Dissolved Oxygen in Coastal Waters

Background

Dissolved oxygen is a measure of the amount of oxygen dissolved in the water column. It is a fundamental requirement for the maintenance of balanced populations of fish, shellfish, and other aquatic organisms, in both estuarine and nearshore ocean waters. Estuarine and nearshore ocean waters influence each other by way of tidal water flow through inlets and from coastal rivers. For example, south-to-west coastal winds can cause ocean upwelling events that carry cold, nutrient-rich water into the estuaries. In the opposite direction, rain events over land can wash nutrient loads into the estuaries and rivers, which will then flow into the ocean. Nutrient contributions from these events can result in algal blooms which, during die-off, can deplete oxygen from the water column. The nature and extent of various organisms' response to low oxygen concentrations depends on several factors, including the concentration of oxygen in the water, the duration of the organism's exposure to reduced oxygen, and the age and physiological conditions of the organism. Because of the effect of low dissolved oxygen on the biological community, dissolved oxygen is used as a surrogate for ecological health.

Based on the importance of dissolved oxygen for marine life, New Jersey has established surface water criteria for oxygen levels in marine waters including estuarine waters and nearshore Atlantic Ocean waters. The Surface Water Quality Standards criterion is five milligrams per liter for ocean waters and four milligrams per liter for estuarine waters. Samples collected throughout the water column including bottom samples of deeper waters are assessed against these criteria. Bottom samples are generally used for assessment in deeper water because they represent a "worst case" for dissolved oxygen concentrations, due to poor mixing with the atmosphere and limited light that would help support aquatic plants that assist in adding oxygen to the water. Low deep-water dissolved oxygen concentrations can also impact non-motile benthic-dwelling organisms, such as worms and shellfish, causing an adverse ecological impact. Dissolved oxygen concentrations below two milligrams per liter are considered lethal to aquatic life, while concentrations above two but below the four or five milligrams per liter designation may support aquatic life but warrant further study. However, prolonged periods of exposure to below optimum conditions may stress some aquatic life.[1]

Status and Trends

Assessment of dissolved oxygen in ocean waters began in 2002 and revealed that 70 percent of the state's ocean waters (bottom waters only, sampled approximately 1 to 3 feet off the bottom) did not meet the state's surface water criterion. DEP, EPA and Rutgers University have performed studies, employed the use of Slocum Gliders which are autonomous underwater vehicles (AUVs) with continuous dissolved oxygen sensors, and developed an Ocean Benthic Index to better understand the impacts of low dissolved oxygen concentrations on the biological community, and the factors that influence low oxygen conditions.

In estuarine waters, dissolved oxygen data collection began in 1989. Figure 1 shows the trend for estuarine waters assessed for summer dissolved oxygen conditions over a 22-year period. The reported impairment has gone through many changes over the years. No clear reason has been identified for this impairment change, but variation year to year can be caused by a variety of factors, such as the weather

