SD Public Utilities

ANNUAL RECEIVING WATERS MONITORING & TOXICITY TESTING QUALITY ASSURANCE REPORT

2023

Environmental Monitoring and Technical Services
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Continual Improvement, Prevention of Pollution, Regulatory Compliance
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Annual Receiving Waters Monitoring & Toxicity Testing Quality Assurance Report

2023

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City of San Diego
Ocean Monitoring Program
Public Utilities Department
Environmental Monitoring and Technical Services Division

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2023 Quality Assurance Report

Introduction

The Environmental Monitoring and Technical Services (EMTS) Division of the City of San Diego Public Utilities Department (PUD) performs comprehensive Quality Assurance (QA)/Quality Control (QC) procedures. These procedures ensure the accuracy and reliability of data collected from receiving waters monitoring and toxicity testing, which are provided to regulatory agencies in compliance with the reporting requirements specified in several National Pollutant Discharge Elimination System (NPDES) permits (Table 1). Furthermore, these QA/QC procedures ensure the quality and consistency of field sampling, laboratory analysis, record keeping, data entry, and electronic data collection/transfer, as well as data analysis and reporting. The procedures are regularly reviewed and revised as necessary to reflect ongoing changes in permit requirements, sample collection methods, technology, and applicability of new analytical methods.

Details of the EMTS Division's QA/QC program for receiving waters monitoring are documented in a separate Quality Assurance Plan (QAP) (City of San Diego 2023a). The Toxicology and Marine Microbiology laboratories also maintain quality manuals with additional technical information specific to their work (City of San Diego 2023b and 2024b, respectively). Additionally, the EMTS Division maintains its certification through the International Organization for Standardization (ISO) 14001 Environmental Management Systems program. As a part of continuation of the ISO 14001 certification process, EMTS underwent and passed an external audit in 2020 conducted by a third-party auditor. The next audit will take place in 2024.

This report summarizes the QA/QC activities that were conducted during 2023 by City of San Diego staff in support of NPDES permit requirements for receiving waters monitoring and toxicity testing for the City's Point Loma Wastewater Treatment Plant (PLWTP) (Table 2) and South Bay Water Reclamation Plant (SBWRP) (Table 3), as well as similar ocean monitoring activities required for the South Bay International Wastewater Treatment Plant (SBIWTP), owned and operated by the International Boundary and Water Commission U.S. Section (USIBWC).

Facilities and Staff

The EMTS Division includes laboratories from three sections that participate in the receiving waters monitoring and toxicity testing activities associated with the above NPDES permits. These sections include: (1) the Marine Biology and Ocean Operations (MBOO) section; (2) the Microbiology section (Marine Microbiology Laboratory - MML, and Toxicology Laboratory - TL); (3) the Environmental Chemistry Services (ECS) section.

MBOO, MML, and TL are located at the EMTS Division's laboratory facility at 2392 Kincaid Road, San Diego, CA 92101. The functions of these labs are described below. ECS comprises work groups located at other City laboratory facilities. Therefore, descriptions of the ECS laboratory functions and their QA procedures are presented in a separate QA report each year.

Marine Biology and Ocean Operations

Staff scientists from the MBOO section are responsible for conducting most field sampling operations, some laboratory analyses, and subsequent biological and oceanographic assessments associated with the City's Ocean Monitoring Program (OMP) including water quality, benthic sediments and macrofauna, trawl caught fishes and invertebrates, and contaminant accumulation in marine fishes. Staff in this section are organized into different work groups based on primary responsibilities and areas of expertise. Brief descriptions of the areas of emphasis for each work group are provided below. Staff with overlapping expertise work across groups.

Program Coordination: One of the primary responsibilities of the Program Coordination (PC) supervisor is to support the Ocean Monitoring Program manager by facilitating collaborations with external entities such as Scripps Institution of Oceanography, Southern California Coastal Water Research Project (SCCWRP), regulatory agencies, and other publicly owned treatment works. Examples include managing contracts for supplemental monitoring (satellite imagery, aerial kelp surveys, kelp forest underwater surveys) as well as serving as Bight Coordinator, SCCWRP Commission's Technical Advisory Group (CTAG) alternate, and Region Nine Kelp Survey Consortium chair. The PC supervisor also works closely with City staff and contract vendors to ensure data collection efforts meet permit requirements. In addition, they help with compliance report management, production, and submission, manage data requests, manage OMP data available via the City's Open Data Portal, and help maintain the City's Ocean Monitoring Program Reports and Data webpages.

Environmental Management: This work group oversees MBOO compliance with environmental and laboratory management standards such as ISO 14001. Oversight includes document control and maintenance of the QAP, Standard Operating Procedures, Work Instructions, and ISO 14001 documentation using the division's compliance software, Ideagen. Staff in this work group coordinate with members of other work groups and sections to produce an annual report of quality assurance activities. Furthermore, this group promotes lab and field safety through training, and environmental systems through hazardous materials and universal waste management. Environmental Management seeks to reduce resource use and exceed regulatory expectations by supporting process development and improvement, data management, and staff training, and to engage the public by supporting MBOO's and the division's outreach efforts.

Ocean Operations: This work group comprises two subsections, Ocean Operations and Vessel Operations. Ocean Operations staff oversee and conduct water quality sampling, benthic sediment and infauna sampling, trawling and rig-fishing, and ocean outfall inspections, including data collection and QA. These staff members maintain and calibrate all oceanographic instrumentation, including the laboratory's remotely operated vehicle (ROV), remotely operated towed vehicle (ROTV), and static/real-time oceanographic moorings. Vessel Operations staff (i.e., Boat Operators) are primarily responsible for the operation and maintenance of the City's two ocean monitoring vessels, the Oceanus, and the Monitor III. When the vessels are in port, the boat operators schedule and oversee all regular vessel maintenance as well as any modifications that may become necessary. While at sea, they are responsible for ensuring the safety of the crew, locating and maintaining the vessel's position at monitoring stations (Figure 1), and assisting with various deck activities during field operations, as appropriate. Members of this and other work groups participate as members of the Southern California Association of Ichthyological Taxonomists and Ecologists (SCAITE).

Laboratory Operations: The Laboratory Operations work group coordinates processing of all benthic infauna, trawl-caught fish and megabenthic invertebrates, and rig fishing samples including label preparation, sample login, and data entry. In addition, they maintain the taxonomic literature and voucher collections, produce in-house identification/voucher sheets and keys, and conduct taxonomic training. This group also oversees fish dissections as part of the analysis of contaminant accumulation in marine fishes. Staff participate in regional taxonomic standardization programs and perform all QA/QC procedures to ensure the accuracy of the taxonomic identifications made by laboratory staff. Members of this and other work groups participate as members of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT).

Marine Microbiology Laboratory

The MML is accredited by the California State Water Resources Control Board Environmental Laboratory Accreditation Program (ELAP) (EPA Lab ID: CA01393; ELAP Cert No.: 2185), which is renewed on a biennial basis. Microbiology staff are responsible for the identification and quantification of bacteria found in environmental samples. Responsibilities include preparation of microbiological media, reagents, sample bottles, supplies and equipment, collection of field samples along the shore, and laboratory analyses using approved and accredited methods to measure concentrations of fecal indicator bacteria. ELAP-accredited analyses include membrane filtration, multiple tube fermentation, Colilert/Colilert-18, and Enterolert chromogenic/fluorogenic substrate analyses as appropriate for the parameter and as required by the NPDES permits. In addition, the group is responsible for the physical maintenance, calibration, and QA of large equipment and instruments such as autoclaves, incubators, water baths, ultra-freezers, a biological safety cabinet, and reagent-grade water point-of-use systems. Members are also responsible for developing sampling, analytical, and QA protocols for special microbiological projects or studies. In addition to being summarized here, the MML maintains a separate, detailed Quality Manual that contains up-to-date revisions to reflect current laboratory practices and procedures and ensures timely document version control in accordance with ELAP requirements and ISO 14001 standards (City of San Diego 2023b).

Toxicology Laboratory

The TL is also certified by ELAP (EPA Lab ID: CA01302; ELAP Cert No.: 1989), with renewal on a biennial basis. Toxicology staff are responsible for conducting or overseeing all acute, chronic, and sediment toxicity testing required by the City's NPDES permits (Table 4) and contractual obligations. Primary responsibilities include collection of wastewater effluent or marine sediment samples, maintaining test organisms and laboratory supplies, calibration of test instruments, conducting acute and chronic bioassays, record keeping, and the statistical evaluation, interpretation, and reporting of all toxicology data. In addition to being summarized here, the TL maintains a separate, detailed Quality Manual that contains up-to-date revisions reflecting current laboratory practices and procedures and ensures timely document version control in accordance with ELAP requirements and ISO 14001 standards (City of San Diego 2024b).

Scope of Work

The City of San Diego Ocean Monitoring Program is responsible for monitoring the coastal San Diego area to document and analyze possible effects on the marine environment due to the discharge of treated municipal wastewater (effluent) to the Pacific Ocean via the Point Loma Ocean Outfall (PLOO) and the South Bay Ocean Outfall (SBOO). Treated effluent from the PLWTP is discharged to the ocean through the PLOO, whereas commingled effluent from the SBWRP and SBIWTP is discharged through the SBOO. The separate orders and permits associated with these treatment facilities define the requirements for receiving waters monitoring and toxicity testing in Attachment E including sampling plans, compliance criteria, laboratory, and statistical analyses, and reporting guidelines.

Core receiving waters monitoring activities include: (1) weekly sampling of ocean waters from recreational areas located along the shoreline and within the Point Loma and Imperial Beach kelp beds to assess nearshore water quality conditions; (2) quarterly sampling of ocean waters at offshore sites to document water quality conditions throughout the region; (3) semi-annual benthic sampling to monitor sediment conditions and the status of resident macrobenthic invertebrate communities; (4) semi-annual trawl surveys to monitor the ecological health of demersal fish and megabenthic invertebrate communities; (5) annual collection of fish liver and muscle tissue samples to monitor levels of chemical constituents that may have ecological or human health implications.

The results of the above receiving waters monitoring activities, and effluent and sediment toxicity tests, are analyzed and presented in various regulatory reports that are submitted to the San Diego Regional Water Quality Control Board (SDRWQCB) and United States Environmental Protection Agency (USEPA) on an ongoing basis. From 2016 through 2018, the City conducted a three-year sediment toxicity pilot study, and presented monitoring recommendations in the final project report that was submitted to the SDRWQCB and USEPA on June 30, 2019 (City of San Diego 2019). As these recommendations have since been incorporated into permit-required monitoring, additional sediment samples are collected and analyzed annually.

