Morro Bay Estuary Bacteria and Dissolved Oxygen Analysis
Water Year 2021

Date Range: Water Year 2021 (October 1, 2020 to September 30, 2021)
Analytes: Dissolved Oxygen, *Enterococcus spp*.

Background

The Morro Bay National Estuary Program's Monitoring Program conducts monitoring in the Morro Bay estuary and watershed to track ambient water quality trends and to assess the impacts of specific implementation projects.

Monitoring data is collected by Estuary Program staff and volunteers, under the guidance of a Quality Assurance Project Plan (QAPP) which is reviewed and approved by the EPA and the State Water Resources Control Board. This quality control document contains the monitoring locations, protocols, equipment specifications, and other details that allow users to assess the quality of the collected data. The full QAPP is available upon request.

Bay Bacteria

The Estuary Program's goal for bay bacteria monitoring is to assess the safety of the bay shoreline waters for recreational contact. Since 2005, program volunteers have sampled monthly at eight bay shoreline sites and analyzed the samples for the indicator bacteria enterococcus. The samples are collected using sterile technique. Typically the samples are analyzed by volunteers at the Morro Bay-Cayucos Wastewater Treatment Plant lab using the IDEXX method. Since the start of the COVID pandemic, samples have instead been analyzed by the San Luis Obispo County Public Health Laboratory utilizing the IDEXX method.

Enterococcus Monitoring Specifications:

Specification	Value
Method	IDEXX Enterolert
Detection Range	10 to 24,190 MPN/100 mL
Hold Time	24 hours
Sample storage conditions	4°C in the dark

The San Luis Obispo County Public Health Laboratory is accredited by the state's Environmental Laboratory Accreditation Program and follows all required procedures to ensure data quality.

For this analysis, a random value between 0.1 and 10 was assigned for all samples that had a result of <10 MPN/100 mL, which is the detection limit for this method. This approach affects the calculated

geomeans for past years and thus, graphs will not match previous reports. This method of handling non-detect data is utilized by the Central Coast Regional Water Quality Control Board (CCRWQCB) in their own analysis.

Monitoring Locations

The eight bay shoreline monitoring sites were selected because they represent the areas with the most recreational contact. The sites are (from north to south) Coleman Beach (site code COL), Tidelands Park (TID), Windy Cove (WIN), State Park Marina (SPM), Pasadena Point (PAS), Baywood Pier (BAY), Cuesta Inlet (CIN), and Sharks Inlet (SIN).

The following map (Figure 1) indicates the monitoring locations.

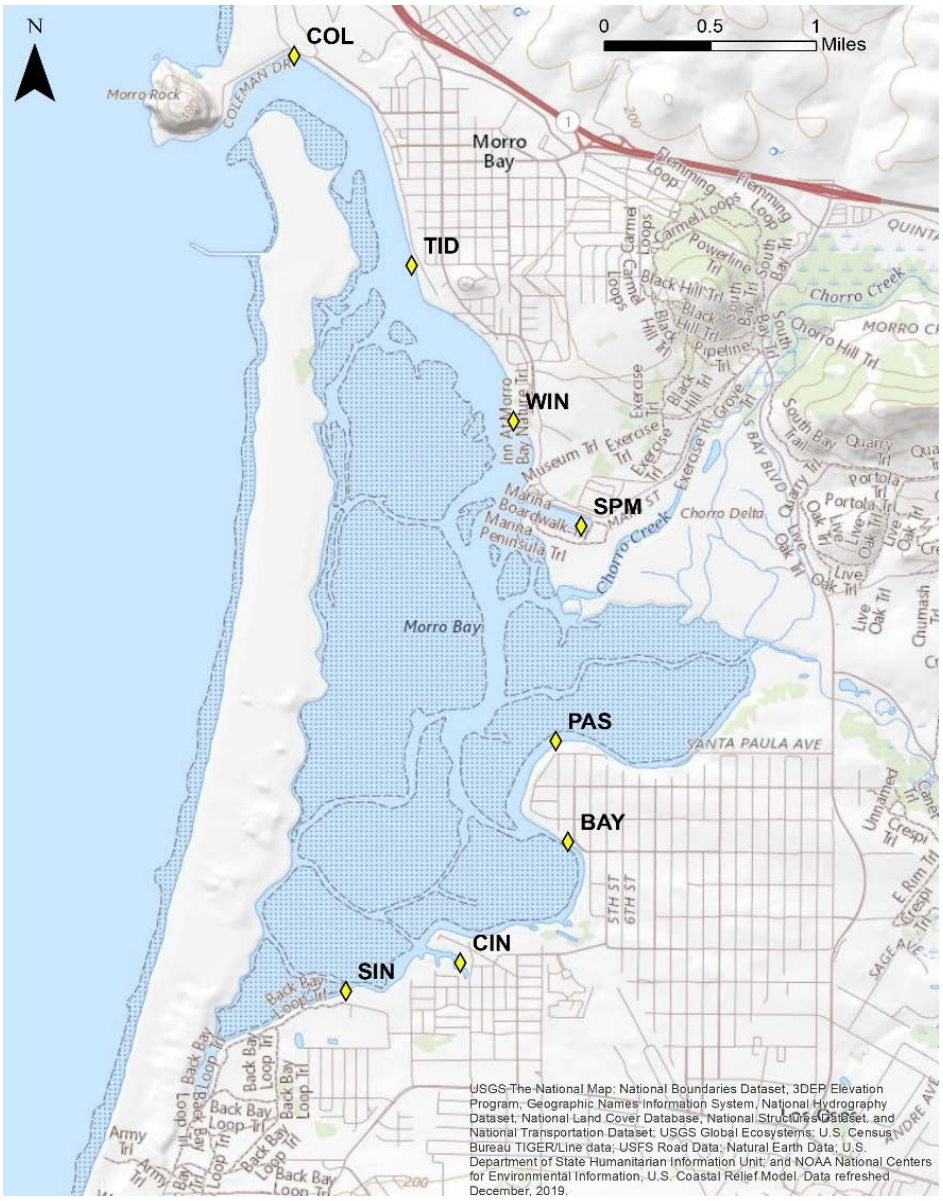


Figure 1. Locations of shoreline bacteria monitoring sites in the Morro Bay estuary.

