *E. estuarius* were exposed for 10 days to both test and control sediments. Response criteria included amphipod mortality, and if considered a measurement of interest, the ability of amphipods to rebury in clean sediment at the end of the bioassay. In addition, a reference toxicant test (using seawater only) was conducted concurrently and under identical environmental conditions as the sediment toxicity tests to determine test organism sensitivity.

Macrobenthic Assemblages
All organisms were separated from the raw material (e.g., sediment grunge, shell hash, debris) and sorted into the following six taxonomic groups by an external contract lab: Annelids (e.g., polychaete and oligochaete worms), Arthropods (e.g., crustaceans and pycnogonids), Molluscs (e.g., clams, snails, scaphopods), non-ophiuroid Echinoderms (e.g., sea urchins, sea stars, sea cucumbers), Ophiuroids (i.e., brittle stars), and other phyla (e.g., flatworms, nemerteans, cnidarians). The sorted macrofaunal samples were then returned to the City's Marine Biology Laboratory where all animals were identified to species, or to the lowest taxon possible, by City Marine Biologists. All identifications followed nomenclatural standards established by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT 2021).

Data Analyses

All raw data for 2022 have been submitted to either the Regional Water Quality Control Board or the California Environmental Data Exchange Network (CEDEN) and will be provided upon request.

Sediment Particle Size and Chemistry
Data summaries for the various sediment parameters included detection rate, mean, minimum and maximum values for all samples by outfall region (i.e., PLOO, SBOO stations) and across the region (i.e., regional stations). All means were calculated using detected values only with no substitutions made for non-detects (i.e., concentrations < MDL). Total DDT (tDDT), total hexachlorocyclohexane (tHCH), total chlordane, total PCB (tPCB), and total PAH (tPAH) were calculated for each sample as the sum of all constituents with reported values for individual constituents. Analyses were performed using R (R Core Team 2022) various functions within the zoo, reshape2, plyr, tidyr, and dplyr packages (Zeileis and Grothendieck 2005, Wickham 2007, 2011, Wickham and Henry 2017, Wickham et al. 2017).

Sediment Toxicity Testing
All data were analyzed in accordance with procedures outlined in Sections 12 and 13 of EPA 600/R-94/0925 using the acceptability criterion of ≥ 90% mean control survival at test termination. Additional information and the standard operation procedures for sediment toxicity testing are provided in Appendix B of the CSDTL's Quality Assurance Manual (City of San Diego 2022b).

Macrobenthic Assemblages
Population characteristics were summarized as percent abundance (number of individuals per species/total abundance of all species), frequency of occurrence (percentage of grabs in which a species occurred), and mean abundance per grab (number of individuals per species/total number of grabs). Additionally, the following community structure parameters were calculated for each station and expressed per 0.1-m^2 grab: species richness (number of species or distinct taxa), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance index (see Swartz et al. 1986, Ferraro et al. 1994), and benthic response index (BRI; see Smith et al. 2001). Unless otherwise noted, the above analyses were performed using R (R Core Team 2022) and various functions within the reshape2, Rmisc, RODBC, tidyverse, and vegan packages (Wickham 2007, Wickham et al. 2019, Hope 2013, Oksanen et al. 2020, Ripley and Lapsley 2021).

Multivariate analyses were performed using PRIMER v7 software to examine spatial patterns in macrofaunal data collected at the 89 PLOO, SBOO, and regional benthic stations sampled during summer 2022 (see Clarke et al. 2008, Clarke et al. 2014). These included ordination and hierarchical agglomerative clustering (cluster analysis) with group-average linking and similarity profile analysis (SIMPROF) to confirm the non-random structure of the resultant cluster dendrograms. The Bray-Curtis measure of similarity was used as the basis for clustering, and data were square-root transformed to lessen the influence of overly abundant species and increase the importance (or impact) of rare species. Major ecologically-relevant clusters receiving SIMPROF support were retained.

Results

Sediment Quality

Sediment grain size (i.e., main particle size fractions) and chemistry data collected during 2022 are summarized for PLOO, SBOO, and regional benthic stations in Tables 3.1 and 3.2. Results for sediment toxicity samples are summarized in Table 3.3.

Macrobenthic Communities

Key community structure parameters, including species richness, abundance, diversity, evenness, dominance, and BRI, are summarized for PLOO, SBOO, and regional benthic stations in Table 3.4. The 25 most abundant macroinvertebrate taxa identified at PLOO and SBOO stations during 2022 are summarized by percent abundance, frequency of occurrence, and abundance per grab in Tables 3.5 and 3.6. The 10 most abundant taxa from each depth stratum are summarized for regional stations in Table 3.7. Ordination and cluster analyses were performed to illustrate and quantify the ecological patterns at the macroinvertebrate community level across the San Diego region; these results are presented in Figure 3.2.

Summary

Preliminary analysis of sediment particle size, chemistry, toxicity, and macroinvertebrate data collected in 2022 indicate that wastewater discharged through the PLOO and SBOO has not negatively impacted benthic communities in the coastal waters off San Diego. During the current reporting period, there was no evidence of fine-particle loading related to wastewater discharge via the PLOO or SBOO. Contaminant concentrations at near-ZID stations were generally within the range of variability observed throughout both outfall regions and did not appear to reflect any significant organic enrichment. The quality of PLOO and SBOO sediments in 2022 was similar to previous years (e.g., City of San Diego 2022a), with overall contaminant concentrations remaining relatively low compared to available thresholds or other southern California coastal areas (Schiff and Gossett 1998, Noblet et al. 2002, Schiff et al. 2006, 2011, Maruya and Schiff 2009, Dodder et al. 2016, Du et al. 2020). No evidence of sediment toxicity was observed at any offshore station tested in the San Diego region during 2022, regardless of depth, sediment type, or proximity to either outfall. These results are consistent with findings from previous regional monitoring programs that have demonstrated minimal sediment toxicity on the southern California continental shelf in contrast to offshore submarine canyons and local embayments (e.g., Bay et al. 2015, Parks et al. 2020). Further, values for most benthic infauna community parameters were similar at stations located both near and far away from the outfall discharge sites. These metrics were within historical ranges reported for the San Diego region (e.g., City of San Diego 2022a), and were representative of those characteristic of similar habitats throughout the Southern California Bight

(Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993a,b, Zmarzly et al. 1994, Diener and Fuller 1995, Bergen et al.1998, 2000, 2001, Ranasinghe et al. 2003, 2007, 2010, 2012, Mikel et al. 2007, Gillett et al. 2017, 2022).

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Chapter 3

Figures & Tables

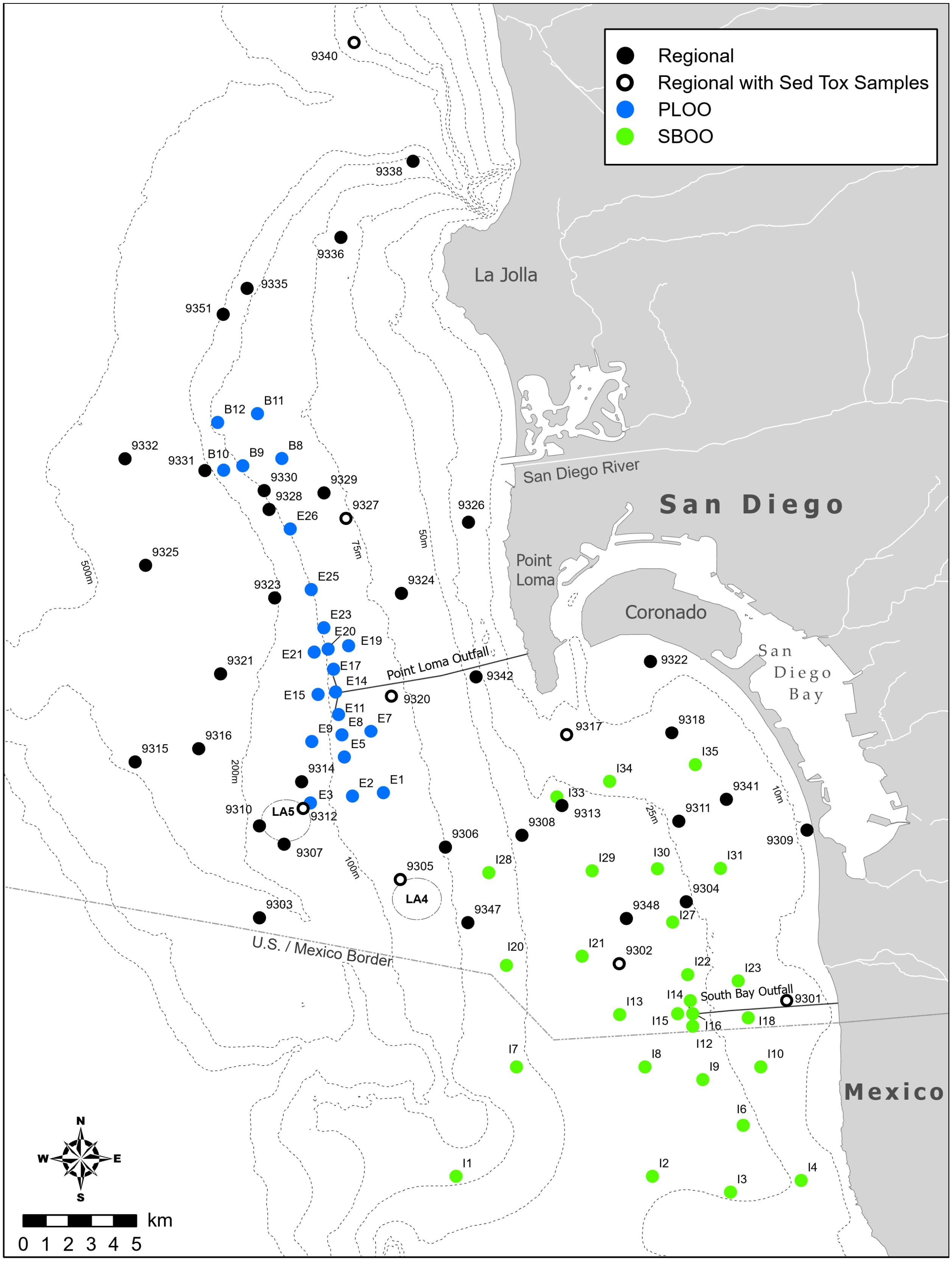

Figure 3.1
Benthic station locations sampled around the PLOO and SBOO as part of the City of San Diego's Ocean Monitoring Program.

Table 3.1

Summary of particle sizes and chemistry concentrations in sediments from PLOO and SBOO benthic stations sampled during 2022. Data include the detection rate (DR), mean, minimum, and maximum values for each survey area. Minimum and maximum values were calculated using all samples, whereas means were calculated on detected values only; n = number of samples; nd = not detected; na = not analyzed.

	PLOO				SBOO			
Parameter	**DR (%)**	**Min**	**Max**	**Mean**	**DR (%)**	**Min**	**Max**	**Mean**
Particle Size (%)								
Coarse Particles	7	0.0	5.4	0.2	50	0.0	25.4	4.4
Med-Coarse Sands	98	0.0	13.1	1.5	100	0.2	97.6	40.2
Fine sands	100	23.5	54.7	39.8	98	0.0	89.3	37.6
Fines	100	44.6	70.6	58.6	94	0.0	67.0	17.8
Organic Indicators								
BOD (ppm)	100	295	660	385	na	—	—	—
Sulfides (ppm)	64	nd	70.10	16.06	24	nd	39.50	10.19
TN (% weight)	100	0.030	0.086	0.052	46	nd	0.074	0.031
TOC (% weight)	100	0.34	3.12	0.73	56	nd	4.03	0.41
TVS (% weight)	100	1.4	3.4	2.1	100	0.2	1.8	0.8
Trace Metals (ppm)								
Aluminum	100	4700	10,900	6965	100	628	7510	3177
Antimony	100	0.4	2.1	1.0	78	nd	1.2	0.7
Arsenic	100	1.81	5.32	2.72	100	0.59	9.81	2.40
Barium	100	17.5	46.6	29.7	100	1.4	46.2	14.9
Beryllium	100	0.1	0.4	0.2	98	nd	0.2	0.1
Cadmium	5	nd	0.10	0.09	2	nd	0.09	0.09
Chromium	100	9.7	27.1	15.3	100	3.4	13.3	8.2
Copper	100	4.6	15.0	7.0	54	nd	4.6	2.9
Iron	100	6470	22,500	10,951	100	1160	8670	4847
Lead	100	1.9	5.4	3.2	100	0.8	2.9	1.5
Manganese	100	56.0	119.0	80.2	100	6.0	91.0	40.5
Mercury	100	0.013	0.048	0.023	72	nd	0.022	0.006
Nickel	100	2.9	8.2	5.0	93	nd	4.4	1.6
Selenium	0	—	—	—	0	—	—	—
Silver	0	—	—	—	0	—	—	—
Thallium	0	—	—	—	0	—	—	—
Tin	100	0.4	1.2	0.7	72	nd	0.6	0.3
Zinc	100	17.6	38.0	26.8	100	1.9	24.0	10.1
Pesticides (ppt)								
Total Chlordane	7	nd	650	247	0	—	—	—
Total DDT	100	101	862	339	22	nd	970	304
Hexachlorobenzene	0	—	—	—	2	nd	196	196
Total HCH	7	nd	175	133	2	nd	32	32
Mirex	0	—	—	—	4	nd	50	41
Total PCB (ppt)	50	nd	50,682	3237	11	nd	558	319
Total PAH (ppb)	32	nd	93	25	19	nd	44	16
Total PBDE (ppt)	61	nd	623	145	4	nd	67	49

Table 3.2

Summary of particle sizes and chemistry concentrations in sediments from San Diego regional benthic stations sampled during summer 2022. Data include detection rate (DR), minimum, maximum, and mean values for the entire survey area, as well as mean value by depth stratum. Minimum and maximum values were calculated using all samples, whereas means were calculated on detected values only; n = number of samples; nd = not detected.

	2022 Survey Area				Depth Strata			
					Inner Shelf	Mid-Shelf	Outer Shelf	Upper Slope
Parameters	DR (%)	Min	Max	Mean	n=10	n=15	n=9	n=6
Particle Size (%)								
Coarse particles	23	0.0	35.5	4.1	10.0	0.5	6.3	0.0
Med-coarse sands	100	0.1	72.5	7.6	18.9	2.0	9.5	0.2
Fine sands	100	7.9	81.1	36.1	46.9	40.0	29.1	19.3
Fines	100	3.4	85.6	52.1	24.3	57.5	55.1	80.4
Organic Indicators								
Sulfides (ppm)	67	nd	34.30	9.79	4.46	7.14	3.66	21.09
TN (% weight)	95	nd	0.223	0.062	0.024	0.050	0.055	0.154
TOC (% weight)	100	0.07	6.17	0.96	0.19	0.58	1.54	2.35
TVS (% weight)	100	0.5	8.1	2.6	0.9	2.2	3.5	5.5
Trace Metals (ppm)								
Aluminum	100	1190	17,500	8299	3766	8491	8933	14,425
Antimony	90	nd	2.6	1.2	0.9	1.2	0.9	1.8
Arsenic	100	1.41	4.82	2.79	1.93	2.91	3.04	3.54
Barium	100	8.2	105.0	38.7	18.4	37.7	41.2	71.0
Beryllium	100	0.02	0.4	0.2	0.1	0.2	0.2	0.3
Cadmium	28	nd	0.41	0.19	NA	0.09	0.17	0.25
Chromium	100	2.8	37.0	16.3	7.3	15.4	18.2	30.6
Copper	100	1.2	30.3	11.1	5.4	10.1	15.4	16.9
Iron	100	3510	19,400	10,786	4870	10,483	13,754	16,950
Lead	100	0.6	7.7	3.5	1.6	3.9	4.1	4.8
Manganese	100	40.3	159.0	89.5	60.4	93.8	91.8	123.9
Mercury	98	nd	0.113	0.031	0.005	0.030	0.043	0.055
Nickel	100	0.6	19.2	6.2	1.6	5.7	6.6	14.4
Selenium	8	nd	0.63	0.55	nd	nd	0.45	0.59
Silver	0	—	—	—	—	—	—	—
Thallium	3	nd	0.341	0.341	0.341	nd	nd	nd
Tin	100	0.09	1.47	0.71	0.29	0.78	0.78	1.13
Zinc	100	9.1	61.4	28.3	11.9	28.1	34.1	47.7
Pesticides (ppt)								
Total Chlordane	3	nd	170	170	nd	nd	170	nd
Total DDT	75	nd	9936	1355	70	1807	561	1705
Hexachlorobenzene	3	nd	173	173	nd	173	nd	nd
Mirex	3	nd	169	169	nd	169	nd	nd
Total PCB (ppt)	53	nd	12,021	2712	nd	2069	6401	712
Total PAH (ppb)	48	nd	996	120	15	162	150	22
Total PBDE (ppt)	18	nd	294	197	—	197	—	—

Table 3.3

Bioassay results (10-day amphipod survival tests) for sediment toxicity testing conducted for San Diego regional benthic stations sampled during summer 2022. Percent fines = percentage of silt + clay combined. Test results are expressed as mean percent survival ± 1 standard deviation.

Survey	Site/Sample	Depth Stratum	Station Depth (m)	Percent Fines	Sample Date	Test Initiation	% Survival (Mean ± SD)
Summer 2022	Lab Control	—	—	—	—	7/26/22	98 ± 2.7
	9301	Inner Shelf	16	33.8	7/19/2022	7/26/22	95 ± 5.0
	9302	Mid Shelf	36	52.9	7/19/2022	7/26/22	97 ± 4.5
	9305	Mid Shelf	87	66.5	7/19/2022	7/26/22	98 ± 4.5
	9312	Outer Shelf	137	61.1	7/19/2022	7/26/22	99 ± 2.2
	9317	Inner Shelf	19	3.4	7/18/2022	7/26/22	96 ± 5.5
	9320	Mid Shelf	81	63.6	7/18/2022	7/26/22	97 ± 2.7
	9327	Mid Shelf	78	70.6	7/18/2022	7/26/22	96 ± 4.2
	9340	Outer Shelf	133	61.8	7/18/2022	7/26/22	96 ± 4.2

Table 3.4

Summary of macrofaunal community parameters for PLOO, SBOO, and San Diego regional benthic stations sampled during 2022. Data for each region include mean, 95% confidence interval (CI), minimum, and maximum values; SR = species richness; Abun = abundance; H' = Shannon diversity index; J' = Pielou's evenness; Dom = Swartz dominance; BRI = benthic response index.

		SR	Abun	H'	J'	Dom	BRI
All PLOO Grabs	Mean	91	320	3.9	0.88	32	11
(n = 44)	95% CI	4	23	0.1	0.01	2	1
	Min	68	177	3.3	0.74	18	5
	Max	121	481	4.3	0.93	47	26
All SBOO Grabs	Mean	66	272	3.2	0.78	20	15
(n = 54)	95% CI	9	46	0.2	0.03	3	2
	Min	23	84	1.7	0.44	3	3
	Max	189	833	4.6	0.90	59	25
All Regional Grabs	Mean	75	292	3.4	0.82	25	15
(n = 40)	95% CI	12	55	0.3	0.04	5	2
	Min	11	41	1.1	0.44	2	0
	Max	184	892	4.5	0.94	60	25

Table 3.5

The 25 most abundant macroinvertebrate taxa collected from PLOO benthic stations during 2022. A total of 44 grabs were collected. PA = percent abundance, FO = frequency of occurrence, MAG = mean abundance per grab.

Taxon	Taxonomic Classification	PA	FO	MAG
Mediomastus sp	Polychaeta: Capitellidae	8	98	24
Amphiodia urtica	Echinodermata: Ophiuroidea	5	98	17
Scoloplos armiger Cmplx	Polychaeta: Orbiniidae	4	93	13
Spiophanes duplex	Polychaeta: Spionidae	4	100	12
Euclymeninae sp A	Polychaeta: Maldanidae	3	100	10
Paradiopatra parva	Polychaeta: Onuphidae	3	100	10
Prionospio jubata	Polychaeta: Spionidae	3	100	9
Prionospio dubia	Polychaeta: Spionidae	3	100	9
Spiophanes kimballi	Polychaeta: Spionidae	2	95	8
Amphiuridae	Echinodermata: Ophiuroidea	2	98	7
Praxillella pacifica	Polychaeta: Maldanidae	2	93	6
Eclysippe trilobata	Polychaeta: Ampharetidae	2	95	6
Axinopsida serricata	Mollusca: Bivalvia	2	75	6
Amphiodia sp	Echinodermata: Ophiuroidea	2	89	5
Euphilomedes producta	Arthropoda: Ostracoda	2	75	5
Heteronemertea sp SD2	Nemertea: Heteronemertea	1	80	4
Rhepoxynius bicuspidatus	Arthropoda: Amphipoda	1	75	4
Lanassa venusta venusta	Polychaeta: Terebellidae	1	68	4
Tellina cadieni	Mollusca: Bivalvia	1	66	4
Dialychone trilineata	Polychaeta: Sabellidae	1	77	3
Ampelisca careyi	Arthropoda: Amphipoda	1	86	3
Caecognathia crenulatifrons	Arthropoda: Isopoda	1	82	3
Clymenura gracilis	Polychaeta: Maldanidae	1	68	3
Euchone incolor	Polychaeta: Sabellidae	1	68	3
Chloeia pinnata	Polychaeta: Amphinomidae	1	66	3

Table 3.6

The 25 most abundant macroinvertebrate taxa collected from SBOO benthic stations during 2022. A total of 54 grabs were collected. PA = percent abundance, FO = frequency of occurrence, MAG = mean abundance per grab.

Taxon	Taxonomic Classification	PA	FO	MAG
Spiophanes norrisi	Polychaeta: Spionidae	15	100	41
Spiophanes duplex	Polychaeta: Spionidae	8	81	21
Jasmineira sp B	Polychaeta: Sabellidae	2	22	6
Cooperella subdiaphana	Mollusca: Bivalvia	2	35	6
Ampharete manriquei	Polychaeta: Ampharetidae	2	28	5
NEMATODA	Nematoda	2	57	4
Euclymeninae sp A	Polychaeta: Maldanidae	1	54	4
Mediomastus sp	Polychaeta: Capitellidae	1	56	4
Sigalion spinosus	Polychaeta: Sigalionidae	1	72	4
Chondrochelia dubia Cmplx	Arthropoda: Tanaidacea	1	63	3
Eusyllis sp SD2	Polychaeta: Syllidae	1	17	3
Euphilomedes carcharodonta	Arthropoda: Ostracoda	1	43	3
Glycinde armigera	Polychaeta: Goniadidae	1	67	3
Prionospio pygmaeus	Polychaeta: Spionidae	1	48	3
Rhepoxynius heterocuspidatus	Arthropoda: Amphipoda	1	43	3
Phyllodoce hartmanae	Polychaeta: Phyllodocidae	1	59	3
Dendraster terminalis	Mollusca: Scaphopoda	1	28	3
Gadila aberrans	Echinodermata: Echinoidea	1	41	3
Kirkegaardia siblina	Polychaeta: Cirratulidae	1	43	2
Lineidae	Nemertea: Heteronemertea	1	83	2
Rhepoxynius menziesi	Arthropoda: Amphipoda	1	59	2
Scoloplos armiger Cmplx	Polychaeta: Orbiniidae	1	63	2
Lanassa venusta venusta	Polychaeta: Terebellidae	1	15	2
Ampelisca brevisimulata	Arthropoda: Amphipoda	1	44	2
Sthenelanella uniformis	Polychaeta: Sigalionidae	1	33	2

Table 3.7

The 10 most abundant macroinvertebrate taxa per depth stratum collected from San Diego regional benthic stations sampled during summer 2022. PA = percent abundance, FO = frequency of occurrence, MAG = mean abundance per grab.

Strata	Taxon	Taxonomic Classification	PA	FO	MAG
Inner Shelf n = 10	*Cooperella subdiaphana*	Mollusca: Bivalvia	11	60	24
	Spiophanes duplex	Polychaeta: Spionidae	8	80	18
	Spiophanes norrisi	Polychaeta: Spionidae	6	90	14
	Callianax alectona	Mollusca: Gastropoda	5	40	11
	Prionospio pygmaeus	Polychaeta: Spionidae	5	60	10
	Tellina modesta	Mollusca: Bivalvia	4	70	9
	Macoma yoldiformis	Mollusca: Bivalvia	3	40	7
	Glycinde armigera	Polychaeta: Goniadidae	2	70	5
	Polydora cirrosa	Polychaeta: Spionidae	2	10	5
	Sigalion spinosus	Polychaeta: Sigalionidae	2	50	4
Mid-shelf n = 15	*Spiophanes duplex*	Polychaeta: Spionidae	7	100	29
	Amphiodia urtica	Echinodermata: Ophiuroidea	6	80	22
	Prionospio jubata	Polychaeta: Spionidae	3	100	12
	Prionospio dubia	Polychaeta: Spionidae	2	93	10
	Prionospio pygmaeus	Polychaeta: Spionidae	2	47	9
	Spiophanes norrisi	Polychaeta: Spionidae	2	53	9
	Paradiopatra parva	Polychaeta: Onuphidae	2	93	9
	Euclymeninae sp A	Polychaeta: Maldanidae	2	93	9
	Mediomastus sp	Polychaeta: Capitellidae	2	100	8
	Spiophanes kimballi	Polychaeta: Spionidae	2	73	7
Outer Shelf n = 9	*Phyllochaetopterus limicolus*	Polychaeta: Chaetopteridae	12	78	35
	Spiophanes kimballi	Polychaeta: Spionidae	9	100	27
	Paradiopatra parva	Polychaeta: Onuphidae	8	100	23
	Axinopsida serricata	Mollusca: Bivalvia	3	67	9
	Spiophanes duplex	Polychaeta: Spionidae	3	89	8
	Prionospio jubata	Polychaeta: Spionidae	3	78	8
	Mediomastus sp	Polychaeta: Capitellidae	3	78	8
	Eclysippe trilobata	Polychaeta: Ampharetidae	2	89	5
	Prionospio dubia	Polychaeta: Spionidae	2	78	5
	Paraprionospio alata	Polychaeta: Spionidae	2	89	5

Table 3.7 *continued*

Strata	Species	Taxonomic Classification	PA	FO	MAG
Upper	*Paraprionospio alata*	Polychaeta: Spionidae	11	100	14
Slope	*Phyllochaetopterus limicolus*	Polychaeta: Chaetopteridae	10	33	12
n = 6	*Spiochaetopterus costarum* Cmplx	Polychaeta: Chaetopteridae	8	50	10
	Mediomastus sp	Polychaeta: Capitellidae	6	33	8
	Paradiopatra parva	Polychaeta: Onuphidae	5	17	6
	Maldane sarsi	Polychaeta: Maldanidae	4	67	5
	Amphiodia digitata	Echinodermata: Ophiuroidea	3	33	4
	Spiophanes kimballi	Polychaeta: Spionidae	3	50	4
	Amphiuridae	Echinodermata: Ophiuroidea	2	50	2
	Prionospio ehlersi	Polychaeta: Spionidae	2	67	2
	Onuphis iridescens	Polychaeta: Onuphidae	2	17	2

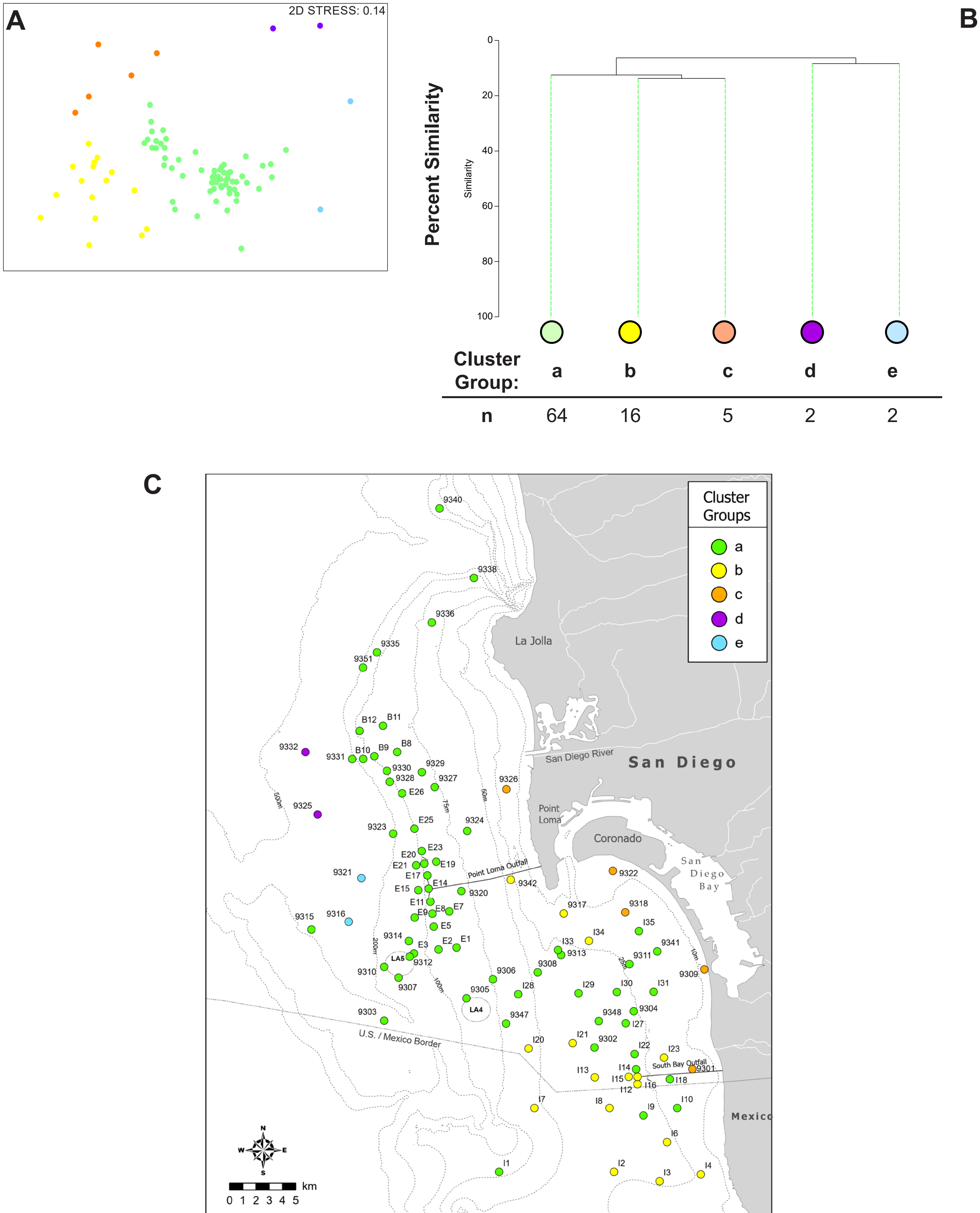

Figure 3.2
Results of ordination and cluster analysis of macrofauna data from PLOO, SBOO, and San Diego regional benthic stations sampled during summer 2022. Results are presented as (A) nMDS ordination; (B) a dendrogram of main cluster groups; (C) a map showing the distribution of cluster groups throughout the region.

Chapter 4
Demersal Fishes and Megabenthic Invertebrates

Chapter 4. Demersal Fishes and Megabenthic Invertebrates

Introduction

The City of San Diego (City) collects bottom dwelling (demersal) fishes and large (megabenthic) invertebrates by otter trawl to examine potential effects of wastewater discharge, or other disturbances, on the marine environment surrounding the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). This chapter presents summaries and preliminary analyses of the demersal fish and megabenthic invertebrate data collected during 2022 at a total of 13 trawl stations surrounding the PLOO and SBOO. Supplemental analyses supporting these results are presented in Appendix C. A more comprehensive assessment of these results will be presented in the 2022–2023 Biennial Assessment Report to be submitted by July 1, 2024.

Materials and Methods

Field Sampling

Trawls were conducted at 13 stations to monitor demersal fish and megabenthic invertebrate populations during winter (January), summer (July) 2022 (Figure 4.1). Due to schedule changes and delays, some summer stations were sampled in fall (October) 2022. The 13 stations included six PLOO stations located along the 100-m depth contour (discharge depth), ranging from 9 km south to 8 km north of the outfall, and seven SBOO stations located along the 28-m depth contour (discharge depth), ranging from 7 km south to 8.5 km north of the outfall. The two PLOO stations (SD10 and SD12) and two SBOO stations (SD17 and SD18) located within 1000 m of the outfall structures are considered to represent nearfield conditions. A single trawl was performed at each station, during each survey, using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. Standard sampling procedures require towing the net for a total of 10 minutes bottom time per trawl, at a speed of about 2 knots along a predetermined heading. Pressure-temperature sensors were attached to one of the trawl doors to measure water temperature, depth, and time of the individual trawls. Data collected by these sensors were used to confirm bottom time and depth of each trawl. The catch from each successful trawl was sorted and inspected aboard ship. All individual fish and invertebrates captured were identified to species, or to the lowest taxon possible, based on accepted taxonomic protocols for the region (Eschmeyer and Herald 1998, Page et al. 2013, SCAMIT 2021). If an animal could not be accurately identified to species in the field, it was returned to the laboratory for an attempt at further identification. The total number of individuals and total biomass (kg, wet weight) were recorded for each fish species. Additionally, each fish was inspected for the presence of physical abnormalities (e.g., tumors, lesions, fin erosion, discoloration) and external parasites (e.g., copepods, cymothoid isopods, leeches). The length of each individual fish was measured to the nearest centimeter to determine size class; total length (TL) was measured for cartilaginous fishes, while standard length (SL) was measured for bony fishes (SCCWRP 2018). For trawl-caught invertebrates, only the total number of individuals was recorded for each species. Parasitic invertebrates no longer attached to their hosts, including the cymothoid isopod *Elthusa vulgaris* and leeches in the subclass Hirudinea, were recorded as present/absent, rather than being counted individually, and are not included in the analyses presented herein.

Data Analyses

Population characteristics of fish and invertebrate species were summarized as percent abundance (number of individuals per species/total abundance of all species), frequency of occurrence (percentage of stations at which a species was collected), mean abundance per haul (number of individuals per species/ total number of stations sampled), and mean abundance per occurrence (number of individuals per species/number of stations at which the species was collected). Additionally, the following community structure parameters were calculated per trawl for both fishes and invertebrates: species richness (number of species or distinct taxa), total abundance (number of individuals), and the Shannon Diversity Index (H'). Total biomass was also measured for each fish species. These analyses were performed using R (R Core Team 2018) and various functions within the devtools, flextable, ggpubr, glue, gtools, magrittr, reshape2, Rmisc, RODBC, tidyverse, and vegan packages (Wickham 2007, Wickham et al. 2019, 2021, Kassambara 2020, Ripley and Lapsley 2021, Bache and Wickham 2022, Gohel 2022, Hester and Bryan 2022, Hope 2022, Oksanen et al. 2022, Warnes et al. 2022)

Multivariate analyses were performed in PRIMER v7 software using demersal fish and megabenthic invertebrate data collected from trawls conducted in the PLOO and SBOO regions during 2022 (Clarke 1993, Warwick 1993, Clarke et al. 2014). These analyses included hierarchical agglomerative clustering (cluster analysis) with group-average linking and similarity profile analysis (SIMPROF) to confirm the non-random structure of the resultant cluster dendrogram (Clarke et al. 2008). The Bray-Curtis measure of dissimilarity was used as the basis for the cluster analysis, and abundance data were either square-root (fish) or fourth-root (invertebrates) transformed to lessen the influence of overly abundant species and increase the importance (or impact) of rare species.