In addition to the above core monitoring efforts, the City may conduct “strategic process studies” (special projects) as part of its regulatory requirements and as defined by the Model Monitoring Program developed for large ocean dischargers in southern California (Schiff et al. 2002). These special studies are determined by the City in coordination with the SDRWQCB and USEPA and are generally designed to address recommendations for enhanced environmental monitoring of the San Diego coastal region as put forth in a peer-reviewed report coordinated by scientists at the Scripps Institution of Oceanography (SIO 2004). Data for such studies are typically subject to the same QA/QC procedures as the routine monitoring data, although the analysis and reporting schedules will likely be customized to meet the targeted study goals. Thus, details and results of ongoing QA/QC activities associated with these special studies are not included in this report unless otherwise indicated.

As a part of its regulatory requirements, the City also participates in regional monitoring activities for the entire Southern California Bight coordinated by the Southern California Coastal Water Research Project (SCCWRP). The intent of these regional programs is to optimize the efforts of the various partner agencies, such as municipal dischargers and research agencies, and leverage their considerable scientific expertise and resources to survey the entire southern California coastal region using a cost-effective monitoring design. These bight-wide surveys began with the 1994 Southern California Bight Pilot Project and have included subsequent Bight regional monitoring efforts every five years from 1998 until the most recent survey in 2023. During these programs, the City’s regular sampling and analytical efforts may be reallocated as necessary with approval from the SDRWQCB and USEPA. As with special studies, the regional monitoring efforts are typically subject to QA/QC procedures like those for routine monitoring data, although the analysis and reporting schedules may vary. Thus, the details and results of the bight-wide monitoring efforts are not included in these annual QA reports unless otherwise indicated. However, planning documents for the current Bight'23 project, including its QAP, are available on SCCWRP's website (www.sccwrp.org).

Summary of Work Performed in 2023

During 2023, a total of 5843 discrete samples were collected by EMTS staff as part of the above scope of work and as part of permit-mandated special studies (Table 5). Of these, about 10% (n = 584) were QC samples, such as lab or field duplicates. In addition, a total of 1604 QA analyses pertaining to macrofauna sorting, microbiological analyses, and toxicity tests were conducted to validate the quality of specific analyses. The results of the QA/QC activities presented in the following sections support the precision and accuracy of the resultant data and validate their use in permit-mandated monitoring, environmental testing, and reporting. These include: (1) intercalibration of the Conductivity-Temperature-Depth (CTD) instruments used to sample water quality parameters; (2) real-time mooring data quality, drift correction, and data acceptance criteria; (3) results of the bacteriological QA procedures; (4) results of the macrofaunal community sample re-sorts and re-IDs; (5) results of toxicology QA procedures.

CTD Calibration and Maintenance

The City of San Diego's MBOO section uses two Sea-Bird Scientific SBE-25plus CTDs integrated with modular sensors. Both systems are configured with Sea-Bird's SBE-55 mini carousel package and outfitted with six 4-liter Niskin bottles. Typically, laboratory staff carry out semi-annual in-house CTD intercalibration exercises to ensure consistency between the two CTD instruments used to collect water column profiling data for the City's Ocean Monitoring Program. In 2023, an intercalibration exercise was conducted in July only. The second intercalibration was scheduled for December, but due to delays in manufacturer instrument service, the intercalibration was delayed and results will thus be included in the 2024 QA report. During intercalibration exercises, two CTDs configured with similar probes are attached to each other and deployed to a depth of 120 m and retrieved three separate times. For each cast, depths greater than 100 m were discarded to minimize bottom effects. After the three casts were completed, comparisons of the results for six different parameters (i.e., temperature, salinity, dissolved oxygen (DO), pH, transmissivity, chlorophyll *a* fluorescence) were performed to assess whether deviations between the instrument assemblies were within acceptable limits. The results are summarized in Table 6A and Figure 2, and compared to results from previous years in Table 6B. The intercalibration exercises conducted for instruments used in July 2023 demonstrated acceptable variability between CTDs for all six measured parameters (Table 6A). There was an approximately 0.10 mean difference in the pH readings during the July intercalibration (Table 6A, Figure 2D). While a discrepancy of this magnitude is outside our targeted sensor calibration range, this difference is within the expected cumulative error associated with these sensors (McLaughlin et al. 2017). Both sensors responded well to oceanographic features in the cast and tracked each other well within the limitations of the instrument (manufacturer states sensor accuracy as within +/- 0.2 pH units).

To verify and calibrate potentiometric pH field measurements and monitor the long-term effects of ocean acidification, water samples are collected quarterly with the CTD at varying depths for spectrophotometric analysis of pH (total scale) and potentiometric analysis of total alkalinity (TA; µmol kg-1) in accordance with best practices for ocean CO2 measurements (Dickson et al. 2007). Quality control is achieved through analysis of Certified Reference Materials (CRM) with a certified pH and TA to achieve standards of precision and accuracy set by Dickson et al. (2007). These data are combined with in-situ temperature, salinity, and pressure data from the CTD to calculate the in-situ pH (total scale) and the aragonite saturation state.

The CTD measures pH with an SBE-18 pH potentiometric glass electrode sensor on the NBS scale, which is on average ~ 0.2 units different from pH on the total scale used by Real Time Mooring SeaFETs and lab-based spectrophotometric analysis (McLaughlin et al. 2017). These pH data from the CTD SBE-18 pH sensor and analyzed water samples are compared to ensure this average offset is maintained in accordance with the relationships set forth by McLaughlin et al. (2017), which allows the City's CTD pH data to be compared with other Southern California Bight pH datasets which may be collected on differing pH scales. A subset of the samples collected in 2023 were analyzed, and the results of lab analyses thus far suggest that the CTD SBE-18 pH sensor does not need a correction and is comparable to other data sets collected on the total scale across the Southern California Bight region (Table 7).

In addition to the semi-annual CTD intercalibration exercises, manufacturers of various probes recommend annual recalibrations at their factories. Since at least four sets of conductivity, temperature, pressure, pH, DO probes, and circulation pumps are inventoried in-house, each instrument is rotated out of service and sent back to the factory every six months for recalibration. Fluorometers (chl *a*), transmissometers, and colored dissolved organic matter (CDOM) probes, are rotated out for external/ factory recalibration service on an annual basis, due to limited numbers of these sensors available. Any time an in-house calibration identifies a problematic probe, that probe is serviced earlier than scheduled. The rotation of probes between CTDs is staggered by six months to ensure that each instrument receives a replacement set within the annual calibration period.

As the WetStar CDOM and chlorophyll sensors we currently use are being phased out by the manufacturer, staff scientists are currently in the process of investigating replacements for the current CDOM and chlorophyll sensors. The replacement sensor (SeaOwl) offered by this manufacturer was mounted and integrated on Unit 5 CTD to compare with the legacy WetStar sensors on Unit 6. Then, data from the SeaOwl CDOM/chlorophyll channels mounted on Unit 5 to the WetStar CDOM and WetStar chlorophyll sensors mounted on Unit 6 were compared (Figures 2H and 2G). Testing of these sensors will continue in parallel in water quality field surveys over the next few months before the WetStar sensors are retired from service.

The probes actively in use on each CTD undergo further in-house evaluations prior to and during each field survey. The DO probe on each CTD is calibrated monthly to check for sensor drift. If the sensor drift is ≥ 5% from factory calibration, the DO sensor coefficients are changed. If the DO sensor drift reaches 10% from factory calibration, it is removed from service, returned to the manufacturer for servicing or repair, and replaced with a newly factory-calibrated probe. The pH and transmissivity probes are inspected in the morning prior to each sampling cruise to ensure proper function. For pH calibrations, three buffer solutions (pH = 7.0, 8.0, 9.0) are used to bracket the expected pH range. If the reading of any buffer solution deviates by more than 0.05 pH units, the probe is recalibrated. The transmissometer on each CTD is checked by cleaning the windows of the LED light path, noting the zero reading by blocking the light path, and then noting the maximum-value reading by removing the obstruction. If any specific probe fails to calibrate or has drifted out of its accepted range, it is removed from the CTD and replaced with a newly calibrated spare. Additionally, the results of each probe are evaluated by reviewing the data for each parameter following each cast. If any probe is determined to be faulty and a field repair cannot be completed, sampling is terminated immediately so that the needed repairs can be completed back at the laboratory. During 2023, no sensors were removed from service before the 6-month rotation.

Real-Time Mooring Data Quality Assessment

Real-time oceanographic mooring systems (RTOMS) are anchored unattended buoys with a suite of sensors that provide nearly continuous physical and biogeochemical measurements. The City maintains RTOMS near both the PLOO and SBOO for up to one year deployments. Real-time data management and integration support are provided by Scripps Institution of Oceanography (SIO). On an annual basis, and prior to any data analysis, all data are subject to a comprehensive suite of QA/QC procedures following Quality Assurance of Real-Time Oceanographic Data (QARTOD) methodologies (US IOOS 2020). These methodologies are a collaborative effort formed to address the data quality issues of the U.S. Integrated Ocean Observing System (US IOOS) community.

Data broadcast in real time by the RTOMS are processed by SIO personnel prior to publication on the SIO website (https://mooring.ucsd.edu) to remove pre/post deployment data and warmup data from burst sensors, and to apply calibrations. City staff assign a QC flag to each datapoint (Table 8) based on gross sensor ranges, climatological ranges built from historical data for each site and depth range, and additional manual data review, per national data standards following QARTOD methodologies. Additional QC includes visual assessment and multi-parameter comparison to identify common sensor failure modes such as biofouling, interference from bubbles or debris, electronic sensor drift, and other malfunctions. These issues can also be identified by spike tests, rate of change tests, and flat line tests. Any data that have been adjusted to accommodate for sensor drift are assigned a unique flag, as are data that are determined to be bad or suspect. Parameters that are associated (i.e., read from the same sensor or otherwise covarying) are cross-referenced when flags are assigned. Notes about suspect data and flagging decisions are recorded in a table that is curated by the RTOMS coordinator and included in annual reports.