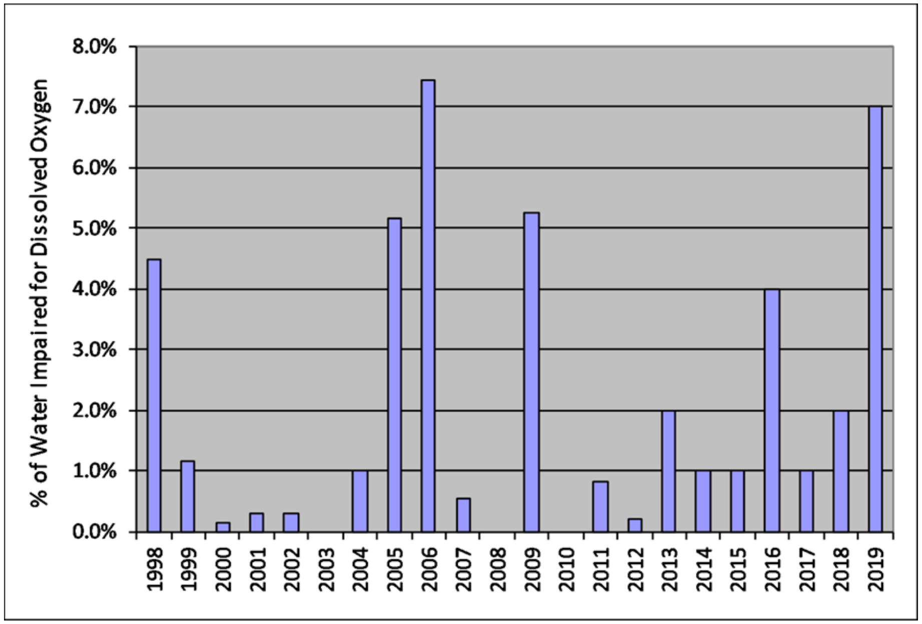

Figure 1. Percentage of NJ Estuarine Waters Impaired for Dissolved Oxygen During the Summer Months

preceding the sample collection, water temperature, tidal stage, nutrients and chlorophyll *a* levels, and the time of sample collection. To look for any long-term changes and their causes, more continuous monitoring is needed to understand daily fluctuations and how they relate to weather conditions, tidal stage, and water quality.

Slocum Glider (Rutgers University Center for Ocean Observing Leadership, 2019)

Slocum Gliders fitted with dissolved oxygen sensors were deployed in the summers of 2011 through 2016, and in the spring and fall starting in 2017 and continuing through 2020, to better understand the oxygen conditions of the ocean during different seasons. Slocum Gliders are AUVs that are 5 feet long, use ocean currents as propulsion, wings for steering, and record locations by GPS. These gliders record dissolved oxygen, salinity, and temperature data every second. They record data from surface to bottom, east to west, and north to south, to give a 3-dimensional view of the dissolved oxygen conditions and can be used to observe the magnitude and duration of low dissolved oxygen events. All data is currently being evaluated for spatial and temporal variability. Based on the results, the lowest oxygen conditions occur during the summer months, and appear to be due to natural conditions that cause stratification (separation of the surface and bottom waters).

An example of the data showing such stratification is below in Figure 2, from the October to November 2019 deployment. This plot shows the ocean dissolved oxygen conditions from 10/25/2019 to 11/15/2019. The colors represent the oxygen concentration – the white color is the ocean floor, with the depth in meters on the left. The graph shows a separation of oxygen levels between the surface and the bottom in the October time frame, with a lower concentration of oxygen (blue color) near the bottom for the period 10/26 – 10/27, followed by mixing of surface and bottom oxygen concentrations. This difference is a normal occurrence and is due to the seasonal mixing of the water column.