All raw data for 2022 have been submitted to either the Regional Water Quality Control Board or the California Environmental Data Exchange Network (CEDEN) and will be provided upon request.

Results

Demersal Fishes

All fish species captured during the 2022 trawl surveys are summarized by percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence in Tables 4.1 and 4.2. Species richness, abundance, diversity, and biomass values for each station are summarized in Table 4.3. Total number of individuals, total biomass, minimum and maximum length, and mean length per species are included in Appendices C.1 and C.2. All abnormalities and parasites found on trawled fish during the reporting period are listed in Appendix C.3. Cluster analyses were performed to evaluate ecological patterns within the demersal fish communities in the San Diego region; these results are presented in Figures 4.2 and 4.3.

Megabenthic Invertebrates

All megabenthic invertebrate species captured during the 2022 trawl surveys are summarized by percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence in Tables 4.4 and 4.5. Species richness, abundance, and diversity values for each station are summarized in Table 4.6. The total number of individuals per species is included in Appendices C.4 and C.5.

Cluster analyses were performed to evaluate ecological patterns within the megabenthic invertebrate communities in the San Diego region; these results are presented in Figures 4.4 and 4.5.

Summary

Preliminary analysis of the demersal fish and megabenthic invertebrate data collected in 2022 indicate that treated wastewater discharged through the PLOO and SBOO has not negatively impacted these communities in the coastal waters off San Diego. Values for most community parameters were similar at stations located both near and far away from the outfall discharge sites. Community metrics, such as species richness, abundance, and diversity, were within historical ranges reported for the San Diego region (City of San Diego 2022) and were representative of those characterizing similar habitats throughout the Southern California Bight (Allen et al. 1998, 2002, 2007, 2011, Walther et al. 2017).

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CHAPTER 4

FIGURES & TABLES

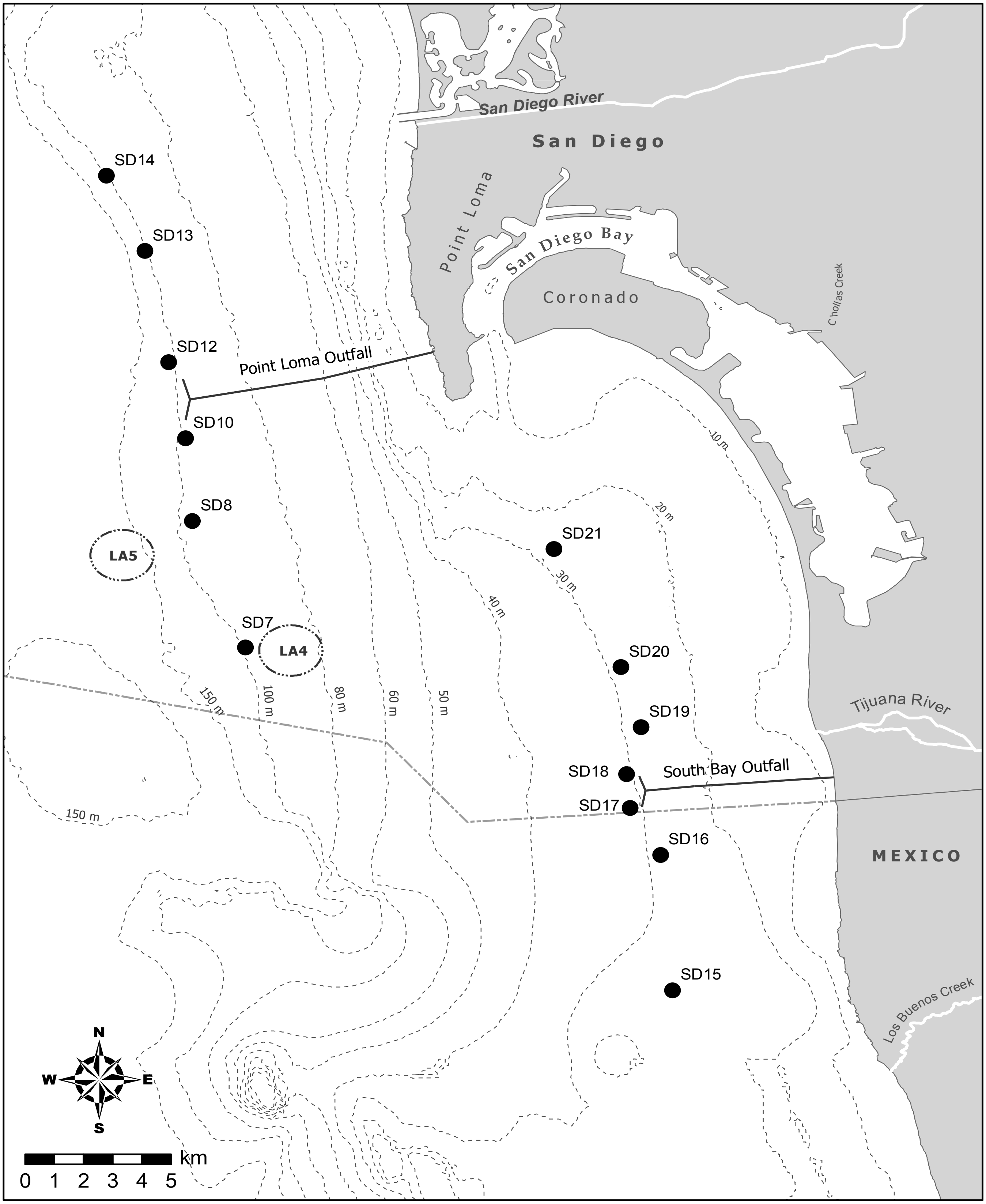

Figure 4.1
Trawl station locations sampled around the PLOO and SBOO as part of the City of San Diego's Ocean Monitoring Program.

Table 4.1

Top 15 demersal fish species collected from the PLOO region during 2022. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurence.

Species	PA	FO	MAH	MAO
Pacific Sanddab	57	100	281	281
Dover Sole	10	100	48	48
Halfbanded Rockfish	8	100	39	39
Longfin Sanddab	6	100	30	30
Shortspine Combfish	4	100	21	21
Stripetail Rockfish	4	92	18	20
Longspine Combfish	3	100	16	16
English Sole	2	92	9	10
Yellowchin Sculpin	2	25	8	33
Bigmouth Sole	1	83	3	3
California Tonguefish	1	83	4	5
Pink Seaperch	1	83	6	7
Blackbelly Eelpout	<1	25	1	3
Blacktip Poacher	<1	8	<1	2
Brown Rockfish	<1	8	<1	3

Table 4.2

Top 15 demersal fish species collected from the SBOO region during 2022. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurence.

Species	PA	FO	MAH	MAO
Speckled Sanddab	60	100	182	182
Longfin Sanddab	14	79	44	56
California Lizardfish	5	93	17	18
California Tonguefish	3	86	8	10
Pacific Sanddab	3	43	10	24
White Croaker	3	14	10	74
Northern Anchovy	2	14	8	53
Yellowchin Sculpin	2	36	6	18
English Sole	1	50	3	6
Hornyhead Turbot	1	93	3	4
Roughback Sculpin	1	93	4	4
Barcheek Pipefish	<1	43	1	3
Bigmouth Sole	<1	29	<1	1
California Halibut	<1	64	1	1
California Scorpionfish	<1	21	<1	1

Table 4.3

Summary of demersal fish community parameters for PLOO and SBOO trawl stations sampled during 2022. Data are included for richness, abundance, diversity (H'), and biomass (kg, wet weight).

		Species Richness			*Abundance*			*Diversity*			*Biomass*		
	Station	**Winter**	**Summer**	**Fall**	**Winter**	**Summer**	**Fall**	**Winter**	**Summer**	**Fall**	**Winter**	**Summer**	**Fall**
PLOO	SD7	17	17	—	338	554	—	1.8	1.3	—	7.2	9.9	—
	SD8	19	16	—	483	642	—	1.8	1.5	—	14.3	13.5	—
	SD10	17	—	16	290	—	498	1.9	—	1.5	8.1	—	9.1
	SD12	16	14	—	374	543	—	2.0	1.6	—	9.7	14.8	—
	SD13	16	15	—	430	661	—	1.4	1.0	—	6.8	10.5	—
	SD14	16	18	—	417	724	—	1.6	1.2	—	7.8	16.8	—
SBOO	SD15	6	8	—	36	307	—	1.2	0.2	—	0.6	2.8	—
	SD16	10	12	—	102	548	—	1.4	1.0	—	2.1	7.6	—
	SD17	17	12	—	108	274	—	2	1.2	—	2.6	3.5	—
	SD18	17	11	—	343	284	—	1.7	0.9	—	11.1	6.7	—
	SD19	11	13	—	201	516	—	1.4	1.2	—	2.3	7.2	—
	SD20	9	—	14	215	—	589	1.1	—	1.0	4.3	—	9.1
	SD21	10	—	11	192	—	574	1.6	—	1.2	3.2	—	9.0

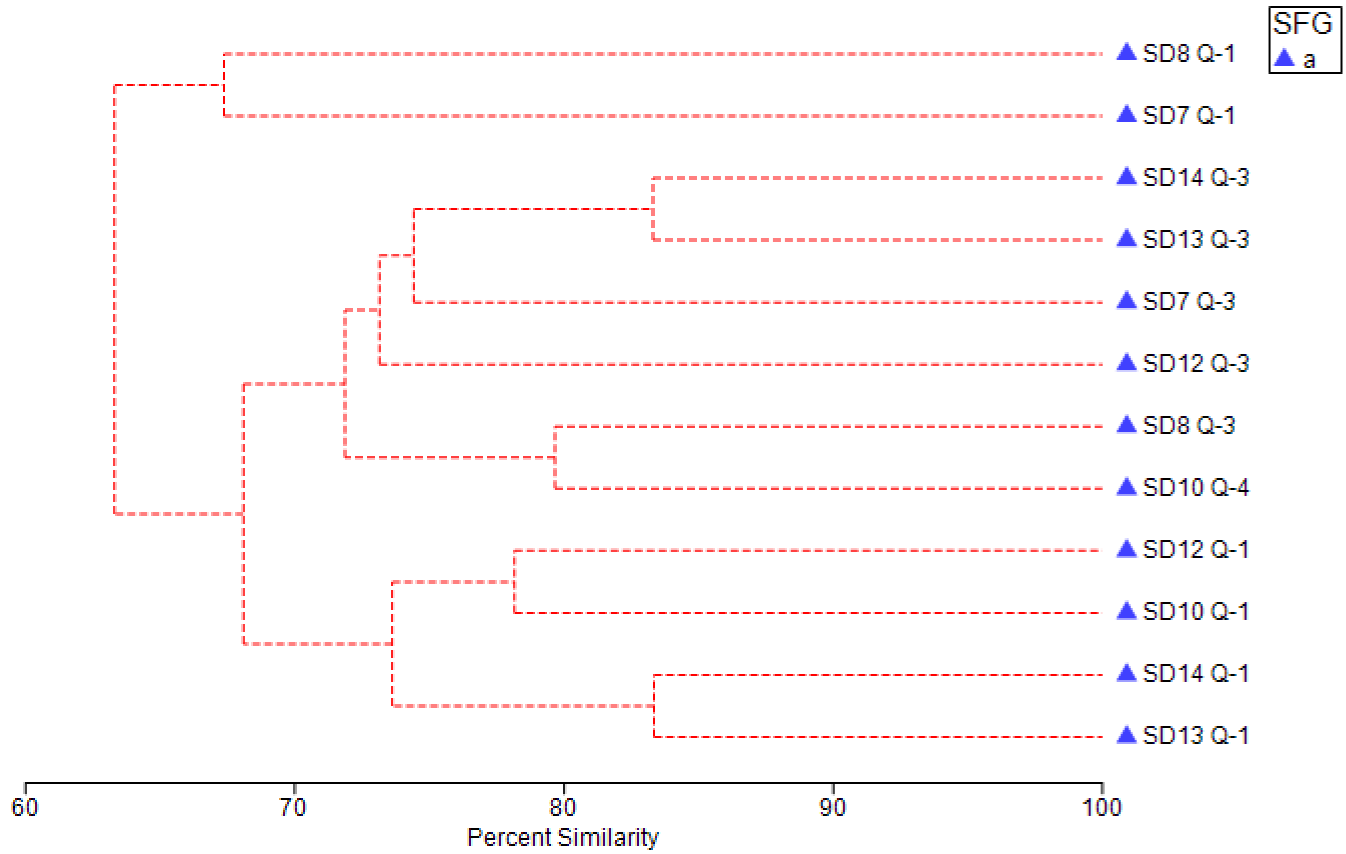

Figure 4.2
Results of cluster analysis of demersal fish data from PLOO trawl stations sampled during 2022. Solid black lines, if present, indicate non-random structure of the dendrogram as confirmed by SIMPROF; SFG = SIMPROF Group, Q-1 = winter survey, Q-3 = summer survey, Q-4 = fall survey.

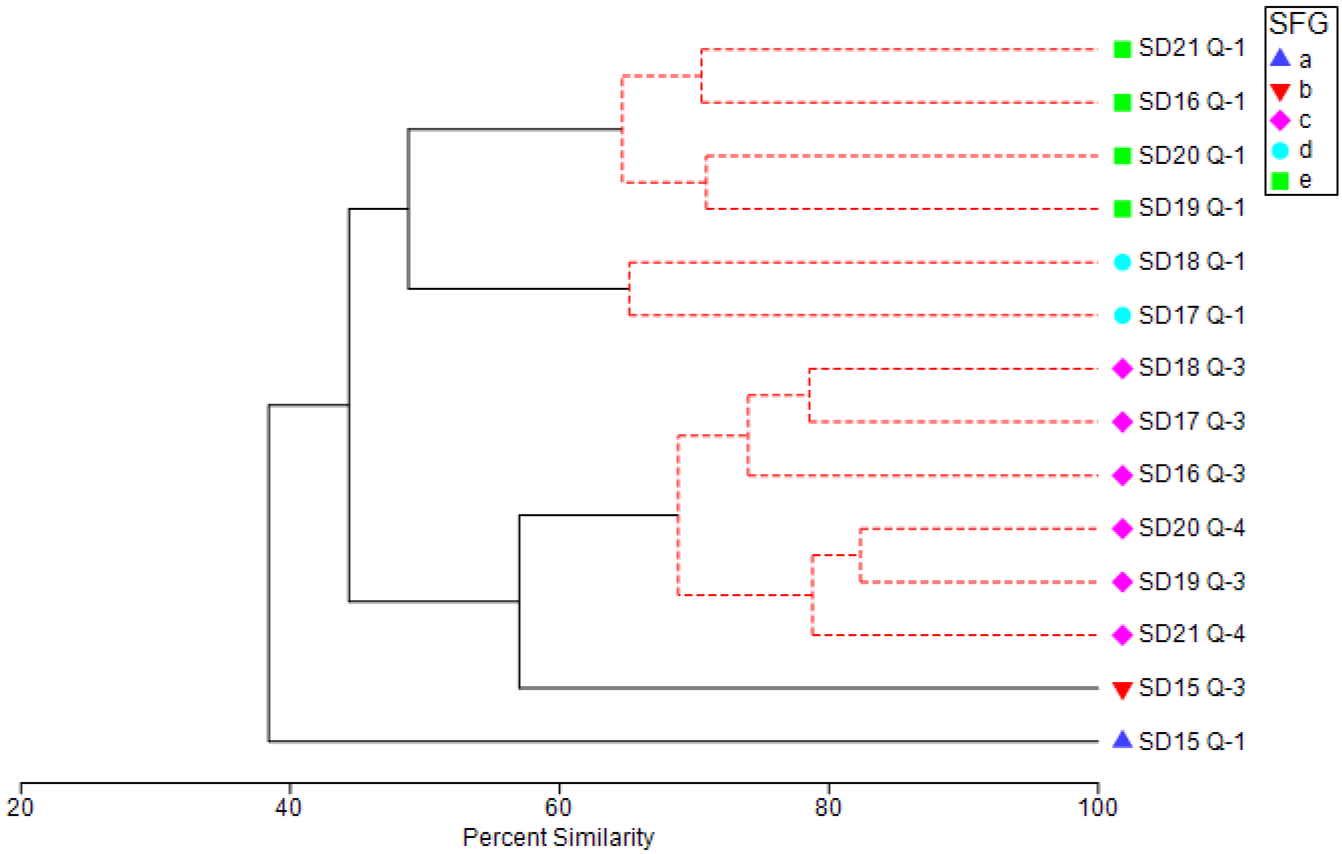

Figure 4.3
Results of cluster analysis of demersal fish data from SBOO trawl stations sampled during 2022. Solid black lines indicate non-random structure of the dendrogram as confirmed by SIMPROF; SFG = SIMPROF Group, Q-1 = winter survey, Q-3 = summer survey, Q-4 = fall survey.

Table 4.4

Top 15 megabenthic invertebrate species collected from the PLOO region during 2022. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurence.

Species	PA	FO	MAH	MAO
Lytechinus pictus	95	83	560	672
Sicyonia ingentis	2	58	10	18
Astropecten californicus	1	83	4	4
Luidia foliolata	1	92	4	4
Acanthoptilum sp	<1	17	<1	1
Antiplanes catalinae	<1	17	<1	1
Aphorme horrida	<1	17	<1	1
Apostichopus californicus	<1	42	1	2
Calliostoma turbinum	<1	8	<1	1
Cancellaria cooperii	<1	8	<1	1
Cancellaria crawfordiana	<1	8	<1	1
Loxorhynchus crispatus	<1	8	<1	1
Luidia asthenosoma	<1	67	1	2
Megasurcula carpenteriana	<1	17	<1	1
Octopus rubescens	<1	50	2	4

Table 4.5

Top 15 megabenthic invertebrate species collected from the SBOO region during 2022. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurence.

Species	PA	FO	MAH	MAO
Astropecten californicus	36	93	32	35
Philine auriformis	21	71	18	26
Crangon nigromaculata	8	79	7	9
Sicyonia penicillata	8	64	7	11
Dendraster terminalis	6	21	6	26
Lovenia cordiformis	3	29	2	8
Crangon alba	2	21	1	6
Luidia armata	2	79	2	3
Lytechinus pictus	2	43	2	5
Ophiothrix spiculata	2	21	2	10
Pyromaia tuberculata	2	43	1	3
Kelletia kelletii	1	29	<1	2
Platymera gaudichaudii	1	29	1	2
Pleurobranchaea californica	1	14	1	4
Acanthodoris brunnea	<1	14	<1	1

Table 4.6

Summary of megabenthic invertebrate community parameters for PLOO and SBOO trawl stations sampled during 2022. Data are included for richness, abundance, and diversity (H').

		Species Richness			Abundance			Diversity		
	Station	Winter	Summer	Fall	Winter	Summer	Fall	Winter	Summer	Fall
PLOO	SD7	9	13	—	61	362	—	1.2	0.4	—
	SD8	12	13	—	2300	2626	—	0.1	0.1	—
	SD10	2	—	11	5	—	198	0.5	—	0.6
	SD12	5	11	—	253	672	—	0.1	0.2	—
	SD13	3	10	—	12	159	—	0.9	1.1	—
	SD14	4	9	—	292	119	—	0.2	1.0	—
SBOO	SD15	8	9	—	110	48	—	1.1	1.7	—
	SD16	10	13	—	33	42	—	1.6	2.2	—
	SD17	12	12	—	23	36	—	2.2	2.0	—
	SD18	12	16	—	64	48	—	1.8	2.1	—
	SD19	10	12	—	145	237	—	1.1	0.9	—
	SD20	5	—	8	120	—	58	0.9	—	1.2
	SD21	5	—	15	23	—	261	0.9	—	1.1

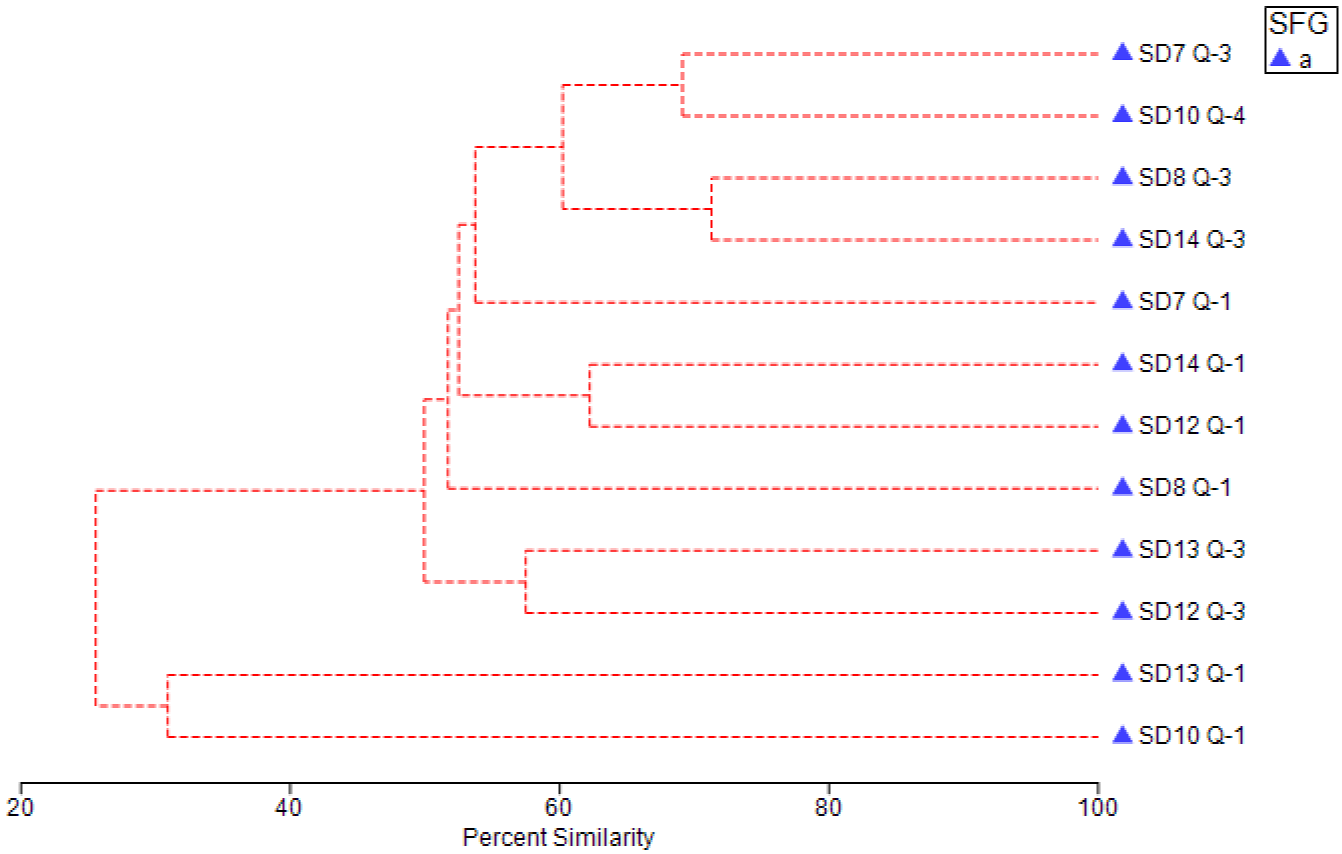

Figure 4.4
Results of cluster analysis of megabenthic invertebrate data from PLOO trawl stations sampled during 2022. Solid black lines, if present, indicate non-random structure of the dendrogram as confirmed by SIMPROF; SFG = SIMPROF Group, Q-1 = winter survey, Q-3 = summer survey, Q-4 = fall survey.

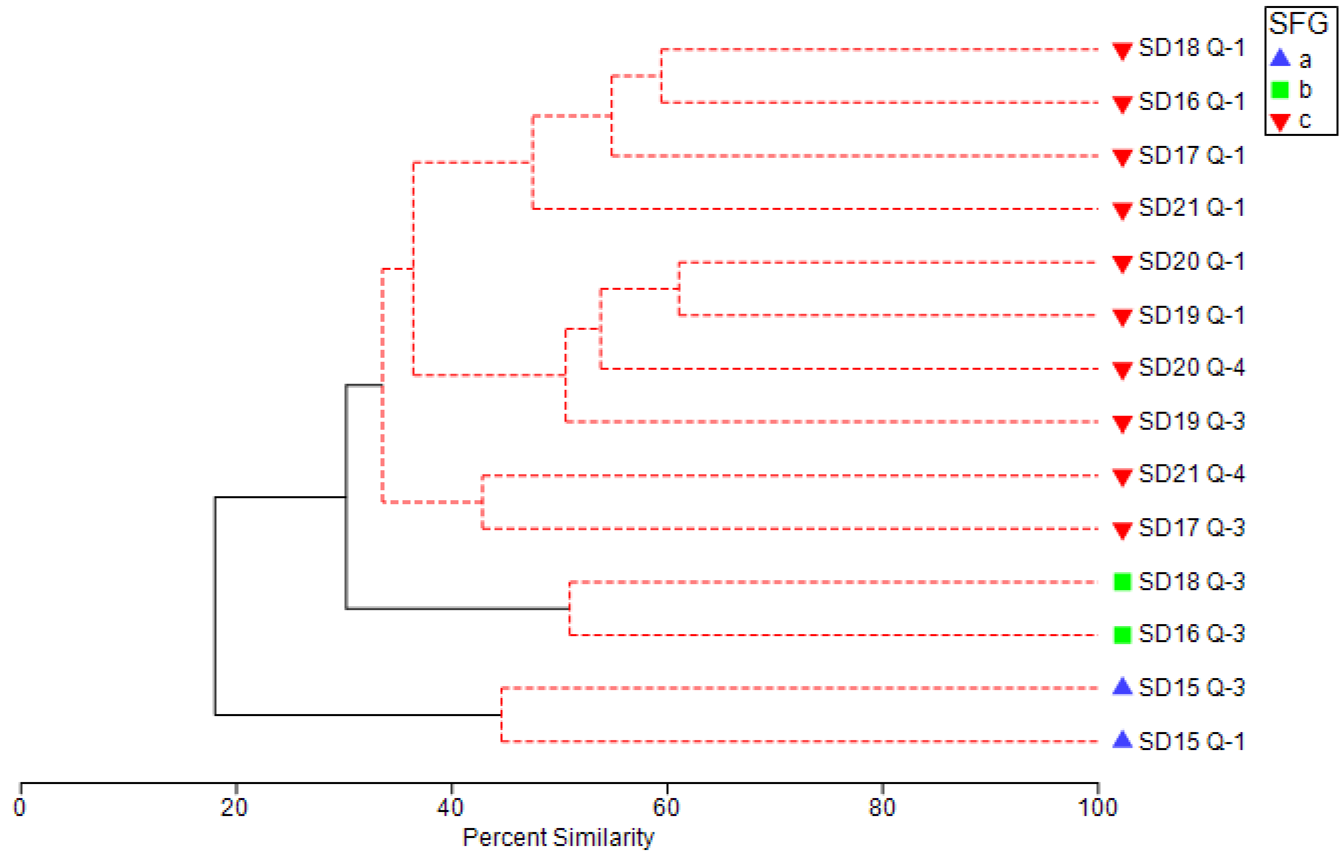

Figure 4.5
Results of cluster analysis of megabenthic invertebrate data from SBOO trawl stations sampled during 2022. Solid black lines indicate non-random structure of the dendrogram as confirmed by SIMPROF; SFG = SIMPROF Group, Q-1 = winter survey, Q-3 = summer survey, Q-4 = fall survey.

Chapter 5
Contaminants in Marine Fishes

Chapter 5. Contaminants in Marine Fishes

Introduction

Bottom dwelling (demersal) fishes are collected by the City of San Diego (City) to evaluate the presence of contaminants in their tissues, which may result from the discharge of wastewater from the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). Anthropogenic inputs to coastal waters can result in increased concentrations of pollutants within the local marine environment, which may subsequently accumulate in the tissues of fishes and their prey. This portion of the City's Ocean Monitoring Program consists of two components: (1) analyzing liver tissues from mostly trawl-caught fishes; (2) analyzing muscle tissues from fishes collected by hook and line (rig fishing). All liver and muscle tissue samples collected were analyzed for contaminants specified in the National Pollutant Discharge Elimination System (NPDES) discharge permits that govern monitoring requirements for the PLOO and SBOO regions. This chapter presents summaries and preliminary analyses of all fish tissue data collected during calendar year 2022 at PLOO and SBOO stations. A more comprehensive assessment of these results will be presented in the 2022-2023 Biennial Assessment Report to be submitted by July 1, 2024.

Materials and Methods

Fishes were collected in fall (October) 2022 from a total of nine trawl zones (TZ1–TZ9) and four rig fishing zones (RF1–RF4) that span the PLOO and SBOO monitoring regions (Figure 5.1). Each trawl zone represents an area centered on one or two trawl stations, as specified in Chapter 4. Trawl Zone 1 includes the "nearfield" area within a 1-km radius of PLOO stations SD10 and SD12, which are located just south and north of the outfall discharge site, respectively. Trawl Zone 2 includes the area within a 1-km radius surrounding the northern "farfield" PLOO stations SD13 and SD14. Trawl Zone 3 represents the area within a 1-km radius surrounding the "farfield" PLOO station SD8, which is located south of the outfall near the LA-5 dredged material disposal site. Trawl Zone 4 is the area within a 1-km radius surrounding the "farfield" PLOO station SD7, which is located several kilometers south of the outfall. Trawl Zone 5 includes the area located within a 1-km radius of the SBOO stations SD17 and SD18, which are located just south and north of the outfall discharge site, respectively. Trawl Zone 6 includes the area within a 1-km radius surrounding the northern SBOO stations SD19 and SD20, while Trawl Zone 7 includes the area within a 1-km radius of the northern SBOO station SD21. Trawl Zone 8 represents the area within a 1-km radius surrounding the southern SBOO station SD16, while Trawl Zone 9 represents the area within a 1-km radius surrounding the southern SBOO station SD15. Rig Fishing Zones 1–4 represent the areas within a 1-km radius of the nominal coordinates for stations RF1, RF2, RF3, and RF4. Stations RF1 and RF3 are located within 1 km of the PLOO and SBOO discharge sites, respectively, and are considered the "nearfield" rig fishing sites. In contrast, station RF2 is located approximately 11 km northwest of the PLOO, while station RF4 is located approximately 13 km southeast of the SBOO. These two sites are considered "farfield", or reference, stations for the analyses herein. Efforts to collect target species by trawl were limited to five 10-minute (bottom time) trawls per site, while rig fishing effort was limited to 5 hours at each station.

A total of 14 species of fish were collected for analysis of liver and muscle tissues during the 2022 survey (Table 5.1). Pacific Sanddab (*Citharichthys sordidus*) were collected by hook and line methods at the PLOO stations, while California Scorpionfish (*Scorpaena guttata*), Fantail Sole (*Xystreurys liolepis*), Hornyhead Turbot (*Pleuronichthys verticalis*), Longfin Sanddab (*Citharichthys xanthostigma*), and Spotted Turbot (*Pleuronichthys ritteri*) were collected using standard otter trawl methods (see Chapter 4) at SBOO stations. Nine additional species of fish were collected for analysis of muscle tissues at the rig fishing stations using standard hook and line fishing techniques. These species included Brown Rockfish (*Sebastes auriculatus*), California Scorpionfish (*Scorpaena guttata*), Copper Rockfish (*Sebastes caurinus*), Flag Rockfish (*Sebastes rubrivinctus*), Gopher Rockfish (*Sebastes carnatus*), Squarespot Rockfish (*Sebastes hopkinsi*), Starry Rockfish (*Sebastes constellatus*), Treefish (*Sebastes serriceps*), and Vermilion Rockfish (*Sebastes miniatus*).

Only fishes with standard lengths ≥ 11 cm were retained to ensure the collection of sufficient tissue for analysis, while minimizing total catch necessary. These fishes were sorted into three composite samples per station, with a minimum of three individuals in each composite. All fishes were wrapped in aluminum foil, labeled, sealed in re-sealable plastic bags, placed on dry ice, and then transported to the City's Marine Biology Laboratory where they were stored at -20°C prior to dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis. A brief summary follows, but see City of San Diego (2022b) for additional details. Prior to dissection, each fish was partially defrosted, cleaned with a paper towel to remove loose scales and excess mucus, and the standard length (cm) and weight (g) were recorded (Appendices D.1, D.2). Dissections were carried out on Teflon® pads that were cleaned between samples. The liver or muscle tissues from each fish were removed and placed in separate glass jars for each composite sample, sealed, labeled, and stored in a freezer at -20°C prior to chemical analyses.

All tissue analyses were performed at the City of San Diego's Environmental Chemistry Laboratory. Detailed analytical protocols are available upon request. Briefly, all fish tissue samples were analyzed on a wet weight basis to determine the concentrations of 18 different trace metals, 9 chlorinated pesticides, 42 polychlorinated biphenyl compound congeners (PCBs), and 24 polycyclic aromatic hydrocarbons (PAHs) (Appendix D.3).

Data Analyses

Data summaries for each parameter include detection rate, minimum, maximum, and mean values for all samples combined by species for each outfall region. All means were calculated using detected values only, with no substitutions made for non-detects (analyte concentrations < method detection limit (MDL)). Results recorded with a qualifier of Detected, But Not Quantified (DNQ) were treated as detected values. Total chlordane, total DDT (tDDT), total hexachlorocyclohexane (tHCH), total PCB (tPCB), total PAH (tPAH), and total PBDE (tPBDE) were calculated for each sample as the sum of all constituents with reported values for individual constituents. Analyses were performed using R (R Core Team 2022) various functions within the zoo, reshape2, plyr, tidyr, and dplyr packages (Zeileis and Grothendieck 2005, Wickham 2007, 2011, Wickham and Henry 2017, Wickham et al. 2017).

All raw data for 2022 have been submitted to either the Regional Water Quality Control Board or the California Environmental Data Exchange Network (CEDEN) and will be provided upon request.