To help identify possible mooring sensor failures, validation CTD casts are completed as near to the mooring as possible on a quarterly basis, and at the beginning and end of each deployment. Relevant CTD parameters are compared to the same RTOMS parameters at the same depths to check for gross offsets, drift, or sensor malfunctions on the moorings. Due to sharing the same sensor technology between the CTD and the RTOMS, temperature, salinity, and dissolved oxygen measurements are summarized for 2023 (Tables 9 and 10; Figures 3 – 6). A total of four CTD validation casts were completed near the PLOO RTOMS (Table 9) and three total CTD casts were completed near the SBOO RTOMS (Table 10). The SBOO RTOMS deployment was delayed to late June 2023 due to replacement and rebuilding needed after the loss of the mooring in early November 2022, so fewer data were available. An example of a CTD cast profile during a time period when surface waters were relatively well-mixed (February 2023 for PLOO; November 2023 for SBOO) is shown for each mooring (Figures 3 and 6), as well as an example profile during a stratified time period (August 2023 for PLOO; July 2023 for SBOO) for each mooring (Figures 4 and 5). Both downcast and upcast CTD data are shown to provide context for variability of ocean conditions. In general, when moorings were operational and functioning as expected, RTOMS temperature, salinity, and dissolved oxygen were within reasonable ranges of CTD cast measurements at similar depths.

Some differences between RTOMS and CTD observations are expected due to spatial and temporal differences in water masses measured by each instrument, particularly when ocean conditions are not well mixed and are rapidly changing. One notable example is the difference between PLOO RTOMS salinity compared to CTD salinity at deep depths (60 – 90 m), which occurs on a frequent basis (Table 9; Figures 3B and 4B). These differences in salinity may likely be due to detection of the PLOO effluent plume by the RTOMS, where the RTOMS may have been closer to the effluent plume. Additionally, salinity differences could be due to a potential reduction in mixing between the freshwater effluent plume and ocean water masses by the equipment itself (see Chapter 4 in City of San Diego 2022). For example, the mooring instruments are suspended passively in the water column at a fixed location, while large profiling packages such as the CTD rosette may result in turbulence and additional mixing as moved through the water (e.g., Paver et al. 2020). Given these factors, these differences in PLOO RTOMS salinity at deep depths are within reasonable ranges and are not used to assess mooring functionality in most cases. However, in early 2023, the PLOO mooring became severely fouled and entangled by several large commercial fishing nets, and this likely impacted data quality by reducing water flow across sensors. For instance, the temperature/salinity sensor at 10 m was completely wrapped in several inches of net, which may explain the discrepancy between RTOMS and CTD data at this depth (Table 9, Figure 3A, 3B). Therefore, PLOO RTOMS data will be carefully assessed for interference from the nets and any suspect data will be flagged.

In addition to data QA, both nitrate + nitrite water samples and spectrophotometric pH/Total Alkalinity (pH/TA) water samples are taken from CTD validation casts on a quarterly basis to provide an additional comparison of sensor performance and to inform sensor calibration offsets and drift. During CTD validation casts, these water samples are collected at the same depths as RTOMS sensors and may be used to provide drift corrections to sensor data as appropriate. For in-situ SUNA nitrate sensors in particular, lamp drift (loss of light intensity over time), as well as fouling drift, can result in the need for periodic field data corrections (Pellerin et al. 2013). Data-correction criteria are based on the uncertainty of the manufacturer-stated accuracy, and correction is recommended for the nitrate SUNA sensor if the sum of the total error is greater than 2 µM or 10% of the measured concentration, whichever is greater (Pellerin et al. 2013). In addition, negative reported nitrate data typically indicate downward drift of the sensor. However, data correction from discrete field samples is only possible if conditions are well mixed at a given depth, are not changing rapidly in time, and sensors are performing as expected. Decisions are left to the best professional judgement and any drift corrections are documented in the flagging table curated by the RTOMS coordinator. For 2023, water samples analyzed for nitrate + nitrite were compared to mooring SUNA nitrate sensor data on similar depth and time scales (Table 11). Overall, sensor drift corrections are recommended for three of the four total SUNA sensors deployed for much of 2023. For the PLOO sensor at 30 m, a linear slope drift correction will be applied for the length of the deployment. For the PLOO sensor at 75 m, the sensor exhibited step changes, so a separate offset drift correction will be applied for each step changes, except for periods where the sensor exhibited excessive noise. For the SBOO sensor at 1 m, the sensor reported slightly negative data throughout much of the deployment, so a single offset correction will be applied. Some corrections are not possible where ocean conditions were too variable, or where problems occurred with water samples or mooring SUNA sensors. Once calculated and applied, drift corrections will be documented in the flagging table for the annual report. Though pH/TA samples at the RTOMS have been collected, analyses have been delayed and not all results are available, but will be included in future QA reports as data become available and analyzed.

Bacteriological Quality Assurance Analyses

Duplicate analyses are run throughout the year as QA checks on bacteriological data reported by the City. Field duplicates are two separate samples taken from the same station at the same time and then processed by a single analyst to measure variability between samples. Laboratory duplicates are designed to test whether analysts can replicate their own results, and consist of two samples that are diluted, filtered, and plated from a single sample container by a single analyst to measure analyst precision. During 2023, a total of 569 QA/QC water samples were collected, which comprised 461 laboratory and 108 field duplicates (Table 5). The results from analyses performed on these samples have been reported previously in the Point Loma and South Bay monthly receiving waters monitoring reports (City of San Diego 2024a).

The sign test (Gilbert 1987) was used to compare the results from the paired laboratory and field duplicate analyses performed in 2023 (Table 12). When matched pairs of regular and duplicate laboratory or field samples are used, the sign test sets the null hypothesis that the probability of observing samples with differing plate counts is equally distributed among positive (sample A > sample B) and negative (sample A < sample B) differences. Samples that do not differ (i.e., A - B = 0) are not included in the test. During 2023, duplicate laboratory sample and regular sample results were equally likely to differ positively or negatively from one another ($p > 0.05$) for each of the three tested indicator bacteria (i.e., total coliforms, fecal coliforms, *Enterococcus*), indicating low variability between samples and high repeatability of laboratory measurements. Results from duplicate field samples were not significantly different ($p > 0.05$) for fecal coliforms and *Enterococcus* but a deviation from the null hypothesis for total coliforms occurred, indicating that there is not equal likelihood of negative versus positive differences between total coliform duplicate samples and regular field samples collected in 2023. A combination of factors may have contributed to such a result. First, the mixing of the water during the few seconds between the collection of the samples causes a natural potential for variation between the samples. Overall higher bacteria concentrations throughout the year at the South Bay shoreline stations create a greater potential for variation in the colony counts between samples. Moreover, at higher concentrations of bacteria, the total coliform analyses tend to be more prone to confluent growth of heterotrophic bacteria that may interfere with the growth of coliforms on the filters. Per Standard Methods 9222 (SM 2006), such plates with confluent growth are not distinct enough for accurate counting and thus not used to determine the final reported value. Therefore, there are instances in which different volumes of sample are used to determine the results for a pair of field duplicate samples.

In addition to the above QA analyses, the Marine Microbiology Lab conducts monthly comparisons of bacterial colony counts to quantify the counting precision of each analyst. Counts are performed on a single plate by pairs of analysts with the requirement that counts by any two analysts must fall within 10% of each other. This calculation is known as the Relative Percent Difference (RPD). During 2023, 384 count comparisons were performed. For total coliform counts, 13 out of 122 count comparisons had an RPD greater than 10% RPD. For fecal coliform counts, 5 out of 133 comparisons had an RPD greater than 10%. For *Enterococcus* counts, 15 out of 129 count comparisons had an RPD greater than 10%. In addition to these QA procedures, all analysts maintain their competency to perform ELAP-certified methods through regular proficiency tests or demonstrations of capability.

Macrofaunal Community Quality Assurance Analysis

Laboratory analyses of benthic macrofaunal samples involve three processes: (1) sample washing and preservation; (2) sample sorting; (3) identification and enumeration of all invertebrate organisms down to species level or the lowest taxon possible. Sorting QC is essential to ensuring the validity of the subsequent steps in the sample analysis process. The sorting of benthic samples into major taxonomic groups is contracted to an outside laboratory, with the contract specifying an expected 95% removal efficiency (i.e., at least 95% of organisms must be removed from the mixed invertebrate/sediment sample). Ten percent of the sorted samples from each sorter at the contract lab are subjected to re-sorting as QA for the contract. The original sorting of a sample fails the QA criterion if the abundance in the re-sorted sample deviates more than 5.0% from the total abundance of all animals from that sample. If more than one failure occurs, the contract requires the re-sorting of all samples previously sorted by an individual contract sorter. All samples re-sorted from the completed 2023 surveys met the acceptance QA criteria for sorting (Table 13). Samples re-sorted as part of the City's Bight'23 efforts are not included in this report pending final analysis of those stations.

Additionally, the laboratory performs re-identifications (re-IDs) as a QA measure to maintain consistency among taxonomists. For 2023, these were performed on six of the 74 grabs and are included in the total count for Benthic Infauna Grab QA (Table 5). All re-identification sample analyses are conducted by taxonomists other than those who originally analyzed the samples and are completed without access to original results. All re-IDs conducted in 2023 met acceptance criteria as specified in the Bight′18 benthic laboratory manual (SCCWRP 2018).

Toxicology Quality Assurance Analyses

All required whole effluent toxicity and sediment toxicity analyses in 2023 were performed by the TL, which conducts routine reference toxicant testing as a part of its quality assurance program. A reference toxicant is a standard chemical used to measure the sensitivity of the test organisms and test precision. Consistency among the reference toxicant test results enhances confidence in the toxicity data concurrently obtained from the test material (wastewater effluent or marine sediment). A specific reference toxicant is used for each combination of test material, test species, test conditions and endpoints, and the material is chosen from a list developed by the USEPA. The reference toxicant is purchased from an approved supplier in aqueous form (stock solution), and the supplier must verify the concentration of the stock solution and provide written documentation of such analysis.

In most instances, a reference toxicant test is performed at the same time the test material is evaluated. A control chart for each test method is maintained by the division QA Manager or Laboratory Supervisor using results from no fewer than 20 of the most recent reference toxicant tests when available. The charted parameters that may be used include effect concentrations (LC_{50}, EC_{50}), control performance, percent minimum significant difference, and coefficient of variability.

Using a nominal error rate of 5.0%, results from 19 of the most recent 20 reference toxicant tests are expected to fall within two standard deviations of the simple moving average (unweighted running mean), while one of these tests may fall outside the control chart limits by chance alone. Additionally, a series of USEPA-recommended quality control limits are used to further evaluate test sensitivity.