Results

Indicator bacteria data shows how often the waters in specific locations along the bay shoreline have levels greater than those safe for recreational contact.

The following graph (Figure 2) shows the percent of samples from Water Year 2021 (WY2021) that exceeded the Statistical Threshold Value (STV) criteria. Ideally, no more than 10% of samples exceed this value of 110 MPN/100 mL. This guiding value is from the State Water Resources Control Board's Bacterial Objectives and is lower than the previous EPA guiding value of 130 MPN/100 mL.

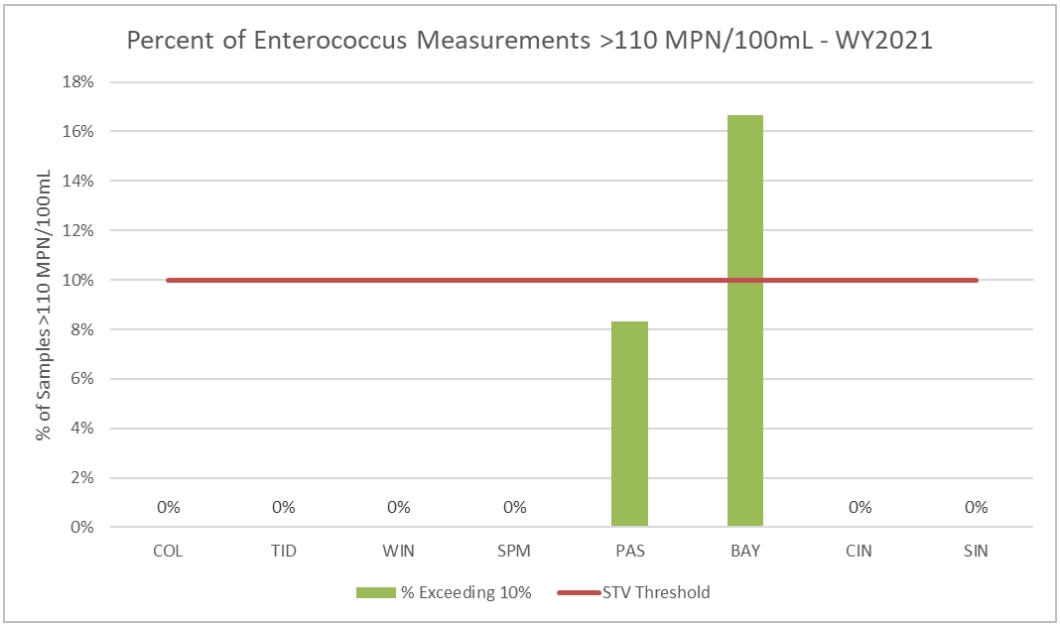


Figure 2. Percent of Enterococcus measurements greater than 110 MPN/100 mL for WY2021. The red line indicates the percent of samples exceeding this threshold Ideally no more than 10% of samples exceed this threshold.

The following graph (Figure 3) shows the geomean of all WY2021 data for each site. Ideally, the sample geomean remains below the guideline of 30 MPN/100 mL. This guideline is from the State Water Resources Control Board's Bacterial Objectives. This is lower than the previous guideline of 35 MPN/100 mL.

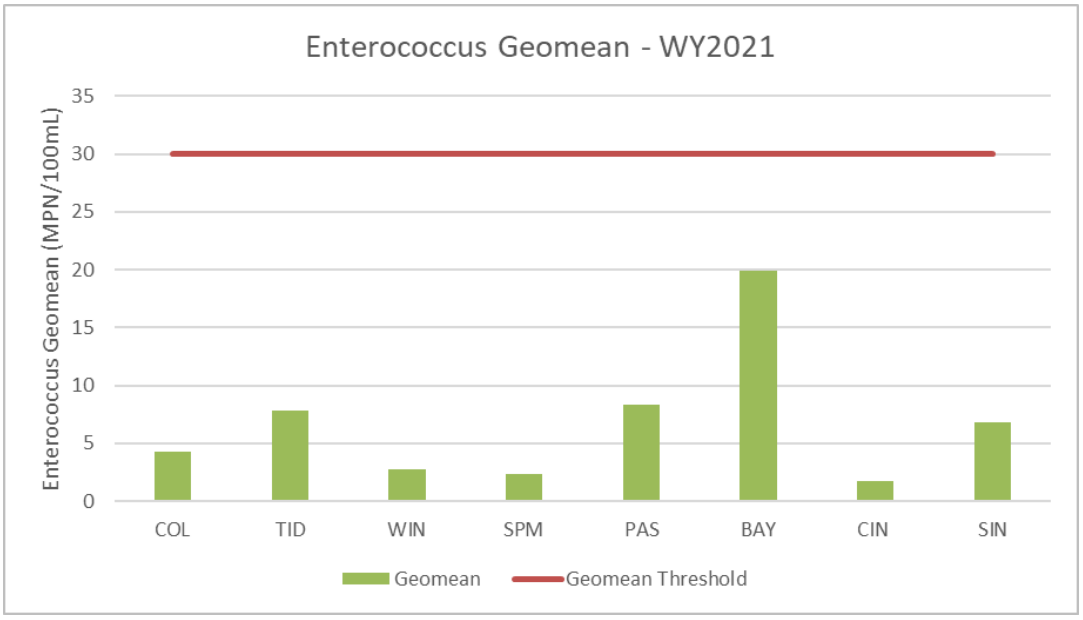


Figure 3. Geomean values from WY2021 collected from Morro Bay estuary shorelines sites. The red line indicates the geomean threshold, using the guideline of 30 MPN/100 mL.