Results

Contaminants in Fish Liver Tissues

Concentrations of trace metals, pesticides, PCBs, PAHs, and PBDEs detected in fish liver tissue samples from PLOO and SBOO trawl zones during 2022 are summarized by species in Tables 5.2 and 5.3.

Contaminants in Fish Muscle Tissues

Concentrations of trace metals, pesticides, PCBs, PAHs, and PBDEs detected in fish muscle tissue samples from PLOO and SBOO rig fishing zones during 2022 are summarized by species in Tables 5.4 and 5.5.

Summary

Preliminary analysis of fish tissue data collected in 2022 provide no evidence of contaminant accumulation in PLOO or SBOO fishes associated with wastewater discharge from either outfall. Concentrations of most contaminants were generally similar across trawl or rig fishing zones, and no relationships with the PLOO or SBOO were evident. These results are consistent with findings of other assessments of bioaccumulation in fishes off San Diego (City of San Diego 2022a, Parnell et al. 2008). Finally, there were no other indications of poor fish health in the region, such as the presence of fin rot or other indicators of disease (see Chapter 4).

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Chapter 5

Figures & Tables

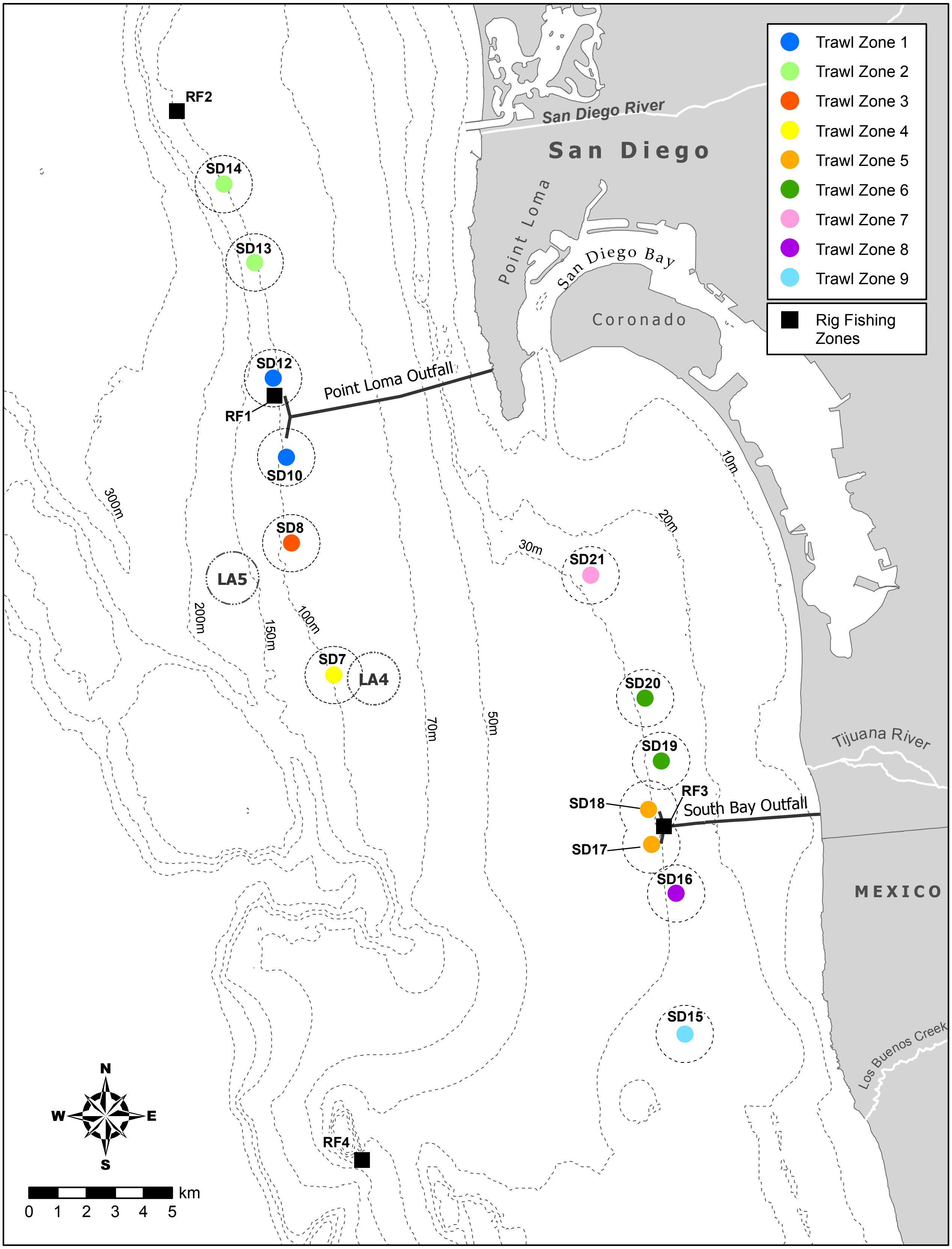


Figure 5.1
Trawl and rig fishing zone locations sampled around the PLOO and SBOO as part of the City of San Diego's Ocean Monitoring Program.

Table 5.1
Species of fish collected from each PLOO and SBOO trawl and rig fishing zone during 2022.

	Zone	Composite 1	Composite 2	Composite 3
PLOO	Rig Fishing Zone 1 (RF1)	Vermilion Rockfish	Vermilion Rockfish	Vermilion Rockfish
	Rig Fishing Zone 2 (RF2)	Squarespot Rockfish	Starry Rockfish	Mixed Rockfish
	Trawl Zone 1 (TZ1)	Pacific Sanddab	Pacific Sanddab	Pacific Sanddab
	Trawl Zone 2 (TZ2)	Pacific Sanddab	Pacific Sanddab	Pacific Sanddab
	Trawl Zone 3 (TZ3)	Pacific Sanddab	Pacific Sanddab	Pacific Sanddab
	Trawl Zone 4 (TZ4)	Pacific Sanddab	Pacific Sanddab	Pacific Sanddab
SBOO	Rig Fishing Zone 3 (RF3)	Brown Rockfish	California Scorpionfish	Mixed Rockfish
	Rig Fishing Zone 4 (RF4)	California Scorpionfish	Gopher Rockfish	Mixed Rockfish
	Trawl Zone 5 (TZ5)	Longfin Sanddab	Longfin Sanddab	Hornyhead Turbot
	Trawl Zone 6 (TZ6)	Longfin Sanddab	Longfin Sanddab	Longfin Sanddab
	Trawl Zone 7 (TZ7)	Longfin Sanddab	Longfin Sanddab	Hornyhead Turbot
	Trawl Zone 8 (TZ8)	Longfin Sanddab	California Scorpionfish	Hornyhead Turbot
	Trawl Zone 9 (TZ9)	Hornyhead Turbot	Spotted Turbot	Fantail Sole

Table 5.2

Summary of metals (ppm) in liver tissues of fishes collected from PLOO and SBOO trawl zones during 2022. Data include the number of detected values (n), minimum, maximum, and mean detected concentrations for each species, and the total number of samples, detection rate, and maximum value for all species within each region. Minimum and maximum values were calculated based on all samples, whereas means were calculated from detected values only; nd = not detected.

		As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Se	Ag	Tl	Zn
PLOO	Pacific Sanddab												
	n	12	12	1	12	12	0	12	12	12	0	3	12
	min	2.06	1.98	nd	3.17	74.0	—	0.52	0.080	1.26	—	nd	17.8
	max	3.82	5.11	0.199	5.17	111.0	—	1.33	0.199	1.76	—	1.35	26.9
	mean	3.04	3.32	0.199	4.55	92.3	—	0.96	0.112	1.47	—	1.24	23.2
	Total Samples	12	12	12	12	12	12	12	12	12	12	12	12
	Detection Rate (%)	100	100	8	100	100	0	100	100	100	0	25	100
	Max	3.82	5.11	0.199	5.17	111.0	nd	1.33	0.199	1.76	nd	1.35	26.9
SBOO	CA Scorpionfish												
	n	1	1	0	1	1	0	1	1	1	0	0	1
	value	1.26	4.29	—	12.80	66.8	—	0.57	0.208	1.22	—	—	83.8
	Fantail Sole												
	n	0	0	0	0	0	0	0	0	0	0	0	0
	Hornyhead Turbot												
	n	4	4	1	4	4	0	4	4	4	1	0	4
	min	4.63	3.70	nd	8.03	43.7	—	0.90	0.059	1.14	nd	—	52.2
	max	6.91	5.31	0.439	16.30	64.3	—	1.21	0.101	1.44	0.235	—	73.3
	mean	5.54	4.43	0.439	10.81	51.2	—	0.98	0.082	1.30	0.235	—	61.9
	Longfin Sanddab												
	n	8	8	0	8	8	0	8	8	8	0	5	8
	min	4.16	1.03	—	5.67	83.5	—	0.54	0.028	1.40	—	nd	18.4
	max	7.55	2.05	—	9.01	116.0	—	0.75	0.057	1.91	—	2.11	24.9
	mean	5.45	1.57	—	6.64	99.5	—	0.65	0.041	1.68	—	1.66	21.0
	Spotted Turbot												
	n	1	1	0	1	1	1	1	1	1	0	0	1
	value	8.20	0.58	—	8.85	120.0	0.49	1.25	0.040	1.96	—	—	46.2
	Total Samples	15	15	15	15	15	15	15	14	15	15	15	15
	Detection Rate (%)	93	93	7	93	93	7	93	100	93	7	33	93
	Max	8.20	5.31	0.439	16.30	120.0	0.49	1.25	0.208	1.96	0.235	2.11	83.8

Table 5.3

Summary of pesticides (ppb), total PCB (ppb), total PAH (ppb), total PBDE (ppb), and lipids (% weight) in liver tissues of fishes collected from PLOO and SBOO trawl zones during 2022. Data include the number of detected values (n), minimum, maximum, and mean detected concentrations for each species, and the total number of samples, detection rate and maximum value for all species within each region. Minimum and maximum values were based on all samples, whereas means were calculated from detected values only; nd = not detected; nr = not reportable.

		Pesticides								
		tChlor	tDDT	HCB	tHCH	Dieldrin	tPCB	tPAH	tPBDE	Lipids
PLOO	Pacific Sanddab									
	n	12	12	12	12	1	12	1	12	12
	min	1.65	71.2	2.93	1.33	nd	58.9	nd	14.29	25.4
	max	8.80	150.0	5.43	2.51	6.9	258.1	96	51.77	47.4
	mean	4.47	96.3	4.19	1.85	6.9	161.0	96	29.80	35.7
	Total Samples	12	12	12	12	12	12	6	12	12
	Detection Rate (%)	100	100	100	100	8	100	17	100	100
	Max	8.80	150.0	5.43	2.51	6.9	258.1	96	51.77	47.4
SBOO	CA Scorpionfish									
	n	1	1	1	1	0	1	nr	1	1
	value	3.32	183.3	0.86	0.67	—	115.6	—	84.10	17.7
	Fantail Sole									
	n	0	1	0	0	0	1	nr	0	0
	value	—	6.2	—	—	—	1.3	—	—	—
	Hornyhead Turbot									
	n	0	4	0	0	0	4	0	4	4
	min	—	12.4	—	—	—	3.6	—	20.59	5.8
	max	—	19.7	—	—	—	21.3	—	52.94	8.6
	mean	—	15.8	—	—	—	10.1	—	41.66	7.3
	Longfin Sanddab									
	n	8	8	8	8	0	8	0	8	8
	min	1.36	95.9	1.68	1.40	—	53.7	—	36.92	38
	max	5.72	230.9	2.82	1.62	—	173.1	—	112.60	47.2
	mean	3.19	174.5	2.19	1.55	—	126.0	—	70.24	44.5
	Spotted Turbot									
	n	0	1	0	0	0	1	nr	0	1
	value	—	3.9	—	—	—	25.5	—	—	2.2
	Total Samples	15	15	15	15	15	15	8	15	15
	Detection Rate (%)	60	100	60	60	0	100	0	87	93
	Max	5.72	230.9	2.82	1.62	nd	173.1	nd	112.60	47.2

Table 5.4

Summary of metals (ppm) in muscle tissues of fishes collected from PLOO and SBOO rig fishing zones during 2022. Data include the number of detected values (n), minimum, maximum, and mean detected concentrations per species and the total number of samples, detection rate, and maximum value for all species within each region. Minimum and maximum values based on all samples, whereas means were calculated from detected values only; nd = not detected.

		As	Cd	Cr	Cu	Fe	Mn	Hg	Ni	Se	Tl	Sn	Zn
PLOO	Mixed Rockfish												
	n	1	1	1	1	1	0	1	0	1	0	0	1
	value	1.99	0.029	0.089	0.374	1.14	—	0.149	—	0.674	—	—	3.61
	Squarespot Rockfish												
	n	1	1	1	1	1	0	1	1	1	1	0	1
	value	1.36	0.028	0.386	0.327	3.32	—	0.111	0.259	0.753	0.368	—	3.32
	Starry Rockfish												
	n	1	1	1	1	0	0	1	1	1	1	0	1
	value	1.57	0.023	0.119	0.263	—	—	0.224	0.038	0.689	0.358	—	3.14
	Vermilion Rockfish												
	n	3	3	3	3	2	1	2	1	3	1	0	3
	min	1.60	0.022	0.102	0.314	nd	nd	0.052	nd	0.463	nd	—	3.64
	max	3.44	0.044	0.158	0.433	6.11	0.135	0.093	0.056	0.799	0.386	—	4.32
	mean	2.65	0.033	0.130	0.392	3.84	0.135	0.073	0.056	0.640	0.386	—	4.09
	Total Samples	6	6	6	6	6	6	5	6	6	6	6	6
	Detection Rate (%)	100	100	100	100	67	17	100	50	100	50	0	100
	Max	3.44	0.044	0.386	0.433	6.11	0.135	0.224	0.259	0.799	0.386	nd	4.32
SBOO	Brown Rockfish												
	n	1	1	1	1	1	1	1	0	1	1	0	1
	value	1.19	0.024	0.100	0.329	4.48	0.119	0.073	—	0.683	0.385	—	3.75
	CA Scorpionfish												
	n	2	2	2	2	2	0	2	0	2	2	0	2
	min	2.03	0.034	0.114	0.338	2.81	—	0.104	—	0.500	0.351	—	3.69
	max	2.39	0.037	0.121	0.368	5.12	—	0.113	—	0.587	0.367	—	4.68
	mean	2.21	0.036	0.118	0.353	3.97	—	0.109	—	0.544	0.359	—	4.19
	Gopher Rockfish												
	n	1	1	1	1	1	0	1	0	1	1	0	1
	value	2.73	0.043	0.114	0.258	3.71	—	0.205	—	0.721	0.340	—	3.68
	Mixed Rockfish												
	n	2	2	2	2	2	1	2	1	2	2	1	2
	min	1.40	0.025	0.159	0.249	7.52	nd	0.084	nd	0.667	0.375	nd	4.19
	max	3.88	0.060	0.195	0.305	20.80	0.127	0.230	0.098	1.220	0.522	1.31	4.54
	mean	2.64	0.043	0.177	0.277	14.16	0.127	0.157	0.098	0.944	0.449	1.31	4.37
	Total Samples	6	6	6	6	6	6	6	6	6	6	6	6
	Detection Rate (%)	100	100	100	100	100	33	100	17	100	100	17	100
	Max	3.88	0.06	0.195	0.368	20.80	0.127	0.230	0.098	1.220	0.522	1.31	4.68

Table 5.5

Summary of pesticides (ppb), total PCB (ppb), total PAH (ppb), total PBDE (ppb), and lipids (% weight) in muscle tissues of fishes collected from PLOO and SBOO rig fishing stations during 2022. Data include the number of detected values (n), minimum, maximum, and mean detected concentrations for each species, and the total number of samples, detection rate and maximum value for all species within region. Minimum and maximum values were based on all samples, whereas means were calculated from detected values only; nd = not detected; nr = not reportable.

		Pesticides							
		tChlor	tDDT	HCB	tHCH	tPCB	tPAH	tPBDE	Lipids
PLOO	Mixed Rockfish								
	n	0	1	1	0	1	0	1	1
	value	—	2.59	0.149	—	1.037	—	0.835	0.835
	Squarespot Rockfish								
	n	0	1	1	0	1	0	1	1
	value	—	2.08	0.187	—	0.443	—	0.472	1.160
	Starry Rockfish								
	n	0	1	1	0	1	0	1	1
	value	—	5.14	0.205	—	2.717	—	1.320	0.797
	Vermilion Rockfish								
	n	1	3	nr	2	3	1	3	3
	min	nd	4.86	—	nd	5.092	nd	1.512	1.100
	max	0.167	6.43	—	0.054	5.820	96.5	2.293	1.630
	mean	0.167	5.68	—	0.051	5.394	96.5	1.773	1.357
	Total Samples	6	6	3	6	6	6	6	6
	Detection Rate (%)	17	100	100	33	100	17	100	100
	Max	0.167	6.43	0.205	0.054	5.820	96.5	2.293	1.630
SBOO	Brown Rockfish								
	n	0	1	nr	0	1	0	1	1
	value	—	1.58	—	—	0.814	—	2.087	0.935
	CA Scorpionfish								
	n	0	2	0	0	2	0	2	2
	min	—	1.55	—	—	0.943	—	0.377	0.495
	max	—	4.37	—	—	3.262	—	3.120	1.150
	mean	—	2.96	—	—	2.103	—	1.749	0.823
	Gopher Rockfish								
	n	0	1	0	0	1	nr	1	1
	value	—	0.92	—	—	0.518	—	0.311	2.450
	Mixed Rockfish								
	n	0	2	0	0	2	0	1	2
	min	—	0.49	—	—	0.104	—	nd	0.618
	max	—	0.56	—	—	0.442	—	1.632	0.729
	mean	—	0.52	—	—	0.273	—	1.632	0.674
	Total Samples	6	6	4	6	6	3	6	6
	Detection Rate (%)	0	100	0	0	100	0	83	100
	Max	nd	4.37	nd	nd	3.262	nd	3.120	2.450

Appendices

Appendix A

Water Quality

2022 Supplemental Analyses

Appendix A.1

Summary of manual QA/QC review findings, including major sensor problems and data quality issues for the PLOO and SBOO RTOMS. Gaps in data resulted during time periods data were not collected or flagged as bad or suspect.

Parameter	Site	Depths (m)	Time Period	Problem	Action Taken
Nitrate + nitrite	PLOO and SBOO	1, 26, 30	All 2022	SUNA sensors displayed occasional noise, or linear downward drift through deployment	When possible, drift corrected data based on water sample results and zero offset. If not possible to correct, flagged data as suspect. See City of San Diego 2023a.
Nitrate + nitrite	PLOO	75	3/16 - 11/22/22	SUNA sensor became noisy and got progressively worse, and sensor intermittently malfunctioned and reported null values	Data qualifed as bad or suspect and not reported
Chlorophyll a, CDOM, and turbidity	PLOO and SBOO	All	All 2022	ECO triplet sensors displayed intermittent noise and unreasonable data (high data spikes) throughout deployments, and impacted by biofouling and electrical issues. Surface sensors (1 m) were most impacted.	Data qualifed as bad or suspect during these intermittent periods and not reported
ADCP	PLOO	Varied seasonally	All 2022	Intermittent poor signal strength from mid and deep depths, particularly during seasonal thermoclines	Data not reported from impacted depth bins
Salinity	PLOO and SBOO	All	All 2022	MicroCAT sensors showed intermittent spiking and large step changes, suspect due to bubbles, fouling, or material trapped in conductivity cell.	Data qualifed as bad or suspect during these intermittent periods and not reported
Salinity	PLOO	20	4/26 - 11/22/22	MicroCAT sensor began downward drift that continued, followed by excess noise and low values outside of range from CTD validation casts.	Data qualifed as suspect and not reported. On recovery, conductivity cell guard missing and cell appeared damaged.
Salinity and DO	PLOO	89	9/11 - 11/22/22	MicroCAT-ODO showed sudden step change in salinity and DO drifted down and flatlined, showed values much different than CTD validation cast. Suspect clogged plumbing.	Data qualifed as suspect and not reported
Salinity and total pH	PLOO	75	12/8 - 12/17/22	MicroCAT-ODO had faulty conductivity measurements upon deployment that were out of range	Data qualified as bad and not reported. Conductivity sensor problem resolved itself and began reporting reasonable values.

Appendix A.1 *continued*

Parameter	Site	Depths (m)	Time Period	Problem	Action Taken
DO, salinity, and temp.	PLOO and SBOO	All	1/2022, 2/2022	Batteries for the MicroCAT-ODO sensors ran out prematurely after 2 to 3 months deployed	No data collected for short periods (days to weeks); probem fixed remotely by switching power source
DO and total pH	PLOO	1	3/22 - 7/18/22	SeapHox sensor suddenly reported unreasonably low DO/pH values, with DO flatling to 0 at times. Suspect severe biofouling that seemed to resolve by mid July and returned to reasonable values.	Data qualifed as suspect and not reported
Total pH, DO, salinity, and temp.	PLOO	1	10/9 - 11/22/22	SeapHox sensor failed, and stopped reporting data	No data collected
Total pH	SBOO	26	8/24 - 11/3/22	SeaFET pH sensor drifted low as DO values increased and exhibited noise; values are suspect until can be validated with water samples.	Data qualifed as suspect and not reported
Total pH	PLOO	75	1/1 - 11/22/22	SeaFET pH sensor failed prematurely and reported out of range pH values	Data qualified as bad and not reported
BOD	PLOO	30, 75	All 2022	Uvilux sensors showed negative data, occasional spikes, and some drift.	When possible, drift corrected data by lowest negative offset values. If correction not possible, then data qualified as suspect and not reported.
xCO2	PLOO	1	1/1 - 11/22/22	Pro-Oceanus pCO2 sensor began showing faulty data after 3 weeks deployed and did not appear to align to other data (pH and DO). No values reported from 10/7/22 to end of deployment due to failure with solar power system.	Data qualifed as suspect and not reported
xCO2	SBOO	1	7/5 - 7/25/22; 10/24 - 11/3/22	Pro-Oceanus pCO2 sensor stopped reporting data due to failure with solar power system.	No data collected until repairs made on buoy and battery was sufficiently charged.
All	PLOO	All	1/23 - 1/28/22	Gap in real-time data record due to surface controller problem	Missing data for time period. Controller was manually reset on buoy.
All	SBOO	All	11/3/2022	Mooring wire broke and retrieval of buoy and associated instruments not possible due to rough seas, most equipment was lost to sea.	Real-time data available only for deployment and no post calibrations for instruments.

Appendix A.2

Ranges used for automated QC data flagging for each parameter for the gross range test. Ranges were defined by manufacturers for each sensor configuration.

Parameter	Units	Min	Max	Qualifer to assign if outside of min/max
BOD equivalent	mg/L	0	50	4
CDOM - ECO triplet	ppb	0	375	4
Chl - ECO triplet	µg/L	0	75	4
xCO_2	ppm	0	2000	4
NO_3 (Nitrate + Nitrite)	µM	0	3000	4
NTU (Turbidity)	NTU	0	100	4
O_2 (DO)	mg/L	0.1	20	4
pH (total; both internal and external)	total pH	6.5	9	4
Salinity (Sal)	PSU	2	42	4
Temperature (Temp)	degC	-2.5	35	4

Appendix A.3

Annual ranges used for automated QC data flagging for each parameter, site, and depth for the climatological range test. Temperature, salinity, DO, and pH ranges were based on the minimum and maximum values recorded at each site and depth range where the sensors were found to be functional and in reasonable agreement with historical CTD ranges from the City's quarterly surveys. BOD ranges were based on the maximum value observed from all deployments, since that is a new parameter and historical data were not available. CDOM ranges were based on maximum of multiple readings recorded at the PLOO mooring due to proximity to plume. Chlorophyll *a* and turbidity ranges were based on the maximum sensor range for the ECO triplet. Nitrate ranges were based on values observed at both moorings where the sensors were found to be functional, and verified in a reasonable range compared to nearshore data collected by the California Cooperative Oceanic Fisheries Investigations (see: https://calcofi.org). Ranges for xCO2 were based on values observed at both moorings, and comparable to ranges recorded by the closest NOAA/SIO carbon program mooring (CCE2, see: https://www.pmel.noaa.gov/co2/story/CCE2).

		PLOO RTOMS						SBOO RTOMS						
		1 m		Mid depths		Bottom depths (>70m)		1 m		Mid depths		Bottom depth (>25 m)		Qualifer to assign if outside of site/ depth range
Parameter	Units	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
BOD equivalent	mg/L	NA	NA	0	10	0	10	NA	NA	0	10	0	10	3
CDOM-ECO triplet	ppb	0	50	0	50	0	50	0	50	0	50	0	50	3
Chl-ECO triplet	µg/L	0	30	0	30	0	30	0	30	0	30	0	30	3
xCO_2	ppm	50	800	NA	NA	NA	NA	50	800	NA	NA	NA	NA	3
NO_3 (Nitrate + Nitrite)	µM	0	39	0	39	0	39	0	39	NA	NA	0	39	3
NTU (Turbidity)	NTU	0	10	0	10	0	10	0	10	0	10	0	10	3
O_2 (DO)	mg/L	5.5	24.0	3.0	9.5	2.0	7.5	5.5	24.0	3.0	11.0	2.5	11.0	3
pH (total; both internal and external)	total pH	7.6	8.9	7.5	8.1	7.4	8.1	7.6	8.7	NA	NA	7.4	8.1	3
Sal (Salinity)	PSU	32.0	34.0	32.3	34.0	32.3	34.0	31.2	34.0	32.0	34.0	33.0	34.0	3
Temp (Temperature)	degC	11.0	26.5	9.0	24.5	9.0	15.0	12.0	26.5	10.0	26.0	9.0	22.0	3

Appendix A.4

Summary of temperature, salinity, DO, pH, transmissivity, and chlorophyll *a* for various depth layers as well as the entire water column for all PLOO stations during 2022. For each quarter: n ≥ 3378 (1–20 m), n ≥ 5282 (21–60 m), n ≥ 1834 (61–80 m), n ≥ 967 (81–98 m). Sample sizes differed due to variations in bottom depth at individual stations.

		Depth (m)				
		1–20	**21–60**	**61–80**	**81–98**	**1–98**
Temperature (°C)						
February	min	13.2	11.7	11.1	10.5	10.5
	max	15.8	15.2	12.4	11.6	15.8
	mean	15.0	13.3	11.7	11.1	13.3
May	min	10.4	9.9	9.6	9.6	9.6
	max	18.0	16.2	10.4	10.1	18.0
	mean	14.8	10.8	10.0	9.8	11.7
August	min	12.4	10.9	10.5	10.2	10.2
	max	23.8	15.9	11.3	11.0	23.8
	mean	17.1	12.0	10.9	10.5	13.2
November	min	13.5	11.3	11.2	10.7	10.7
	max	17.6	17.4	12.2	11.6	17.6
	mean	16.5	13.1	11.6	11.1	13.7
Salinity (ppt)						
February	min	33.41	33.37	33.45	33.58	33.37
	max	33.52	33.54	33.70	33.94	33.94
	mean	33.47	33.44	33.57	33.75	33.50
May	min	33.59	33.56	33.84	33.95	33.56
	max	33.91	33.98	34.07	34.18	34.18
	mean	33.71	33.82	33.96	34.08	33.83
August	min	33.30	33.36	33.58	33.62	33.30
	max	33.65	33.64	33.79	33.95	33.95
	mean	33.48	33.52	33.64	33.78	33.55
November	min	33.38	33.34	33.48	33.58	33.34
	max	33.56	33.55	33.70	33.83	33.83
	mean	33.51	33.43	33.58	33.73	33.50

Appendix A.4 *continued*

		Depth (m)				
		1–20	**21–60**	**61–80**	**81–98**	**1–98**
DO (mg/L)						
February	min	6.2	4.9	3.9	3.4	3.4
	max	8.2	7.9	5.6	4.8	8.2
	mean	7.7	6.4	4.9	4.1	6.3
May	min	3.2	3.1	2.9	2.5	2.5
	max	10.1	8.1	3.9	3.5	10.1
	mean	7.0	4.2	3.4	3.0	4.8
August	min	5.3	4.3	4.0	3.6	3.6
	max	9.1	9.0	5.2	4.6	9.1
	mean	7.9	5.8	4.5	4.2	6.1
November	min	5.7	4.1	3.7	3.6	3.6
	max	8.1	7.7	5.4	4.2	8.1
	mean	7.4	5.8	4.4	3.9	5.9
pH						
February	min	7.9	7.8	7.7	7.7	7.7
	max	8.2	8.1	7.9	7.8	8.2
	mean	8.1	7.9	7.8	7.8	7.9
May	min	7.7	7.7	7.7	7.7	7.7
	max	8.3	8.1	7.8	7.7	8.3
	mean	8.1	7.8	7.7	7.7	7.9
August	min	7.7	7.6	7.6	7.7	7.6
	max	8.2	8.2	7.8	7.8	8.2
	mean	8.1	7.9	7.8	7.8	7.9
November	min	7.9	7.8	7.8	7.7	7.7
	max	8.2	8.2	7.9	7.8	8.2
	mean	8.1	8.0	7.8	7.8	8.0

Appendix A.4 *continued*

		Depth (m)				
		1–20	**21–60**	**61–80**	**81–98**	**1–98**
Transmissivity (%)						
February	min	61	84	60	44	44
	max	89	90	90	90	90
	mean	87	88	88	87	88
May	min	58	75	84	52	52
	max	90	91	91	91	91
	mean	82	89	89	90	87
August	min	71	76	85	87	71
	max	91	93	93	93	93
	mean	87	90	91	91	89
November	min	48	87	84	63	48
	max	92	93	93	93	93
	mean	89	92	91	91	91
Chlorophyll *a* (µg/L)						
February	min	0.5	0.6	0.5	0.4	0.4
	max	3.5	2.6	1.1	0.7	3.5
	mean	1.0	1.4	0.7	0.5	1.1
May	min	1.2	1.1	1.0	1.0	1.0
	max	20.8	12.3	2.5	1.7	20.8
	mean	4.3	2.1	1.4	1.4	2.6
August	min	0.3	0.3	0.2	0.2	0.2
	max	5.5	13.6	0.8	0.4	13.6
	mean	1.1	1.9	0.4	0.3	1.3
November	min	0.4	0.4	0.3	0.3	0.3
	max	5.2	3.2	0.8	0.6	5.2
	mean	1.4	1.1	0.5	0.4	1.0

Appendix A.5

Summary of temperature, salinity, DO, pH, transmissivity, and chlorophyll *a* for various depth layers as well as the entire water column from all SBOO stations during 2022. For each quarter: n ≥ 1440 (1–9 m), n ≥ 1232 (10–19 m), n ≥ 740 (20–28 m), n ≥ 351 (29–38 m), n ≥ 290 (39–55 m). Sample sizes differed due to slight variations in depth at individual stations.