Each run that is in violation of control limits would trigger an investigation of animal supply, reference toxicant stock quality, and laboratory practices. Additional testing may also be conducted to determine whether an exceedance is anomalous or if corrective actions are needed. All NPDES-mandated tests conducted with the affected animals are flagged, reviewed for anomalous responses, and in certain cases, tests are repeated with a new batch of animals. Results for each toxicity test are reported regularly to the San Diego RWQCB in a Self-Monitoring Report, as defined in each NPDES permit. In 2023, all reference toxicant control charts for bioassays conducted by the TL met the acceptability criteria as specified in Standard Operating Procedures and USEPA Methods.

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FIGURES & TABLES

Table 1
NPDES permits and associated orders issued by the San Diego Regional Water Quality Control Board for the City of San Diego's PLWTP and SBWRP, and the U.S. Section of the International Boundary and Water Commission's SBIWTP.

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

[a] As amended by Order No. R9-2022-0078

Table 2

Core receiving waters monitoring requirements for the Point Loma Ocean Outfall region. Sampling effort excludes FIB resamples, QA/QC activities, new plume tracking requirements, and special studies.

Monitoring Component	Location	No. of Stations/ Zones	Sample Type	Discrete No. Samples/Site	Sampling Frequency	Sampling Times/Yr	Discrete No. Samples/Yr	Parameters	No. "Samples" Analyzed/Yr	Notes
Water Quality, Microbiology,	shore	8	Seawater - FIB	1	1/Week	52	416	T, F, E [a]	1248	1 sample/station
Oceanographic	kelp/	8	Seawater - FIB	3	1/Week	52	1248	T, F, E [a]	3744	3 depths/station
Conditions	nearshore	8	CTD	1	1/Week	52	416	CTD profile [c]	3744	1 cast/station (1-m batch avg samples)
	offshore	3	Seawater - FIB	3	1/Quarter	4	36	E [b]	36	3 depths/station (18-m stns)
		11	Seawater - FIB	3	1/Quarter	4	132	E [b]	132	3 depths/station (60-m stns)
		11	Seawater - FIB	4	1/Quarter	4	176	E [b]	176	4 depths/station (80-m stns)
		11	Seawater - FIB	5	1/Quarter	4	220	E [b]	220	5 depths/station (98-m stns)
		36	CTD	1	1/Quarter	4	144	CTD profile [c]	1296	1 cast/station (1-m batch avg samples)
Sediment Chemistry	offshore	22	Grab	1	2/Year	2	44	sed chem [d]	352	1° and 2° core stations (Jan, Jul)
	offshore	12	Grab	1	2/Year	2	24	sed chem [e]	24	1° core stations (Jan, Jul)
	offshore	40	Grab	1	1/Year	1	40	sed chem [d]	320	Randomized stations (Jul) [g]
Benthic Infauna	offshore	22	Grab	1	2/Year	2	44	community structure	44	1° and 2° core stations (Jan, Jul)
	offshore	40	Grab	1	1/Year	1	40		40	Randomized stations (Jul) [g]
Sediment Toxicity	offshore	8-28	Grab	1	1/Year	1	8-28	acute toxicity	8-28	Rotating offshore stations [h]
Demersal Fishes & Invertebrates	offshore	6	Trawl	1	2/Year	2	12	community structure	12	1 trawl/station (Jan, Jul)
Bioaccumulation in Fish Tissues	offshore	4	Trawl/ Hook & Line	3	1/Year	1	12	liver tissue [f]	60	3 composites/zone (Oct)
	offshore	2	Hook & Line	3	1/Year	1	6	muscle tissue [f]	30	3 composites/zone (Oct)
Totals							**3038**		**11,506**	

[a] Fecal Indicator Bacteria (FIB) parameters = total coliform (T), fecal coliform (F), *Enterococcus* bacteria (E); n = 3 parameters required at shore and kelp water quality stations.
[b] *Enterococcus* = only FIB indicator required at offshore water quaility stations.
[c] CTD profile = temperature, depth, pH, salinity, dissolved oxygen, light transmittance (transmissivity), and chlorophyll *a* (n = 7 required parameters), plus density and CDOM (n = 9 parameters total)
[d] Sediment constituents = sediment particle size, total organic carbon, total nitrogen, sulfides, metals, PCBs, chlorinated pesticides, PAHs (n = 8 parameter categories; see NPDES permit for complete list of constituents).
[e] Sediment constituents = BOD at 12 primary core stations only (voluntary sampling per agreement with USEPA Region IX)
[f] Fish tissue constituents = lipids, metals, PCBs, chlorinated pesticides, and PAHs (n = 5 parameter categories; see NPDES permit for complete list of constituents)
[g] Random (regional) benthic survey = joint requirement of Point Loma and South Bay outfall monitoring programs (i.e., 40 stations/year total)
[h] Continued Sediment Toxicity Monitoring as recommended by the Final Project Report for the Sediment Toxicity Pilot Study for the San Diego Ocean Outfall Monitoring Regions (City of San Diego 2019)

Table 3

Core receiving waters monitoring requirements for the South Bay Ocean Outfall region. Sampling effort excludes FIB resamples, QA/QC activities, new plume tracking requirements, and special studies.

Monitoring Component	Location	No. of Stations/ Zones	Sample Type	Discrete No. Samples/Site	Sampling Frequency	Sampling Times/Yr	Discrete No. Samples/Yr	Parameters	No. "Samples" Analyzed/Yr	Notes
Water Quality,	shore	11	Seawater - FIB	1	1/Week	52	572	T, F, E[a]	1716	1 sample/station
Microbiology,										
Oceanographic	kelp/	7	Seawater - FIB	3	1/Week	52	1092	T, F, E[a]	3276	3 depths/station
Conditions	nearshore	7	CTD	1	1/Week	52	364	CTD profile[b]	3276	1 cast/station (1-m batch avg samples)
	offshore	21	Seawater - FIB	3	1/Quarter	4	252	T, F, E[a]	756	3 depths/station
		33	CTD	1	1/Quarter	4	132	CTD profile[b]	1188	1 cast/station (1-m batch avg samples)
		3	Seawater - pH/TA	2-3	1/Quarter	4	32	pH, TA[c]	64	2-3 depths/station
Sediment Chemistry	offshore	27	Grab	1	2/Year	2	54	sed chem[d]	432	1° and 2° core stations (Jan, Jul)
	offshore	40	Grab	1	1/Year	1	40	sed chem[d]	320	Randomized stations (Jul)[f]
Benthic Infauna	offshore	27	Grab	1	2/Year	2	54	community structure	54	1° and 2° core stations (Jan, Jul)
	offshore	40	Grab	1	1/Year	1	40		40	Randomized stations (Jul)[f]
Sediment Toxicity	offshore	8-28	Grab	1	1/Year	1	8-28	acute toxicity	8-28	Rotating offshore stations[g]
Demersal Fishes & Invertebrates	offshore	7	Trawl	1	1/Year	2	14	community structure	14	1 trawl/station (Jan, Jul)
Bioaccumulation in Fish Tissues	offshore	5	Trawl/Hook & Line	3	1/Year	1	15	liver tissue[e]	75	3 composites/zone (Oct)
	offshore	2	Hook & Line	3	1/Year	1	6	muscle tissue[e]	30	3 composites/zone (Oct)
Totals							**2695**		**11,269**	

[a] Fecal Indicator Bacteria (FIB) = total coliform (T), fecal coliform (F), and *Enterococcus* bacteria (E); n = 3 parameters required at all shore, kelp nearshore and offshore water quality stations
[b] CTD profile = temperature, depth, pH, salinity, dissolved oxygen, light transmittance (transmissivity), chlorophyll *a* (n = 7 required parameters), plus density and CDOM (n = 9 parameters total)
[c] As of July 1, 2021, samples were collected and analyzed for pH/TA at offshore stations (see SBWRP and SBIWTP NPDES permits for details)
[d] Sediment constituents = sediment particle size, total organic carbon, total nitrogen, sulfides, metals, PCBs, chlorinated pesticides, PAHs (n = 8 parameter categories; see NPDES permits for complete list of constituents)
[e] Fish tissue constituents = lipids, metals, PCBs, chlorinated pesticides, and PAHs (n = 5 parameter categories; see NPDES permits for complete list of constituents)
[f] Random (regional) benthic survey = joint requirement of Point Loma and South Bay outfall monitoring programs (i.e., 40 stations/year total)
[g] Continued Sediment Toxicity Monitoring as recommended by the Final Project Report for the Sediment Toxicity Pilot Study for the San Diego Ocean Outfall Monitoring Regions (City of San Diego 2019)