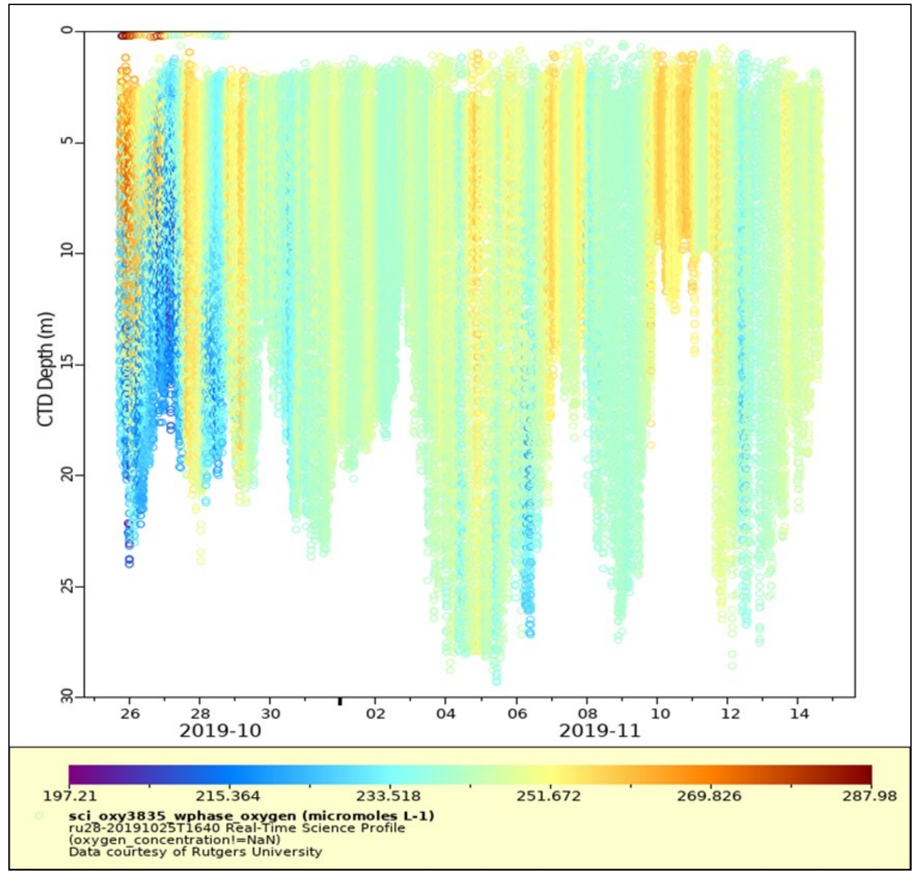

Figure 2. Slocum Glider Data from the October to November 2019 Deployment

Evaluation of the data by area and depth can also be performed. Due to the large amount of data generated by the glider, the state's estuarine and nearshore ocean waters were divided into grids to facilitate statistical analysis (see Figure 3).

Analysis of Grid 28 is shown in Figure 4 for July through September 2015. The data shows the onset of low dissolved oxygen conditions and the depth where it occurs, as well as when stratified conditions occur. A full database and analysis tool for all glider data is currently under development, so all data collected since 2011 can be evaluated effectively.

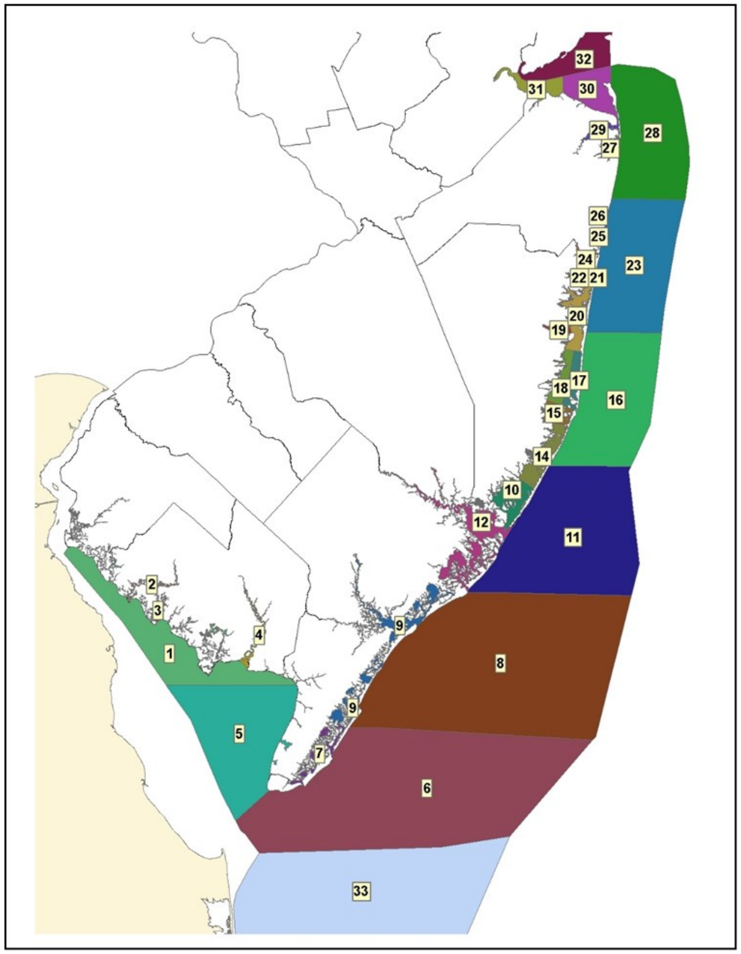

Figure 3. Map of Slocum Glider Data Analysis Grids

Continuous data – Estuarine Buoys

Four continuous water quality monitoring buoys have been deployed during the summer in Barnegat Bay since 2012, with an additional buoy added in 2017 for a total of five. Three other buoys, two in Raritan Bay and one in the Navesink River, were deployed in 2017. The sensors in the buoys collect data from 5 feet below the surface of the water. In deeper waters this depth is representative of the surface