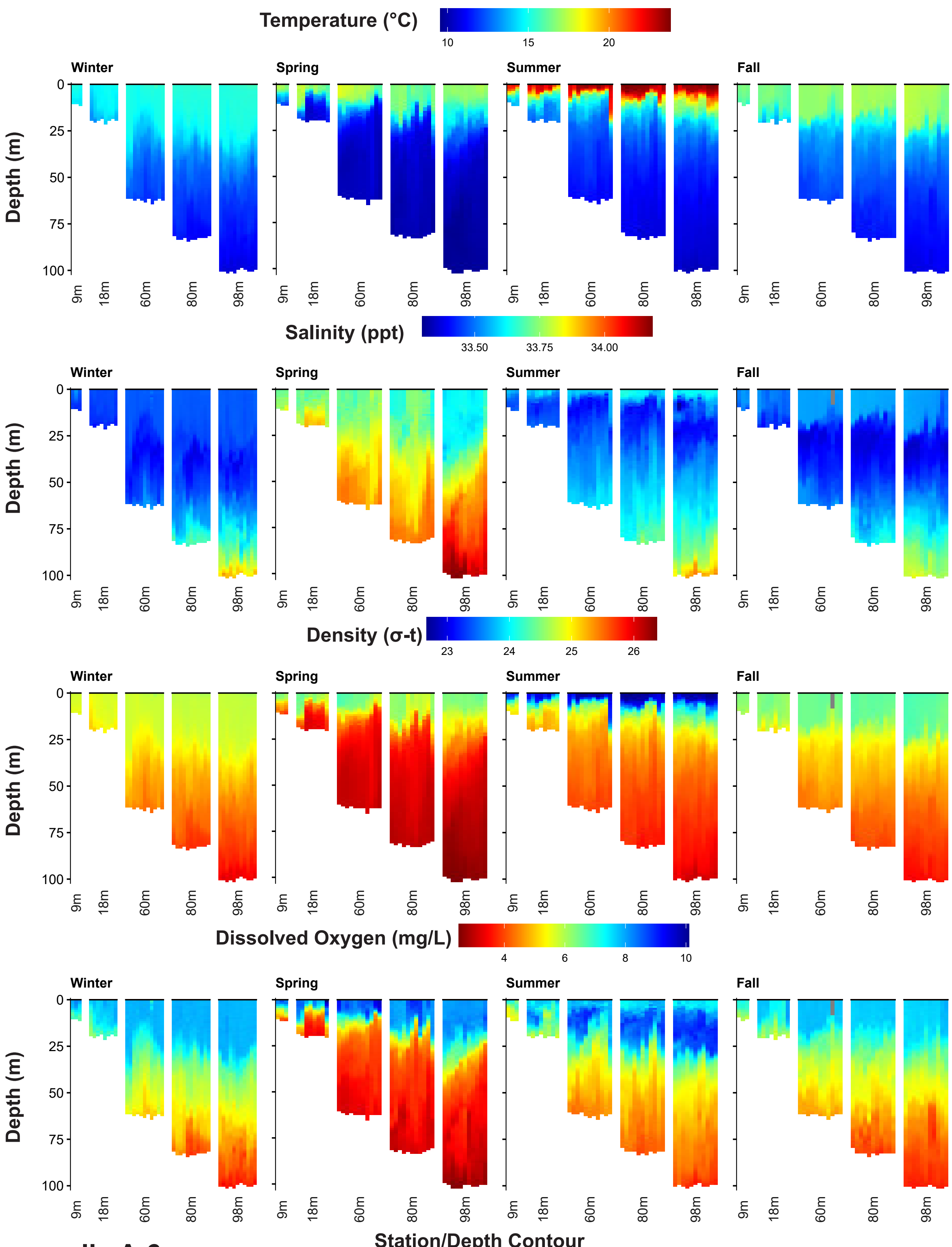
		Depth (m)					
		1–9	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
Temperature (°C)							
February	min	14.4	13.5	12.9	12.4	11.4	11.4
	max	15.6	15.6	15.4	14.8	14.2	15.6
	mean	14.8	14.7	14.3	13.7	12.8	14.4
May	min	14.1	10.9	10.6	10.4	10.3	10.3
	max	17.4	16.2	12.6	11.5	10.8	17.4
	mean	15.9	13.4	11.4	10.8	10.4	13.5
August	min	12.8	12.2	11.9	11.7	10.7	10.7
	max	22.7	20.9	15.5	13.9	12.7	22.7
	mean	17.2	14.0	12.6	12.2	11.5	14.5
November	min	14.3	14.2	13.9	13.6	12.4	12.4
	max	16.6	16.1	15.5	14.7	14.1	16.6
	mean	15.3	15.1	14.5	14.0	13.4	14.8
Salinity (ppt)							
February	min	33.37	33.38	33.38	33.38	33.37	33.37
	max	33.48	33.48	33.46	33.46	33.59	33.59
	mean	33.44	33.43	33.42	33.41	33.47	33.43
May	min	33.59	33.53	33.63	33.74	33.79	33.53
	max	33.72	33.76	33.83	33.90	33.95	33.95
	mean	33.66	33.68	33.74	33.81	33.88	33.71
August	min	33.33	33.23	33.40	33.45	33.47	33.23
	max	33.65	33.57	33.51	33.53	33.69	33.69
	mean	33.48	33.44	33.47	33.49	33.56	33.47
November	min	33.27	33.33	33.38	33.36	33.37	33.27
	max	33.49	33.49	33.46	33.45	33.47	33.49
	mean	33.45	33.44	33.41	33.40	33.41	33.43

Appendix A.5 *continued*

		Depth (m)					
		1–9	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
DO (mg/L)							
February	min	7.2	6.6	6.3	5.8	4.7	4.7
	max	9.7	8.7	7.9	7.7	7.1	9.7
	mean	8.0	7.6	7.1	6.7	5.8	7.4
May	min	7.2	4.0	3.3	3.1	3.0	3.0
	max	10.2	10.3	6.3	4.7	3.9	10.3
	mean	9.4	7.4	4.6	3.9	3.5	7.0
August	min	4.8	3.4	4.8	4.7	4.2	3.4
	max	8.8	9.0	8.9	8.0	6.4	9.0
	mean	7.6	7.0	6.0	5.6	5.0	6.8
November	min	6.8	6.6	6.0	5.9	5.3	5.3
	max	8.4	8.2	8.0	7.3	6.7	8.4
	mean	7.8	7.6	7.0	6.6	6.0	7.4
pH							
February	min	8.1	8.1	8.0	8.0	7.9	7.9
	max	8.3	8.2	8.2	8.2	8.1	8.3
	mean	8.2	8.1	8.1	8.1	8.0	8.1
May	min	8.1	7.8	7.7	7.7	7.6	7.6
	max	8.3	8.3	8.1	7.9	7.8	8.3
	mean	8.3	8.1	7.8	7.8	7.7	8.1
August	min	7.8	7.7	7.8	7.8	7.8	7.7
	max	8.2	8.2	8.2	8.1	8.0	8.2
	mean	8.1	8.0	7.9	7.9	7.8	8.0
November	min	8.0	8.0	8.0	8.0	7.9	7.9
	max	8.2	8.2	8.1	8.1	8.0	8.2
	mean	8.1	8.1	8.0	8.0	8.0	8.1

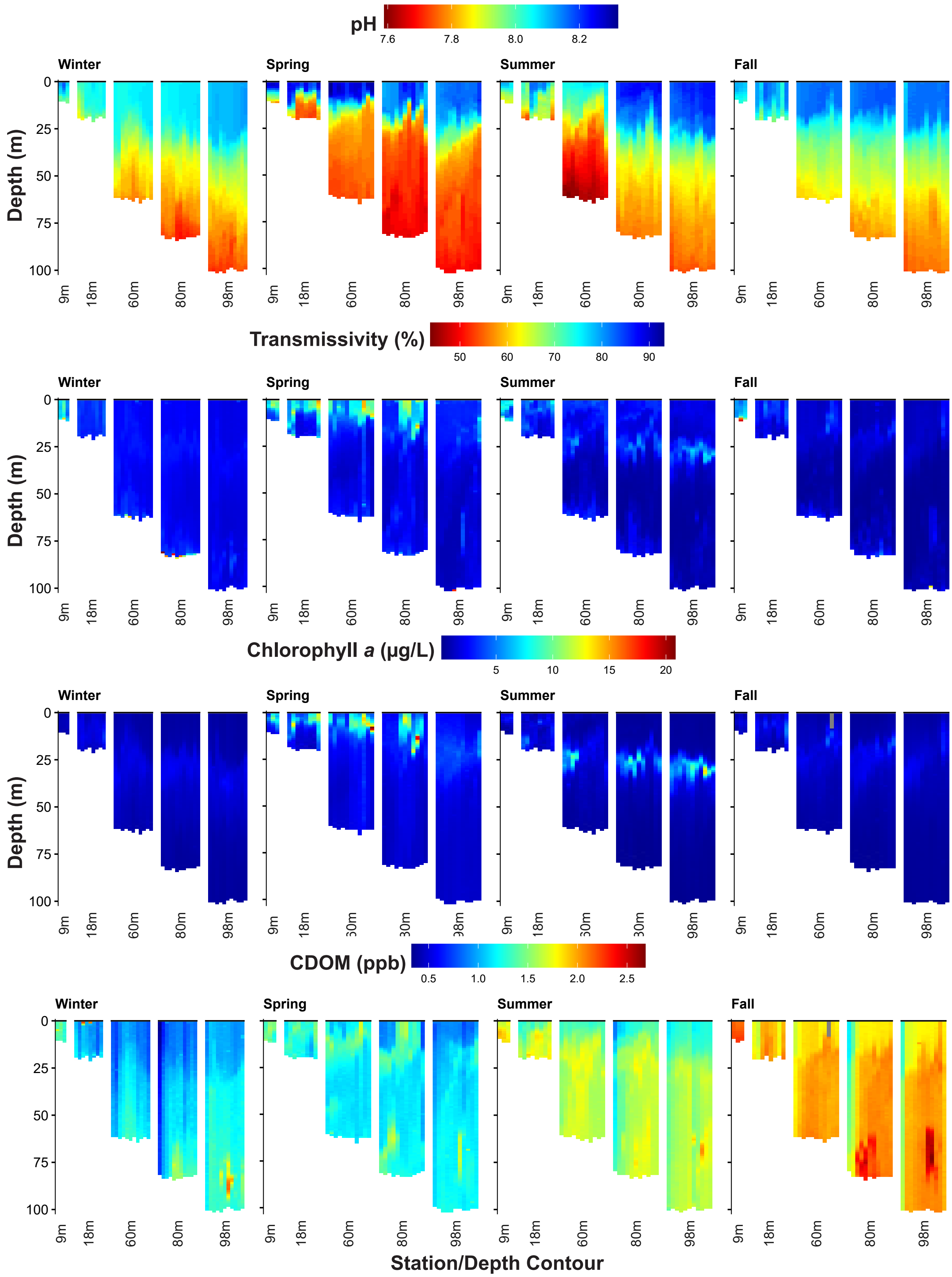
Appendix A.5 *continued*

		Depth (m)					
		1–9	10–19	20–28	29–38	39–55	1–55
Transmissivity (%)							
February	min	58	60	80	80	87	58
	max	89	89	89	89	89	89
	mean	81	84	85	87	88	84
May	min	62	45	47	59	40	40
	max	83	88	90	90	90	90
	mean	78	81	85	86	87	82
August	min	58	59	80	88	88	58
	max	91	91	91	92	92	92
	mean	83	86	88	90	91	86
November	min	54	44	61	78	88	44
	max	91	91	92	92	92	92
	mean	85	86	86	89	90	86
Chlorophyll *a* (µg/L)							
February	min	0.6	0.7	0.9	1.1	0.7	0.6
	max	21.5	8.2	3.7	2.4	1.5	21.5
	mean	3.0	2.2	1.7	1.4	1.0	2.2
May	min	1.3	1.4	1.0	0.9	0.8	0.8
	max	11.9	13.2	12.8	6.2	9.1	13.2
	mean	3.4	3.6	2.3	2.0	1.3	3.0
August	min	0.3	0.3	0.7	0.9	0.3	0.3
	max	9.6	10.2	7.6	2.5	1.8	10.2
	mean	1.6	1.8	1.9	1.4	0.8	1.6
November	min	0.6	1.1	1.2	1.1	0.6	0.6
	max	11.7	6.9	3.8	2.6	1.4	11.7
	mean	1.8	1.8	1.8	1.4	1.1	1.7

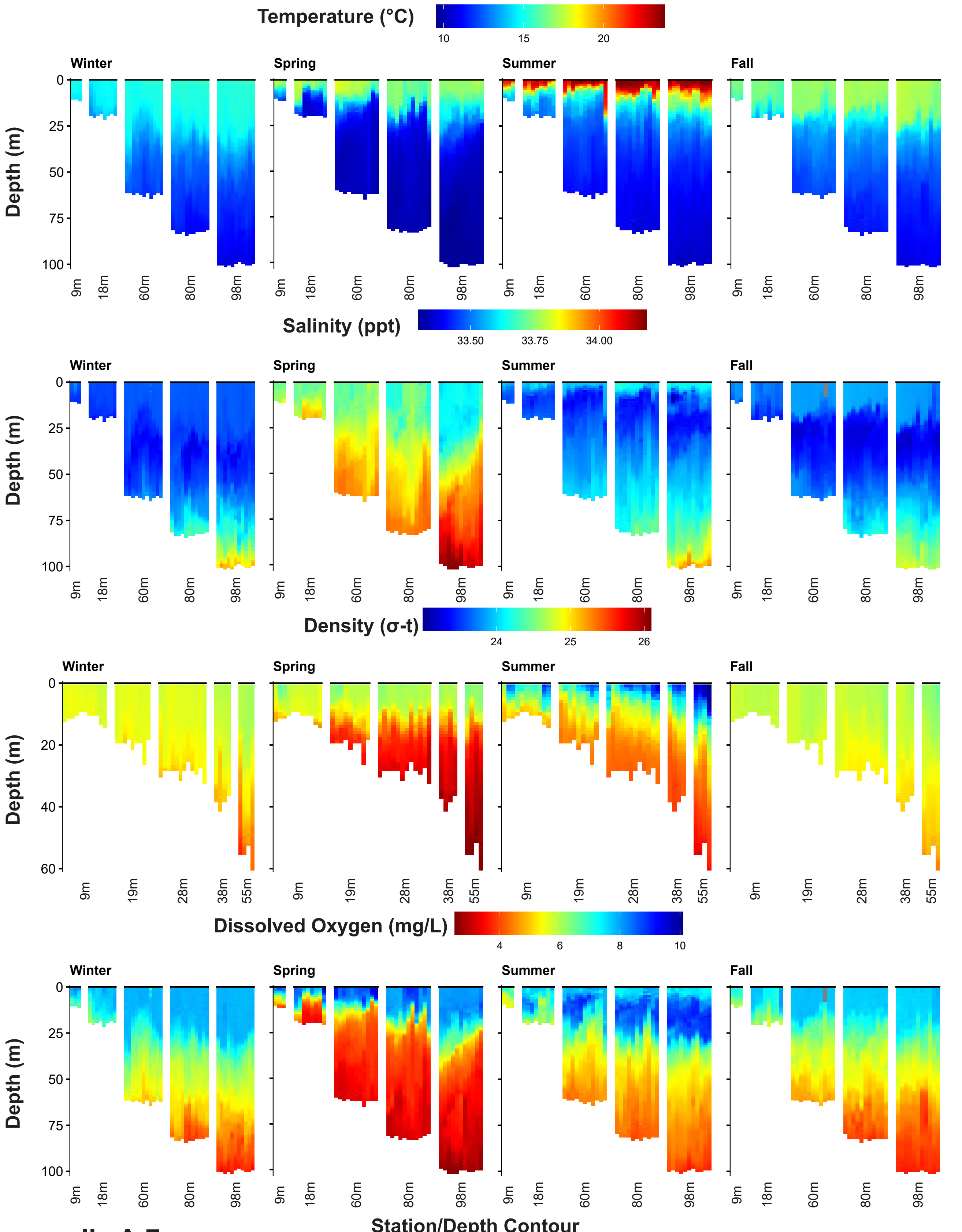


Appendix A.6

Temperature, salinity, density, dissolved oxygen, pH, transmissivity, chlorophyll *a*, and CDOM recorded in the PLOO region during 2022. Data are 1-m binned values per depth for each station and were collected over 4–5 days during each quarterly survey. Stations are depicted from north to south along each depth contour.

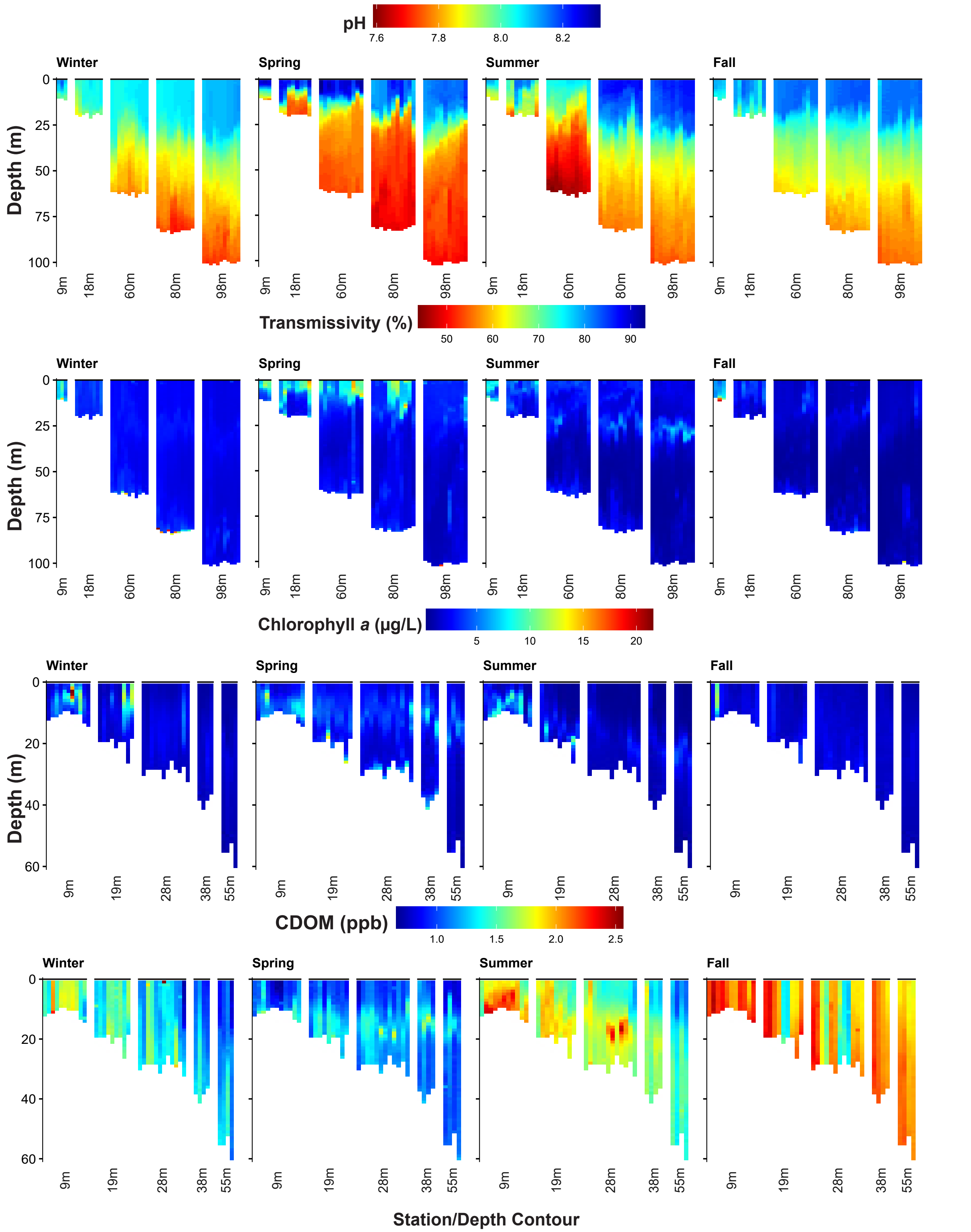


Appendix A.6 *continued*



Appendix A.7

Temperature, salinity, density, dissolved oxygen, pH, transmissivity, chlorophyll *a*, and CDOM recorded in the SBOO region during 2022. Data are 1-m binned values per depth for each station and were collected over 4–5 days during each quarterly survey. Stations are depicted from north to south along each depth contour.



Appendix A.7 *continued*

Appendix A.8

Summary of temperature, salinity, DO, pH (total), chlorophyll *a*, CDOM, turbidity, nitrate + nitrite, BOD, and xCO_2 recorded at various depths by the PLOO RTOMS in 2022. Data include mean, minimum, and maximum values, sample size (n), and proportion recovered (n_prop) for each depth by season. Sample sizes differed due to variations in sampling interval, deployment date, and data quality (see Appendices A.1 to A.3); id = insufficient data (<40% data recovery, based on expected number of samples for each season).

Parameter	Season		1m	10m	20m	30m	45m	60m	75m	90m
Temperature (°C)	*Winter*	mean	15.5	15.1	14.5	14.1	12.4	11.6	11.2	10.9
		min	14.2	11.4	10.9	10.7	10.2	9.9	9.7	9.7
		max	17.3	16.5	15.9	15.7	15.3	13.5	12.8	12.4
		n	9576	11808	11801	8728	11808	11802	11413	11771
		n_prop	0.74	0.91	0.91	0.67	0.91	0.91	0.88	0.91
	Spring	mean	17.9	16	12.8	11.4	10.7	10.3	10.1	10
		min	12.8	11.1	10.3	9.9	9.6	9.5	9.4	9.4
		max	23.3	21	17.8	15.8	12.7	11.8	11	10.6
		n	12542	12716	12710	12625	12715	12703	12613	12670
		n_prop	0.96	0.97	0.97	0.96	0.97	0.97	0.96	0.97
	Summer	mean	21.8	17.7	14.5	13	11.9	11.2	10.9	10.7
		min	17	11.6	11.3	10.8	10.4	10	9.7	9.6
		max	24.7	23.7	21.6	19.4	17.7	15.9	14.6	14
		n	13025	13108	13109	13050	13131	13114	13050	13047
		n_prop	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.98
	Fall	mean	—	17.2	15.3	13.7	12.6	12	11.5	11.3
		min	—	13.8	12.5	12.1	11.3	11	10.8	10.4
		max	—	20.9	19.1	17.9	15.2	13.9	12.7	12.4
		n	id	10708	10710	10634	10709	10726	10652	10648
		n_prop	0.33	0.81	0.81	0.8	0.81	0.81	0.8	0.8
Salinity (psu)	*Winter*	mean	33.48	33.47	33.44	33.45	33.5	33.5	33.47	33.52
		min	33.37	33.36	32.73	33.24	33.13	33.22	33.12	33.19
		max	33.58	33.65	33.63	33.73	33.9	33.81	33.8	33.77
		n	9575	11808	11616	8728	11808	11802	11412	11771
		n_prop	0.74	0.91	0.9	0.67	0.91	0.91	0.88	0.91
	Spring	mean	33.54	33.56	—	33.63	33.71	33.54	33.7	33.61
		min	33.29	33.25	—	33.32	33.4	33.05	33.4	33.32
		max	33.73	33.92	—	33.98	34.05	33.97	33.99	33.85
		n	12143	12710	id	12622	12715	12702	12613	12670
		n_prop	0.93	0.97	0.28	0.96	0.97	0.97	0.96	0.97
	Summer	mean	33.57	33.45	—	33.42	33.49	33.27	33.56	33.35
		min	33.3	33.21	—	32.98	33.23	32.79	33.21	32.93
		max	33.71	33.71	—	33.62	33.75	33.69	33.79	33.65
		n	13006	12789	id	13036	13126	13110	13050	10316
		n_prop	0.98	0.97	0	0.98	0.99	0.99	0.99	0.78
	Fall	mean	—	33.47	—	33.33	33.38	33.23	33.37	—
		min	—	33.22	—	32.92	33.18	32.75	33.1	—
		max	—	33.63	—	33.56	33.54	33.65	33.69	—
		n	id	10731	id	10019	10719	10746	9460	id
		n_prop	0.33	0.81	0.24	0.76	0.81	0.81	0.71	0.24

Appendix A.8 *continued*

Parameter	Season		1m	10m	20m	30m	45m	60m	75m	90m
DO (mg/L)	*Winter*	mean	8.6	—	—	7.4	—	—	3.8	3.9
		min	7.3	—	—	4.2	—	—	1.6	2.5
		max	12.1	—	—	8.9	—	—	6.1	5.5
		n	8261	—	—	8774	—	—	11473	11835
		n_prop	0.64	—	—	0.68	—	—	0.89	0.91
	Spring	mean	—	—	—	5.4	—	—	3.1	3.2
		min	—	—	—	3.2	—	—	1.4	1.9
		max	—	—	—	9.2	—	—	5.4	4.7
		n	id	—	—	12725	—	—	12713	12770
		n_prop	0	—	—	0.97	—	—	0.97	0.97
	Summer	mean	7.9	—	—	6.8	—	—	4.4	4
		min	6.8	—	—	4.8	—	—	3.1	2.8
		max	11.1	—	—	9.1	—	—	7.2	6
		n	10681	—	—	13146	—	—	13146	10393
		n_prop	0.81	—	—	0.99	—	—	0.99	0.78
	Fall	mean	—	—	—	7	—	—	4.6	—
		min	—	—	—	5.5	—	—	3.4	—
		max	—	—	—	9	—	—	6.5	—
		n	id	—	—	10723	—	—	10612	id
		n_prop	0.33	—	—	0.81	—	—	0.8	0.24
pH (total pH)	*Winter*	mean	8.1	—	—	8	—	—	—	—
		min	8	—	—	7.7	—	—	—	—
		max	8.3	—	—	8.1	—	—	—	—
		n	8261	—	—	8775	—	—	id	—
		n_prop	0.64	—	—	0.68	—	—	0	—
	Spring	mean	—	—	—	7.8	—	—	—	—
		min	—	—	—	7.6	—	—	—	—
		max	—	—	—	8.1	—	—	—	—
		n	id	—	—	12750	—	—	id	—
		n_prop	0	—	—	0.97	—	—	0	—
	Summer	mean	8.1	—	—	7.9	—	—	—	—
		min	7.9	—	—	7.7	—	—	—	—
		max	8.2	—	—	8.1	—	—	—	—
		n	10681	—	—	13156	—	—	id	—
		n_prop	0.81	—	—	0.99	—	—	0	—
	Fall	mean	—	—	—	7.9	—	—	—	—
		min	—	—	—	7.8	—	—	—	—
		max	—	—	—	8.1	—	—	—	—
		n	id	—	—	10736	—	—	id	—
		n_prop	0.33	—	—	0.81	—	—	0.15	—

Appendix A.8 *continued*

Parameter	Season		1m	10m	20m	30m	45m	60m	75m	90m
Chlorophyll *a* (µg/L)	*Winter*	mean	0.2	—	—	0.6	—	—	0.04	—
		min	0.02	—	—	0.04	—	—	0	—
		max	1.3	—	—	4.3	—	—	0.7	—
		n	9141	—	—	11654	—	—	11643	—
		n_prop	0.71	—	—	0.9	—	—	0.9	—
	Spring	mean	—	—	—	0.6	—	—	0.04	—
		min	—	—	—	0.02	—	—	0	—
		max	—	—	—	7.5	—	—	0.7	—
		n	id	—	—	12551	—	—	12508	—
		n_prop	0	—	—	0.96	—	—	0.95	—
	Summer	mean	—	—	—	—	—	—	0.07	—
		min	—	—	—	—	—	—	0	—
		max	—	—	—	—	—	—	0.89	—
		n	id	—	—	id	—	—	12971	—
		n_prop	0.34	—	—	0.33	—	—	0.98	—
	Fall	mean	0.4	—	—	0.6	—	—	0.08	—
		min	0.04	—	—	0.2	—	—	0.01	—
		max	2	—	—	3.4	—	—	0.8	—
		n	10504	—	—	10557	—	—	10593	—
		n_prop	0.79	—	—	0.8	—	—	0.8	—
CDOM (ppb)	*Winter*	mean	1	—	—	0.6	—	—	0.2	—
		min	0.6	—	—	0	—	—	0	—
		max	4.9	—	—	1.1	—	—	0.7	—
		n	8357	—	—	11662	—	—	11645	—
		n_prop	0.64	—	—	0.9	—	—	0.9	—
	Spring	mean	—	—	—	0.7	—	—	0.01	—
		min	—	—	—	0.5	—	—	0	—
		max	—	—	—	1.3	—	—	0.2	—
		n	id	—	—	12571	—	—	12508	—
		n_prop	0	—	—	0.96	—	—	0.95	—
	Summer	mean	—	—	—	—	—	—	0.4	—
		min	—	—	—	—	—	—	0	—
		max	—	—	—	—	—	—	1.2	—
		n	id	—	—	id	—	—	12971	—
		n_prop	0	—	—	0.35	—	—	0.98	—
	Fall	mean	—	—	—	0.7	—	—	0.6	—
		min	—	—	—	0.4	—	—	0.2	—
		max	—	—	—	3.8	—	—	1.4	—
		n	id	—	—	9732	—	—	10593	—
		n_prop	0.26	—	—	0.73	—	—	0.8	—

Appendix A.8 *continued*

Parameter	Season		1m	10m	20m	30m	45m	60m	75m	90m
Turbidity (NTU)	*Winter*	mean	0.01	—	—	0.1	—	—	0.1	—
		min	0	—	—	0.04	—	—	0.02	—
		max	1	—	—	1	—	—	3.2	—
		n	9140	—	—	11660	—	—	11645	—
		n_prop	0.71	—	—	0.9	—	—	0.9	—
	Spring	mean	—	—	—	0.09	—	—	0.1	—
		min	—	—	—	0.02	—	—	0.02	—
		max	—	—	—	1	—	—	2.8	—
		n	id	—	—	12566	—	—	12507	—
		n_prop	0	—	—	0.96	—	—	0.95	—
	Summer	mean	—	—	—	—	—	—	0.2	—
		min	—	—	—	—	—	—	0.02	—
		max	—	—	—	—	—	—	3.1	—
		n	id	—	—	id	—	—	12969	—
		n_prop	0.34	—	—	0.31	—	—	0.98	—
	Fall	mean	0.06	—	—	0.1	—	—	0.2	—
		min	0.01	—	—	0.04	—	—	0.04	—
		max	0.9	—	—	1	—	—	2.8	—
		n	10492	—	—	7502	—	—	10593	—
		n_prop	0.79	—	—	0.57	—	—	0.8	—
Nitrate + nitrite (µM)	*Winter*	mean	—	—	—	7.5	—	—	12.8	—
		min	—	—	—	0	—	—	0.01	—
		max	—	—	—	21.5	—	—	31.6	—
		n	—	—	—	1613	—	—	1501	—
		n_prop	—	—	—	0.75	—	—	0.69	—
	Spring	mean	—	—	—	15.2	—	—	—	—
		min	—	—	—	0.07	—	—	—	—
		max	—	—	—	24.3	—	—	—	—
		n	—	—	—	2042	—	—	id	—
		n_prop	—	—	—	0.93	—	—	0	—
	Summer	mean	—	—	—	8.2	—	—	—	—
		min	—	—	—	0	—	—	—	—
		max	—	—	—	18.2	—	—	—	—
		n	—	—	—	1950	—	—	id	—
		n_prop	—	—	—	0.88	—	—	0	—
	Fall	mean	—	—	—	8.1	—	—	—	—
		min	—	—	—	1.1	—	—	—	—
		max	—	—	—	14.6	—	—	—	—
		n	—	—	—	1738	—	—	id	—
		n_prop	—	—	—	0.79	—	—	0.22	—

Appendix A.8 *continued*

Parameter	Season		1m	10m	20m	30m	45m	60m	75m	90m
BOD (mg/L)	*Winter*	mean	—	—	—	0.1	—	—	0.8	—
		min	—	—	—	0.07	—	—	0.05	—
		max	—	—	—	1.3	—	—	2.8	—
		n	—	—	—	11681	—	—	11651	—
		n_prop	—	—	—	0.9	—	—	0.9	—
	Spring	mean	—	—	—	0.1	—	—	0.5	—
		min	—	—	—	0.06	—	—	0	—
		max	—	—	—	1.8	—	—	5.1	—
		n	—	—	—	12608	—	—	12471	—
		n_prop	—	—	—	0.96	—	—	0.95	—
	Summer	mean	—	—	—	0.2	—	—	0.2	—
		min	—	—	—	0.09	—	—	0.04	—
		max	—	—	—	1.8	—	—	2.1	—
		n	—	—	—	13024	—	—	12998	—
		n_prop	—	—	—	0.98	—	—	0.98	—
	Fall	mean	—	—	—	0.1	—	—	0.3	—
		min	—	—	—	0	—	—	0	—
		max	—	—	—	1.6	—	—	2.8	—
		n	—	—	—	10619	—	—	10623	—
		n_prop	—	—	—	0.8	—	—	0.8	—
xCO2 (ppm)	*Winter*	mean	—	—	—	—	—	—	—	—
		min	—	—	—	—	—	—	—	—
		max	—	—	—	—	—	—	—	—
		n	id	—	—	—	—	—	—	—
		n_prop	0	—	—	—	—	—	—	—
	Spring	mean	—	—	—	—	—	—	—	—
		min	—	—	—	—	—	—	—	—
		max	—	—	—	—	—	—	—	—
		n	id	—	—	—	—	—	—	—
		n_prop	0	—	—	—	—	—	—	—
	Summer	mean	—	—	—	—	—	—	—	—
		min	—	—	—	—	—	—	—	—
		max	—	—	—	—	—	—	—	—
		n	id	—	—	—	—	—	—	—
		n_prop	0	—	—	—	—	—	—	—
	Fall	mean	—	—	—	—	—	—	—	—
		min	—	—	—	—	—	—	—	—
		max	—	—	—	—	—	—	—	—
		n	id	—	—	—	—	—	—	—
		n_prop	0.25	—	—	—	—	—	—	—

Appendix A.9

Summary of temperature, salinity, DO, pH (total), chlorophyll *a*, CDOM, turbidity, nitrate + nitrite, BOD, and xCO_2 recorded at various depths by the SBOO RTOMS in 2022. Data include mean, minimum, and maximum values, sample size (n), and proportion recovered (n_prop) for each depth by season. Sample sizes differed due to variations in sampling interval, deployment date, and data quality (see Appendices A.1 to A.3); id = insufficient data (<40% data recovery, based on expected number of samples for each season).

Parameter	Season		1 m	10 m	18 m	26 m
Temperature (°C)	*Winter*	mean	15.1	14.5	14.2	13.3
		min	13.2	11.8	11.4	11
		max	17.3	16.3	15.9	15.4
		n	10952	12454	10615	10381
		n_prop	0.85	0.96	0.82	0.8
	Spring	mean	17.3	14	12.1	11.4
		min	12.7	10.2	10.1	10.1
		max	21.6	20.8	19	15.1
		n	12929	13010	12932	12953
		n_prop	0.99	0.99	0.99	0.99
	Summer	mean	20.3	15.5	13.7	13.1
		min	15.6	12	11.6	11.4
		max	24.8	22	20.6	19.7
		n	13121	13202	13134	13137
		n_prop	0.99	1	0.99	0.99
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	id	id	id
		n_prop	0.36	0.36	0.36	0.36
Salinity (psu)	*Winter*	mean	33.44	33.44	33.44	33.46
		min	32.96	33.1	33.04	33.18
		max	33.55	33.68	33.62	33.68
		n	10933	12454	9044	10373
		n_prop	0.84	0.96	0.7	0.8
	Spring	mean	33.49	33.56	—	33.66
		min	32.79	32.9	—	33.36
		max	33.69	34.09	—	33.99
		n	11850	12996	id	12065
		n_prop	0.9	0.99	0.32	0.92
	Summer	mean	33.46	33.24	—	33.42
		min	33.11	32.64	—	33.04
		max	33.63	33.73	—	33.62
		n	13113	12658	id	13021
		n_prop	0.99	0.96	0	0.98
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	id	id	id
		n_prop	0.35	0.35	0	0.36

Appendix A.9 *continued*

Parameter	Season		1 m	10 m	18 m	26 m
DO (mg/L)	*Winter*	mean	8.6	—	7.6	6.5
		min	6.9	—	4.8	4.3
		max	13.3	—	9.3	9.7
		n	11039	—	8827	10407
		n_prop	0.85	—	0.68	0.8
	Spring	mean	9	—	5.6	4.6
		min	6.6	—	2.6	2.7
		max	15.4	—	12.4	8.1
		n	13032	—	13034	13056
		n_prop	0.99	—	0.99	1
	Summer	mean	8.8	—	6.8	5.2
		min	6.7	—	3.5	1.7
		max	14.7	—	10.8	8.3
		n	13207	—	13220	13223
		n_prop	1	—	1	1
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	id	id
		n_prop	0.36	—	0.36	0.36
pH (total pH)	*Winter*	mean	8.1	—	—	7.9
		min	8	—	—	7.7
		max	8.3	—	—	8.1
		n	11040	—	—	10460
		n_prop	0.85	—	—	0.81
	Spring	mean	8.1	—	—	7.8
		min	7.9	—	—	7.6
		max	8.4	—	—	8.1
		n	12898	—	—	13056
		n_prop	0.98	—	—	1
	Summer	mean	8.1	—	—	7.8
		min	7.9	—	—	7.5
		max	8.3	—	—	7.9
		n	13208	—	—	7778
		n_prop	1	—	—	0.59
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	—	id
		n_prop	0.35	—	—	0

Appendix A.9 *continued*

Parameter	Season		1 m	10 m	18 m	26 m
Chlorophyll *a* (µg/L)	*Winter*	mean	0.4	—	1.1	0.8
		min	0.1	—	0.2	0.2
		max	8	—	13.4	5.2
		n	12052	—	11147	11443
		n_prop	0.93	—	0.86	0.88
	Spring	mean	—	—	1.6	0.8
		min	—	—	0.1	0
		max	—	—	11.8	6.5
		n	id	—	12843	11426
		n_prop	0.24	—	0.98	0.87
	Summer	mean	0.3	—	2	1.4
		min	0.1	—	0.2	0.1
		max	4.7	—	21.5	10.9
		n	10029	—	13135	11460
		n_prop	0.76	—	0.99	0.87
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	id	id
		n_prop	0.35	—	0.27	0.35
CDOM (ppb)	*Winter*	mean	1.1	—	0.8	0.8
		min	0.6	—	0.5	0.1
		max	4	—	3.3	1.6
		n	12021	—	12223	11446
		n_prop	0.93	—	0.94	0.88
	Spring	mean	1.1	—	1.1	0.8
		min	0.6	—	0.6	0.5
		max	4	—	4	1.5
		n	5599	—	8604	11427
		n_prop	0.43	—	0.66	0.87
	Summer	mean	0.9	—	1.2	0.9
		min	0.4	—	0.6	0.5
		max	3.7	—	4	3.1
		n	10023	—	8632	11455
		n_prop	0.76	—	0.65	0.86
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	id	id
		n_prop	0.35	—	0.18	0.35

Appendix A.9 *continued*

Parameter	Season		1 m	10 m	18 m	26 m
Turbidity (NTU)	*Winter*	mean	0.02	—	0.2	0.4
		min	0	—	0.04	0.07
		max	0.9	—	3	4.4
		n	12047	—	12223	11446
		n_prop	0.93	—	0.94	0.88
	Spring	mean	0.02	—	0.3	0.3
		min	0	—	0.04	0.05
		max	1	—	2	2
		n	5331	—	12373	11427
		n_prop	0.41	—	0.94	0.87
	Summer	mean	0.02	—	0.3	0.3
		min	0	—	0.06	0.05
		max	1	—	2	2.5
		n	9958	—	12728	11417
		n_prop	0.75	—	0.96	0.86
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	id	id
		n_prop	0.35	—	0.16	0.35
Nitrate + nitrite (µM)	*Winter*	mean	3.8	—	—	7.8
		min	0	—	—	0
		max	10.5	—	—	20
		n	1930	—	—	1895
		n_prop	0.89	—	—	0.88
	Spring	mean	4	—	—	15.7
		min	0	—	—	0
		max	14.8	—	—	25.5
		n	1724	—	—	2027
		n_prop	0.79	—	—	0.93
	Summer	mean	4.5	—	—	7.1
		min	0.8	—	—	0
		max	11.5	—	—	17.2
		n	1626	—	—	1627
		n_prop	0.74	—	—	0.74
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	—	id
		n_prop	0	—	—	0.23

Appendix A.9 *continued*

Parameter	Season		1 m	10 m	18 m	26 m
BOD (mg/L)	*Winter*	mean	—	—	—	0.1
		min	—	—	—	0.1
		max	—	—	—	0.5
		n	—	—	—	12455
		n_prop	—	—	—	0.96
	Spring	mean	—	—	—	0.1
		min	—	—	—	0.1
		max	—	—	—	0.8
		n	—	—	—	12814
		n_prop	—	—	—	0.98
	Summer	mean	—	—	—	0.2
		min	—	—	—	0.1
		max	—	—	—	0.8
		n	—	—	—	13217
		n_prop	—	—	—	1
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	—	—	—	id
		n_prop	—	—	—	0.36
xCO2 (ppm)	*Winter*	mean	362	—	—	—
		min	179	—	—	—
		max	483	—	—	—
		n	2090	—	—	—
		n_prop	0.97	—	—	—
	Spring	mean	336	—	—	—
		min	137	—	—	—
		max	610	—	—	—
		n	2184	—	—	—
		n_prop	1	—	—	—
	Summer	mean	364	—	—	—
		min	148	—	—	—
		max	478	—	—	—
		n	1715	—	—	—
		n_prop	0.78	—	—	—
	Fall	mean	—	—	—	—
		min	—	—	—	—
		max	—	—	—	—
		n	id	—	—	—
		n_prop	0.24	—	—	—

Appendix A.10

Summary of current velocity magnitude and direction from the PLOO RTOMS ADCP during 2022. Data are presented by depth bin as seasonal recovered observations (n), minimum (min), maximum (max), and means with 95% confidence intervals (CI). Proportion of recovered observations (n_prop) differed due to variations in data quality (see Appendices A.1 to A.3). Minimum and maximum angles of velocity are not shown due to the circular nature of the measurement.