Discussion

Of the eight sites monitored, historical trends have shown six sites only rarely exceeding recreational contact standards. The four sites toward the mouth of the bay (COL, TID, WIN, and SPM) have historically had very few elevated bacteria results. These sites are along the well-mixed main channel and are thought to be primarily influenced by ocean water entering the bay with the incoming tide. The two sites furthest back in the bay, Cuesta Inlet (CIN) and Sharks Inlet (SIN), also have had minimal exceedances of recreational standards. These sites may experience some water circulation issues, as the back bay is shallow and experiences minimal mixing with the incoming tides during certain times of year.

Two sites, Baywood Pier (BAY) and Pasadena Point (PAS), have had frequent exceedances of recreational standards historically, although these trends did not apply to WY2018 or WY2019. During WY2020, PAS had three exceedances and BAY had one. During WY2021, PAS had one exceedance and BAY had two. Figures 4 and 5 illustrate historic exceedances of 110 MPN/100 ml, from WY2008 to WY2021.

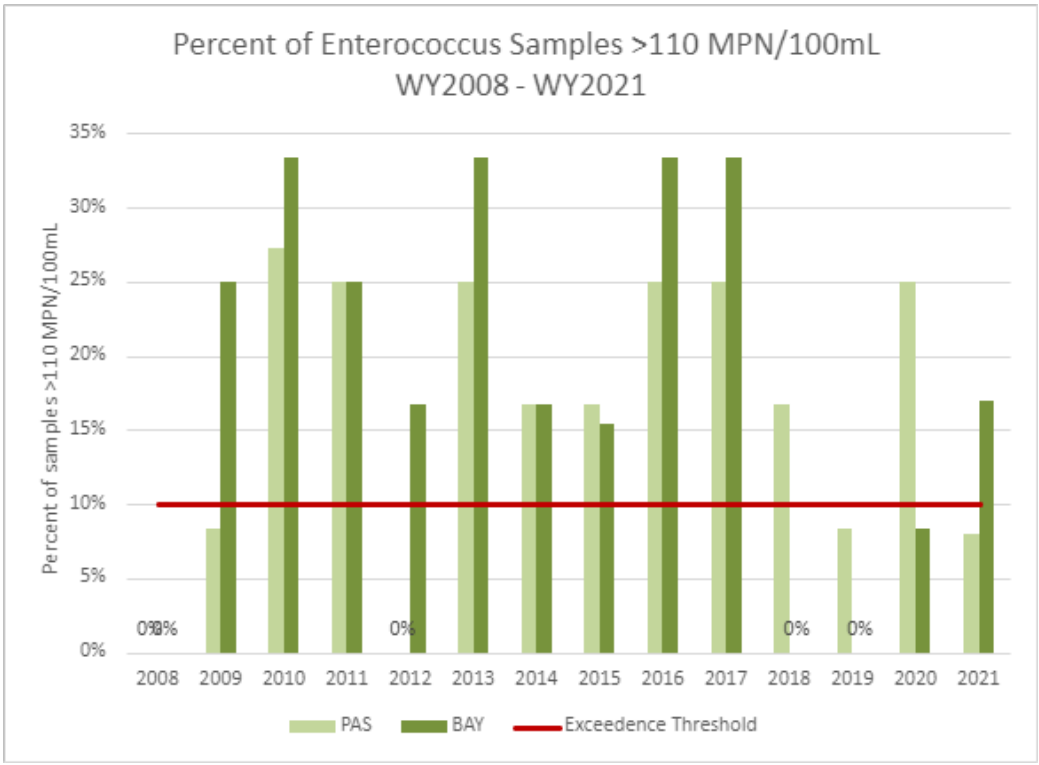


Figure 4. Percent of Enterococcus samples greater than the Statistical Threshold Value (STV) of 110MPN/100ml over the last 14 years. Note – the absence of a bar indicates that 0% of samples exceeded the threshold for the year. The red line indicates the STV, or Exceedance Threshold.

Figure 4 shows the exceedances of the recreational standard for the last fourteen years. BAY had ten and PAS had nine years where more than 10% of samples were at levels unsafe for swimming, although these did not always occur during the same year. In certain years, such as during WY2008, PAS and BAY did not exceed 110 MPN/100 mL. This is represented in the graph with the absence of a line, or 0% noted.

The following graph (Figure 5) shows the geomean of bacteria results by water year from WY2008 to WY2021. For PAS, four of fourteen years exceeded the criteria of 30 MPN/100 mL. For BAY, seven of fourteen years exceeded the criteria of 30 MPN/100 mL.