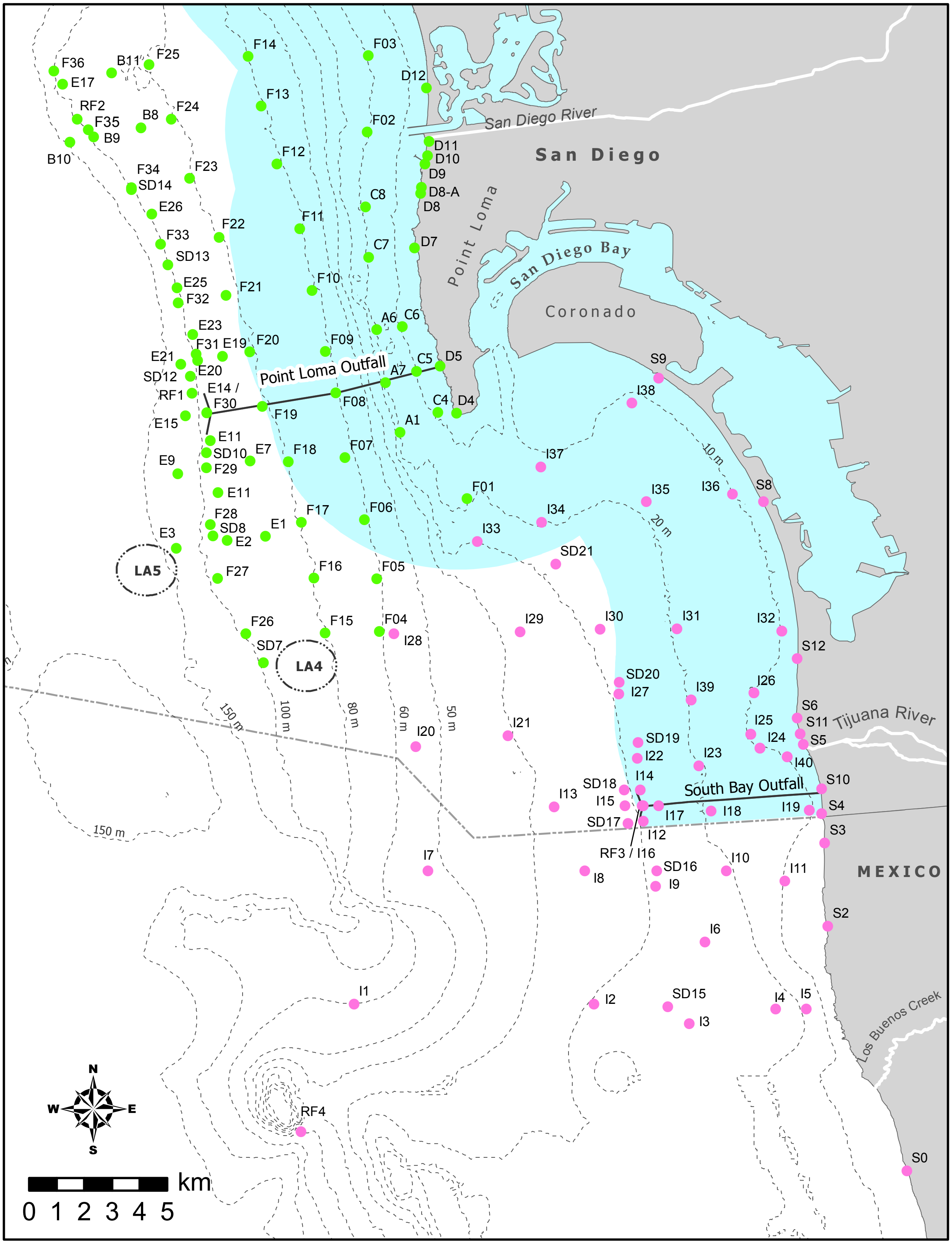

Figure 1

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

Table 4

Toxicity testing required in accordance with various NPDES permits. Listed effort excludes accelerated testing requirements (e.g., triggered by Notice of Violation), additional QA/QC procedures, and special studies.

Testing Component	Location/ Project	Sample Type	No. samples	Sampling Frequency	Sampling Times/Yr	No. test Species	Effluent/Ref Tox Tests/Yr[b]	Total Tests/Yr	Endpoints[c]	Dilutions per bioassay	Notes
Point Loma Chronic toxicity	PLWTP	Final effluent	1	Monthly	12	1	12 + 12 Ref Tox	24	Sensitive lifestage	1[a] + control	Species: giant kelp
	(Biennial screening)	Final effluent	1	3 x per 2 yrs	3 x per 2 yrs	3	9 + 9 Ref Tox per 2 yrs	18 per 2 yrs	Sensitive lifestage	1[a] + control	Screening spp: giant kelp, red abalone, and topsmelt
South Bay Chronic toxicity	SBWRP	Final effluent	1	Quarterly	4	1	4 + 4 Ref Tox	8	Sensitive lifestage	1[d] + control	Species: giant kelp
	(Biennial screening)	Final effluent	1	3 x per 2 yrs	3 x per 2 yrs	3	9 + 9 Ref Tox per 2 yrs	18 per 2 yrs	Sensitive lifestage	1[d] + control	Screening spp: giant kelp, red abalone, and topsmelt

[a] The In-stream Waste Concentration (IWC) of 0.49% effluent, using the of Test of Significant Toxicity (TST)

[b] Ref Tox = Reference Toxicant Test

[c] Sensitive lifestage endpoints: (1) red abalone = development; (2) giant kelp = germination and growth; (3) topsmelt = survival and growth

[d] The IWC of 1.06% effluent, using the test of significant toxicity (TST)

Table 5

Number of discrete samples collected and analyzed by EMTS staff for NPDES permit-related activities during 2023. NA = not applicable.

	Number of Samples Collected		Number of Analyses per Sample Type	
Sample Type	**Regular**	**QC**	**Regular**	**QA**
Sediment Grab				
Particle Size Subsample	74	NA	(performed by ECS)	
Chemistry Subsample	321[a]	NA	(performed by ECS)	
Benthic Infauna Grab	74	NA	74	6
Otter Trawl	13	NA	13	NA
Fish Tissue	0	NA	(performed by ECS)	
Water Quality				
CTD Cast	1056	NA	9466[c]	NA
Microbiology	4163[b]	569	11,303[d]	1579[d]
pH/TA	74[e]	15[e]	(performed by SCCWRP)	
Toxicology				
Sediment Toxicity	0	NA	0	0
Chronic Bioassay	25	NA	25	19
Bight'18 Ocean Acidification				
CTD Cast	7	NA	63[c]	NA
pH/TA	14	NA	(performed by SCCWRP)	
Zooplankton	14	NA	(performed by SCCWRP)	
Totals	**5843**	**584**	**20,944**	**1604**

[a] PLOO primary core stations had five subsamples per grab; all other stations had four subsamples per grab
[b] Includes resamples
[c] Includes up to nine parameters per cast (depth, temperature, salinity, DO, light transmittance, chlorophyll *a*, pH, density, CDOM)
[d] Includes up to three types of fecal indicator bacteria (total coliform, fecal coliform, *Enterococcus*)
[e] Not all pH/TA samples have yet been analyzed, see text for details.

Table 6

Summary of the CTD intercalibration results for casts conducted during 2023, including (A) mean difference (MeanΔ) and max difference (MaxΔ) between Unit #5 and Unit #6 across casts and depths, and the cast number (1, 2, 3) and depth (0–100 m) at which the maximum difference occurred and (B) results of CTD intercalibration exercises conducted during the last five years. Values are the MeanΔ between Unit #5 and Unit #6.

A	**July 2023**				**December 2023[a]**			
Parameter	**MeanΔ**	**MaxΔ**	**Cast**	**Depth (m)**	**MeanΔ**	**MaxΔ**	**Cast**	**Depth (m)**
Temperature (°C)	0.09	0.77	3	8	—	—	—	—
Salinity (ppt)	0.01	0.03	2	57	—	—	—	—
DO (mg/L)	0.08	0.41	3	34	—	—	—	—
pH	0.10	0.15	3	34	—	—	—	—
Transmissivity (%)	1.66	3.62	1	2	—	—	—	—
Chlorophyll *a* (µg/L)	0.06	0.38	3	30	—	—	—	—

B **Parameter**	**Jan 2018**	**Nov 2018**	**Jul 2019**	**Dec 2019**	**Jul 2020**	**Jan 2021**	**Jun 2021**	**Dec 2021**	**Jun 2022**	**Dec 2022**	**Jun 2022**	**Jul 2023**
Temperature (°C)	0.04	0.03	0.02	0.01	0.01	0.01	0.04	0.01	0.02	0.01	0.02	0.09
Salinity (ppt)	0.02	0.02	0.00	0.02	0.01	0.01	0.01	0.01	0.003	0.003	0.003	0.01
DO (mg/L)	0.03	0.11	0.31	0.39	0.06	0.29	0.16	0.18	0.04	0.12	0.04	0.08
pH	0.03	0.06	0.11	0.06	0.18	0.07	0.05	0.22	0.06	0.07	0.06	0.10
Transmissivity (%)[b]	—	2.39	2.84	3.88	3.97	5.56	1.96	0.80	11.10	0.14	11.10	1.66
Chlorophyll *a* (µg/L)	0.11	0.11	0.22	0.74	0.30	0.08	0.28	0.13	0.86	0.12	0.86	0.06

[a]The December 2023 intercalibration was delayed due to manufacturer instrument service, see text for details

[b]Transmissivity results not available from January 2018 intercalibration casts due to probe failure

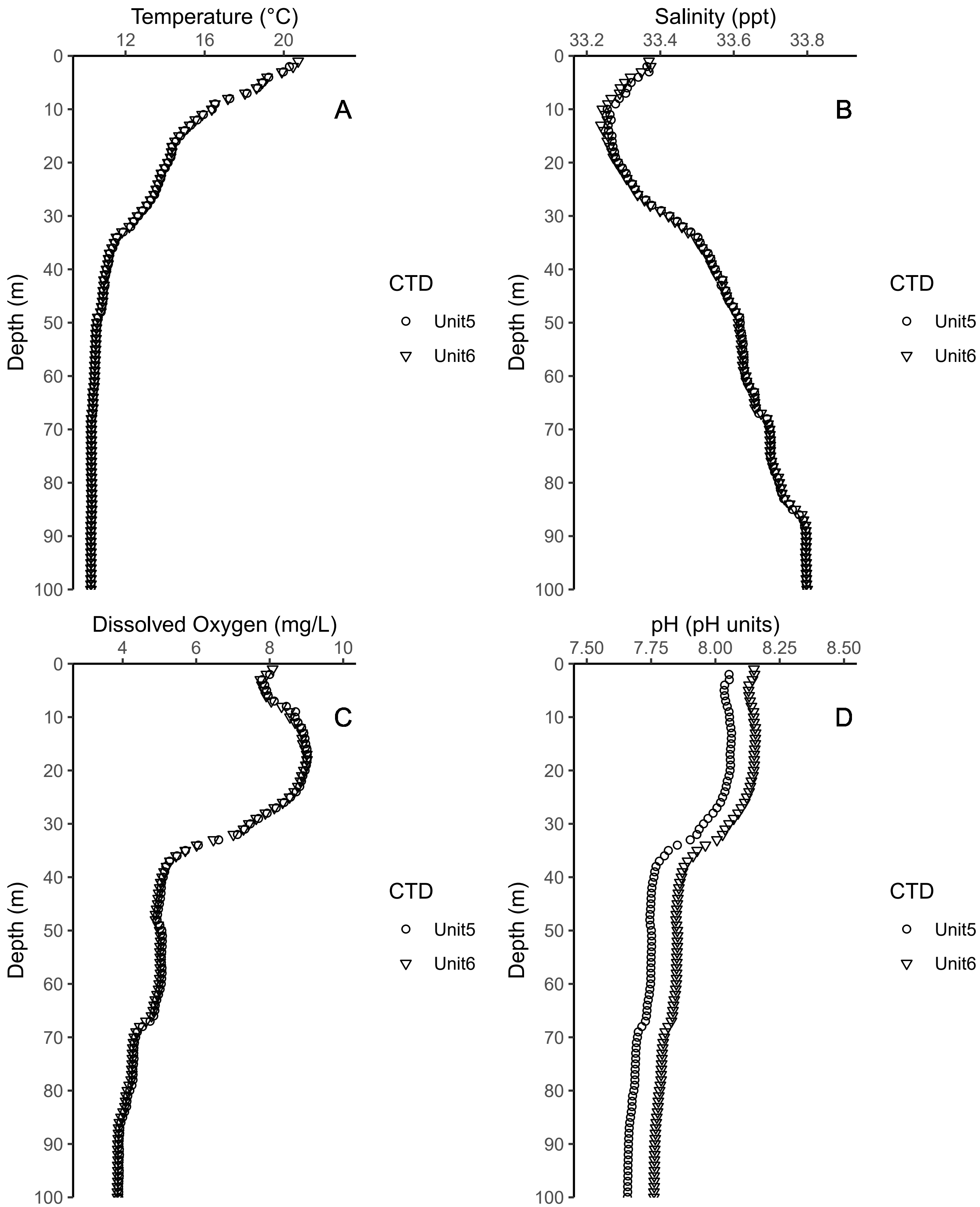

Figure 2

Comparison of results from CTD Unit #5 and Unit #6 from one representative cast made during the July 2023 CTD intercalibration exercise. Data include 1 m bin-averaged cast profiles for (A) temperature, (B) salinity, (C) dissolved oxygen, (D) pH, (E) transmissivity, and (F) chlorophyll *a*.