				Magnitude (mm/s)				Angle	
Season	**Depth (m)**	**n**	**n_prop**	**Min**	**Max**	**Mean**	**95% CI**	**Mean**	**95% CI**
Winter	3	11729	1.00	1	365	119	2	156	69
	4	11728	1.00	1	436	124	2	156	67
	5	11728	1.00	1	416	131	2	157	67
	6	11728	1.00	2	406	136	2	158	70
	7	11729	1.00	1	386	138	2	158	71
	8	11727	1.00	2	363	138	2	160	71
	9	11728	1.00	3	361	141	2	159	72
	10	11729	1.00	8	353	143	2	158	72
	11	11728	1.00	11	363	143	2	158	73
	12	11727	1.00	9	357	143	2	157	72
	13	11727	1.00	13	361	143	2	158	73
	14	11727	1.00	2	363	142	2	158	73
	15	11727	1.00	6	364	141	1	158	73
	16	11727	1.00	2	363	140	1	158	73
	17	11727	1.00	6	359	138	1	158	73
	18	11728	1.00	1	355	139	1	156	73
	19	11726	1.00	4	356	138	1	155	73
	20	11727	1.00	0	360	138	1	154	73
	21	11727	1.00	5	354	136	1	154	73
	22	11727	1.00	5	349	134	1	154	74
	23	11726	1.00	5	350	134	1	153	74
	24	11728	1.00	3	346	132	1	152	74
	25	11725	1.00	2	349	129	1	152	75
	26	11726	1.00	3	330	122	1	159	75
	27	11725	1.00	0	309	115	1	159	77
	28	11726	1.00	3	332	125	1	148	75
	29	11726	1.00	7	318	121	1	147	76
	30	11727	1.00	8	305	119	1	147	76
	31	11727	1.00	7	304	116	1	147	76
	32	11726	1.00	12	296	114	1	145	76
	33	11725	1.00	11	282	112	1	145	76
	34	11725	1.00	4	276	110	1	142	76
	35	11727	1.00	4	269	107	1	140	76
	36	11725	1.00	5	253	104	1	138	76
	37	11724	1.00	1	249	102	1	135	76
	38	11726	1.00	6	244	100	1	134	76
	39	11727	1.00	1	240	98	1	132	77
	40	11725	1.00	5	233	95	1	130	76
	41	11724	1.00	6	233	93	1	130	76

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s) Min	Max	Mean	95% CI	Angle Mean	95% CI
Winter	42	11724	1.00	4	235	92	1	124	75
cont.	43	11722	1.00	3	234	90	1	125	75
	44	11724	1.00	1	232	89	1	124	75
	45	11725	1.00	2	232	87	1	122	75
	46	11725	1.00	1	229	85	1	120	74
	47	11724	1.00	7	228	84	1	117	75
	48	11725	1.00	3	221	81	1	115	74
	49	11724	1.00	3	211	80	1	111	74
	50	11726	1.00	5	210	79	1	107	74
	51	11720	1.00	4	204	78	1	103	73
	52	11723	1.00	3	196	76	1	99	73
	53	11723	1.00	3	195	76	1	97	72
	54	11727	1.00	1	193	75	1	95	73
	55	11724	1.00	1	190	73	1	90	72
	56	11726	1.00	0	190	73	1	87	73
	57	11725	1.00	1	188	73	1	87	72
	58	11721	1.00	4	183	72	1	84	73
	59	11723	1.00	1	179	70	1	81	73
	60	11723	1.00	1	178	72	1	80	73
	61	11722	1.00	0	175	70	1	78	73
	62	11722	1.00	1	174	69	1	74	73
	63	11724	1.00	8	170	69	1	74	73
	64	11724	1.00	6	171	68	1	74	74
	65	11726	1.00	1	169	68	1	69	73
	66	11720	1.00	2	161	66	1	70	73
	67	11724	1.00	0	156	64	1	66	73
	68	11722	1.00	1	163	64	1	64	74
	69	11724	1.00	2	156	62	1	63	74
	70	11723	1.00	4	150	64	1	68	73
	71	11723	1.00	5	142	68	1	75	70
	72	11723	1.00	0	139	69	1	76	70
	73	11719	1.00	5	141	67	1	75	70
	74	11721	1.00	0	130	65	1	77	70
	75	11723	1.00	3	134	64	1	77	70
	76	11720	1.00	6	132	64	1	78	69
	77	11721	1.00	0	138	64	1	76	69
	78	11722	1.00	1	123	62	0	76	69
	79	11720	1.00	3	121	60	0	78	68
	80	11718	1.00	1	118	58	0	73	69
	81	11720	1.00	1	120	58	0	77	70
	82	11716	1.00	0	111	55	0	75	64
	83	11709	1.00	1	112	57	0	73	67
	84	11704	1.00	1	137	55	0	81	66

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s) Min	Max	Mean	95% CI	Angle Mean	95% CI
Winter	85	11695	1.00	0	111	52	0	79	70
cont.	86	11680	1.00	2	119	52	0	74	67
	87	11650	0.99	2	104	51	0	332	66
	88	11668	0.99	1	107	48	0	323	65
	89	11714	1.00	2	81	36	0	302	60
	90	11720	1.00	1	84	26	0	620	54
	91	11721	1.00	0	69	21	0	573	46
	92	11722	1.00	0	69	17	0	167	46
Spring	3	12714	1.00	4	568	167	2	160	71
	4	12714	1.00	2	681	202	3	157	67
	5	12714	1.00	10	699	211	3	157	67
	6	12714	1.00	12	689	211	3	159	67
	7	12713	1.00	1	678	209	2	160	68
	8	12711	1.00	1	624	201	2	163	70
	9	12712	1.00	2	618	203	2	164	70
	10	12713	1.00	1	584	199	2	166	71
	11	12713	1.00	14	537	194	2	167	71
	12	12712	1.00	14	515	189	2	167	72
	13	12713	1.00	9	501	184	2	167	72
	14	12713	1.00	5	484	179	2	167	72
	15	12713	1.00	2	480	175	2	166	73
	16	12711	1.00	1	454	171	2	166	73
	17	12712	1.00	2	440	165	2	165	73
	18	12712	1.00	1	442	163	2	162	73
	19	12712	1.00	3	438	161	2	162	74
	20	12713	1.00	2	414	157	2	161	74
	21	12711	1.00	4	406	155	2	160	74
	22	12711	1.00	2	398	152	2	160	75
	23	12711	1.00	2	382	149	2	159	75
	24	12711	1.00	4	374	146	2	158	75
	25	12711	1.00	0	350	142	1	158	76
	26	12710	1.00	3	313	134	1	163	76
	27	12711	1.00	5	322	126	1	166	77
	28	12709	1.00	3	363	135	1	150	75
	29	12709	1.00	9	353	137	1	147	75
	30	12712	1.00	2	343	132	1	149	75
	31	12708	1.00	1	334	130	1	150	76
	32	12707	1.00	0	329	128	1	149	76
	33	12710	1.00	2	322	125	1	147	76
	34	12710	1.00	4	326	123	1	145	76
	35	12707	1.00	5	312	120	1	144	76
	36	12712	1.00	3	315	119	1	143	75
	37	12710	1.00	3	308	117	1	140	76

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s)				Angle	
				Min	Max	Mean	95% CI	Mean	95% CI
Spring	38	12711	1.00	8	304	115	1	140	76
cont.	39	12711	1.00	1	296	113	1	137	76
	40	12711	1.00	2	296	112	1	135	76
	41	12712	1.00	3	291	111	1	132	76
	42	12710	1.00	3	289	109	1	129	76
	43	12710	1.00	2	283	108	1	126	75
	44	12711	1.00	2	284	107	1	125	76
	45	12711	1.00	4	269	106	1	121	76
	46	12711	1.00	3	270	104	1	119	76
	47	12711	1.00	3	270	103	1	116	76
	48	12712	1.00	5	266	102	1	112	76
	49	12710	1.00	13	262	101	1	111	76
	50	12710	1.00	4	256	100	1	106	76
	51	12711	1.00	3	253	99	1	105	76
	52	12709	1.00	2	245	97	1	103	76
	53	12711	1.00	10	240	96	1	100	76
	54	12710	1.00	15	238	94	1	97	76
	55	12711	1.00	15	228	93	1	94	76
	56	12711	1.00	21	223	93	1	93	75
	57	12709	1.00	20	228	93	1	92	75
	58	12708	1.00	15	229	92	1	90	75
	59	12711	1.00	21	228	91	1	89	75
	60	12711	1.00	19	224	90	1	89	74
	61	12707	1.00	27	224	90	1	89	74
	62	12707	1.00	27	220	88	1	88	73
	63	12709	1.00	25	218	89	1	87	73
	64	12706	1.00	20	207	88	1	86	72
	65	12707	1.00	17	196	86	1	88	72
	66	12709	1.00	22	192	84	1	86	72
	67	12705	1.00	17	181	81	1	85	72
	68	12709	1.00	19	170	79	1	83	71
	69	12709	1.00	14	187	77	1	83	71
	70	12708	1.00	12	177	78	1	83	71
	71	12709	1.00	19	206	81	1	89	70
	72	12703	1.00	14	213	84	1	92	68
	73	12702	1.00	3	203	84	1	92	68
	74	12705	1.00	8	205	79	1	90	69
	75	12707	1.00	1	190	78	1	89	69
	76	12703	1.00	2	193	77	1	90	69
	77	12701	1.00	2	176	75	1	88	70
	78	12701	1.00	5	182	74	1	89	70
	79	12697	1.00	2	187	73	1	87	70
	80	12702	1.00	0	185	71	1	88	69

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s) Min	Max	Mean	95% CI	Angle Mean	95% CI
Spring	81	12704	1.00	3	177	70	1	81	70
cont.	82	12703	1.00	0	193	69	1	84	70
	83	12703	1.00	1	178	67	1	74	71
	84	12705	1.00	0	180	68	1	78	72
	85	12700	1.00	0	172	66	1	72	72
	86	12696	1.00	1	175	66	1	35	72
	87	12694	1.00	0	153	62	1	15	72
	88	12690	1.00	0	138	52	1	313	73
	89	12695	1.00	1	114	46	0	321	68
	90	12698	1.00	2	121	37	0	302	64
	91	12699	1.00	0	79	34	0	277	51
	92	12698	1.00	0	98	32	0	623	39
Summer	3	13175	1.00	1	418	130	2	163	74
	4	13175	1.00	1	463	149	2	161	73
	5	13175	1.00	0	450	159	2	157	73
	6	13175	1.00	0	466	161	2	155	72
	7	13175	1.00	1	478	157	2	155	73
	8	13175	1.00	1	472	147	2	155	74
	9	13175	1.00	0	489	144	2	154	74
	10	13175	1.00	0	500	137	2	153	75
	11	13174	1.00	1	520	131	1	151	75
	12	13174	1.00	4	531	125	1	150	76
	13	13174	1.00	0	548	120	1	147	76
	14	13175	1.00	4	553	115	1	144	76
	15	13175	1.00	2	561	110	1	140	77
	16	13175	1.00	5	566	107	1	135	76
	17	13174	1.00	4	576	102	1	131	76
	18	13174	1.00	0	577	99	1	126	77
	19	13174	1.00	2	583	100	2	120	77
	20	13174	1.00	3	592	97	2	112	77
	21	13173	1.00	1	592	94	2	103	77
	22	13174	1.00	4	592	93	2	92	77
	23	13174	1.00	2	598	92	2	79	77
	24	13174	1.00	0	602	90	2	71	78
	25	13172	1.00	2	605	91	2	64	78
	26	13173	1.00	0	580	89	2	51	78
	27	13173	1.00	0	572	85	1	38	77
	28	13172	1.00	0	575	88	1	49	78
	29	13172	1.00	2	568	92	1	50	79
	30	13174	1.00	1	559	91	1	43	79
	31	13172	1.00	1	558	91	2	42	79
	32	13172	1.00	3	546	93	1	40	80
	33	13172	1.00	0	540	93	1	40	80

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s)				Angle	
				Min	Max	Mean	95% CI	Mean	95% CI
Summer	34	13171	1.00	2	529	94	1	37	79
cont.	35	13172	1.00	1	522	94	1	38	80
	36	13172	1.00	1	518	94	1	38	79
	37	13173	1.00	0	503	95	1	39	79
	38	13172	1.00	1	495	96	1	37	78
	39	13172	1.00	0	481	96	1	36	78
	40	13171	1.00	1	473	97	1	33	77
	41	13171	1.00	1	466	98	1	33	77
	42	13173	1.00	1	456	98	1	35	76
	43	13170	1.00	2	435	99	1	33	76
	44	13172	1.00	1	427	100	1	34	76
	45	13171	1.00	3	422	101	1	33	76
	46	13174	1.00	2	418	101	1	34	76
	47	13172	1.00	1	411	101	1	34	76
	48	13172	1.00	4	413	101	1	32	76
	49	13172	1.00	1	418	102	1	33	75
	50	13172	1.00	3	421	103	1	34	76
	51	13173	1.00	1	415	103	1	35	76
	52	13173	1.00	2	414	102	1	35	76
	53	13171	1.00	2	414	102	1	34	76
	54	13170	1.00	0	415	102	1	35	76
	55	13171	1.00	2	416	101	1	33	76
	56	13172	1.00	3	418	101	1	35	76
	57	13170	1.00	7	413	100	1	37	77
	58	13171	1.00	1	412	99	1	38	77
	59	13171	1.00	0	409	98	1	37	77
	60	13172	1.00	4	407	97	1	37	77
	61	13173	1.00	0	405	97	1	38	78
	62	13169	1.00	5	412	95	1	39	78
	63	13170	1.00	2	410	94	1	40	78
	64	13171	1.00	2	405	93	1	40	78
	65	13170	1.00	4	403	92	1	40	79
	66	13169	1.00	4	396	92	1	40	79
	67	13167	1.00	1	396	91	1	41	79
	68	13169	1.00	9	392	89	1	41	79
	69	13170	1.00	6	387	89	1	38	79
	70	13168	1.00	15	380	87	1	37	79
	71	13168	1.00	14	385	87	1	42	79
	72	13169	1.00	14	386	87	1	44	79
	73	13170	1.00	14	374	86	1	45	78
	74	13169	1.00	18	371	86	1	46	78
	75	13172	1.00	5	374	84	1	43	78
	76	13168	1.00	12	372	84	1	42	78

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s) Min	Max	Mean	95% CI	Angle Mean	95% CI
Summer	77	13168	1.00	4	370	82	1	41	77
cont.	78	13167	1.00	8	371	81	1	39	77
	79	13167	1.00	5	372	82	1	36	76
	80	13168	1.00	3	369	81	1	33	77
	81	13169	1.00	9	357	78	1	28	76
	82	13166	1.00	8	360	78	1	25	77
	83	13167	1.00	7	354	78	1	17	76
	84	13168	1.00	1	357	76	1	12	77
	85	13168	1.00	1	351	76	1	2	76
	86	13163	1.00	1	346	75	1	352	76
	87	13162	1.00	1	343	73	1	346	77
	88	13165	1.00	1	330	72	1	340	77
	89	13161	1.00	0	304	67	1	329	78
	90	13161	1.00	0	250	60	1	323	76
	91	13165	1.00	2	171	48	1	317	74
	92	13162	1.00	0	96	33	0	293	62
Fall	3	10712	1.00	0	253	76	1	546	73
	4	10712	1.00	0	261	75	1	174	74
	5	10697	1.00	1	249	83	1	168	73
	6	10688	1.00	1	223	86	1	170	73
	7	10687	1.00	5	229	89	1	169	74
	8	10688	1.00	1	242	90	1	165	74
	9	10688	1.00	1	223	92	1	163	76
	10	10689	1.00	3	227	91	1	160	76
	11	10687	1.00	2	221	90	1	157	76
	12	10690	1.00	1	225	90	1	144	76
	13	10688	1.00	0	226	88	1	144	75
	14	10689	1.00	1	233	87	1	117	76
	15	10689	1.00	0	237	86	1	89	76
	16	10688	1.00	0	239	85	1	57	75
	17	10687	1.00	0	247	85	1	42	76
	18	10687	1.00	2	246	84	1	35	77
	19	10686	1.00	0	241	82	1	32	77
	20	10685	1.00	0	240	82	1	26	76
	21	10687	1.00	1	240	82	1	23	76
	22	10684	1.00	0	225	81	1	21	76
	23	10688	1.00	4	224	80	1	18	76
	24	10685	1.00	1	218	80	1	12	77
	25	10687	1.00	1	223	77	1	11	78
	26	10686	1.00	1	215	77	1	2	77
	27	10687	1.00	0	217	74	1	357	77
	28	10685	1.00	1	213	75	1	10	77
	29	10685	1.00	0	220	77	1	9	77

Appendix A.10 *continued*

				Magnitude (mm/s)				Angle	
Season	**Depth (m)**	**n**	**n_prop**	**Min**	**Max**	**Mean**	**95% CI**	**Mean**	**95% CI**
Fall	30	10689	1.00	1	225	77	1	9	77
cont.	31	10685	1.00	2	224	78	1	9	75
	32	10684	1.00	1	223	79	1	9	76
	33	10685	1.00	1	222	79	1	9	75
	34	10688	1.00	0	219	78	1	8	75
	35	10687	1.00	1	228	78	1	8	74
	36	10684	1.00	0	224	78	1	9	73
	37	10686	1.00	2	210	75	1	9	73
	38	10688	1.00	0	214	75	1	10	72
	39	10684	1.00	1	214	75	1	10	72
	40	10686	1.00	4	212	76	1	11	72
	41	10684	1.00	5	210	75	1	12	72
	42	10686	1.00	6	208	73	1	13	72
	43	10684	1.00	2	206	73	1	12	73
	44	10685	1.00	3	207	73	1	12	72
	45	10683	1.00	1	206	73	1	14	72
	46	10684	1.00	1	204	72	1	14	72
	47	10683	1.00	1	201	72	1	13	73
	48	10684	1.00	1	211	71	1	14	73
	49	10683	1.00	1	202	71	1	14	72
	50	10685	1.00	1	207	72	1	12	71
	51	10679	1.00	0	202	71	1	12	72
	52	10680	1.00	1	206	71	1	12	71
	53	10683	1.00	2	206	71	1	14	72
	54	10680	1.00	1	205	70	1	14	72
	55	10680	1.00	2	210	69	1	12	72
	56	10676	1.00	2	209	69	1	14	71
	57	10679	1.00	3	205	69	1	16	71
	58	10680	1.00	1	198	67	1	17	72
	59	10686	1.00	1	195	67	1	19	70
	60	10682	1.00	2	196	68	1	22	69
	61	10679	1.00	4	195	65	1	21	71
	62	10682	1.00	2	199	65	1	23	70
	63	10680	1.00	0	191	62	1	25	70
	64	10681	1.00	2	189	61	1	28	70
	65	10679	1.00	5	187	60	1	30	70
	66	10677	1.00	5	178	59	1	33	69
	67	10675	1.00	4	175	57	1	33	69
	68	10677	1.00	5	167	56	1	36	70
	69	10673	1.00	2	165	53	1	35	68
	70	10675	1.00	3	169	53	1	39	67
	71	10678	1.00	2	170	53	1	45	67
	72	10673	1.00	4	162	53	1	52	67

Appendix A.10 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s)				Angle	
				Min	Max	Mean	95% CI	Mean	95% CI
Fall	73	10673	1.00	0	167	52	1	52	68
cont.	74	10668	1.00	2	168	51	1	53	68
	75	10671	1.00	2	173	51	1	56	69
	76	10675	1.00	1	173	49	1	59	70
	77	10675	1.00	1	174	48	1	61	71
	78	10674	1.00	3	176	47	1	62	70
	79	10671	1.00	1	181	47	1	63	71
	80	10675	1.00	1	180	46	1	65	71
	81	10674	1.00	0	177	45	1	64	72
	82	10672	1.00	1	186	45	1	61	73
	83	10674	1.00	1	186	45	1	70	71
	84	10671	1.00	1	183	44	1	54	72
	85	10672	1.00	0	186	43	1	574	73
	86	10667	1.00	0	177	43	1	600	69
	87	10668	1.00	1	180	43	1	621	72
	88	10663	1.00	1	179	42	1	619	66
	89	10669	1.00	1	171	38	0	619	66
	90	10674	1.00	1	137	31	0	622	63
	91	10671	1.00	1	81	22	0	615	58
	92	10672	1.00	0	62	16	0	553	40

Appendix A.11

Summary of current velocity magnitude and direction from the SBOO RTOMS ADCP during 2022. Data are presented by depth bin as seasonal recovered observations (n), minimum (min), maximum (max), and means with 95% confidence intervals (CI). Proportion of recovered observations (n_prop) differed due to variations in data quality (see Appendices A.1 to A.3). Minimum and maximum angles of velocity are not shown due to the circular nature of the measurement.

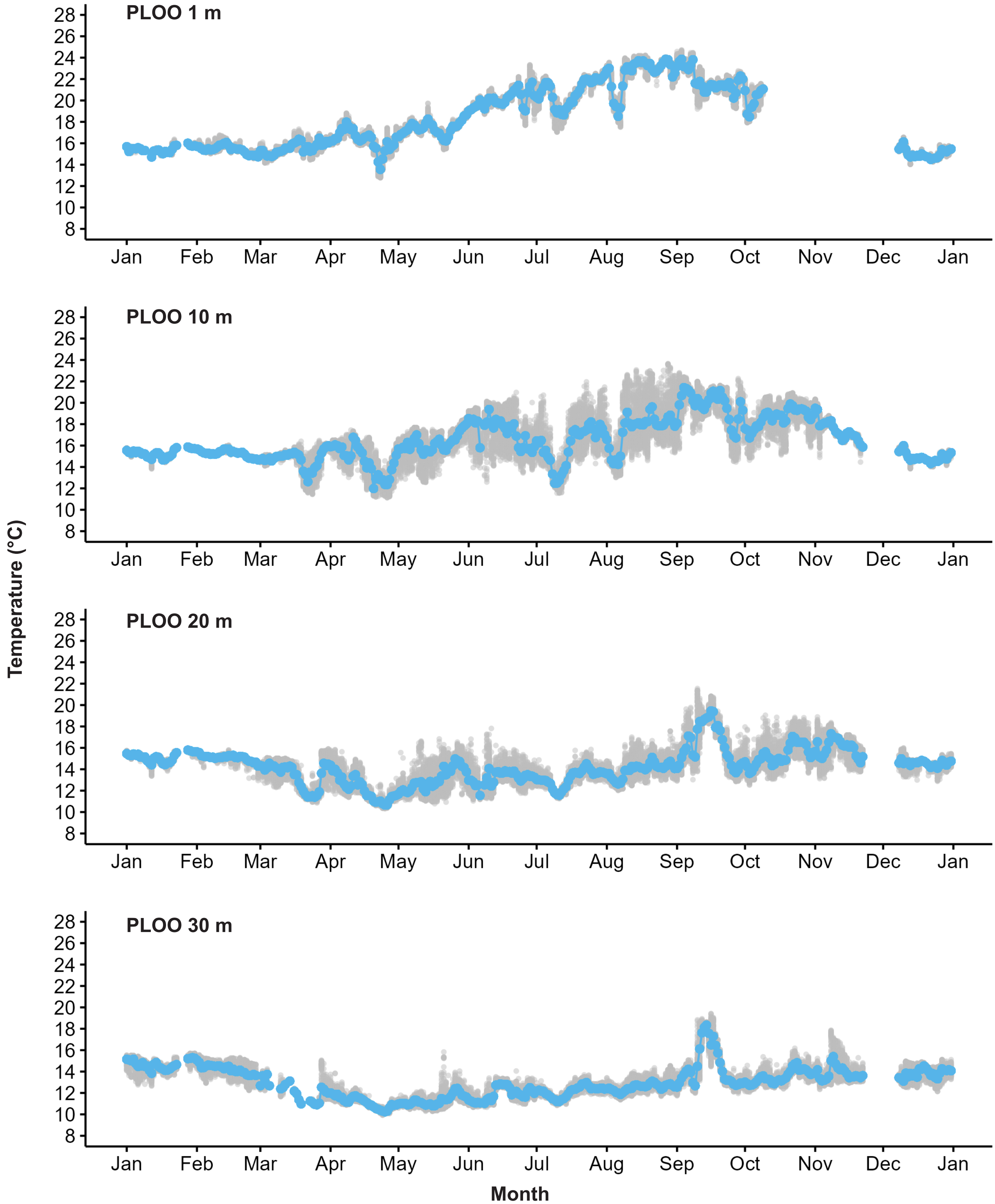
				Magnitude (mm/s)				Angle	
Season	**Depth (m)**	**n**	**n_prop**	**Min**	**Max**	**Mean**	**95% CI**	**Mean**	**95% CI**
Winter	3	12445	1.00	3	297	112	1	178	74
	4	12445	1.00	1	308	116	1	174	75
	5	12446	1.00	1	304	114	1	173	75
	6	12445	1.00	5	300	113	1	172	75
	7	12446	1.00	5	309	113	1	169	75
	8	12445	1.00	0	316	110	1	166	75
	9	12444	1.00	4	295	101	1	169	74
	10	12445	1.00	4	302	102	1	162	75
	11	12446	1.00	4	305	101	1	159	75
	12	12446	1.00	0	294	99	1	157	75
	13	12445	1.00	2	289	97	1	155	76
	14	12446	1.00	1	278	94	1	153	76
	15	12446	1.00	2	265	91	1	149	76
	16	12444	1.00	6	253	86	1	148	75
	17	12444	1.00	2	238	84	1	146	76
	18	12446	1.00	5	260	86	1	143	77
	19	12445	1.00	5	263	88	1	139	78
	20	12445	1.00	8	259	86	1	138	78
	21	12445	1.00	3	249	83	1	134	78
	22	12444	1.00	5	224	75	1	133	79
	23	12445	1.00	0	182	64	1	134	76
	24	12445	1.00	0	203	61	1	144	76
	25	12443	1.00	1	215	62	1	131	76
	26	12446	1.00	2	200	57	1	124	75
	27	12443	1.00	1	190	51	1	106	72
Spring	3	13093	1.00	1	336	80	1	166	71
	4	13092	1.00	1	350	86	1	160	72
	5	13093	1.00	1	335	85	1	157	74
	6	13092	1.00	2	317	83	1	152	74
	7	13091	1.00	4	316	80	1	148	75
	8	13091	1.00	0	293	77	1	141	75
	9	13091	1.00	1	230	71	1	138	75
	10	13092	1.00	3	246	70	1	121	77
	11	13091	1.00	1	253	71	1	112	76
	12	13091	1.00	0	247	70	1	91	75
	13	13091	1.00	4	241	70	1	75	74
	14	13090	1.00	2	236	71	1	64	74
	15	13091	1.00	1	216	70	1	48	75
	16	13090	1.00	3	203	68	1	32	75

Appendix A.11 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s) Min	Max	Mean	95% CI	Angle Mean	95% CI
Winter	17	13090	1.00	1	198	67	1	26	76
cont.	18	13088	1.00	1	207	70	1	40	77
	19	13089	1.00	1	196	73	1	49	77
	20	13088	1.00	1	189	73	1	52	76
	21	13090	1.00	0	185	73	1	49	77
	22	13087	1.00	1	172	68	1	40	78
	23	13089	1.00	1	155	62	1	17	75
	24	13089	1.00	4	160	63	1	7	74
	25	13089	1.00	3	155	64	1	30	77
	26	13088	1.00	9	148	63	1	36	75
	27	13090	1.00	11	132	57	1	30	75
Summer	3	13240	1.00	4	261	78	1	541	74
	4	13240	1.00	5	340	95	1	169	74
	5	13239	1.00	1	335	92	1	165	74
	6	13239	1.00	0	350	85	1	163	75
	7	13239	1.00	0	359	82	1	160	75
	8	13238	1.00	0	363	75	1	161	74
	9	13239	1.00	4	368	67	1	166	74
	10	13239	1.00	3	371	65	1	162	74
	11	13239	1.00	1	379	65	1	164	74
	12	13239	1.00	0	381	62	1	163	75
	13	13238	1.00	3	383	62	1	98	74
	14	13237	1.00	2	377	61	1	32	75
	15	13237	1.00	0	373	62	1	30	76
	16	13238	1.00	1	376	62	1	23	77
	17	13239	1.00	1	373	63	1	24	78
	18	13237	1.00	1	363	66	1	33	78
	19	13236	1.00	9	366	70	1	34	79
	20	13235	1.00	5	348	70	1	35	79
	21	13236	1.00	5	344	70	1	36	79
	22	13237	1.00	3	341	68	1	31	79
	23	13236	1.00	0	324	63	1	19	79
	24	13237	1.00	0	313	60	1	14	78
	25	13238	1.00	1	303	59	1	24	77
	26	13237	1.00	1	289	57	1	26	75
	27	13236	1.00	3	265	52	1	19	74
Fall	3	4840	1.00	3	220	100	2	179	71
	4	4814	0.99	5	327	124	2	160	72
	5	4809	0.99	1	300	118	2	156	72
	6	4810	0.99	7	269	114	2	153	73
	7	4810	0.99	6	245	107	2	151	73
	8	4809	0.99	2	222	104	2	148	73
	9	4812	0.99	1	206	97	1	147	70

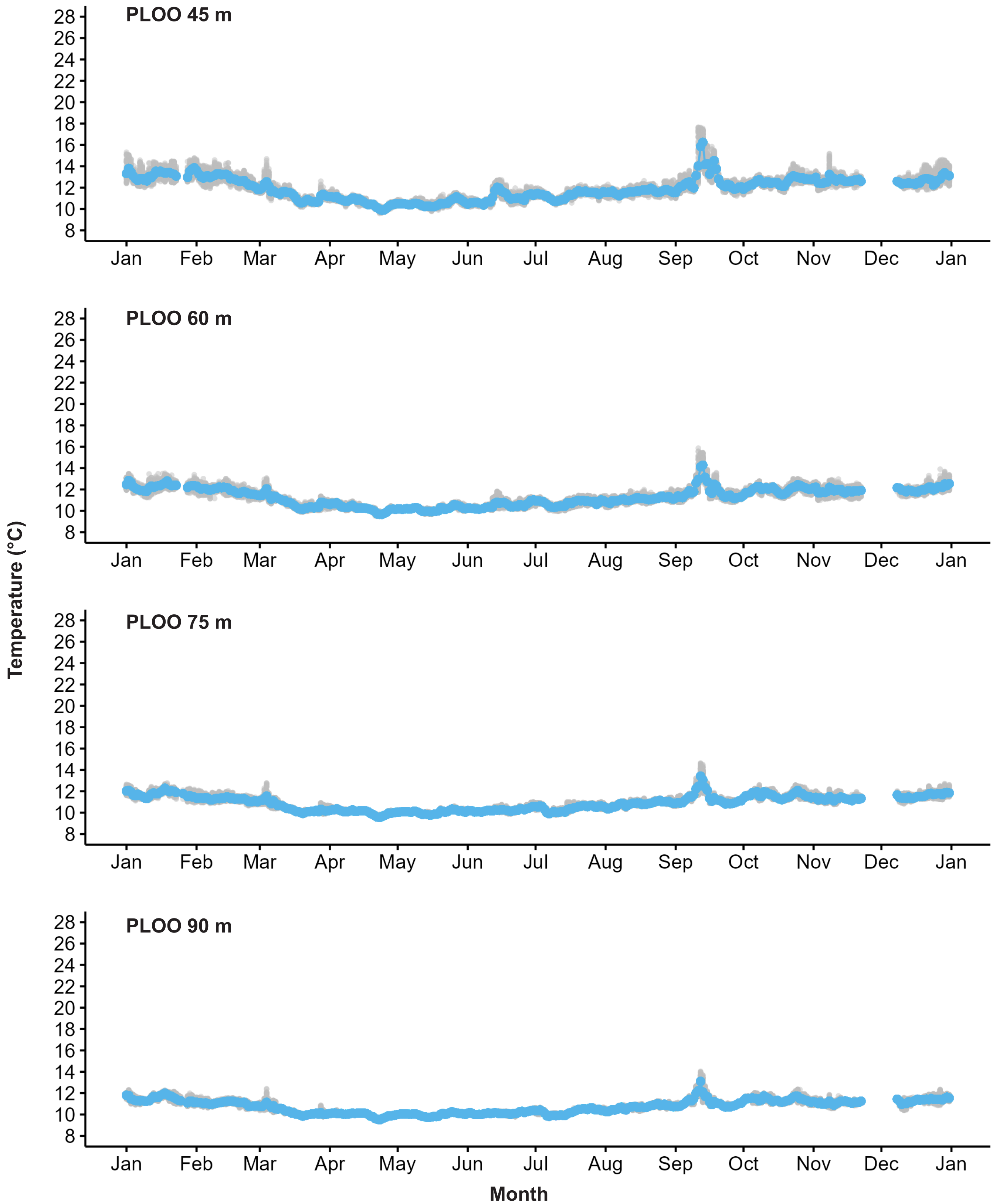
Appendix A.11 *continued*

Season	Depth (m)	n	n_prop	Magnitude (mm/s)				Angle	
				Min	Max	Mean	95% CI	Mean	95% CI
Fall	10	4810	0.99	2	172	92	1	137	74
cont.	11	4809	0.99	5	165	89	1	131	76
	12	4809	0.99	4	172	85	1	106	77
	13	4810	0.99	4	193	84	1	71	79
	14	4811	0.99	1	191	82	1	40	77
	15	4810	0.99	1	196	81	1	25	78
	16	4810	0.99	4	188	82	1	14	77
	17	4809	0.99	5	186	80	1	15	80
	18	4811	0.99	11	185	81	1	20	80
	19	4810	0.99	12	177	79	1	25	82
	20	4809	0.99	8	173	81	1	25	80
	21	4810	0.99	3	168	79	1	20	78
	22	4811	0.99	1	157	75	1	18	77
	23	4811	0.99	2	157	71	1	11	78
	24	4809	0.99	0	145	66	1	10	81
	25	4809	0.99	1	138	61	1	14	81
	26	4809	0.99	2	128	56	1	9	81
	27	4809	0.99	1	114	49	1	13	81



Appendix A.12

Temperature, salinity, DO, pH (total), chlorophyll *a*, CDOM, turbidity, nitrate + nitrite, BOD, and xCO_2 recorded at various depths by the PLOO and SBOO RTOMS during 2022. Grey points represent raw data and blue points represent daily averaged data.