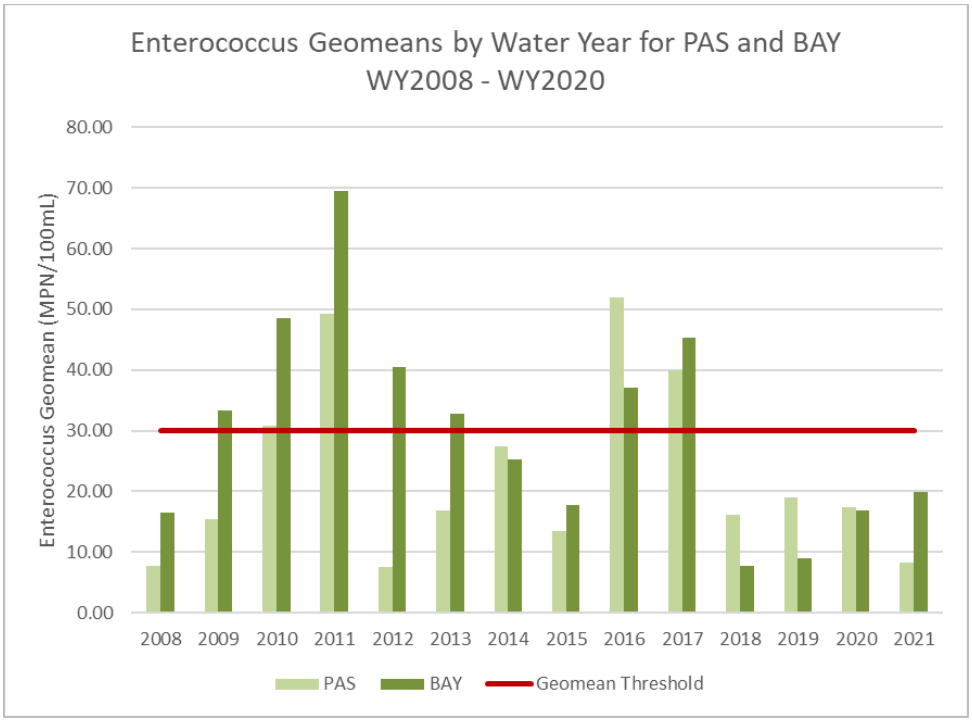


Figure 5. Enterococcus geomean by year for PAS and BAY. The red line indicates the geomean threshold of 30 MPN/100 mL. Ideally, geomean values remain below this threshold.

Pathogens are often flushed downstream by rainfall events. Correlations indicate how runoff following rain events can result in elevated bacteria levels along coastal sites, like that of BAY and PAS (Figure 6). Linear regressions comparing the monthly-averaged dataset found PAS bacteria levels to be significantly correlated with total precipitation ($p=0.006$). The correlation at BAY was not statistically significant ($p=0.207$). The lack of correlation with rainfall at BAY could indicate a land-based source of bacteria, such as urban runoff from a large culvert that continually drains into the bay at this site.

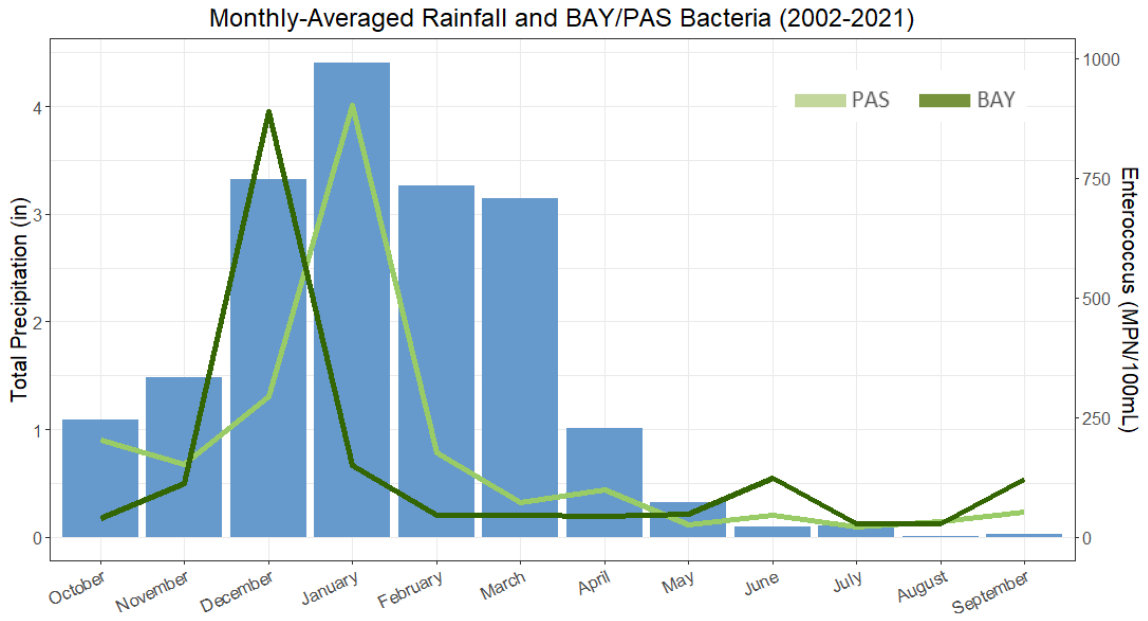


Figure 6. Total precipitation (in) and Enterococcus counts from 2002 to 2021 averaged by month. Rainfall is depicted by the blue bars, BAY bacteria is displayed with the dark green line, and PAS bacteria is displayed with the light green line. Total precipitation values were taken from CIMIS station 52, located in San Luis Obispo.

Potential sources of bay bacteria could include runoff from land, contaminated groundwater, and wildlife. The California Department of Public Health (CDPH) monitors freshwater seeps, which are areas where shallow groundwater is pushing up to the surface and draining into the bay. The Estuary Program monitors a series of them along the back bay, and data indicates elevated levels of the fecal coliform indicator bacteria. Additional information on this seeps data set is available on the Estuary Program website.