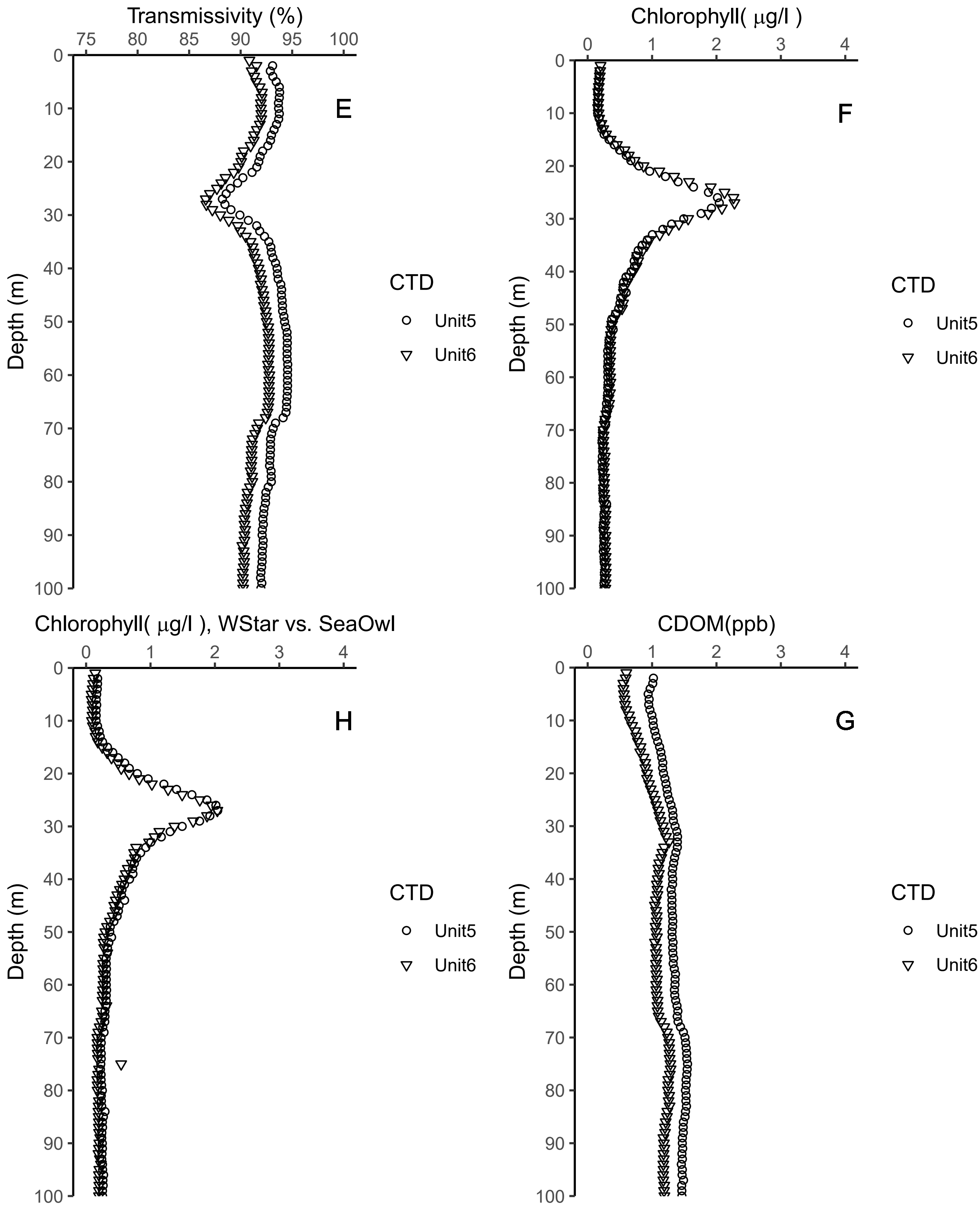

Figure 2 *continued*

Table 7

Comparison of CTD (Sea-Bird 25Plus) pH sensor and bottle sample results from samples collected in 2023.

Region	Station	Sample Date	Target Depth (m)	CTD Temp (degC)	CTD Salinity (PSU)	CTD pH (NBS scale)	Bottle pH (total scale)	Bottle Alkalinity (µmol/kg)	Aragonite Saturation State (Ω)
PLOO	F35	28-Feb-23	1	13.56	33.36	8.069	8.026	2231.9	1.74
			50	11.58	33.55	7.792	7.791	2234.5	1.02
			100	10.91	33.82	7.713	7.714	2243.0	0.86
			100[a]	10.93	33.82	7.715	7.720	2246.8	0.87
	F13	02-Mar-23	1	13.28	33.30	8.104	8.034	2239.6	1.76
			60	10.87	33.81	7.724	7.721	2254.5	0.87
	F15	03-Mar-23	1	13.53	33.28	8.156	8.057	2233.8	1.85
			80	10.72	33.88	7.739	7.706	2245.0	0.84
SBOO	I1	07-Feb-23	1	14.25	33.35	8.000	8.031	2230.7	1.76
			30	13.40	33.37	7.881	7.937	2229.7	1.44
			60	12.00	33.56	7.723	7.793	2237.8	1.03
			60[a]	12.00	33.56	7.723	7.788	2232.9	1.02
	I21	08-Feb-23	1	13.78	33.29	8.073	8.024	2232.4	1.73
			41	11.56	33.61	7.788	7.763	2233.7	0.97
	I28	09-Feb-23	1	13.79	33.28	8.069	8.013	2229.9	1.68
			55	11.22	33.66	7.775	7.748	2240.3	0.92

[a] Duplicate sample

Table 8
RTOMS data qualifier definitions for QC flag columns. Follows national data standards for summary real-time data flagging (UNESCO/QARTOD), and post-processing flagging (NOAA/Argo program) (US IOOS 2023).

QC_Flag	Designation	Use
1	Pass/good	For data reviewed both automatically and manually
2	Provisional/unreviewed	For data that is not reviewed; or data received review but quality could not be determined
3	Suspect/questionable	Failed automated test but not unreasonable (such as climatology test) or manually flagged as possible instrument drift (such as due to bio-fouling)
4	Bad	Failed automated test (such as out of range test) or manually flagged as clearly bad (such as due to instrument malfunction)
5	Value changed/drift-corrected	Used only in post-processing. Values have been corrected based on new information, such as water sample results to correct for drift or new calibration factors. For data use purposes, this flag can be treated as a “pass.” Original data are also to be retained separately.
9	Missing	Placeholder to show missing real-time data; may be able to be filled in later by downloaded data when available and after mooring recovery

Table 9

Summary of CTD (Sea-Bird 25Plus) and PLOO RTOMS temperature (Temp), salinity (Sal), and dissolved oxygen (DO) results from validation casts completed in 2023. NA = not available.

Sample Date	Actual Depth (m)	Temp_CTD (°C)	Temp_RTOMS (°C)	Sal_CTD (ppt)	Sal_RTOMS (PSU)	DO_CTD (mg/L)	DO_RTOMS (mg/L)
28-Feb-23	1	13.7	13.7	33.33	33.35	8.2	8
	10	13.6	13.6	33.36	33.27	8.2	NA
	20	13.6	13.6	33.36	33.35	8.2	NA
	30	13.3	13.4	33.38	33.36	7.6	7.6
	45	11.8	11.8	33.52	33.51	5.4	NA
	60	11.1	11.2	33.65	33.58	3.9	NA
	75	11.1	11.2	33.65	NA	3.8	NA
	89	11.3	11.1	33.73	33.59	4	3.8
23-May-23	1	17.4	17.3	33.49	33.44	8.3	8.3
	10	17.3	17.3	33.49	33.37	8.4	NA
	20	14.9	14.7	33.46	33.38	9.5	NA
	30	13.1	12.9	33.42	33.34	8.5	8.3
	45	11.5	11.5	33.38	33.31	6.5	NA
	60	10.9	10.8	33.57	33.21	5.3	NA
	75	10.3	10.3	33.75	NA	3.9	NA
	89	10.2	10.2	33.84	33.44	3.7	3.5
15-Aug-23	1	21	21.2	33.45	33.37	8.1	8
	10	15.3	15.2	33.37	33.17	8.9	NA
	20	13.1	13.1	33.32	33.21	8	NA
	30	12.4	12.5	33.35	33.24	7.2	7
	45	11.9	11.9	33.4	33.35	6.4	NA
	60	11.3	11.4	33.48	33.28	5.3	NA
	75	11.1	11.1	33.48	NA	4.7	NA
	89	11	11.1	33.61	NA	4.8	4.8
24-Oct-23	1	17.8	17.8	33.14	33.12	6.9	7.7
	10	14.5	15.1	34.03	32.96	7.1	NA
	20	13.9	13.9	33.27	33.1	7.1	NA
	30	13.9	14	33.36	33.18	6.4	6.3
	45	13.7	13.7	33.32	33.26	6.2	NA
	60	13.3	13.3	33.44	33.31	5.6	NA
	75	12.9	12.8	33.42	NA	5.5	NA
	89	12.5	12.5	33.45	NA	5.3	5.1

Table 10

Summary of CTD (Sea-Bird 25Plus) and SBOO RTOMS temperature (Temp), salinity (Sal), and dissolved oxygen (DO) results from validation casts completed in 2023. NA = not available.