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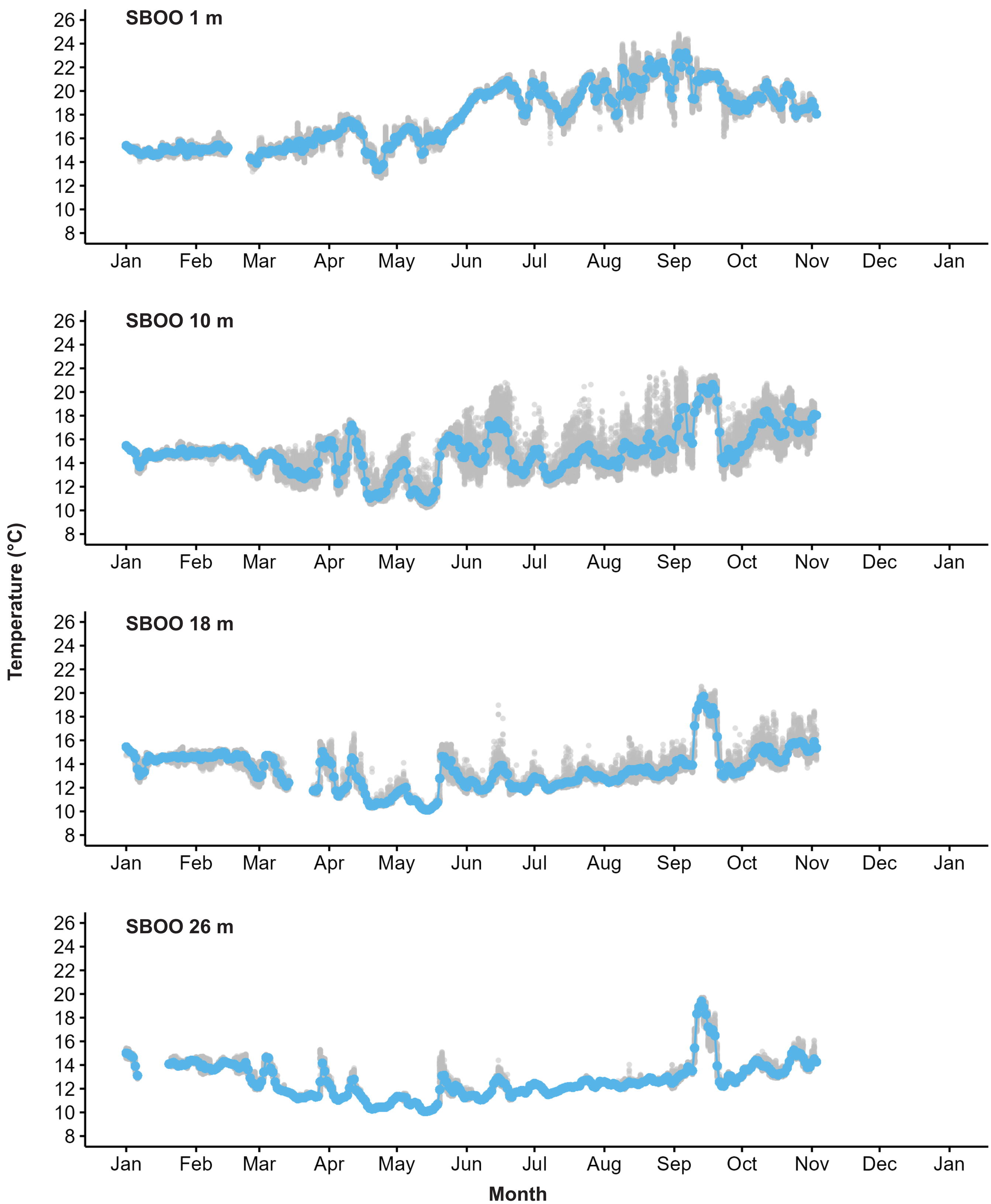

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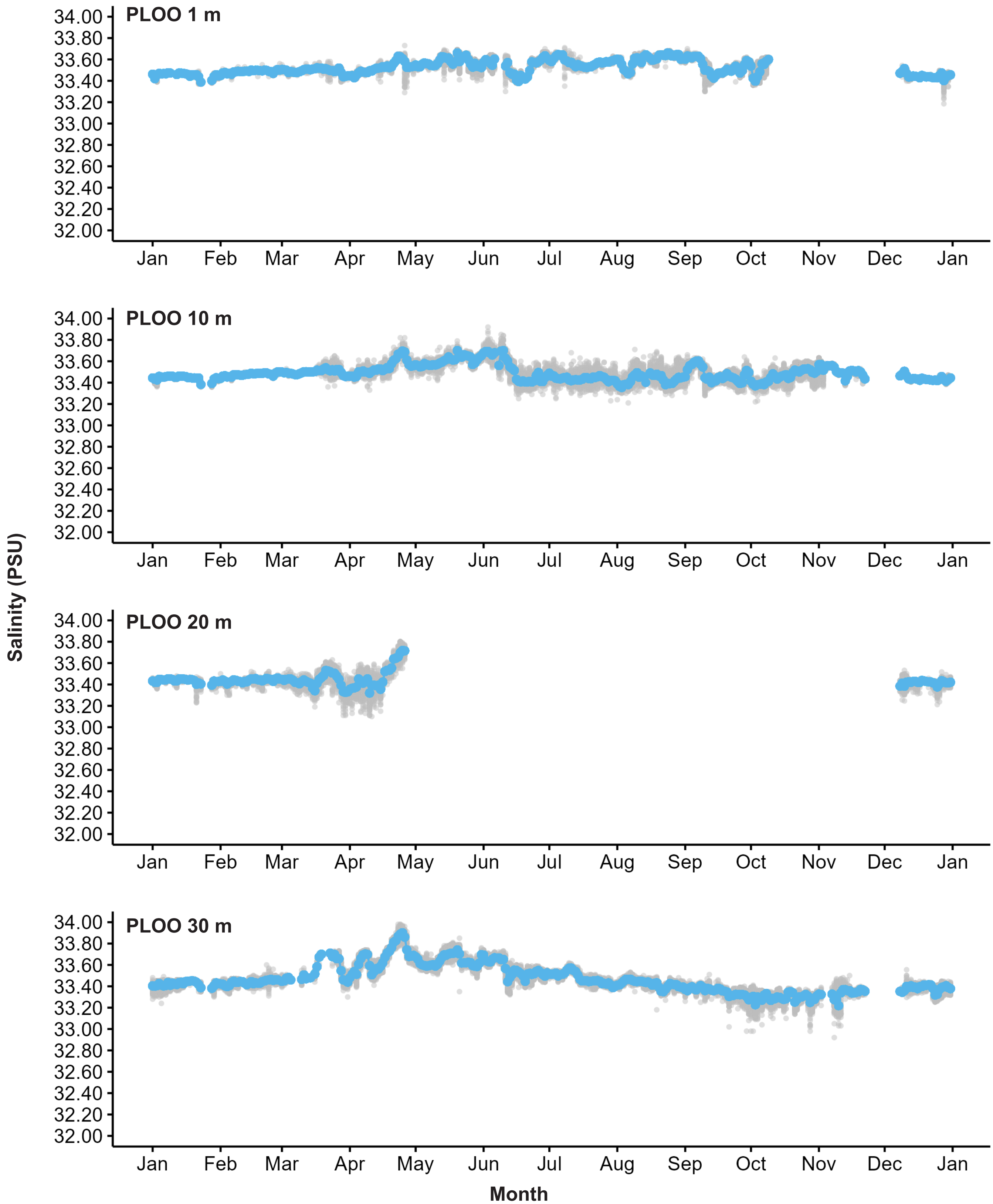

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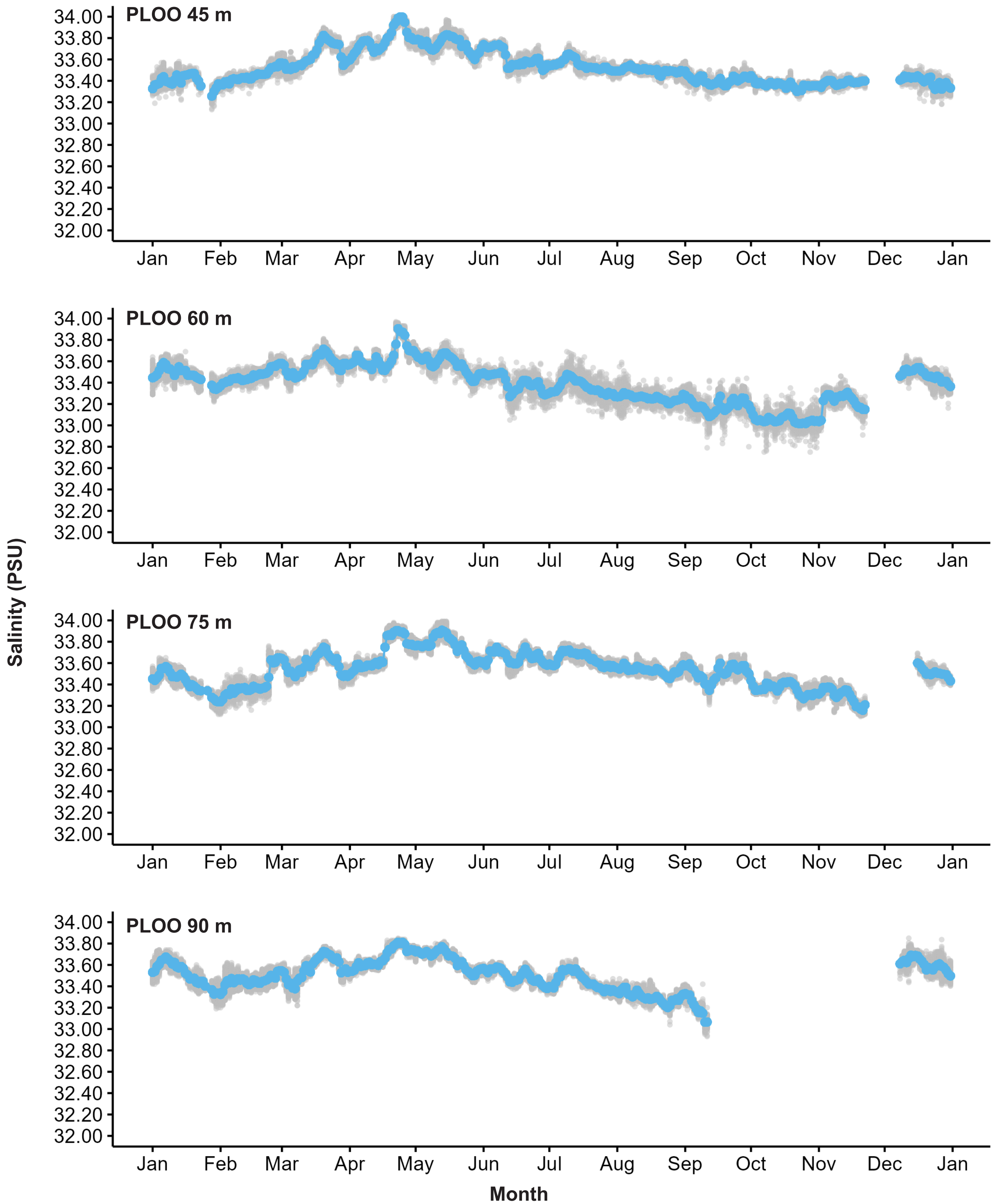

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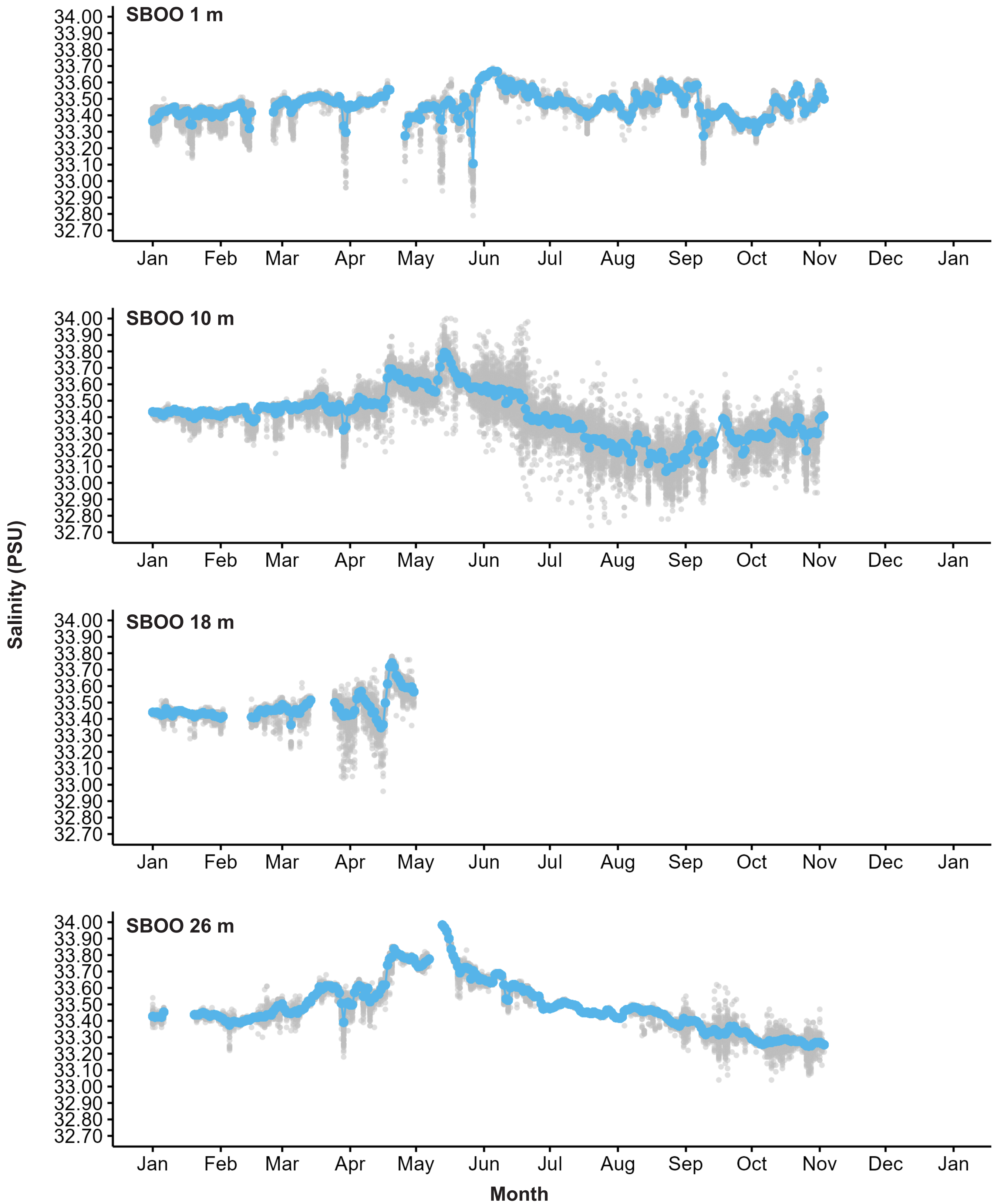

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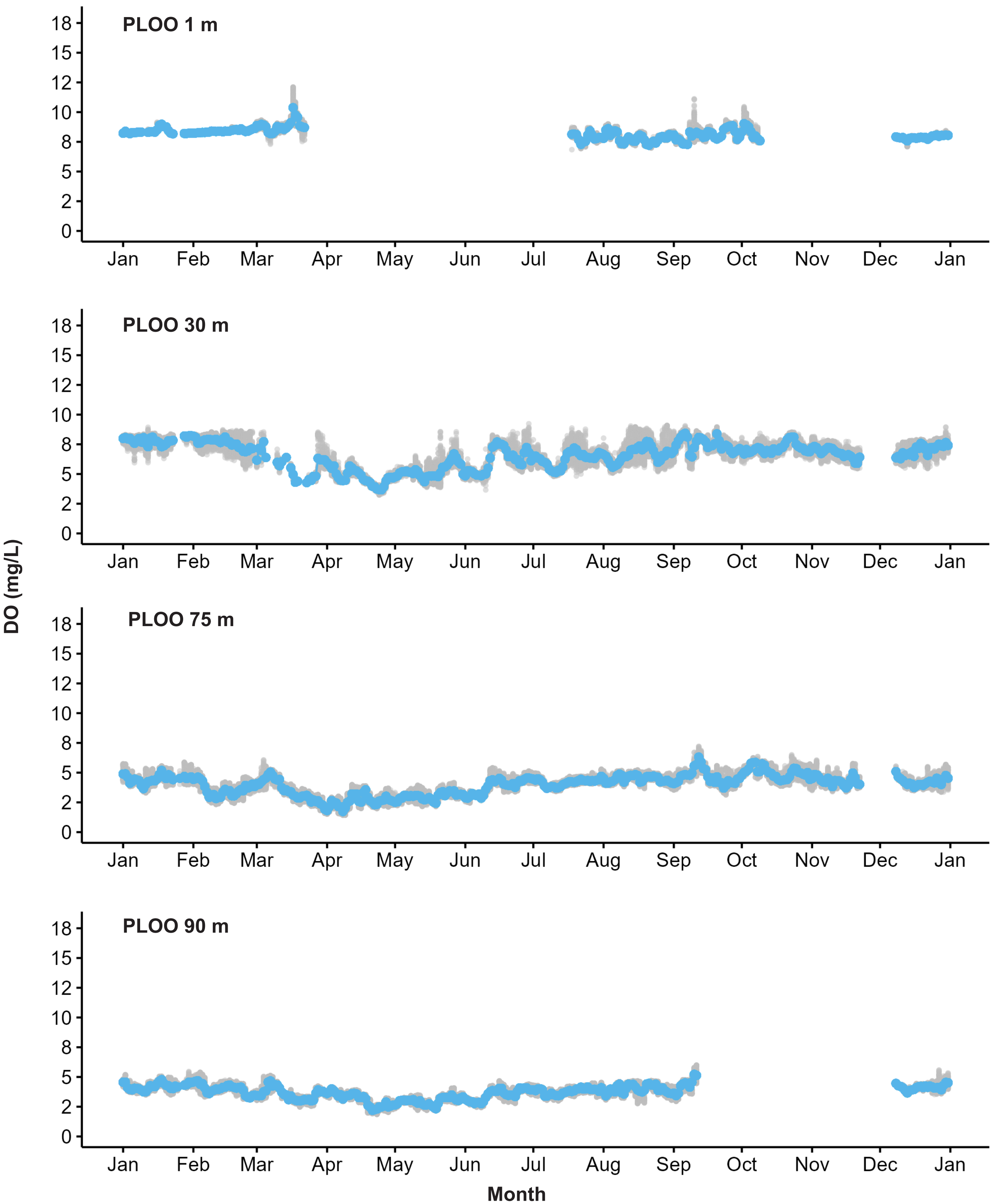

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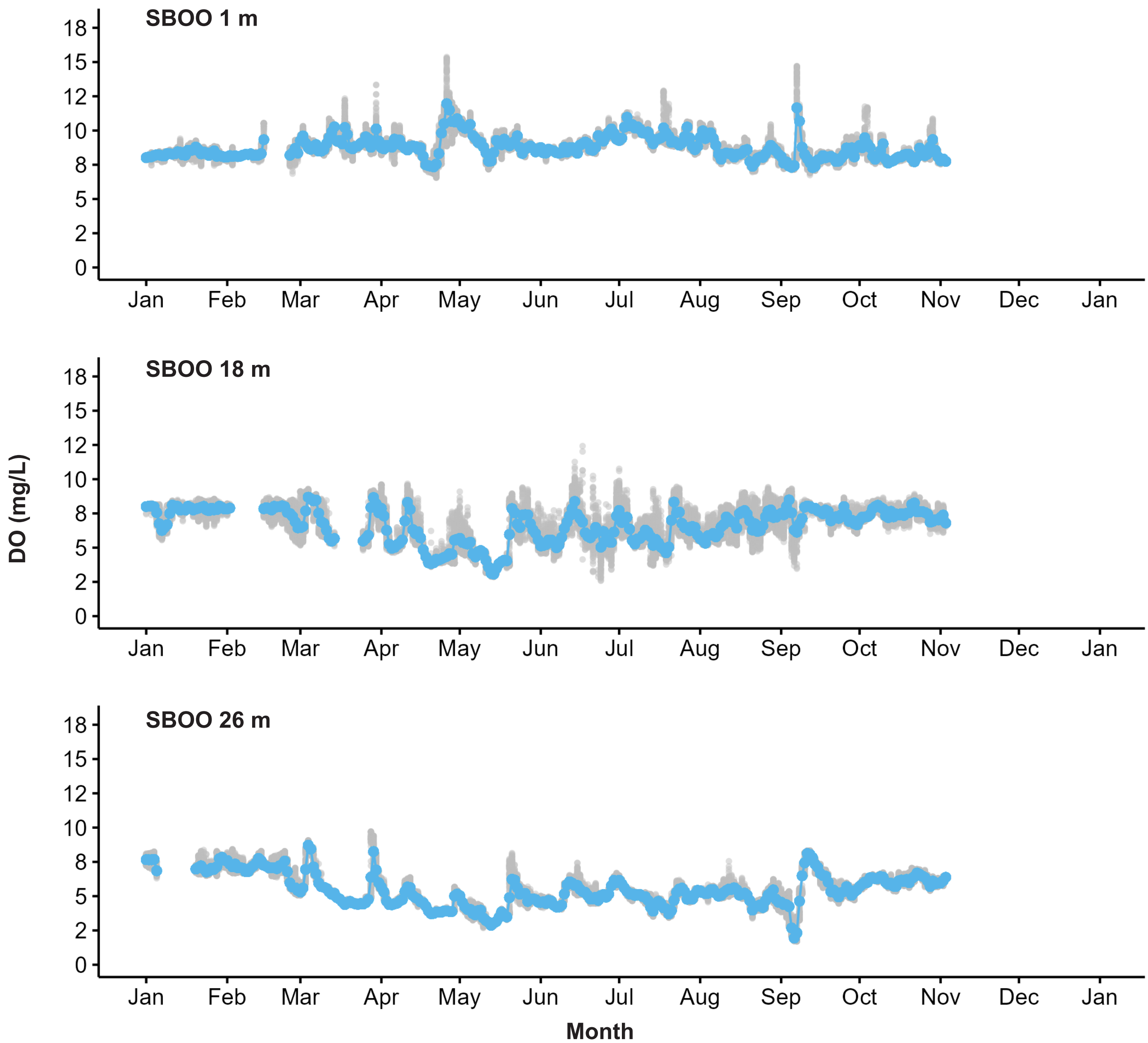

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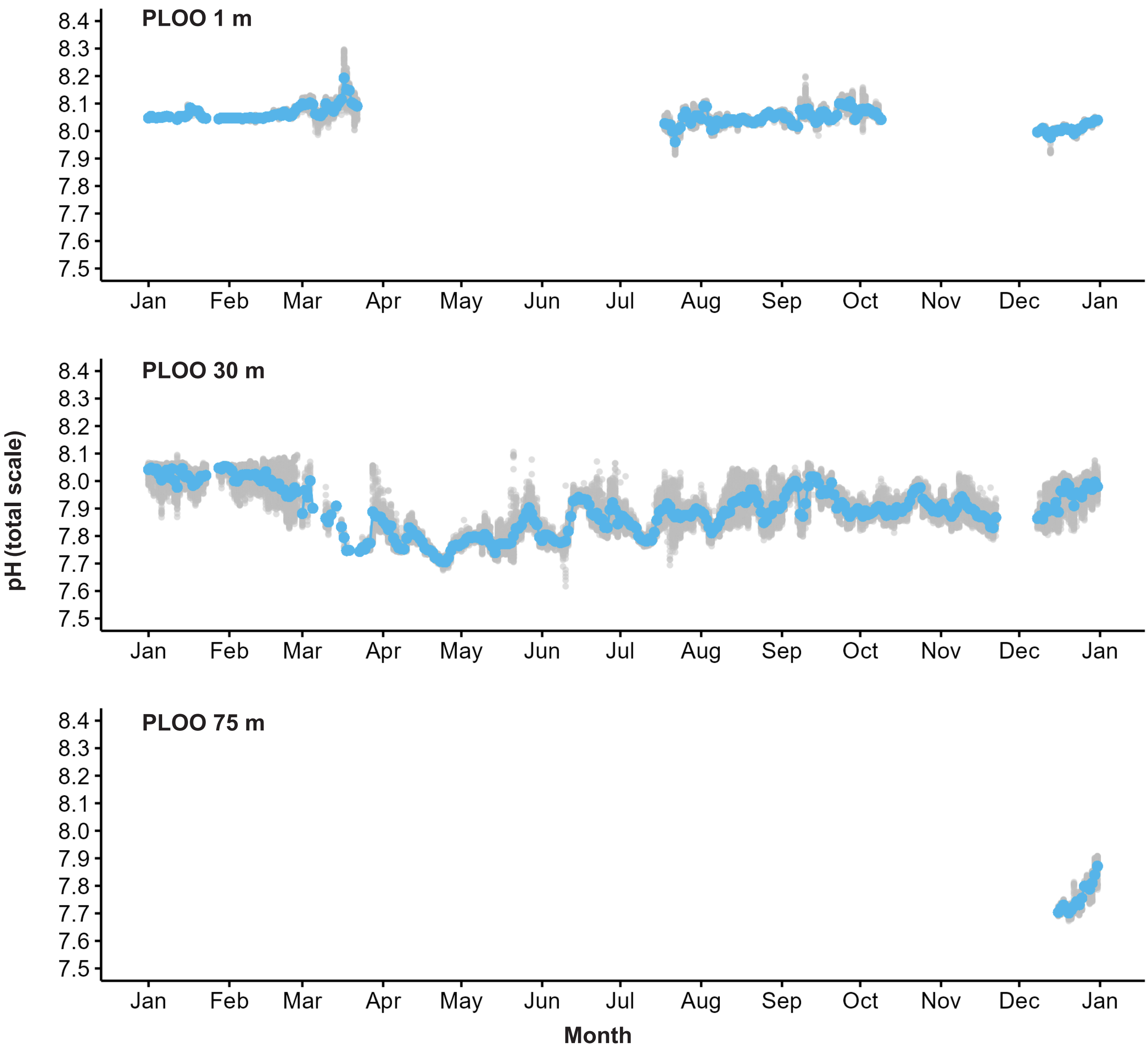

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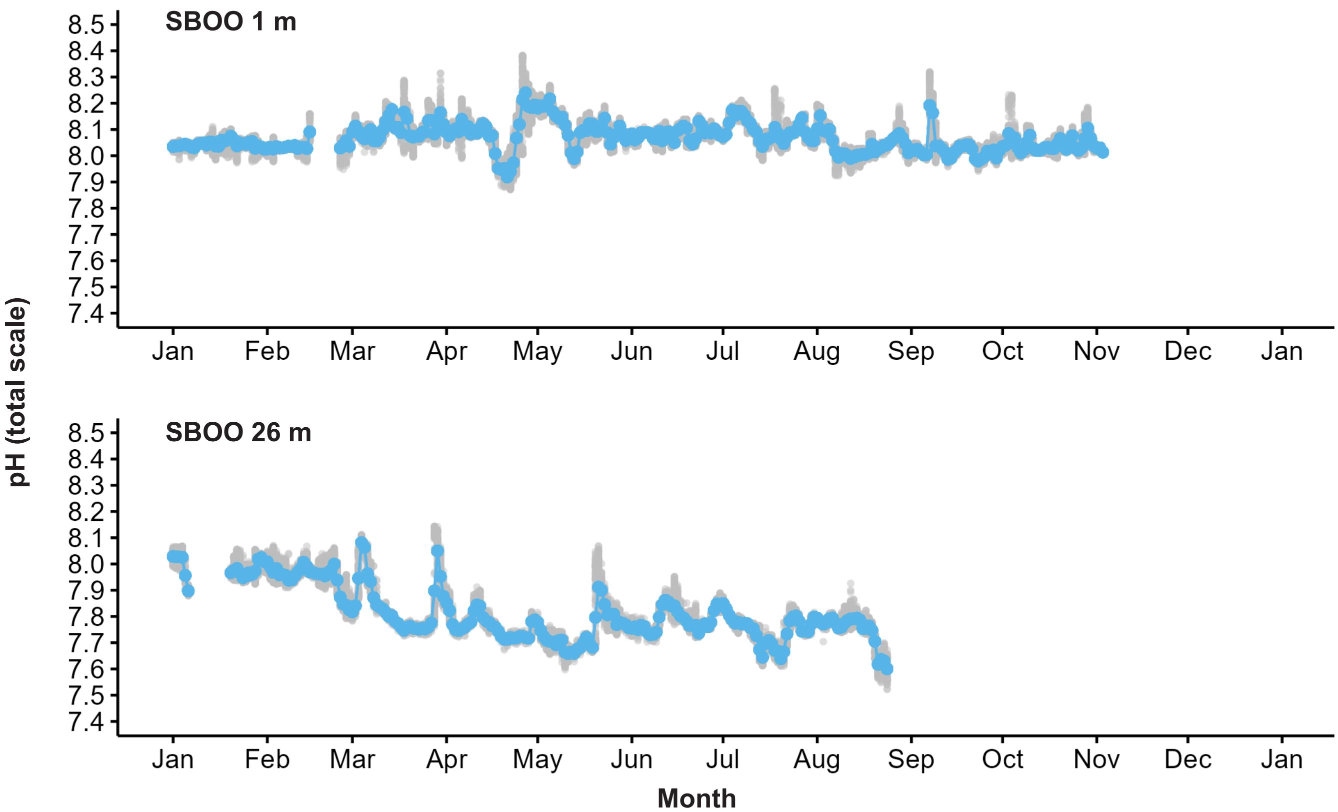