Bay Dissolved Oxygen

The Estuary Program wanted to assess the dissolved oxygen (DO) concentrations at the lowest levels in the diurnal cycle. Since 2002, program volunteers monitor monthly at seven bay sites and collect surface measurements for DO concentration, temperature, and salinity. The monitoring occurs in the early morning hours within two hours of sunrise on an adequate tide for safe access.

Equipment Specification

The Estuary Program uses a YSI Pro 2030 meter, which measures DO concentration (mg/L), DO % saturation, temperature, specific conductance (µS/cm), and salinity (ppt).

The equipment specifications for DO are as follows:

Specification	Value
Sensor Type	Polarographic
Measurement Range	0 to 50 mg/L
Calibrated Range	0 to 20 mg/L; 0 to 35°C
Accuracy	±2% of reading for 0 to 20 mg/L; ±6% of reading for 20 to 50 mg/L
Resolution	0.01 mg/L

To ensure data quality, the Estuary Program calibrates the meters weekly for DO using an internal calibration and testing against a Winkler titration twice a month. For specific conductance and salinity, the meters are calibrated using known standards.

Monitoring Locations

Seven bay monitoring sites were selected to represent different regions of the bay. The sites are (from north to south) Tidelands (site code ATP), State Park Marina (SPO), Los Osos Channel (LO2), Pasadena Point (PSP), Cuesta Channel (CHI), Cuesta Inlet (CSI), and Sharks Inlet (SHI).

The following map (Figure 7) shows the seven monitoring locations. Sites are grouped into two sets of sites: Front Bay and Back Bay. Sites within each group are sampled on the same day, but the two groups are generally not sampled on the same day.

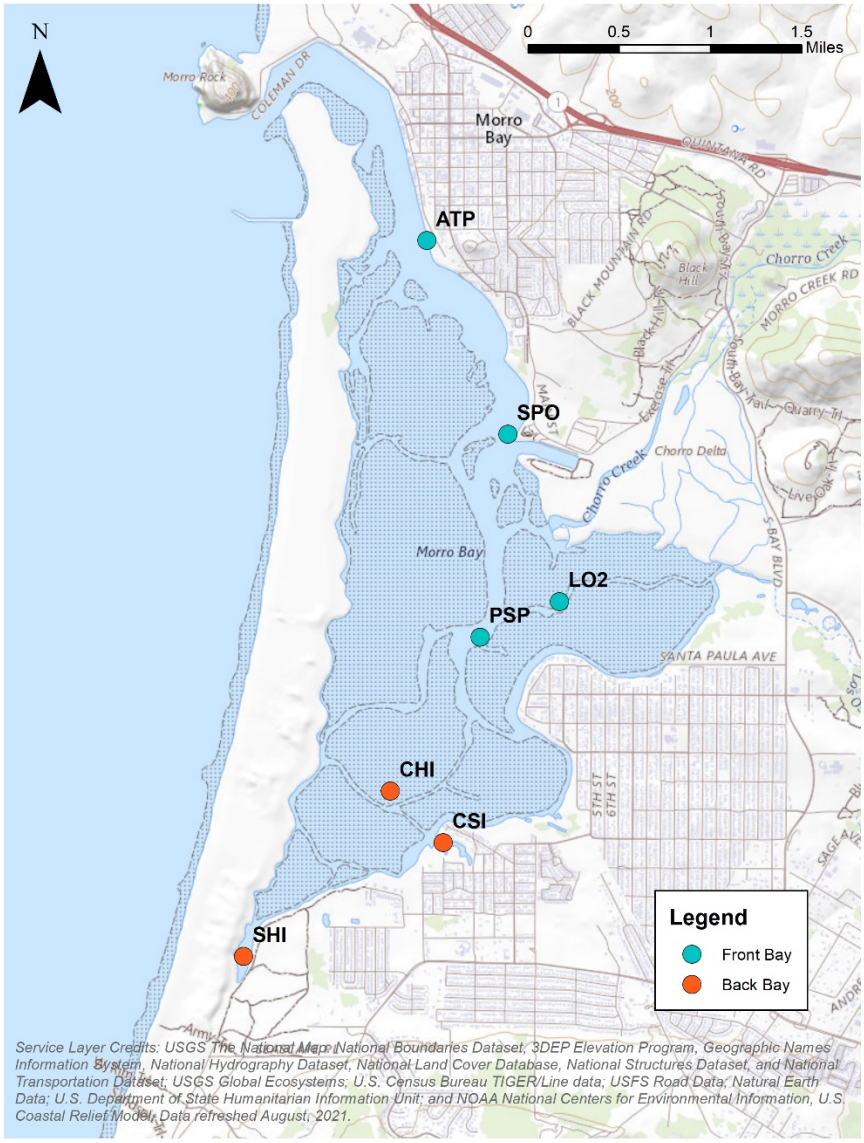


Figure 7. Map of bay dissolved oxygen monitoring locations.

Results

Analysis compares measured DO levels compared to standards protective of aquatic life. The CCRWQCB has designated the Morro Bay estuary as Marine Habitat (code MAR) and lists an objective that DO concentrations must not fall below 7 mg/L to be protective of aquatic life.

Data collected in the Front Bay during May, June, August, and September of 2021 were excluded due to equipment errors that resulted in inaccurate readings. Thus, a full year of readings are not available for those four sites for WY2021.

The following graphs show the DO concentration data for WY2021 at each of the seven sites. Figure 8 shows the distribution of measurements for each site over WY2021 using a Box-and-Whisker Plot.

