

LONG BAY HYPOXIA MONITORING CONSORTIUM

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ABSTRACT. In October 2011, the coastal municipalities of North Myrtle Beach, Myrtle Beach, Surfside, and Horry County signed a resolution, under the aegis of their Coastal Alliance of mayors, to develop and implement the Long Bay Hypoxia Monitoring Consortium. The goal of this consortium is to support monitoring and studies that further characterize hypoxia and its causes in Long Bay. The baseline data will enable assessments of water quality management efforts. Monitoring stations are to be maintained at four piers, Cherry Grove (NMB), Apache (Horry County), Second Ave N. Pier (Myrtle Beach), and Surfside (Surfside). Turbidity and chlorophyll sensors will be deployed at two piers and radon detectors at three piers. All piers will have weather stations. Data will be accessible via a real-time public website. Biological responses to low DO will be assessed via monitoring of larval recruitment and net plankton. SC DNR is also conducting creel surveys at the piers. These efforts are being coordinated with a marine education outreach campaign that includes signage at the piers, presentations at pier events, and web-based content.

INTRODUCTION

In July 2004, hypoxic conditions were discovered to be present in the nearshore waters of Long Bay during a period of unusually prolific flounder catches. Long Bay is a coastal embayment that borders the sandy beaches of the Grand Strand in northeastern South Carolina (Figure 1). This area is a focal point for beach-based tourism, hosting 15 million visitors a year. Hypoxic conditions in Long Bay were unexpected given the shallow water depths and lack of nearby rivers. Since no routine dissolved oxygen (DO) concentration measurements had ever been made in Long Bay, several state agencies partnered to establish continuous water quality monitoring platforms on the seaward ends of two fishing piers in water depths that range from 5 to 7 m depending on the tides. These sites (Apache and Springmaid Piers) were

operational by 2006 and featured measurements of salinity, DO and temperature, collected every 15 minutes in the surface and bottom waters using YSI and Hydrolab datasondes. Data access was provided through public websites. These data were used to support research efforts investigating the causes of low DO in Long Bay and for educational outreach targeted at reducing nonpoint source pollution into these coastal waters. Some of these research efforts are described in McCoy et al. 2011 and Sanger et al. 2012. The educational outreach has been conducted under the aegis of the Coastal Waccamaw Stormwater Education Consortium (CWSEC) (<http://cwsec-sc.org/>).

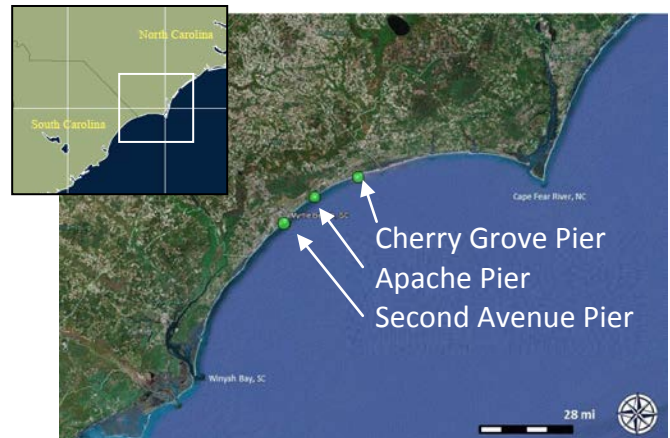


Figure 1. Long Bay, South Carolina. Green circles mark the positions of the pier monitoring stations.

PROJECT OBJECTIVES

In recognition of a likely linkage between low DO and terrestrial inputs of oxygen-demanding substances, the municipalities of the Grand Strand agreed in August 2011 to form a monitoring consortium. The mission of the Long Bay Hypoxia Monitoring Consortium is two-fold: (1) to collaboratively support water quality monitoring that will help determine the causes and effects of low DO,

and (2) to help identify and implement management activities that will mitigate undesirable impacts to water quality. Continued monitoring will be performed to help evaluate the effectiveness of these management interventions.