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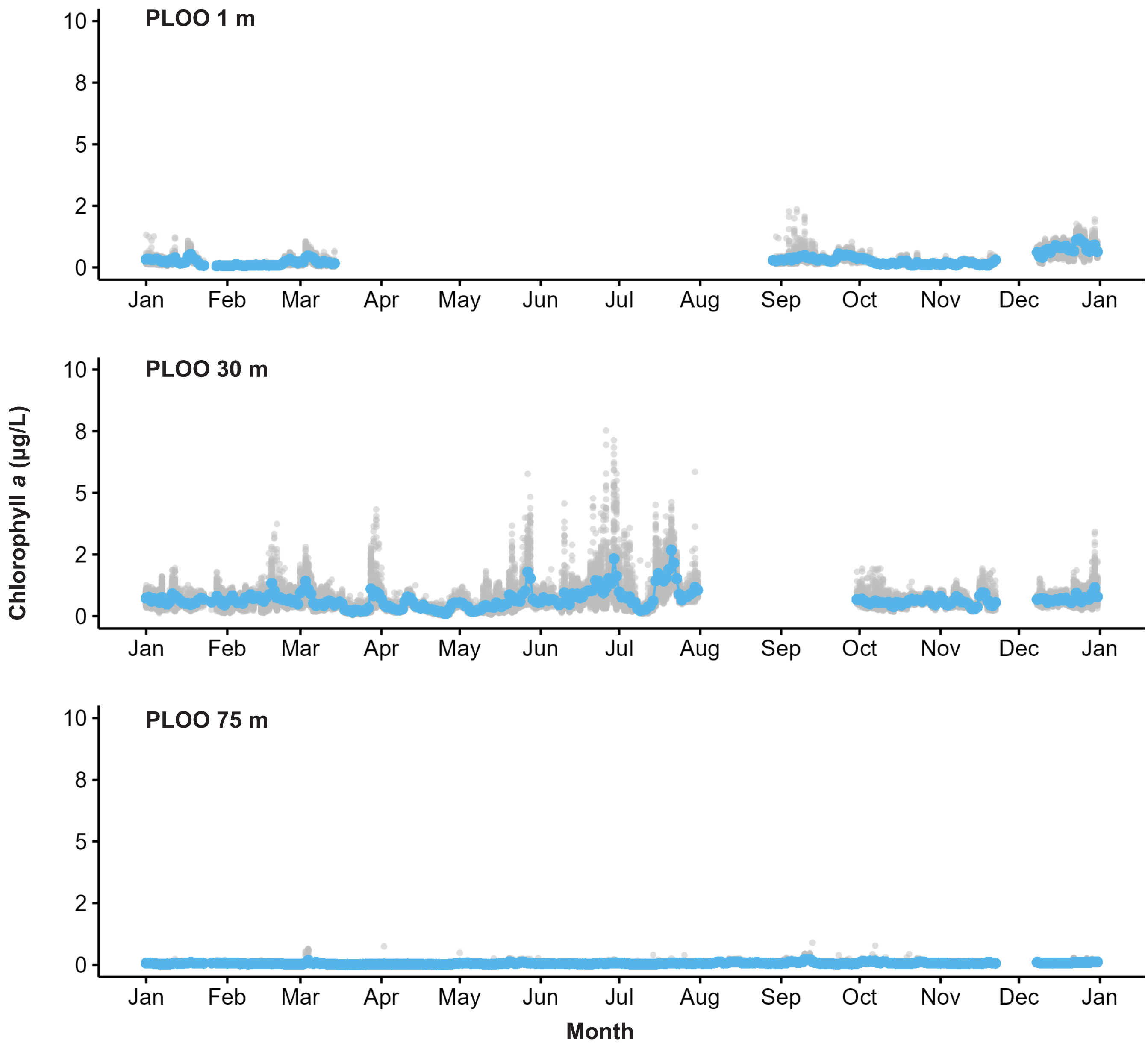

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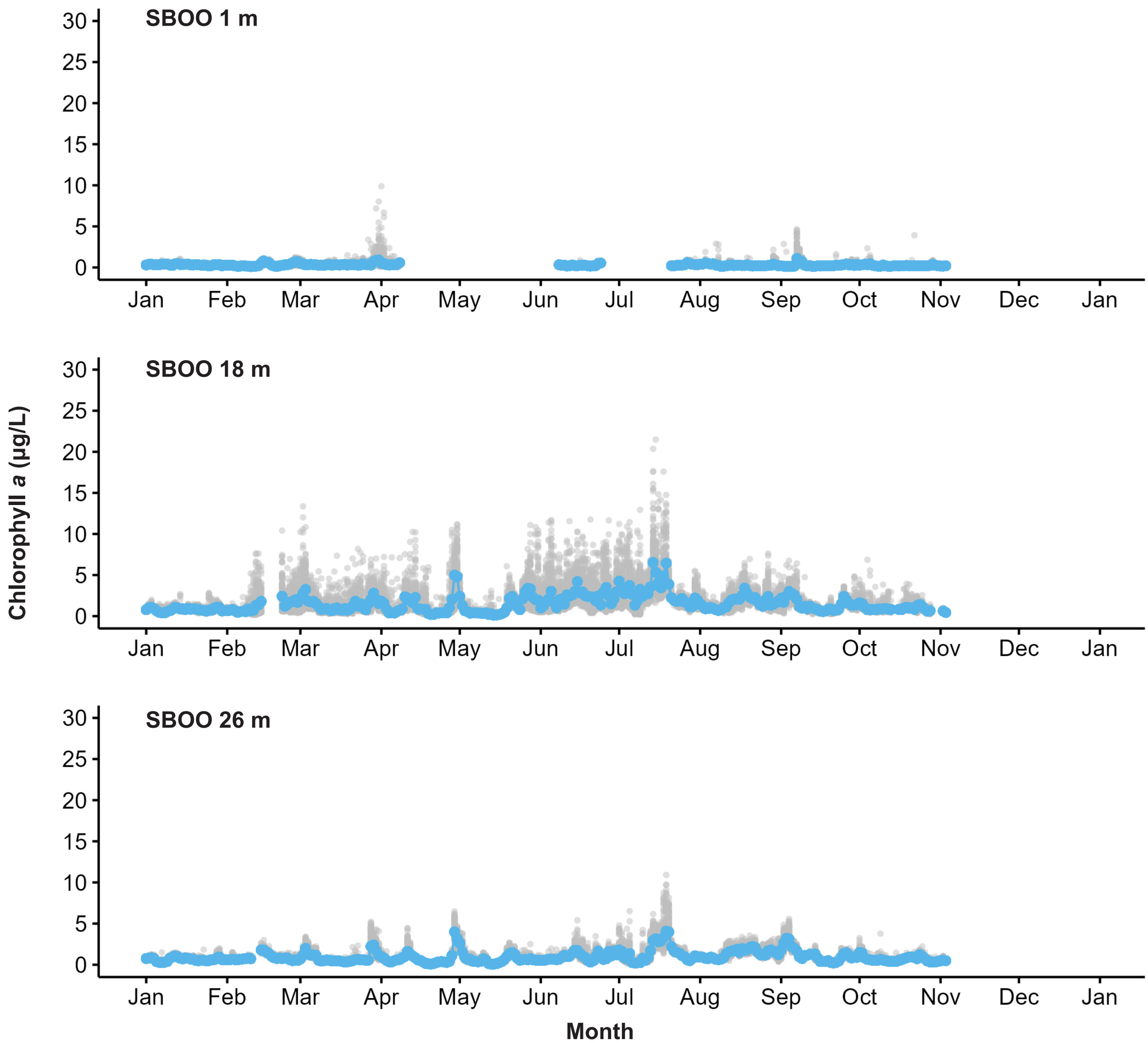

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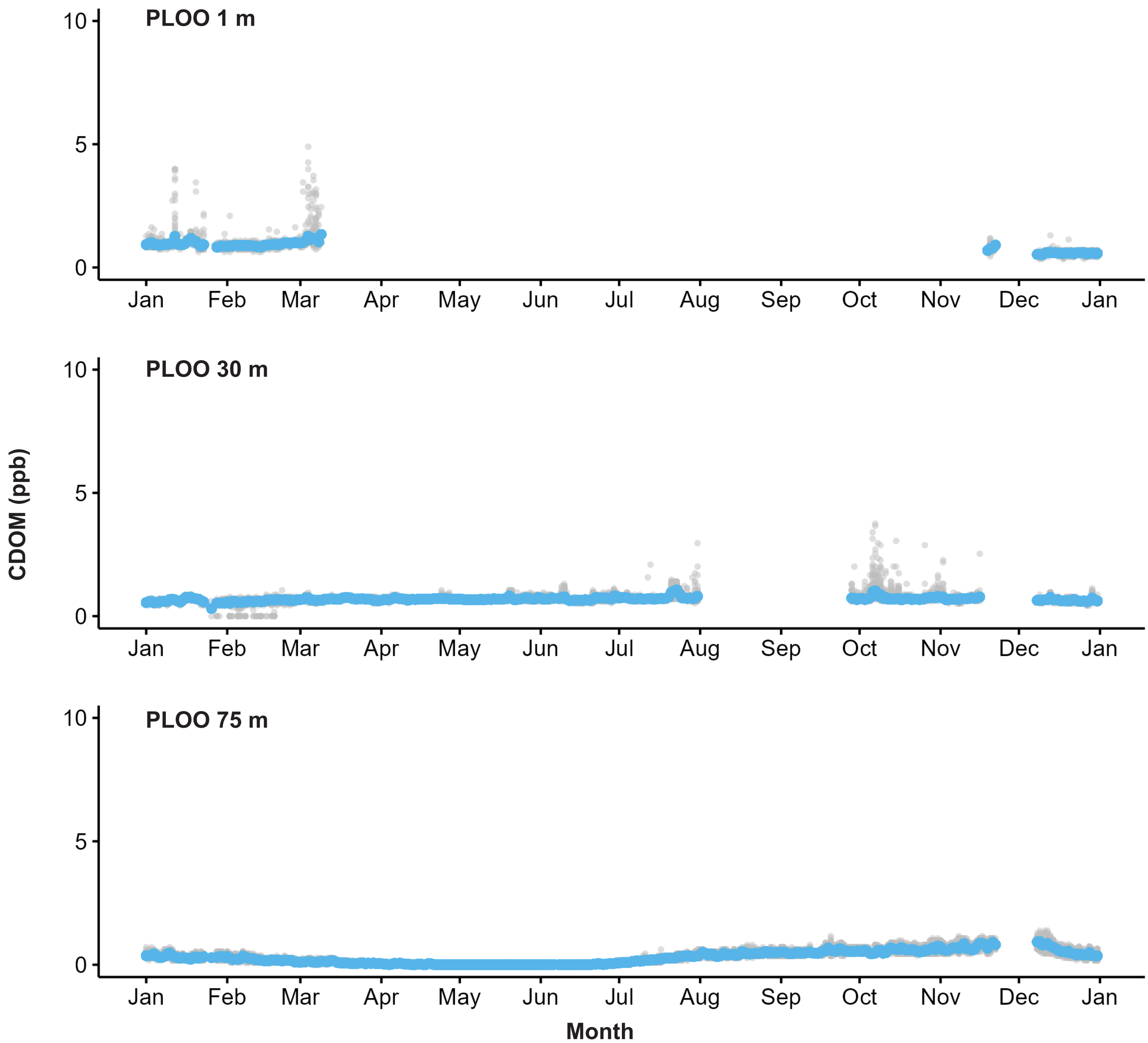

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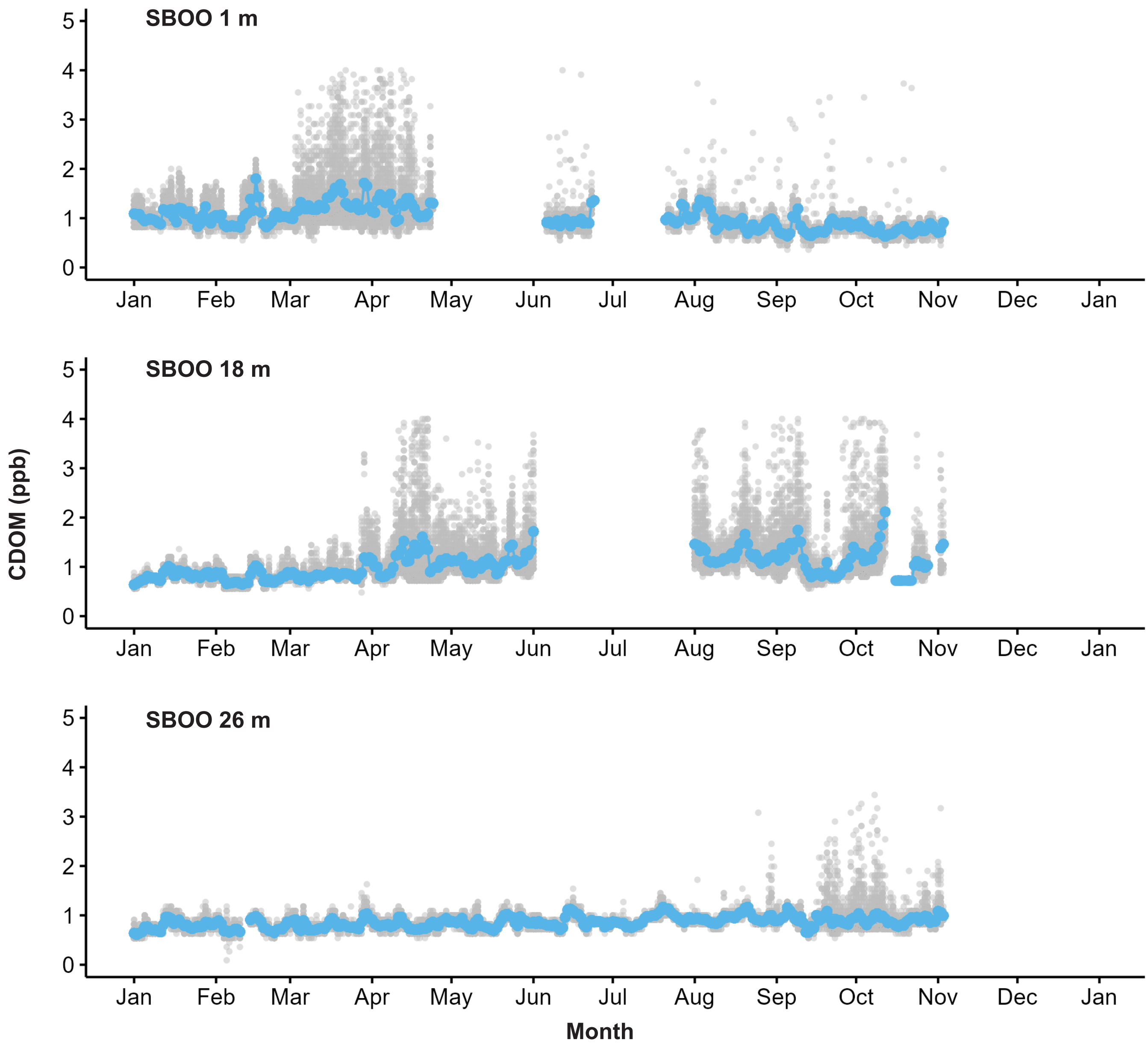

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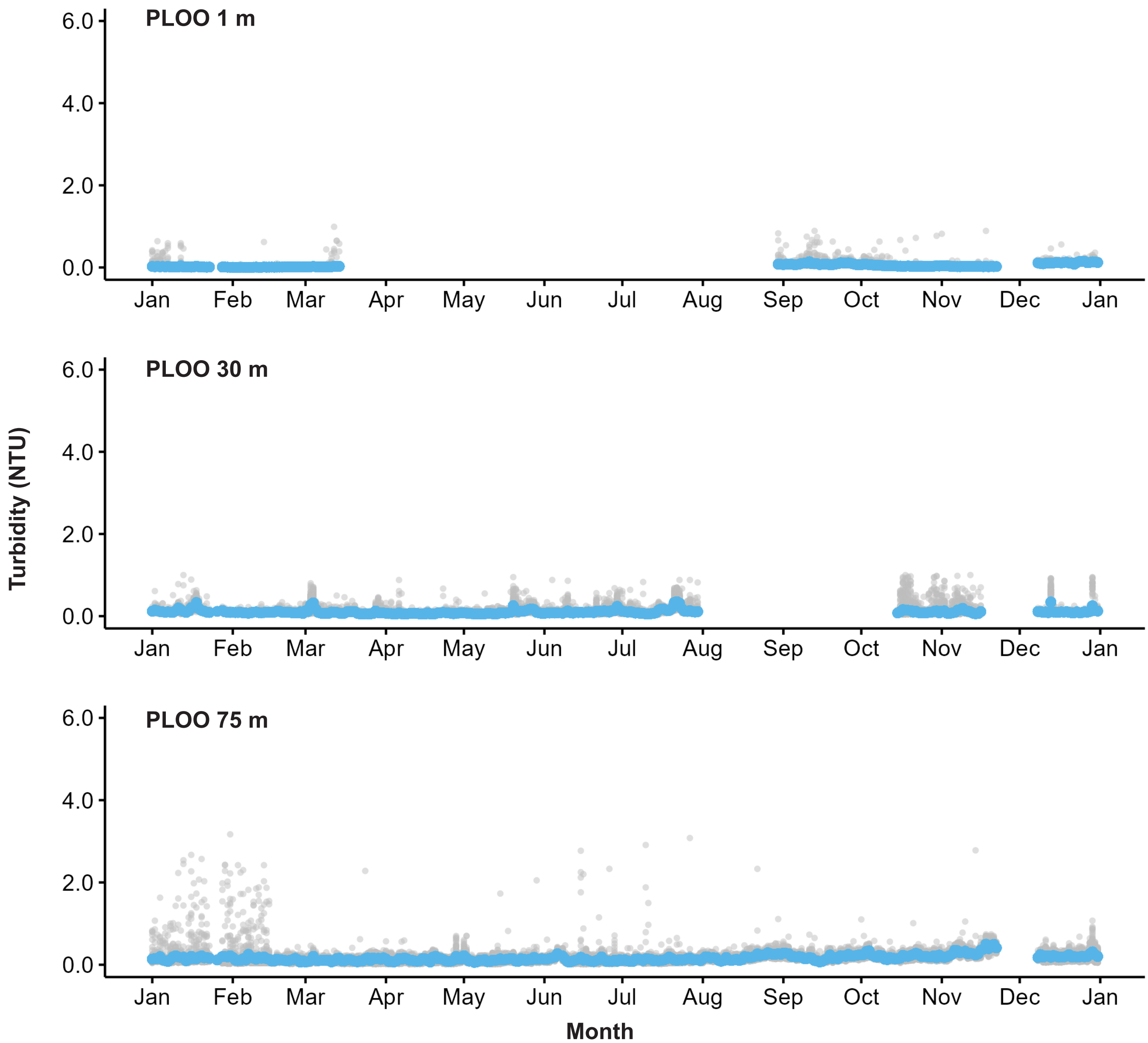

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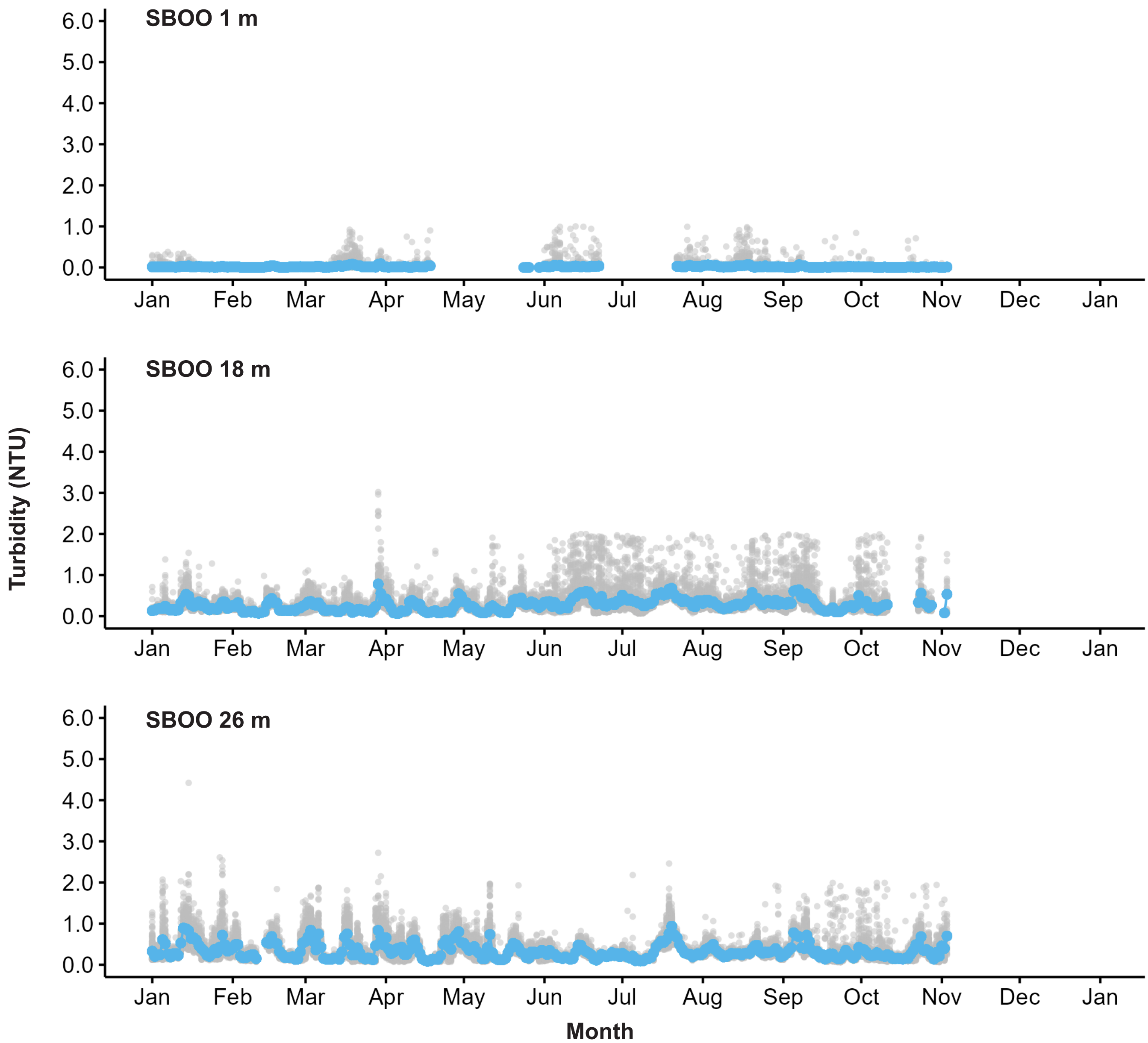

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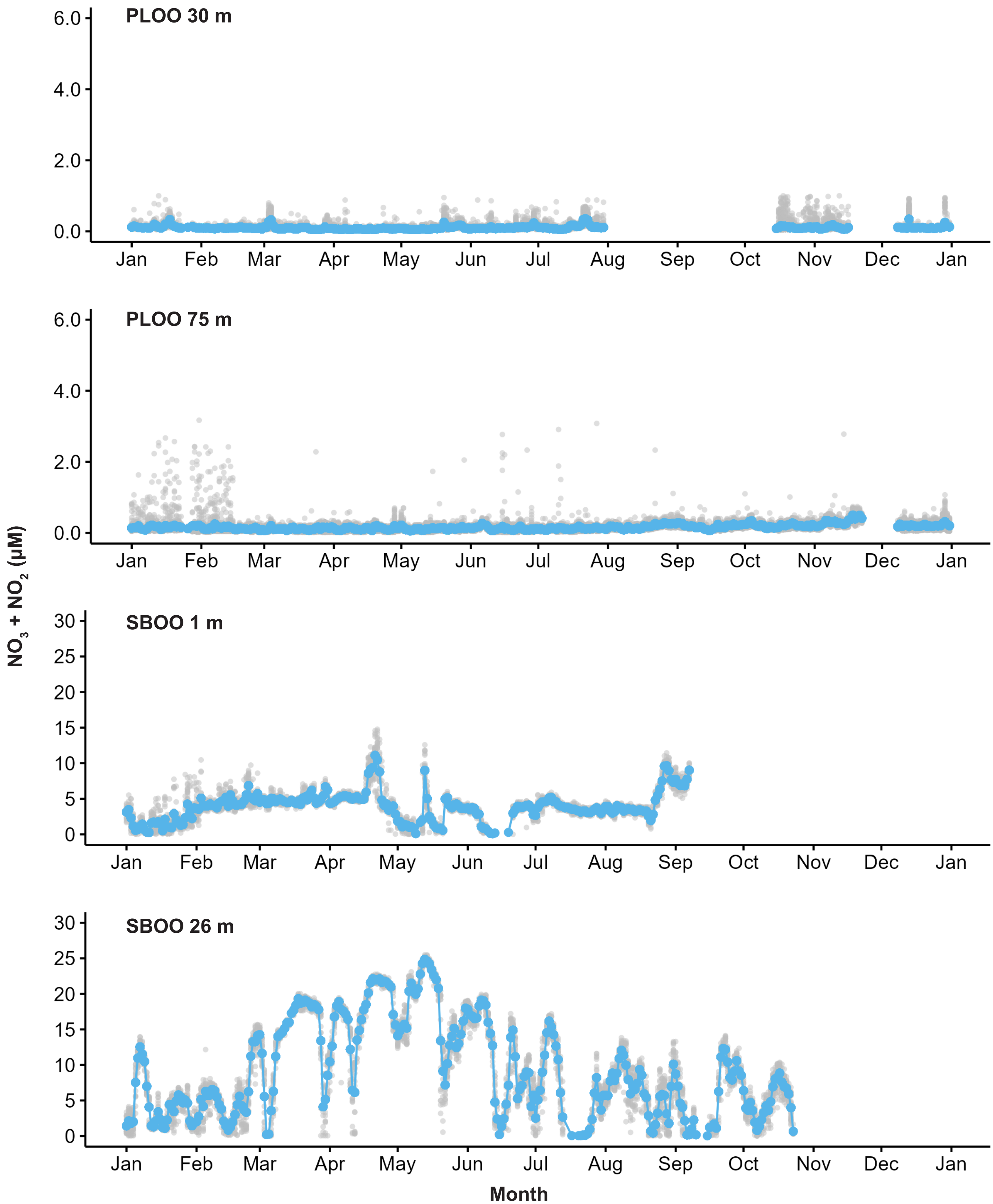

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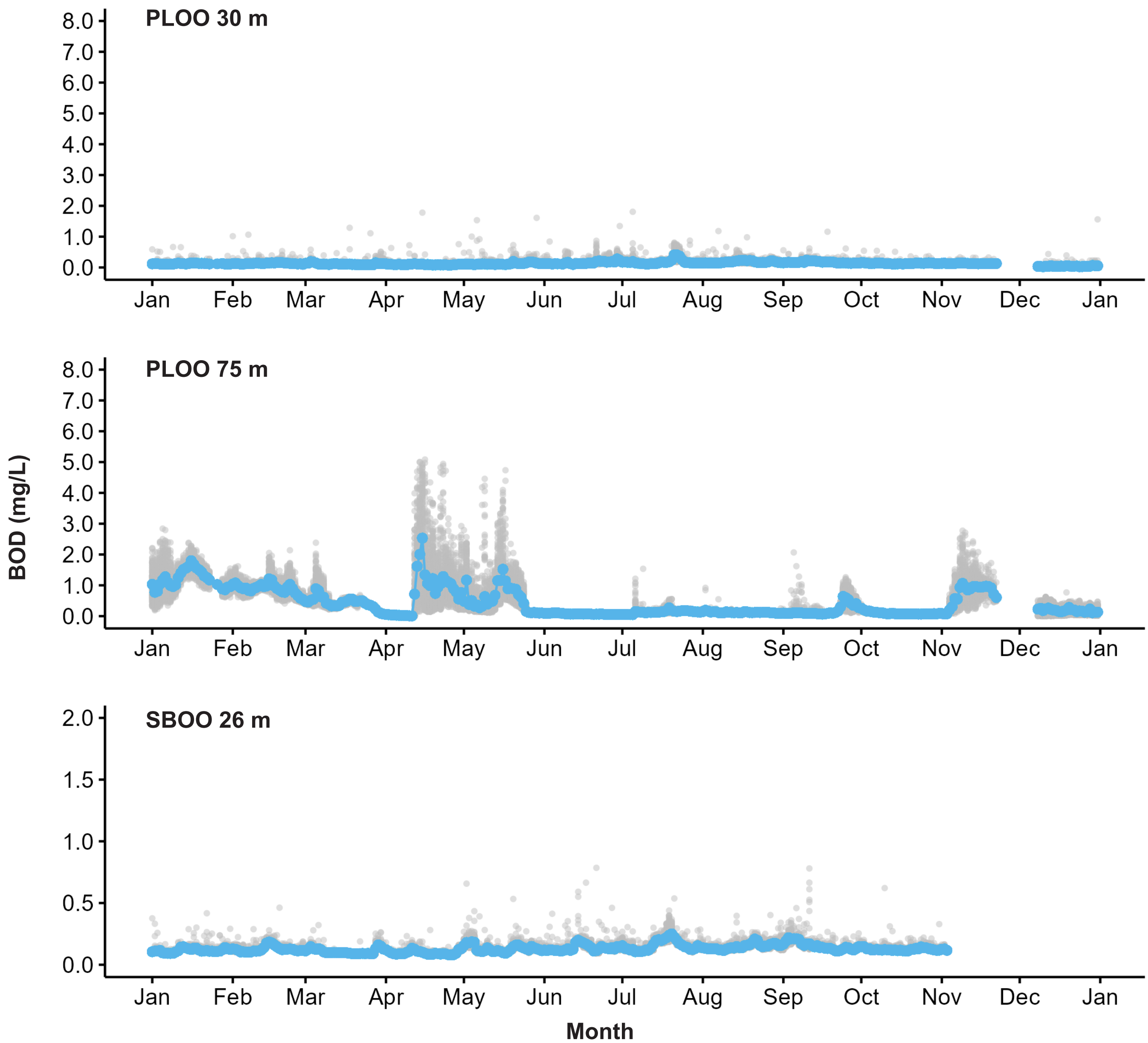

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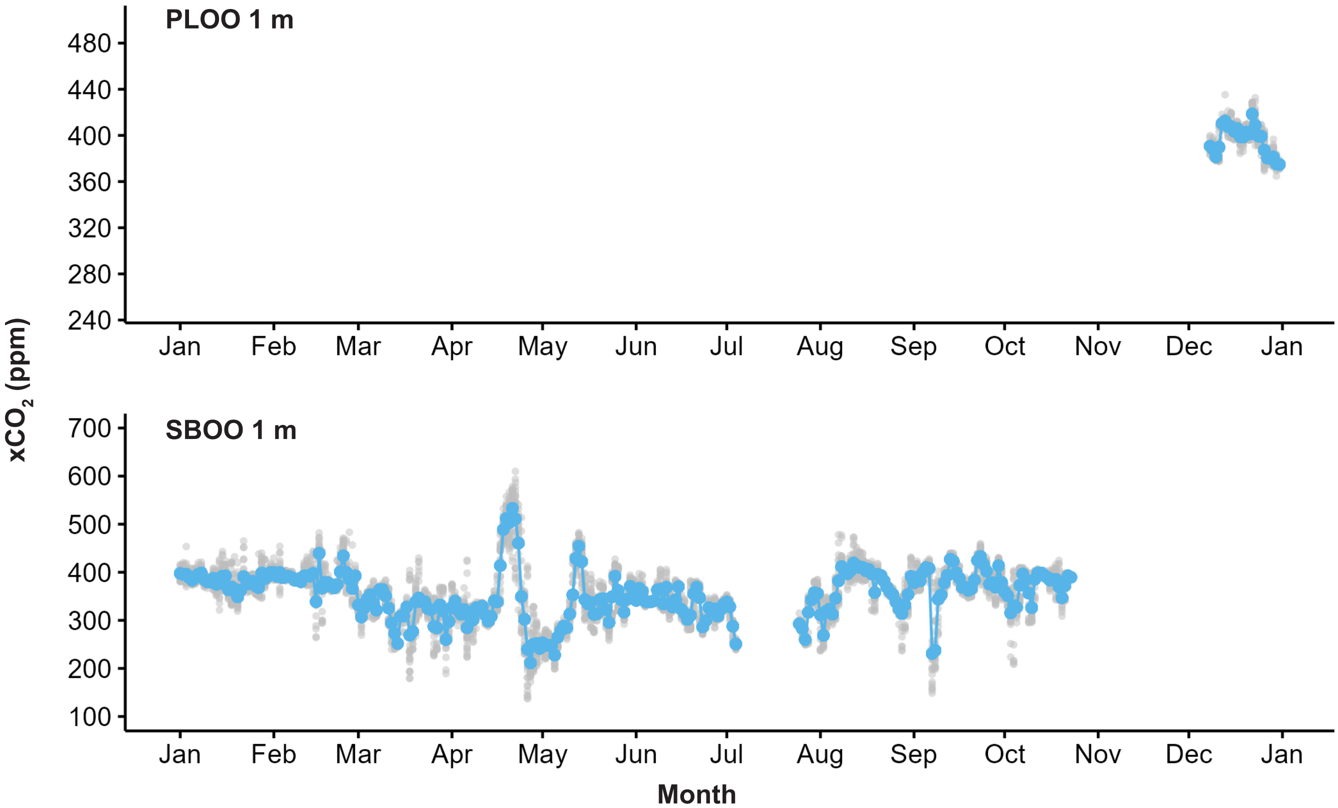

Appendix A.12 *continued*

Appendix A.13

Water quality objectives for water-contact areas, California Ocean Plan (SWRCB 2015).

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

(a) 30-day Geometric Mean - The following standards are based on the geometric mean of the five most recent samples from each site:

1) Total coliform density shall not exceed 1000 CFU/100 mL
2) Fecal coliform density shall not exceed 200 CFU/100 mL
3) *Enterococcus* density shall not exceed 35 CFU/100 mL

(b) Single Sample Maxium:

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

B. Physical Characteristics

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

C. Chemical Characteristics

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

Appendix A.14

Compliance rates for the three geometric mean water-contact standards and for the four single sample maximum water contact standards for PLOO monitoring stations sampled during 2022. PLOO offshore stations are sampled quarterly, and total and fecal coliform bacteria are not analyzed at these stations; ns = not sampled.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Geometric Mean												
Shore Stations												
Total	100	100	100	100	100	100	100	100	100	100	100	100
Fecal	100	100	100	100	100	100	100	100	100	100	100	100
Entero	100	98	100	98	100	100	100	100	100	100	85	100
Kelp Stations												
Total	100	100	100	100	100	100	100	100	100	100	100	100
Fecal	100	100	100	100	100	100	100	100	100	100	100	100
Entero	100	100	100	100	100	100	100	100	100	100	100	100
Single Sample Maximum												
Shore Stations												
Total	100	100	100	100	100	100	100	100	100	100	100	100
Fecal	100	100	100	100	100	100	100	98	100	100	98	100
Entero	100	97	98	97	100	98	97	100	100	94	85	97
F:T	100	100	100	100	100	100	100	100	100	100	95	100
Kelp Stations												
Total	100	100	100	100	100	100	100	100	100	100	100	100
Fecal	100	100	100	100	100	100	100	100	100	100	100	100
Entero	100	100	100	100	100	100	100	100	100	100	100	100
F:T	100	100	100	100	100	100	100	100	100	100	100	100
Offshore Stations												
Entero	ns	95	ns	ns	95	ns	ns	94	ns	ns	94	ns

Appendix B

Benthic Conditions

2022 Supplemental Analyses

Appendix B.1

Particle size classification schemes (based on Folk 1980) used in the analysis of sediments during 2022. Included is a subset of the Wentworth scale presented as "phi" categories with corresponding Horiba channels, sieve sizes, and size fractions.