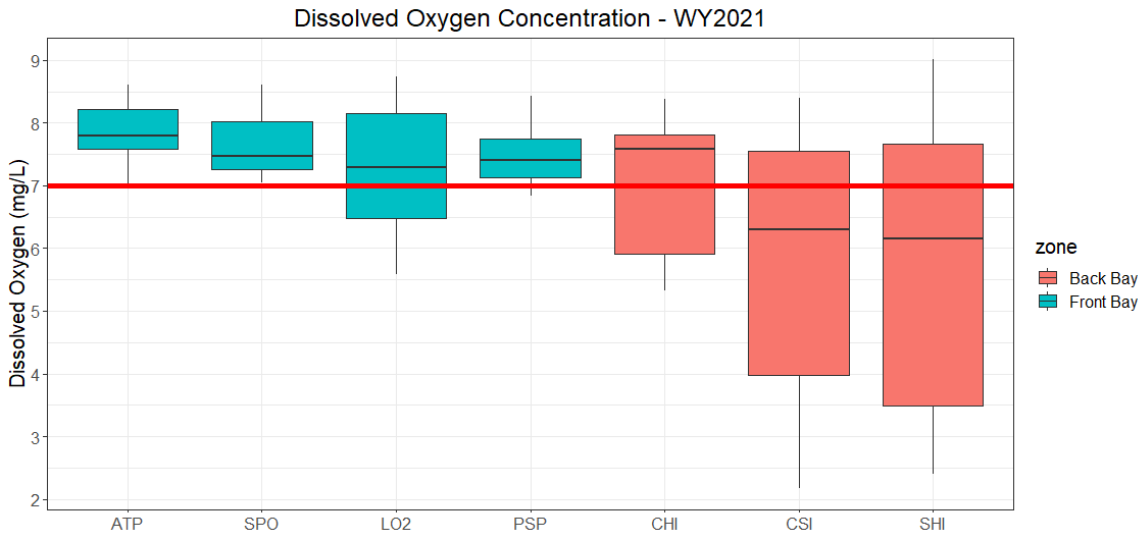


Figure 8. Dissolved oxygen concentration distribution at seven representative sites during WY2021. The horizontal red line depicts the 7 mg/L protective limit. Ideally DO concentrations remain above 7 mg/L at all times. Four months of Front Bay data were excluded due to inaccurate sensor readings.

The second graph (Figure 9) shows the percent of DO concentration readings in WY2021 that were less than 7 mg/L, meaning that the recorded DO measurements failed the numeric objective set by the CCRWQCB for marine waters. Ideally, no more than 10% of results would fall below the standard.

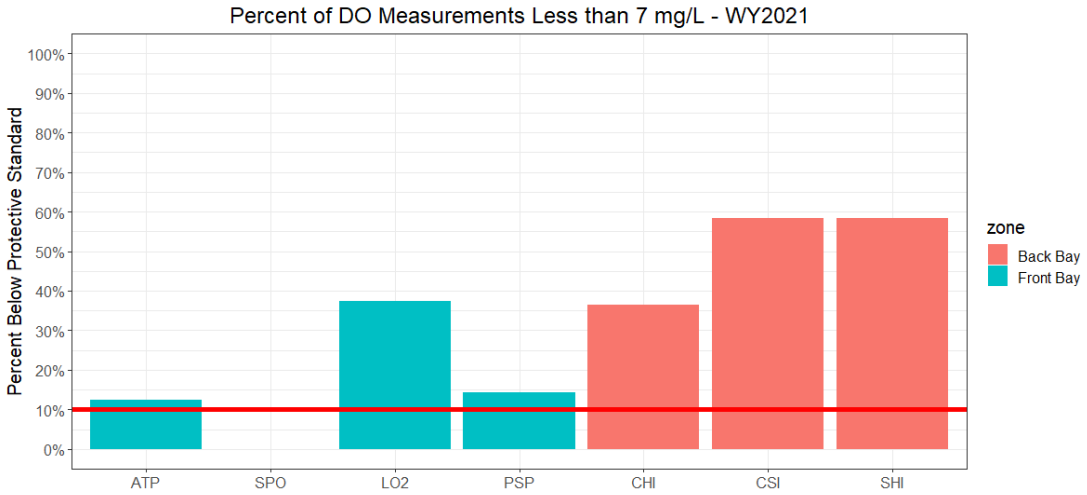


Figure 9. Percent of DO measurements less than 7 mg/L during WY2021. Only SPO had less than 10% of samples fall below 10%. The horizontal red line depicts the 10% limit. Four months of Front Bay data were excluded due to inaccurate sensor readings.

Figure 10 shows the average DO values for WY2021 data. Ideally, all readings are greater than 7 mg/L to ensure adequate oxygen to be protective of aquatic life and comply with CCRWQCB standards.