Sample Date	Actual Depth (m)	Temp_CTD (°C)	Temp_RTOMS (°C)	Sal_CTD (ppt)	Sal_RTOMS (PSU)	DO_CTD (mg/L)	DO_RTOMS (mg/L)
19-Jul-23	1	20.7	20.7	33.44	33.47	8.7	8.8
	10	16.3	15.9	33.45	33.33	9.1	NA
	18	14.8	14.7	33.37	33.32	9	9.1
	26	13.1	13	33.43	33.38	8.2	8.1
9-Aug-23	1	20.6	21	33.26	33.42	8.4	8.6
	10	14.8	14.9	33.29	33.2	8.9	NA
	18	13.7	13.6	33.38	33.3	8.6	8.7
	26	12.9	NA	33.37	NA	7.2	NA
8-Nov-23	1	16.9	17	33.17	33.14	8.8	8.5
	10	16.5	NA	33.17	NA	8.6	NA
	18	15.1	15	33.1	33.12	7.8	7.7
	26	14.9	NA	33.2	NA	7.7	NA

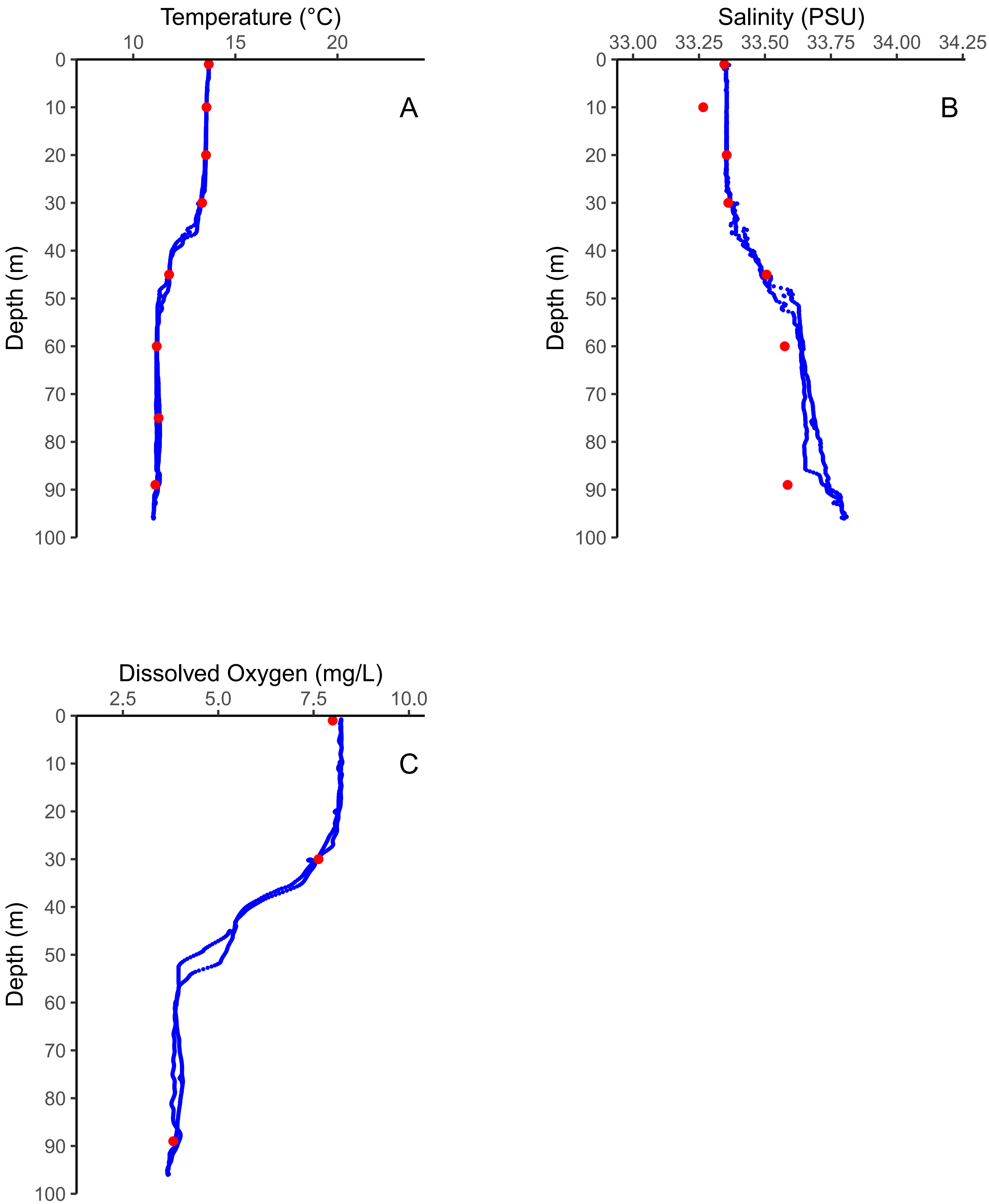

Figure 3

Comparison of results from the Sea-Bird 25Plus CTD profiles (blue line) and the PLOO RTOMS sensors (red dots) during the February 2023 CTD validation cast. Data include (A) temperature, (B) salinity, and (C) dissolved oxygen.

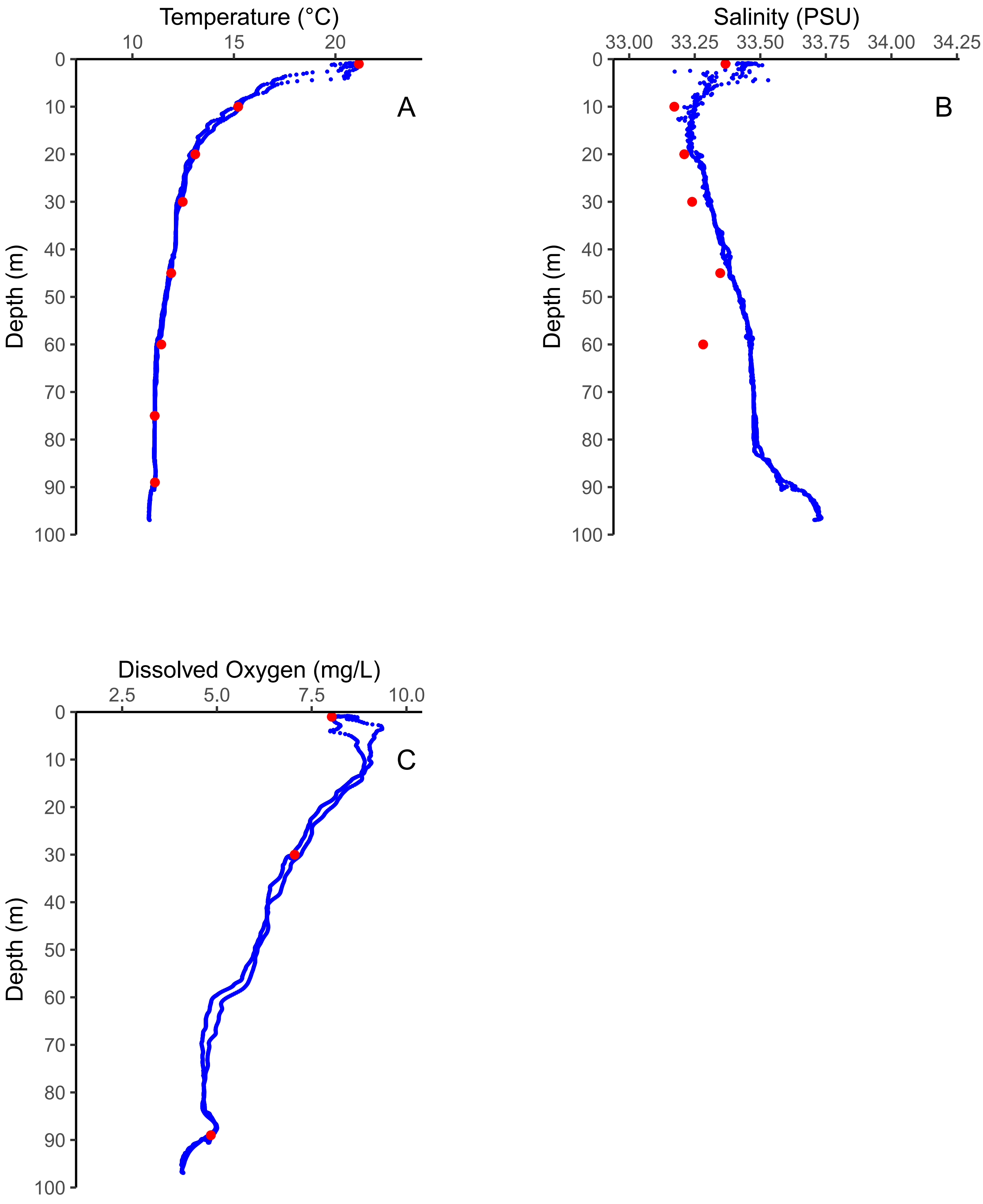

Figure 4

Comparison of results from the Sea-Bird 25Plus CTD profiles (blue line) and the PLOO RTOMS sensors (red dots) during the August 2023 CTD validation cast. Data include (A) temperature, (B) salinity, and (C) dissolved oxygen.