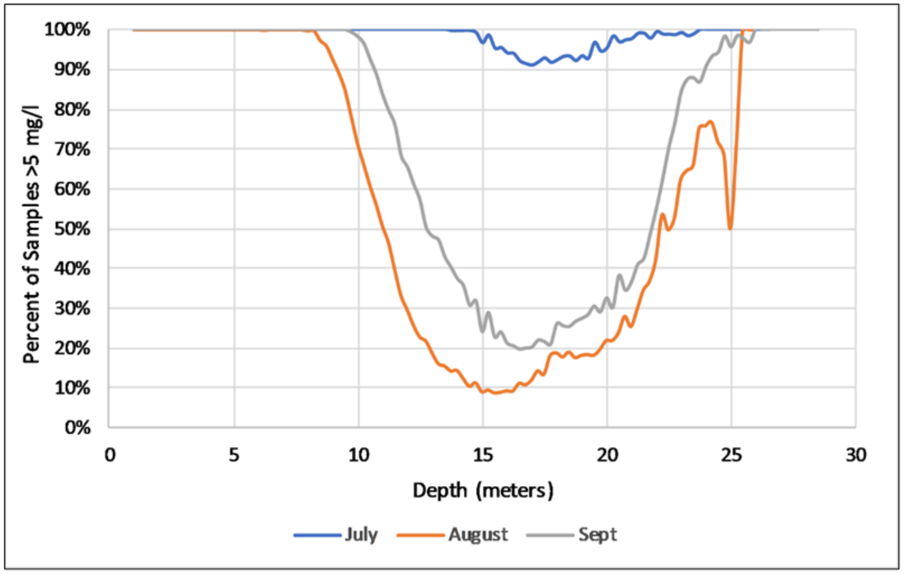

Figure 4. Grid 28 Percent of Sample Results >5 mg/l D.O. by Depth from July to September 2015

water quality, however, in shallow bays like Barnegat Bay, the sensors collect data that typically represents the lower half of the water column. Eight years of data from Barnegat Bay are presented in Figure 5, showing that the Barnegat Bay generally exhibits healthy oxygen conditions, with few samples recorded as less than 4 parts per million.

The continuous monitoring data generates over 9,000 results for each hour and can be used to evaluate the time of day that the dissolved oxygen conditions are the lowest, thus assisting in the design of fixed station monitoring programs (see Figure 6). This data indicates that the lowest dissolved oxygen measurements occur between 4 am and 9 am.

Outlook and Implications

The trend for New Jersey's estuarine (bay) waters shows a high degree of variability from year to year. The factors responsible for long-term changes in dissolved oxygen levels are poorly understood. In recent years, data on the health of the benthic community in New Jersey's estuarine waters have been collected to

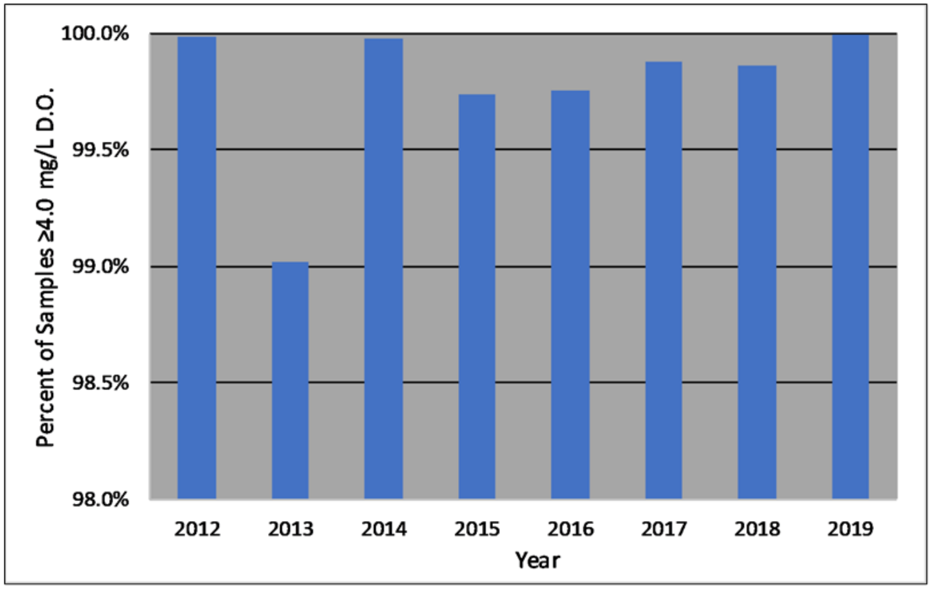

Figure 5. Barnegat Bay Continuous Dissolved Oxygen Monitoring Data, Percent of June to September Monitoring Results ≥4.0 mg/l by Year