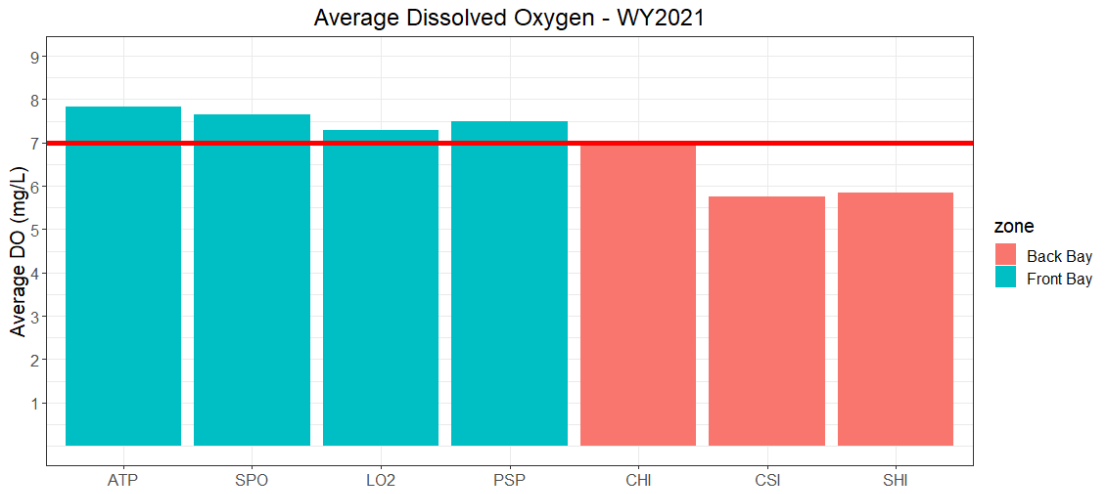


Figure 10. Average of dissolved oxygen levels measured during WY2021. The horizontal red line depicts the 7 mg/L protective limit, and ideally DO concentrations stay above that limit at all times. Four months of Front Bay data were excluded due to inaccurate sensor readings.

For the following figure, all Front Bay sites were compiled (ATP, SPO, LO2, PSP) and all Back Bay sites were compiled (CHI, CSI, SHI) to show how dissolved oxygen levels varied throughout WY2021 in the Back vs. the Front Bay. The Front Bay remained above the level of concern from October to April and dipped slightly below in July. The Back Bay was above the level of concern for the first half of WY2021 and dropped beneath the level for the rest of the year. This can be seen in more detail in Figure 11.

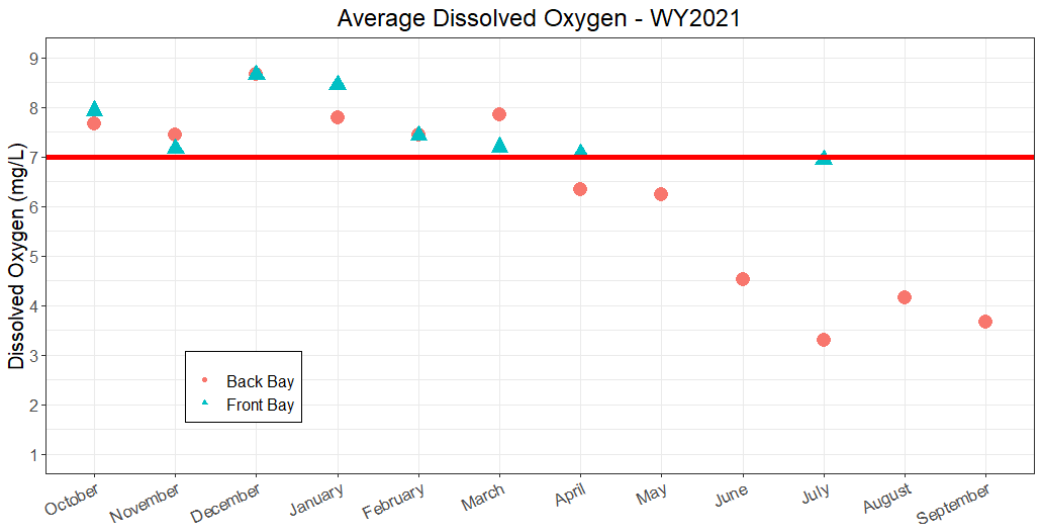


Figure 11. Average dissolved oxygen levels among Front and Back Bay sites for each month during WY2021. The horizontal red line depicts the 7 mg/L protective limit, and ideally DO concentrations stay above that limit at all times.

In Figure 11, dissolved oxygen in the Front Bay and Back Bay appears to follow a trend throughout the water year, which can also be seen when looking at five-year averages for Front and Back Bay sites. Dissolved oxygen stays above the protective limit during cooler months and drops below the limit during

warmer months, with the Back Bay sites experiencing the largest decrease in concentration. Five-year averages for the Front and Back Bay sites can be seen in more detail in Figure 12.