PROJECT DESCRIPTION

Background and related work

Since 2006, low DO has been observed primarily during June through September. In 2009, anoxic conditions were present for several days in August and September. Related field work suggests that low DO is restricted to a narrow band paralleling the shoreline (Koepfler et al. 2010 and Sanger et al. 2012). The origin of the low DO during the summer is thought to arise from a physical constraint on mixing caused by the combined effects of solar heating and southwesterly winds. The resulting frontal conditions keep nearshore waters close to coastline. This constrained mixing is most pronounced at the maximum concavity of Long Bay, which is the location of the urbanized center of the Grand Strand.

Scientists agree that polluted stormwater runoff is one potential contributor of oxygen-demanding materials to Long Bay, suggesting management actions can be undertaken to prevent further degradation and to remediate if necessary.

The nearshore waters of Long Bay are also prone to contraventions of water quality standards for fecal indicator bacteria. This has given rise to numerous 303(d) listings for recreational impairments requiring development of Total Maximum Daily Loads (TMDLs). Hence generalized concern exists over managing terrestrial flows into Long Bay, with monitoring needed to help develop and evaluate the success of these strategies.

Although water quality monitoring at the Springmaid Pier ended in 2007 due to lack of continued funding, observations were continued and enhanced at Apache Pier with short-term financial support from several state agencies, i.e. SC Department of Natural Resources (SC DNR), SC Department of Health and Environmental Control – Ocean and Coastal Resource Management (SC DHEC OCRM), SC Sea Grant Consortium and the SC Chapter of the Coastal Conservation Association. All but the latter of these groups have provided funding to support research into the causes of low DO in Long Bay.

By the summer of 2011, grant funds for monitoring had been exhausted. State and federal agencies that traditionally engage in long-term water quality monitoring in South Carolina did not have the capacity to expand their networks. Unless another funding approach was developed, continuous DO monitoring would have to be terminated. This was especially problematic as the local municipalities of the Grand Strand have recently been required under the federal Clean Water Act's National

Pollution Discharge Elimination System (NPDES) program to protect local water quality through development and implementation of local stormwater management programs. Water quality monitoring information will be required to demonstrate improvements to impaired waters.

Experimental Design

The Long Bay Hypoxia Monitoring Consortium was established by a resolution of the Coastal Alliance signed in August 2011. The Coastal Alliance is comprised of the mayors from the coastal municipalities of the Grand Strand, including the cities of Myrtle Beach and North Myrtle Beach, the towns of Surfside Beach and Atlantic Beach, and the unincorporated areas of Horry County. The Long Bay Hypoxia Monitoring Consortium is now supporting water quality and biological monitoring at three fishing piers on the Grand Strand.

Funding for the monitoring at the Apache Family Campground and Pier, the Second Avenue Pier and the Cherry Grove Pier is being provided by Horry County, and the cities of Myrtle Beach and North Myrtle Beach, respectively. The pier owners and operators are providing essential support services. The National Oceanic and Atmospheric Administration maintains a federally funded weather and tide station at Springmaid Pier. Discussions are still underway for instrumenting a fourth pier in Surfside Beach.

Coastal Carolina University's Environmental Quality Lab, under the aegis of the Burroughs & Chapin Center for Marine and Wetland Studies, is responsible for equipment installation, maintenance, and data management. This was the group who made the initial discovery of low DO in July 2004, while performing unrelated field work at Springmaid Pier.

The new installations at the Cherry Grove and Second Ave piers provide information on water quality at the northern end of Long Bay and at a site near its maximum concavity, respectively. These monitoring stations have sondes that are collecting turbidity and chlorophyll data to provide more information on the causes of low DO, i.e. the relative abundance of particulate matter and phytoplankton. Also being measured at these station is pH to obtain insight into another stressor, ocean acidification, which should be enhanced by the processes that cause hypoxia (aerobic respiration of organic matter). Bottom-water radon (Rn-222) detectors have been deployed at the Apache and Second Avenue piers to document constrained mixing and groundwater inputs to Long Bay. Funding has also been provided to engage in a larval recruitment study to document effects of low DO on local biota.