complement ongoing dissolved oxygen measurements and provide a more complete picture of the health of the state's estuarine waters.

An Ocean Benthic Index was developed in 2012, and the assessment of the health of the nearshore ocean waters benthic community was determined to be non-impaired. Subsequent investigation of potential impacts to larval and juvenile fish was conducted. A review of the occurrence of major finfish spawning and the life stages in the New Jersey Ocean waters showed that the spawning, larval stage, and the juvenile stage are not occurring in the summer months in the ocean waters, with one exception: bluefish. Bluefish eggs and larvae do not appear to be impacted by the low dissolved oxygen in the bottom waters, as they are buoyant and the larvae feed on plankton in the upper four meters of the water column. All of the other species spawn in ocean waters in fall through spring, resulting in larvae and juvenile stages growing in the estuaries during the summer months.

Dissolved oxygen is a fundamental requirement for organisms living in coastal waters. Continued monitoring will allow NJDEP to determine whether surface

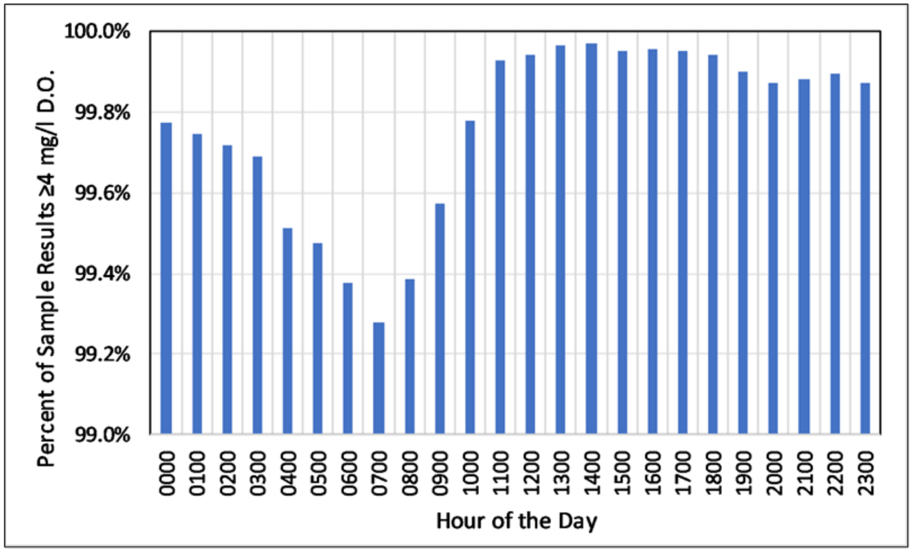

Figure 6. Barnegat Bay Continuous Dissolved Oxygen Monitoring Data, Results≥4 mg/l by Hour of the Day from 2012 to 2019

water criteria are being met. Data from the Slocum Glider will lead to a greater understanding of the depth and temporal influences on dissolved oxygen in marine and estuarine waters.

More Information

Additional information can be obtained by contacting DEP's Bureau of Marine Water Monitoring at (609) 748-2000 or by visiting https://www.nj.gov/dep/bmw/.

References

[1] Bricker, S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. 1999. National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science. Silver Spring, MD: 71 pp.

[2] Ramey, P.A., M.J. Kennish, and R. M. Pterecca. December 2011. Benthic Index Development: Assessment of Ecological Status of Benthic Communities in New Jersey Marine Coastal Waters. Prepared for: US Environmental Protection Agency and the New Jersey Department of Environmental Protection, by the Institute of Marine and Coastal Sciences, Rutgers University. New Brunswick, NJ: 70 pp.