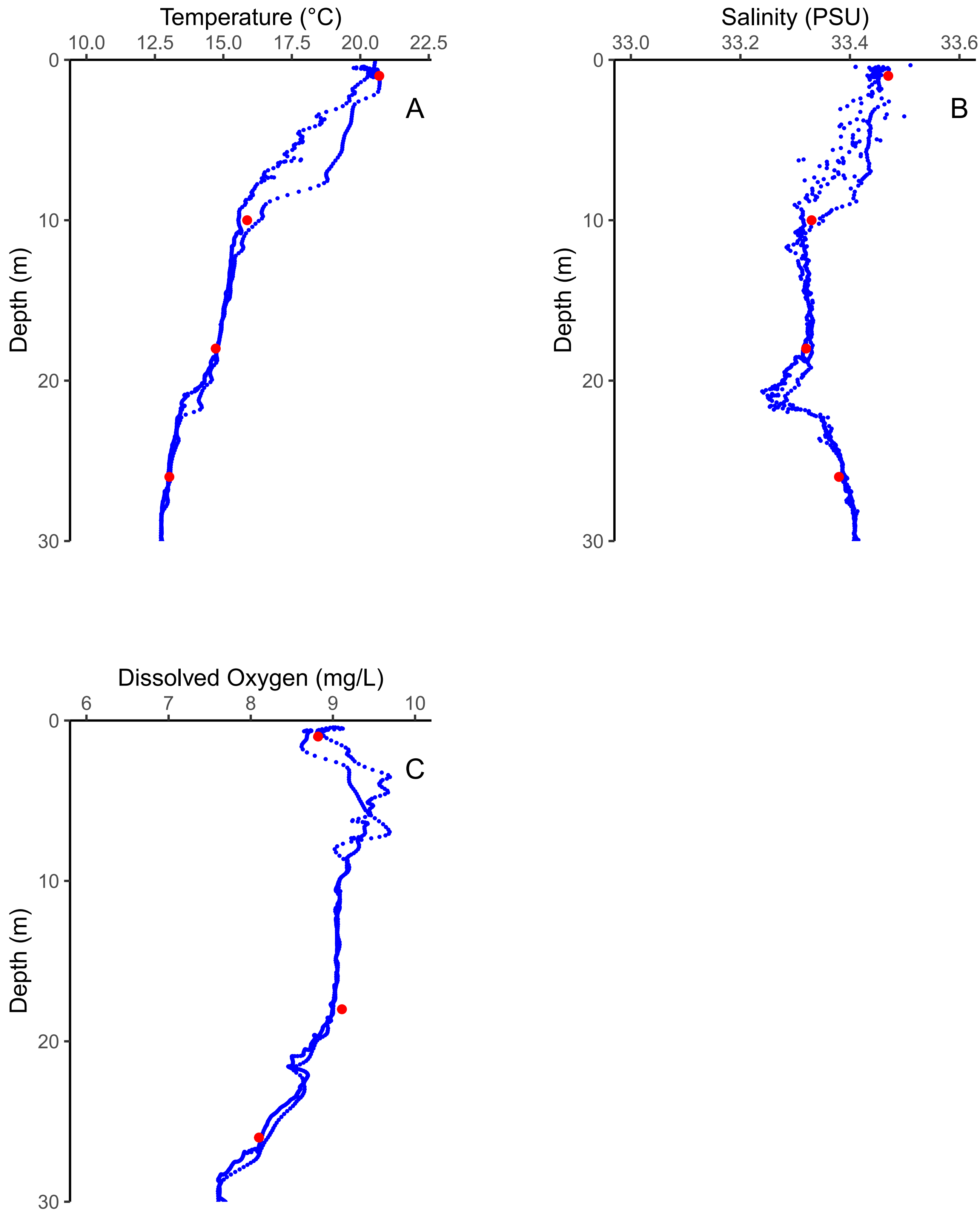

Figure 5
Comparison of results from the Sea-Bird 25Plus CTD profiles (blue line) and the SBOO RTOMS sensors (red dots) during the July 2023 CTD validation cast. Data include (A) temperature, (B) salinity, and (C) dissolved oxygen.

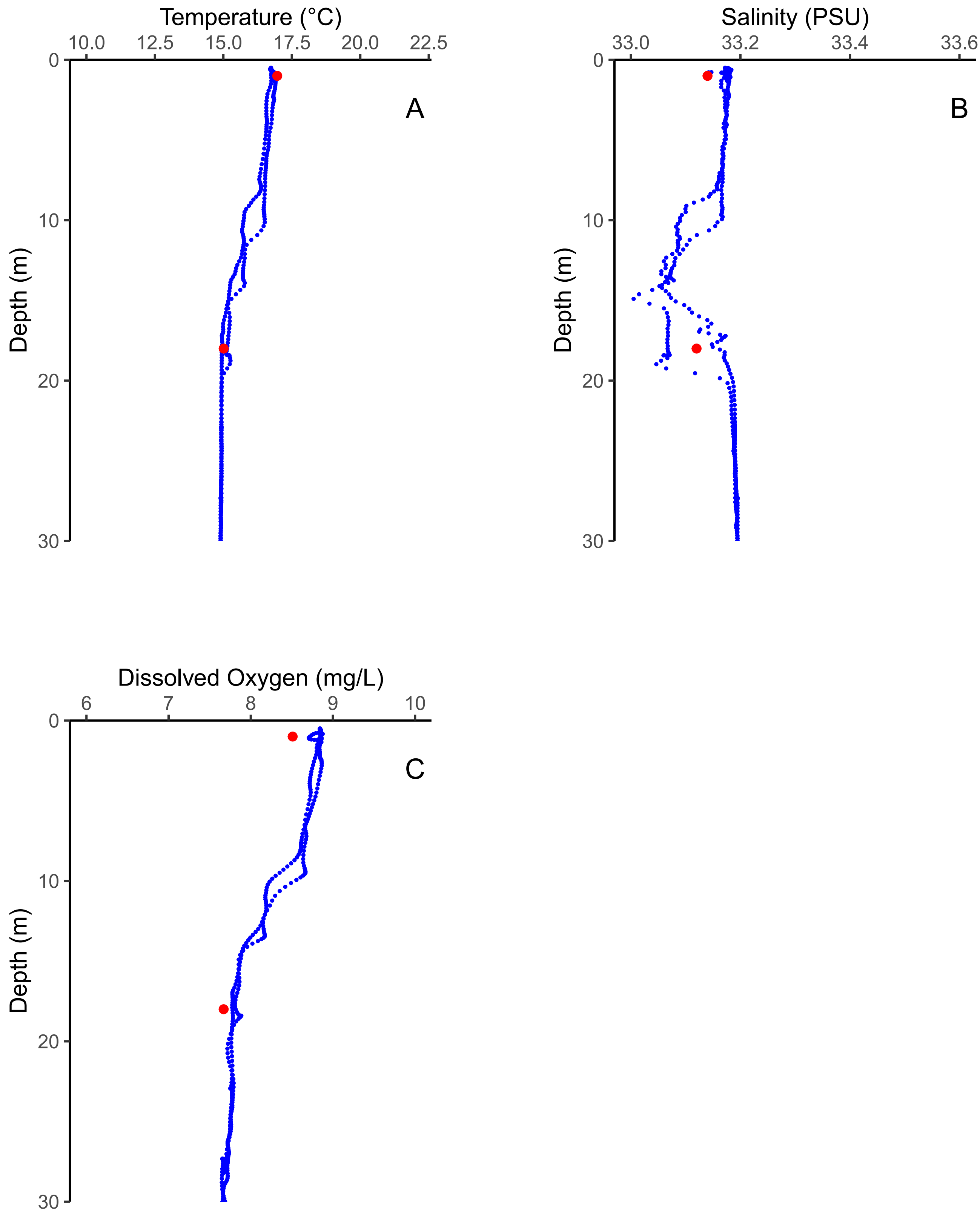

Figure 6
Comparison of results from the Sea-Bird 25Plus CTD profiles (blue line) and the SBOO RTOMS sensors (red dots) during the November 2023 CTD validation cast. Data include (A) temperature, (B) salinity, and (C) dissolved oxygen.

Table 11

Summary of water samples (lab) and RTOMS SUNA sensor nitrate + nitrite results from samples collected during 2023. Negative SUNA data indicate downward sensor drift that requires correction. ND = non-detect (<1.3 µM for lab water samples); NA = not available; NS = not sampled.

Mooring	Sample Date	Target Depth (m)	Niskin Depth (m)	Lab Nitrate + Nitrite (µM)	SUNA Nitrate + Nitrite (µM)	Comments
PLOO	28-Feb-23	30	30.4	5.2	6.8	Apply drift correction for SUNA
		75	75.7	20.4	16.4	"
		75	75.7	19.6	16.4	"
	23-May-23	30	30.6	4.1	7.9	Apply drift correction for SUNA
		75	75.4	24.4	10.9	Step change in SUNA; apply new drift correction
		75	75.8	22.3	10.9	"
	15-Aug-23	30	30.4	9.2	13.5	Apply drift correction for SUNA
		75	75.7	18.8	24.5	High variability and noise in SUNA data
		75	75.4	18.3	24.5	"
	24-Oct-23	30	30.3	7.1	11.9	Apply drift correction for SUNA
		75	75.3	12.3	17.2	Step change in SUNA; apply new drift correction
		75	75.3	11.9	17.2	"
SBOO	19-Jul-23	1	1.0	ND	-1.9	Apply drift correction for SUNA
		26	26.8	7.8	7.8	SUNA and lab results in alignment
		26	26.8	NS	7.8	Field error; lab 26m duplicate not collected
	9-Aug-23	1	0.7	5.3	-2.0	Apply drift correction for SUNA
		26	26.0	5.6	NA	Controller malfunction; no SUNA data
		26	26.1	5.7	NA	"
	8-Nov-23	1	0.9	ND	-0.3	Apply drift correction for SUNA
		26	28.1	ND	NA	Controller malfunction; no SUNA data
		26	28.0	ND	NA	"

Table 12

Summary of bacteriological QA analyses conducted during 2023 for the City of San Diego's Ocean Monitoring Program. n = number of sample pairs with different colony counts (samples without differences are not included); B = the number of positive differences between pairs; Z_b = sign test outcome; H_o = the probability of observing positive and negative differences in plate counts between paired samples is equal (see text). Paired samples were compared using the sign test (see Gilbert 1987) at a $p = 0.05$ level of significance.

Sample Type	Parameter	n	B	Z_b	*p*	H_o
Lab Duplicate	Total Coliform	213	109	0.34	1.96	Fail to Reject
	Fecal Coliform	177	97	1.28	1.96	Fail to Reject
	Enterococcus	194	88	-1.29	1.96	Fail to Reject
Field Duplicate	Total Coliform	46	15	-2.36	1.96	Reject
	Fecal Coliform	53	28	0.41	1.96	Fail to Reject
	Enterococcus	61	32	0.38	1.96	Fail to Reject

Table 13

Results of benthic macrofauna sample re-sort analyses conducted during 2023 by the City of San Diego's Ocean Monitoring Program. Percent = (# of animals found in the resorted sample/total sample abundance) X 100.

PLOO			SBOO			REGIONAL[a]		
Survey	**Station**	**Percent**	**Survey**	**Station**	**Percent**	—	—	—
Jan-23	B8	0.0%	**Jan-23**	I8	0.0%			
	B9	0.0%		I10	0.0%			
	E3	0.0%		I12	0.0%			
	E11	0.0%		I21	0.0%			
	E23	0.0%		I23	4.1%			
				I31	0.0%			
Jul-23	B9	0.0%		I34	0.0%			
	E8	0.0%						
	E14	2.0%	**Jul-23**	I3	0.0%			
	E17	0.0%		I9	0.0%			
	E20	0.0%		I12	1.4%			
				I16	0.1%			

[a] Regional samples were not collected during 2023 due to resource exchange for participation in Bight '23 Regional Sampling