METHODS

Water Quality and Meteorology

At the seaward end of each pier, just beyond the surf zone, YSI sondes are deployed in the surface and bottom waters on stainless steel ziplines. This approach minimizes sampling artifacts associated with standpipes, but requires a robust design to withstand high-energy conditions characteristic of the nearshore environment. The surface sondes are maintained ~1m below the sea surface using an innovative counterweighting system shown in Figure 2. The bottom sonde is stationed ~1m above the seafloor in water depths that range from 5 to 7 meters depending on the tides.

At the Apache pier, YSI 600 OMS sondes are deployed with optical DO, temperature, conductivity and depth sensors. YSI 6600 EDS sondes are being used at the other two piers with additional sensors that measure turbidity, chlorophyll, and pH. (As of July 2012, a YSI 6600 EDS sonde has been installed in the bottom waters at Apache Pier). Meteorological observations are provided by a Vaisala WXT520 weather station mounted ~10m above sea level. These units measure air temperature, barometric pressure, relative humidity, precipitation, wind direction and speed. Each of the sondes are equipped with unvented depth sensors.

The sensors report every 15 min via a dedicated cell modem to a server maintained by YSI Econet, Inc. The data are relayed in real-time at a public web portal:

<http://www.yсиеconet.com/public/WebUI/Default.aspx?hidCustomerID=131>. This site also provides an option to download all data to a .csv file across a user-selectable data range. Various entities, such as Southeastern Coastal Ocean Observing Regional Association (SECOORA), are streaming the pier data in real-time. The SECOORA data stream at <http://secoora.org/maps/> is part of the national Integrated Ocean Observing System (IOOS).

The sondes are equipped with all available antifouling accessories. Nevertheless, manual cleaning is required at least three times a week during warm weather. During these visits, secchi depths are measured. Field QC includes pre and post deployment comparison with a manually deployed sonde. Chlorophyll results are produced via regression of the sensor signal against acetone-extracted measurements on grab samples collected at least weekly from each site and depth. In-situ accuracy is ± 0.4 mg/L for DO, ± 0.1 C for temperature and ± 0.25 psu for salinity. Efforts are underway to characterize true in-situ accuracy of the pH, chlorophyll, and turbidity sensors. Data QC records are created using Aquarius software from Aquatic Informatics, Inc.

Shore power is required to support data relay and the radon pump (as described below). Lightning protection features an extensive set of grounding wires and pom-pom diffusers. YSI Econet maintains a back-up system for their servers. In the event of a long-term power or communication failure, the sondes are programmed to log sensor data with a capacity to cover several weeks.



Figure 2. Pier monitoring station at the Second Avenue Pier showing ziplines and counterweighting. (a) Left photograph shows the surface sonde strapped to a PVC “sled” that slides vertically on the ziplines. The blue buoy is flotation that maintains the surface sonde’s position about 1 m below the sea surface. (b) Right-hand photograph shows the zipline and PVC sled. The blue box in the upper left corner houses the RAD-7 detector. Red hoses in the lower right-hand corner are part of a filter manifold that prevents particles from clogging the Rn detector.

Radon

Radon-222 is a naturally occurring radionuclide that is released into groundwaters from the decay of radium, a common component of sedimentary rocks, such as limestone. As a result, this radionuclide is released into nearshore waters as a natural component of submarine groundwater discharge. The Rn-222 decays rapidly, so measurement of episodic elevations of radon in the nearshore water provides a quantitative estimate of groundwater inputs and nearshore mixing constraints.

A short-term deployment in 2011 at Apache Pier demonstrated a highly significant inverse correlation of Rn-222 with DO, suggesting that this natural tracer can serve as a low-cost approach to documenting the degree to which nearshore water mixing is being constrained, i.e., inhibited from mixing with offshore waters. These are the conditions under which low DO is most commonly observed in the bottom waters off the fishing piers.

At this time, the Apache and Second Ave piers have each been outfitted with a RAD-7 (Durridge Co.) radon detector which is located on the pier deck (Figure 2) and continuously fed bottom water via a submersible pump. Alpha decay counts are integrated for reporting on 30-minute intervals. A filter manifold is required to prevent introduction of particles from the highly turbid bottom waters. Data are manually downloaded and returned to the lab for processing.