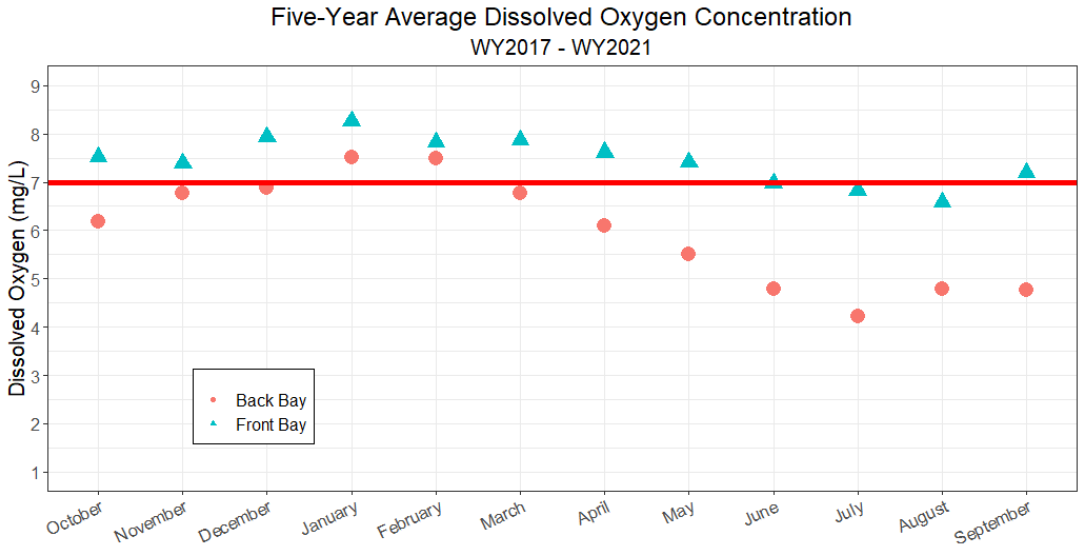


Figure 12. Five-year average of Front and Back Bay dissolved oxygen concentrations from WY2017 to WY2021. Averages are shown here on a monthly basis to show seasonal trends, with the 7 mg/L level of concern in red. Ideally DO concentrations stay above that limit at all times.

Discussion

The estuary waters frequently have DO levels below the 7 mg/L water quality objective protective of the beneficial uses of the estuary, as outlined by the Water Quality Control Plan for the Central Coastal Basin. These trends also apply to data prior to WY2021. Sites located closer to well-mixed channels (ATP, SPO, LO2, and PSP) had fewer readings that fell below 7 mg/L, although all sites except SPO frequently violated the Basin Plan standard during WY2021.

The depressed DO levels may be due in part to bay circulation. Waters in the back bay are shallower, meaning they heat up faster in the sun. Warmer water cannot hold onto as much DO as cooler water. Sites toward the back of the bay seem to have lower DO concentrations on average than those located in the channel and towards the front of the bay. Macroalgae, which is typically more prevalent in the Back Bay than the Front Bay, could be contributing to the depressed DO levels as well.

Data Availability

The data is available from the California Environmental Data Exchange Network (CEDEN), a State Water Resources Control Board data portal. To retrieve data,

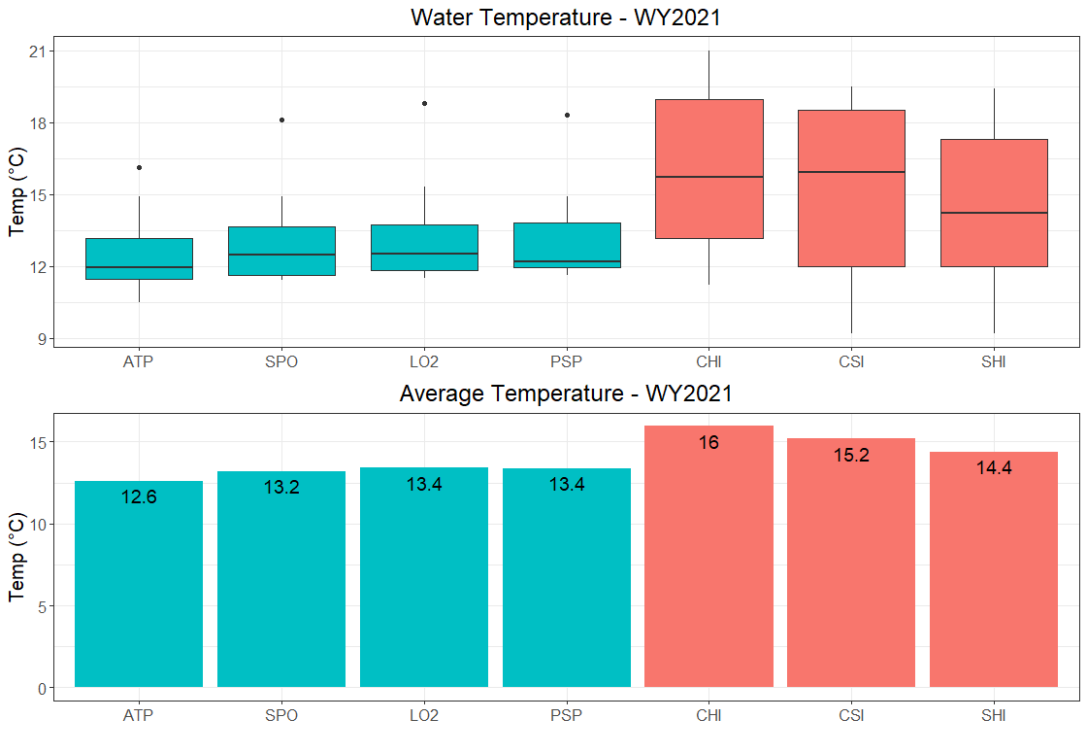
- Visit www.CEDEN.org.
- Click on Find Data.
- For Program, choose Morro Bay National Estuary Program.
- Bay Bacteria: For Stations, choose Morro Bay sites Coleman Beach shoreline, Tidelands Park shoreline, Windy Cove, State Park Marina shoreline, Pasadena Point shoreline, Baywood Pier shoreline, Cuesta Inlet shoreline, and Sharks Inlet shoreline.

- Bay DO: For Stations, choose Tidelands Park, State Park Marina bay, Sharks Inlet bay, Pasadena Point Bay, Near Cuesta Inlet, North of Cuesta Inlet Mouth, and Los Osos Creek Channel.
- Click on Retrieve Data.

For additional details, contact the Estuary Program at 805-772-3834 or staff@mbnep.org

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement CE-98T25101 to the Bay Foundation of Morro Bay. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

Appendix A
Bay Water Temperatures



Figures showing how estuary water temperature relates to DO values. Elevated temperature in the Back Bay correlates with lower DO measurements. The outliers for the boxplot of the Front Bay sites are due to unusually warm temperature readings in July.