Wentworth Scale

	Horiba[a]				
Phi size	**Min µm**	**Max µm**	**Sieve Size**	**Sub-Fraction**	**Fraction**
-1	—	—	SIEVE_2000	Granules	Coarse Particles
0	1000	2000	SIEVE_1000	Very coarse sand	Coarse Particles
1	500	1000	SIEVE_500	Coarse sand	Med-Coarse Sands
2	250	500	SIEVE_250	Medium sand	Med-Coarse Sands
3	125	250	SIEVE_125	Fine sand	Fine Sands
3.5	88	125	SIEVE_75	Very fine sand	Fine Sands
4	62.5	88	SIEVE_63	Very fine sand	Fine Sands
5	31	62.5	SIEVE_0[b]	Coarse silt	Fine Particles[c]
6	15.6	31	—	Medium silt	Fine Particles[c]
7	7.8	15.6	—	Fine silt	Fine Particles[c]
8	3.9	7.8	—	Very fine silt	Fine Particles[c]
9	≤	3.9	—	Clay	Fine Particles[c]

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

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

[c] Fine particles also referred to as percent fines

Appendix B.2

Summary of visual observations for each PLOO and SBOO station sampled during 2022. Visual observations are from sieved "grunge" (i.e., particles retained on 1-mm mesh screen and preserved with infauna for benthic community analysis).

		Winter 2022	Summer 2022
PLOO			
88-m Stations	B11	coarse sand; shell hash	gravel; shell hash
	B8	—	—
	E19	—	—
	E7	—	—
	E1	large cobble; shell hash	shell hash
98-m Stations	B12	gravel; shell hash	gravel; shell hash
	B9	pea gravel; organic debris	pea gravel
	E26	—	—
	E25	—	shell hash; organic debris
	E23	shell hash	shell hash; organic debris
	E20	shell hash	—
	E17 [a]	—	worm tubes
	E14 [a]	gravel; shell hash	coarse black sand; shell hash; organic debris
	E11 [a]	—	—
	E8	coarse sand; shell hash	—
	E5	shell hash; organic debris	shell hash; organic debris
	E2	cobble, shell hash	gravel; cobble; shell hash
116-m Stations	B10	shell hash; organic debris	—
	E21	—	—
	E15 [a]	gravel; shell hash; organic debris	—
	E9	coarse black sand; shell hash	coarse black sand; shell hash
	E3	gravel; shell hash	coarse sand

[a] Near-ZID station

Appendix B.2 *continued*

		Winter 2022	Summer 2022
SBOO			
19-m Stations	I35	—	—
	I34	—	—
	I31	—	—
	I23	coarse sand; shell hash	coarse sand; shell hash
	I18	—	—
	I10	—	—
	I4	shell hash; cobble	—
28-m Stations	I33	—	—
	I30	—	—
	I27	—	—
	I22	—	—
	I14[a]	—	—
	I16[a]	—	—
	I15[a]	—	—
	I12[a]	shell hash	shell hash
	I9	—	—
	I6	shell hash	—
	I2	—	—
	I3	—	—
38-m Stations	I29	—	—
	I21	—	—
	I13	—	shell hash
	I8	coarse sand; shell hash	—
55-m Stations	I28	coarse black sand; shell hash; organic debris	gravel; shell hash
	I20	red relict sand	red relict sand; shell hash
	I7	red relict sand	red relict sand
	I1	—	—

[a] Near-ZID station

Appendix B.3

Summary of visual observations for each regional station sampled during 2022. Visual observations are from sieved "grunge" (i.e., particles retained on 1-mm mesh screen and preserved with infauna for benthic community analysis).

	Summer 2022		
Strata	Station	Depth (m)	Vis Obs
Inner Shelf	9309	8	—
	9322	8	shell hash
	9301	16	—
	9318	17	—
	9326	18	—
	9341	18	—
	9317	19	red relict sand; shell hash
	9311	23	—
	9304	25	—
	9342	30	shell hash
Mid Shelf	9313	32	organic debris
	9348	35	—
	9302	36	gravel; shell hash; organic debris
	9308	46	coarse sand; shell hash; organic debris
	9336	63	-—
	9324	66	—
	9347	69	-—
	9306	76	shell hash; organic debris
	9327	78	—
	9320	81	—
	9329	81	—
	9305	87	shell hash
	9338	92	coarse sand; shell hash
	9330	99	—
	9328	103	coarse sand; shell hash; organic debris
Outer Shelf	9335	123	cobble; shell hash
	9314	126	shell hash; organic debris
	9303	129	coralline debris; shell hash
	9340	133	coarse sand; shell hash; organic debris
	9312	137	cobble; shell hash
	9307	173	coarse sand
	9351	179	—
	9310	189	worm tubes; coarse sand; shell hash
	9323	199	worm tubes
Upper Slope	9316	236	worm tubes
	9331	237	cobble; shell hash
	9321	249	—
	9315	321	gravel; shell hash
	9332	422	—
	9325	453	—

Appendix B.4

Constituents and method detection limits (MDL) used for the analysis of sediments during 2022. NA = not available.

Parameter	MDL	Parameter	MDL
Organic Indicators			
Biological Oxygen Demand (BOD, ppm)	2	Total Sulfides (ppm)	2.2
Total Nitrogen (TN, % wt.)	0.004-0.022	Total Volatile Solids (TVS, % wt.)	0.11
Total Organic Carbon (TOC, % wt.)	0.054-0.134		
Metals (ppm)			
Aluminum	1.52-1.84	Lead	0.1-0.143
Antimony	0.385	Manganese	0.151
Arsenic	0.152-0.237	Mercury	0.001-0.004
Barium	0.43-0.49	Nickel	0.1
Beryllium	0.009-0.01	Selenium	0.434-0.44
Cadmium	0.073-0.078	Silver	0.133
Chromium	0.102-0.106	Thallium	0.122-0.261
Copper	1.19	Tin	0.059-0.088
Iron	1.88-1.92	Zinc	0.384-0.402
Chlorinated Pesticides (ppt)			
Hexachlorocyclohexane (HCH)			
HCH, Alpha isomer	24.8-49.3	HCH, Delta isomer	42.7-94.7
HCH, Beta isomer	77.3-154	HCH, Gamma isomer	67-133
Total Chlordane			
Alpha (cis) Chlordane	46.8-93	Heptachlor epoxide	35-149
Cis Nonachlor	44.7-88.9	Methoxychlor	430-855
Gamma (trans) Chlordane	30.1-115	Oxychlordane	67.3-134
Heptachlor	80.6-160	Trans Nonachlor	61-121
Total Dichlorodiphenyltrichloroethane (DDT)			
o,p-DDD	74.7-149	p,p-DDE	53.5-106
o,p-DDE	49.8-99.1	p,p-DDMU	36-71.7
o,p-DDT	29.7-59	p,p-DDT	57.9-115
p,p-DDD	32.8-65.3		
Miscellaneous Pesticides			
Aldrin	32-141	Endrin	93.8-187
Alpha Endosulfan	60.2-120	Endrin aldehyde	319-635
Beta Endosulfan	590-1170	Hexachlorobenzene	123-246
Dieldrin	57.1-205	Mirex	26.8-53.4
Endosulfan Sulfate	111-222		

Appendix B.4 *continued*

Parameter	MDL	Parameter	MDL
Polychlorinated Biphenyl Congeners (PCBs) (ppt)			
PCB 8	42-88.1	PCB 126	54.5-109
PCB 18	53-106	PCB 128	41.7-82.9
PCB 28	24-47.8	PCB 138	47.4-94.3
PCB 37	60.7-121	PCB 149	65.4-130
PCB 44	44.5-88.5	PCB 151	36.6-72.8
PCB 49	60.8-121	PCB 153/168	162-323
PCB 52	64.3-128	PCB 156	60.3-120
PCB 66	50.8-101	PCB 157	66.6-132
PCB 70	55-109	PCB 158	66.6-132
PCB 74	51.2-102	PCB 167	41.6-82.7
PCB 77	26.2-52.1	PCB 169	40.4-80.3
PCB 81	28.9-57.5	PCB 170	33.9-67.4
PCB 87	52.9-105	PCB 177	21.8-43.3
PCB 99	42-83.6	PCB 180	36.7-73
PCB 101	38.9-77.3	PCB 183	24.9-49.5
PCB 105	82.8-165	PCB 187	31-61.6
PCB 110	33.1-65.9	PCB 189	61.7-123
PCB 114	48.6-96.7	PCB 194	47.1-93.7
PCB 118	50.8-101	PCB 195	19-2802
PCB 119	61-121	PCB 201	41.2-82.1
PCB 123	52.4-104	PCB 206	81.8-163
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)			
1-methylnaphthalene	5.93-12	Benzo[G,H,I]perylene	10.2-20.6
1-methylphenanthrene	6.05-12.2	Benzo[K]fluoranthene	7.08-14.3
2,3,5-trimethylnaphthalene	7.26-14.7	Biphenyl	5.47-11.1
2,6-dimethylnaphthalene	6.16-12.5	Chrysene	4.81-9.72
2-methylnaphthalene	6.39-12.9	Dibenzo(A,H)anthracene	9.96-20.1
3,4-benzo(B)fluoranthene	3.93-7.94	Fluoranthene	6.8-13.7
Acenaphthene	5.87-11.9	Fluorene	5.99-12.1
Acenaphthylene	7.37-14.9	Indeno(1,2,3-CD)pyrene	7.78-15.7
Anthracene	7.43-15	Naphthalene	7.78-15.7
Benzo[A]anthracene	6.22-12.6	Perylene	6.51-13.2
Benzo[A]pyrene	4.37-8.83	Phenanthrene	6.91-14
Benzo[e]pyrene	5.61-11.3	Pyrene	5.6-11.3

Appendix B.4 *continued*

Parameter	MDL	Parameter	MDL
Polybrominated Diphenyl Ethers (PBDEs) (ppt)			
BDE-28	53-106	BDE-138	32.4-64.4
BDE-47	25.8-50.8	BDE-153	40-79.7
BDE-49	38.4-76.5	BDE-154	37.6-74.8
BDE-66	43.5-86.6	BDE-17	66.1-132
BDE-85	15.2-30.2	BDE-183	68.1-136
BDE-99	46.4-92.5	BDE-190	33.5-66.8
BDE-100	39.6-78.9		

Appendix C

Demersal Fishes and Megabenthic Invertebrates

2022 Supplemental Analyses

Appendix C.1

Taxonomic listing of demersal fish species captured at PLOO trawl stations during 2022. Data are total number of fish (n), biomass (BM, wet weight, kg), minimum (Min), maximum (Max), and mean length (standard length, cm). Taxonomic arrangement follows Eschmeyer and Herald (1998) and Page et al. (2013).

Taxonomic Classification			Common Name	n	BM	Length (cm)		
						Min	Max	Mean
RAJIFORMES								
	Rajidae	*Bathyraja interrupta*	Sandpaper Skate [a]	2	0.2	20	23	22
		Raja inornata	California Skate [a]	4	1.1	19	49	28
		Raja rhina	Longnose Skate [a]	1	1.2	—	—	55
ARGENTINIFORMES								
	Argentinidae	*Argentina sialis*	Pacific Argentine	10	0.4	6	9	7
AULOPIFORMES								
	Synodontidae	*Synodus lucioceps*	California Lizardfish	6	0.4	14	25	20
GADIFORMES								
	Merlucciidae	*Merluccius productus*	Pacific Hake	3	0.3	23	23	23
BATRACHOIDIFORMES								
	Batrachoididae	*Porichthys notatus*	Plainfin Midshipman	16	0.7	6	16	12
SCORPAENIFORMES								
	Scorpaenidae	*Scorpaena guttata*	California Scorpionfish	15	3.4	13	22	18
	Sebastidae	*Sebastes auriculatus*	Brown Rockfish	3	0.3	15	22	19
		Sebastes elongatus	Greenstriped Rockfish	5	0.3	5	10	7
		Sebastes eos	Pink Rockfish	2	0.1	10	15	12
		Sebastes goodei	Chilipepper	8	0.4	12	16	13
		Sebastes levis	Cowcod	1	0.1	—	—	9
		Sebastes rosenblatti	Greenblotched Rockfish	4	0.4	5	10	8
		Sebastes rubrivinctus	Flag Rockfish	3	0.2	7	9	8
		Sebastes saxicola	Stripetail Rockfish	222	2.9	7	11	9
		Sebastes semicinctus	Halfbanded Rockfish	473	12.4	7	16	11
		Sebastes sp	Rockfish Unidentified	14	0.6	3	7	4
	Hexagrammidae	*Zaniolepis frenata*	Shortspine Combfish	257	3.7	7	18	11
		Zaniolepis latipinnis	Longspine Combfish	195	2.4	6	16	12
	Cottidae	*Chitonotus pugetensis*	Roughback Sculpin	4	0.1	10	11	10
		Icelinus quadriseriatus	Yellowchin Sculpin	100	0.5	3	8	6
	Agonidae	*Xeneretmus latifrons*	Blacktip Poacher	2	0.1	12	13	12
PERCIFORMES								
	Sciaenidae	*Genyonemus lineatus*	White Croaker	1	0.1	—	—	17
	Embiotocidae	*Zalembius rosaceus*	Pink Seaperch	67	1.3	4	13	10
	Zoarcidae	*Lycodes pacificus*	Blackbelly Eelpout	8	0.3	13	23	18
	Uranoscopidae	*Kathetostoma averruncus*	Smooth Stargazer	1	0.1	—	—	10
PLEURONECTIFORMES								
	Paralichthyidae	*Citharichthys sordidus*	Pacific Sanddab	3367	51.3	4	25	9
		Citharichthys xanthostigma	Longfin Sanddab	358	10.9	5	19	12
		Hippoglossina stomata	Bigmouth Sole	33	1.9	14	24	17
		Paralichthys californicus	California Halibut	1	2.7	—	—	67
	Pleuronectidae	*Lyopsetta exilis*	Slender Sole	21	0.3	6	14	11
		Microstomus pacificus	Dover Sole	572	18.3	5	21	13
		Parophrys vetulus	English Sole	109	6.9	11	24	16
		Pleuronichthys verticalis	Hornyhead Turbot	19	1.2	12	20	15
	Cynoglossidae	*Symphurus atricaudus*	California Tonguefish	47	1	11	17	14

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

Appendix C.2

Taxonomic listing of demersal fish species captured at SBOO trawl stations during 2022. Data are total number of fish (n), biomass (BM, wet weight, kg), minimum (Min), maximum (Max), and mean length (standard length, cm). Taxonomic arrangement follows Eschmeyer and Herald (1998) and Page et al. (2013).

Taxonomic Classification			Common Name	n	BM	Length (cm)		
						Min	Max	Mean
RAJIFORMES								
	Rhinobatidae	*Rhinobatos productus*	Shovelnose Guitarfish [a]	2	0.9	37	55	46
	Rajidae	*Raja inornata*	California Skate [a]	2	1.6	41	49	45
		Raja rhina	Longnose Skate [a]	1	0.4	—	—	37
MYLIOBATIFORNES								
	Urolophidae	*Urobatis halleri*	Round Stingray	4	1.7	28	39	31
CLUPEIFORMES								
	Engraulidae	*Engraulis mordax*	Northern Anchovy	106	0.8	9	12	11
AULOPIFORMES								
	Synodontidae	*Synodus lucioceps*	California Lizardfish	232	4.2	10	26	13
OPHIDIIFORMES								
	Ophidiidae	*Chilara taylori*	Spotted Cusk-eel	1	0.1	—	—	12
BATRACHOIDIFORMES								
	Batrachoididae	*Porichthys myriaster*	Specklefin Midshipman	20	0.4	7	21	11
		Porichthys notatus	Plainfin Midshipman	4	0.4	4	7	6
GASTEROSTEIFORMES								
	Syngnathidae	*Syngnathus californiensis*	Kelp Pipefish	1	0.1	—	—	19
		Syngnathus exilis	Barcheek Pipefish	18	0.6	13	23	19
SCORPAENIFORMES								
	Scorpaenidae	*Scorpaena guttata*	California Scorpionfish	3	0.6	17	20	19
	Sebastidae	*Sebastes* sp	Rockfish Unidentified	2	0.2	3	3	3
	Hexagrammidae	*Zaniolepis latipinnis*	Longspine Combfish	20	0.5	12	14	13
	Cottidae	*Chitonotus pugetensis*	Roughback Sculpin	55	1.3	3	11	7
		Icelinus quadriseriatus	Yellowchin Sculpin	89	0.6	3	8	6
PERCIFORMES								
	Malacanthidae	*Caulolatilus princeps*	Ocean Whitefish	4	0.3	4	6	5
	Sciaenidae	*Genyonemus lineatus*	White Croaker	147	4.8	10	17	13
	Clinidae	*Heterostichus rostratus*	Giant Kelpfish	1	0.1	—	—	12
	Stromateidae	*Peprilus simillimus*	Pacific Pompano	19	0.3	10	13	11
PLEURONECTIFORMES								
	Paralichthyidae	*Citharichthys sordidus*	Pacific Sanddab	144	0.6	3	10	5
		Citharichthys stigmaeus	Speckled Sanddab	2555	17.5	3	14	7
		Citharichthys xanthostigma	Longfin Sanddab	612	9.5	4	17	8
		Hippoglossina stomata	Bigmouth Sole	5	1.5	20	38	25
		Paralichthys californicus	California Halibut	12	11	17	66	33
		Xystreurys liolepis	Fantail Sole	11	2.4	7	26	20
	Pleuronectidae	*Parophrys vetulus*	English Sole	42	4.1	11	28	16
		Pleuronichthys decurrens	Curlfin Sole	1	0.1	—	—	15
		Pleuronichthys ritteri	Spotted Turbot	11	1.4	14	21	17
		Pleuronichthys verticalis	Hornyhead Turbot	48	2.9	4	22	12
	Cynoglossidae	*Symphurus atricaudus*	California Tonguefish	117	1.2	7	16	10

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

Appendix C.3

Summary of demersal fish abnormalities and parasites at PLOO and SBOO trawl stations during 2022.

Region	Survey	Station	Species	Abnormality/Parasite	n
PLOO	*Winter*	SD7	Pacific Sanddab	*Phrixocephalus cininnatus*	1
		SD10	Dover Sole	Lesion	1
		SD10	Pacific Sanddab	*Phrixocephalus cininnatus*	3
		SD13	Pacific Sanddab	*Phrixocephalus cininnatus*	1
		SD14	Pacific Sanddab	*Phrixocephalus cininnatus*	6
	Summer	SD8	Pacific Sanddab	*Phrixocephalus cininnatus*	1
		SD12	Pacific Sanddab	*Phrixocephalus cininnatus*	1
		SD13	Longfin Sanddab	*Phrixocephalus cininnatus*	1
		SD13	Pacific Sanddab	*Phrixocephalus cininnatus*	1
	Fall	SD10	Pacific Sanddab	*Phrixocephalus cininnatus*	2
SBOO	*Winter*	SD20	Speckled Sanddab	*Elthusa vulgaris*	1
	Summer	SD16	Hornyhead Turbot	Hiruidinea	1
		SD16	Speckled Sanddab	*Phrixocephalus cininnatus*	1

Appendix C.4

Taxonomic listing of megabenthic invertebrate taxa captured at PLOO trawl stations during 2022. Data are number of individuals (n). Taxonomic arrangement follows SCAMIT (2021).

Taxonomic Classification				**n**
SILICEA	Hexactinellida	Rossellidae	*Aphorme horrida*	2
	Demospongiae	Suberitidae	*Suberites latus*	2
CNIDARIA	Anthozoa	Plexauridae	*Thesea* sp B	1
		Virgulariidae	*Acanthoptilum* sp	2
MOLLUSCA	Gastropoda	Calliostomatidae	*Calliostoma turbinum*	1
		Cancellariidae	*Cancellaria cooperii*	1
			Cancellaria crawfordiana	1
		Pseudomelatomidae	*Antiplanes catalinae*	2
			Megasurcula carpenteriana	2
		Pleurobranchidae	*Pleurobranchaea californica*	16
		Philinidae	*Philine auriformis*	2
	Cephalopoda	Sepiolidae	*Rossia pacifica*	3
		Octopodidae	*Octopus rubescens*	23
			Octopus veligero	5
ARTHROPODA	Malacostraca	Sicyoniidae	*Sicyonia ingentis*	126
		Pandalidae	*Pandalus danae*	1
		Diogenidae	*Paguristes bakeri*	5
			Paguristes turgidus	1
		Calappidae	*Platymera gaudichaudii*	5
		Epialtidae	*Loxorhynchus crispatus*	1
ECHINODERMATA	Asteroidea	Luidiidae	*Luidia asthenosoma*	17
			Luidia foliolata	45
		Astropectinidae	*Astropecten californicus*	45
	Ophiuroidea	Ophiuridae	*Ophiura luetkenii*	10
		Ophiopholidae	*Ophiopholis bakeri*	1
		Ophiotrichidae	*Ophiothrix spiculata*	1
	Echinoidea	Toxopneustidae	*Lytechinus pictus*	6725
		Strongylocentrotidae	*Strongylocentrotus fragilis*	1
		Spatangidae	*Spatangus californicus*	3
	Holothuroidea	Stichopodidae	*Apostichopus californicus*	9

Appendix C.5

Taxonomic listing of megabenthic invertebrate taxa captured at SBOO trawl stations during 2022. Data are number of individuals (n). Taxonomic arrangement follows SCAMIT (2021).

Taxonomic Classification				n
CNIDARIA	Anthozoa	Plexauridae	*Thesea* sp B	1
		Virgulariidae	*Acanthoptilum* sp	1
			Stylatula elongata	6
MOLLUSCA	Polyplacophora	Ischnochitonidae	*Lepidozona scrobiculata*	1
	Gastropoda	Calliostomatidae	*Calliostoma gloriosum*	1
		Turbinidae	*Megastraea turbanica*	1
		Velutinidae	*Lamellaria diegoensis*	2
		Naticidae	*Glossaulax reclusiana*	2
			Neverita draconis	1
		Bursidae	*Crossata ventricosa*	4
		Buccinidae	*Kelletia kelletii*	7
		Muricidae	*Pteropurpura festiva*	1
			Pteropurpura vokesae	1
		Pseudomelatomidae	*Burchia semiinflata*	6
			Megasurcula carpenteriana	1
		Onchidorididae	*Acanthodoris brunnea*	2
			Acanthodoris rhodoceras	2
		Flabellinopsidae	*Flabellinopsis iodinea*	1
		Pleurobranchidae	*Pleurobranchaea californica*	9
		Philinidae	*Philine auriformis*	259
	Cephalopoda	Octopodidae	*Octopus rubescens*	2
ARTHROPODA	Malacostraca	Hemisquillidae	*Hemisquilla californiensis*	4
		Penaeidae	*Farfantepenaeus californiensis*	2
		Sicyoniidae	*Sicyonia penicillata*	103
		Thoridae	*Eualus subtilis*	4
			Heptacarpus stimpsoni	1
		Crangonidae	*Crangon alba*	19
			Crangon nigromaculata	99
		Palinuridae	*Panulirus interruptus*	1
		Diogenidae	*Paguristes bakeri*	1
		Paguridae	*Pagurus spilocarpus*	5
		Calappidae	*Platymera gaudichaudii*	8
		Epialtidae	*Pugettia dalli*	2
			Loxorhynchus grandis	4
		Inachidae	*Ericerodes hemphillii*	5
		Inachoididae	*Pyromaia tuberculata*	20
		Parthenopidae	*Latulambrus occidentalis*	4
		Cancridae	*Metacarcinus anthonyi*	1
			Metacarcinus gracilis	3
		Portunidae	*Portunus xantusii*	2
ECHINODERMATA	Asteroidea	Luidiidae	*Luidia armata*	30
		Astropectinidae	*Astropecten californicus*	449
	Ophiuroidea	Ophiuridae	*Ophiura luetkenii*	1
		Ophiotrichidae	*Ophiothrix spiculata*	30

Appendix C.5 *continued*

Taxonomic Classification				n
	Echinoidea	Toxopneustidae	*Lytechinus pictus*	28
		Dendrasteridae	*Dendraster terminalis*	79
		Loveniidae	*Lovenia cordiformis*	32

Appendix D

Contaminants in Marine Fishes

2022 Supplemental Analyses

Appendix D.1

Lengths and weights of fishes used for each composite (Comp) tissue sample from PLOO trawl and rig fishing zones during 2022. Data are summarized as number of individuals (n), minimum, maximum, and mean values.

				Length (cm)			Weight (g)		
Zone	**Comp**	**Species**	**n**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
RF1	1	Vermilion Rockfish	3	18	29	22	164	765	375
RF1	2	Vermilion Rockfish	3	23	28	25	439	683	521
RF1	3	Vermilion Rockfish	3	21	31	27	269	930	655
RF2	1	Squarespot Rockfish	3	18	22	20	102	249	162
RF2	2	Starry Rockfish	3	19	26	22	142	506	310
RF2	3	Mixed Rockfish	3	18	32	24	156	1057	490
TZ1	1	Pacific Sanddab	7	16	22	19	67	163	102
TZ1	2	Pacific Sanddab	7	15	24	17	44	236	85
TZ1	3	Pacific Sanddab	8	16	51	22	48	98	72
TZ2	1	Pacific Sanddab	5	18	24	20	98	202	133
TZ2	2	Pacific Sanddab	4	17	20	19	88	145	120
TZ2	3	Pacific Sanddab	7	16	20	18	69	138	95
TZ3	1	Pacific Sanddab	6	13	22	18	30	178	99
TZ3	2	Pacific Sanddab	5	16	21	18	64	194	105
TZ3	3	Pacific Sanddab	6	14	23	20	43	185	124
TZ4	1	Pacific Sanddab	7	14	169	38	41	131	75
TZ4	2	Pacific Sanddab	6	15	24	19	57	242	113
TZ4	3	Pacific Sanddab	4	18	24	21	103	248	174

Appendix D.2

Lengths and weights of fishes used for each composite (Comp) tissue sample from SBOO trawl and rig fishing zones during 2022. Data are summarized as number of individuals (n), minimum, maximum, and mean values.

				Length (cm)			Weight (g)		
Zone	**Comp**	**Species**	**n**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
RF3	1	Brown Rockfish	3	24	26	25	349	470	428
RF3	2	California Scorpionfish	3	22	24	23	389	461	416
RF3	3	Mixed Rockfish	3	23	25	24	392	465	425
RF4	1	California Scorpionfish	3	21	28	25	329	618	478
RF4	2	Gopher Rockfish	3	21	23	22	290	410	352
RF4	3	Mixed Rockfish	3	21	23	22	269	418	340
TZ5	1	Longfin Sanddab	13	12	15	14	35	67	49
TZ5	2	Longfin Sanddab	13	13	16	14	38	71	51
TZ5	3	Hornyhead Turbot	7	17	19	18	126	224	161
TZ6	1	Longfin Sanddab	10	14	16	15	48	74	60
TZ6	2	Longfin Sanddab	11	13	14	14	36	66	50
TZ6	3	Longfin Sanddab	11	13	16	15	40	63	55
TZ7	1	Longfin Sanddab	10	13	19	15	42	117	62
TZ7	2	Longfin Sanddab	14	12	14	13	31	47	40
TZ7	3	Hornyhead Turbot	7	16	20	18	106	211	159
TZ8	1	Longfin Sanddab	12	13	15	13	34	64	46
TZ8	2	California Scorpionfish	3	16	22	19	123	305	238
TZ8	3	Hornyhead Turbot	10	12	19	14	44	163	82
TZ9	1	Hornyhead Turbot	10	12	18	14	38	146	68
TZ9	2	Spotted Turbot	8	12	16	14	46	131	74
TZ9	3	Fantail Sole	3	14	17	16	61	99	80

Appendix D.3

Constituents and method detection limits (MDL) used for the analysis of liver and muscle tissues of fishes collected during 2022.

Parameter	MDL Liver	MDL Muscle	Parameter	MDL Liver	MDL Muscle
Metals (ppm)					
Aluminum (Al)	6.448-6.650	2.168-3.022	Lead (Pb)	0.257-0.265	0.087-0.121
Antimony (Sb)	0.527-0.543	0.177-0.247	Manganese (Mn)	0.302-0.311	0.102-0.142
Arsenic (As)	0.813-0.838	0.274-0.382	Mercury (Hg)	0.003-0.007	0.001-0.002
Barium (Ba)	0.543-0.560	0.183-0.255	Nickel (Ni)	0.102-0.105	0.034-0.048
Beryllium (Be)	0.045-0.046	0.015-0.021	Selenium (Se)	0.564-0.963	0.315-0.439
Cadmium (Cd)	0.055-0.057	0.019-0.026	Silver (Ag)	0.216-0.222	0.073-0.101
Chromium (Cr)	0.181-0.187	0.061-0.085	Thallium (Tl)	0.939-0.968	0.316-0.44
Copper (Cu)	0.254-0.262	0.086-0.119	Tin (Sn)	3.250-3.350	1.099-1.532
Iron (Fe)	3.030-3.130	1.01-1.408	Zinc (Zn)	0.512-0.527	0.173-0.242
Chlorinated Pesticides (ppb)					
Hexachlorocyclohexane (HCH)					
HCH, Alpha isomer	0.457-0.595	0.049-0.060	HCH, Delta isomer	0.660-0.859	0.070-0.086
HCH, Beta isomer	0.318-0.414	0.042-0.051	HCH, Gamma isomer	0.634-0.825	0.067-0.083
Total Chlordane					
Alpha (cis) chlordane	0.856-1.120	0.091-0.112	Heptachlor epoxide	0.58-0.756	0.062-0.076
Cis nonachlor	0.670-0.873	0.071-0.087	Methoxychlor	3.980-5.190	0.422-0.519
Gamma (trans) chlordane	0.722-0.941	0.077-0.094	Oxychlordane	0.714-0.930	0.076-0.093
Heptachlor	0.718-0.936	0.076-0.094	Trans nonachlor	0.948-1.230	0.100-0.123
Total Dichlorodiphenyltrichloroethane (DDT)					
o,p-DDD	0.910-1.180	0.096-0.118	p,p-DDD	2.690-3.500	0.285-0.350
o,p-DDE	0.406-0.529	0.043-0.053	p,p-DDE	0.401-0.523	0.043-0.052
o,p-DDT	0.423-0.552	0.045-0.055	p,p-DDT	0.571-0.744	0.061-0.074
p,-p-DDMU	0.511-0.666	0.054-0.067			
Miscellaneous Pesticides					
Aldrin	1.030-1.340	0.109-0.134	Endrin	0.482-0.627	0.051-0.063
AlphaEndosulfan	0.657-0.855	0.07-0.086	Endrin aldehyde	1.320-1.720	0.140-0.172
BetaEndosulfan	2.490-3.250	0.264-0.325	Hexachlorobenzene (HCB)	0.643-0.837	0.068-0.084
Dieldrin	0.803-1.050	0.085-0.105	Mirex	0.709-0.924	0.075-0.092
EndosulfanSulfate	1.220-1.580	0.129-0.158			

Appendix D.3 *continued*

Parameter	MDL Liver	MDL Muscle	Parameter	MDL Liver	MDL Muscle
Polychlorinated Biphenyls Congeners (PCBs) (ppb)					
PCB 8	0.636-0.828	0.067-0.083	PCB 126	0.739-0.963	0.078-0.096
PCB 18	0.396-0.516	0.042-0.052	PCB 128	0.626-0.815	0.066-0.082
PCB 28	0.520-0.677	0.055-0.068	PCB 138	0.682-0.888	0.072-0.089
PCB 37	0.362-0.472	0.038-0.047	PCB 149	0.755-0.984	0.080-0.098
PCB 44	0.376-0.490	0.040-0.049	PCB 151	0.635-0.827	0.067-0.083
PCB 49	0.718-0.936	0.076-0.094	PCB 153/168	0.533-0.694	0.057-0.069
PCB 52	0.423-0.552	0.045-0.055	PCB 156	1.210-1.570	0.128-0.157
PCB 66	0.645-0.840	0.068-0.084	PCB 157	0.600-0.782	0.064-0.078
PCB 70	0.744-0.970	0.079-0.097	PCB 158	0.749-0.976	0.079-0.098
PCB 74	0.670-0.873	0.071-0.087	PCB 167	0.735-0.957	0.078-0.096
PCB 77	0.560-0.730	0.059-0.073	PCB 169	0.955-1.240	0.101-0.124
PCB 81	0.871-1.140	0.092-0.113	PCB 170	0.521-0.678	0.055-0.068
PCB 87	0.795-1.040	0.084-0.104	PCB 177	1.090-1.420	0.116-0.142
PCB 99	0.366-0.477	0.039-0.048	PCB 180	0.695-0.905	0.074-0.091
PCB 101	0.386-0.503	0.041-0.050	PCB 183	0.925-1.20	0.098-0.120
PCB 105	0.621-0.809	0.066-0.081	PCB 187	0.750-0.977	0.080-0.098
PCB 110	0.489-0.637	0.052-0.064	PCB 189	0.636-0.828	0.067-0.083
PCB 114	1.200-1.560	0.127-0.156	PCB 194	0.482-0.627	0.051-0.063
PCB 118	0.519-0.676	0.055-0.068	PCB 195	0.925-1.20	0.098-0.120
PCB 119	0.750-0.977	0.080-0.098	PCB 201	1.02-1.320	0.108-0.132
PCB 123	0.668-0.870	0.071-0.087	PCB 206	0.984-1.250	0.103-0.126
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)					
1-methylnaphthalene	125-148	126-149	Benzo[G,H,I]perylene	108-128	109-126
1-methylphenanthrene	86.6-102	87.3-103	Benzo[K]fluoranthene	152-179	153-177
2-methylnaphthalene	84.9-100	85.6-101	Biphenyl	123-145	124-143
2,3,5-trimethylnaphthalene	137-161	138-163	Chrysene	113-134	114-132
2,6-dimethylnaphthalene	102-120	103-121	Dibenzo(A,H)anthracene	95.8-113	96.6-114
3,4-benzo(B)fluoranthene	108-127	108-125	Fluoranthene	128-150	129-152
Acenaphthene	110-130	111-131	Fluorene	112-132	113-133
Acenaphthylene	109-129	110-130	Indeno(1,2,3-CD)pyrene	94.1-111	94.9-110
Anthracene	118-139	119-140	Naphthalene	63.9-75.2	64.4-76
Benzo[A]anthracene	89.9-106	90.7-105	Perylene	120-142	121-143
Benzo[A]pyrene	125-148	126-146	Phenanthrene	109-129	110-127
Benzo[e]pyrene	134-158	136-157	Pyrene	126-149	127-147
Polybrominated Diphenyl Ethers (PBDEs)					
BDE-17	0.417-0.544	0.044-0.054	BDE-100	0.902-1.170	0.096-0.117
BDE-28	0.702-0.915	0.075-0.092	BDE-138	2.450-3.200	0.260-0.320
BDE-47	2.140-2.790	0.227-0.279	BDE-153	1.910-2.490	0.203-0.249
BDE-49	1.380-1.790	0.146-0.179	BDE-154	0.910-1.180	0.096-0.118
BDE-66	0.772-1.010	0.082-0.101	BDE-183	4.060-5.290	0.430-0.529
BDE-85	1.830-2.390	0.194-0.239	BDE-190	4.520-5.880	0.479-0.588
BDE-99	1.470-1.910	0.156-0.191			