Larval recruitment

A low-cost approach to documenting the impact of low DO on native marine life is being conducted biweekly year-round by monitoring larval recruitment onto a hard substrate. Many marine invertebrates live as epifauna attached to hard substrates including piers, jetties, and natural hard bottom features. These animals occupy intermediate positions in food webs and can be very abundant. They serve as indicator species that record the ecological effects of abnormal events, such as low DO.

The epifaunal monitoring involves identification of common taxa (presence/absence), characterization of these taxa as live or dead, estimation of density (number per unit area) and community composition. These data will be used to relate seasonal and interannual patterns of abundance to ambient water quality.

Monitoring is being conducted by deploying recruitment substrates at two depths (mid-depth and surface) at each pier. Two replicate substrate strings (1 string = 4 PVC tiles, 8 settlement surfaces) are being deployed and retrieved at biweekly intervals. Substrates are examined immediately to characterize epifauna as live or dead and to identify the more delicate taxa. Substrates are then preserved by freezing to enable later counting and faunal identification work.

The image shows a vertical educational poster with a light blue background and a wavy blue border at the top. The main title is "We care about our LOCAL WATER QUALITY" in a mix of bold and regular fonts. Below this, the text reads "Water quality monitoring equipment is installed at this pier." A central paragraph states: "Fishermen, boaters and swimmers may find the real-time data gathered by this equipment useful. Visit the online data page to find information on:" followed by a list of parameters: Air & Water Temperature, Wind Direction & Speed, Salinity, Water Depth, Dissolved Oxygen, Relative Humidity, Air Pressure, Rainfall, Turbidity, and Chlorophyll & pH. At the bottom, it says "Go to www.ysiiconet.com and click on Long Bay Hypoxia Monitoring, SC" next to a QR code. The footer contains logos for Coastal Carolina University, Horry County, and other local entities.

Figure 3. Educational signage posted at pier monitoring stations.

Educational Outreach

Educational outreach is being conducted as part of the activities of CWSEC due to the relationship of nearshore water quality with the transport of pollutants via stormwater runoff. The stormwater managers of each coastal municipality are engaged in this outreach education as it is a required component of the state's NPDES Phase II stormwater program permit.

The YSI Econet portal web pages include extensive information on the reason for the monitoring and the meaning of each parameter being measured. Educational signage has been posted at each pier (Figure 3). At the Apache pier, a plasma screen is mounted in the bait shop to present the real-time data. Other outreach efforts include press conferences and participation in pier activities, such as Local Appreciation days. A business-style card has been developed as a handout to spread information on the website location.

RESULTS AND DISCUSSION

Diaz and Rosenberg (2008) have included Long Bay in their inventory of the world ocean's hypoxia zones. With this dubious distinction has come the realization that more

careful stewardship is required to protect and enhance water quality in Long Bay, especially since the ocean is the base of the Grand Strand's tourist-driven economy.

The formation of the Long Bay Hypoxia Monitoring Consortium is one step along a path towards better stewardship that began with a pro-bono response by various state agencies and universities to a singular event, discovery of hypoxic conditions in Long Bay in July 2004. The collaborative nature by which this response initially evolved is described by Sanger et al. 2010.

The timing of these science-based stewardship efforts has been fortuitous; occurring during the period when local municipalities are developing their federally mandated stormwater programs, whose goal is reduction of polluted runoff. A major management approach has been relocation of runoff from hundreds of pipes that discharge on the beach face to a few ocean outfalls. The latter discharge onto the seafloor at the water depths where hypoxia is observed to occur. Water quality treatment practices have been installed upstream of most of these outfalls. Installation of the pier monitoring stations provides a resource to help assess the efficacy of these practices.

A major unknown is the source of the oxygen demanding substances responsible for sustaining low DO in Long Bay. Various efforts have been undertaken to identify the dominant sources, including a NOAA-funded study that is quantifying the export of nutrients and organic matter from local tidal creeks, called "swashes", into Long Bay. This project was funded in recognition of strong community support, as evidenced by actions such as funding pier monitoring, and involves local stormwater managers in site selection and data interpretation.

Ancillary benefits provided by the pier monitoring program include: (1) Meteorology information that is of general interest to tourists and locals; (2) Depth data that provide tidal elevation information; (3) Information on sea state that can be inferred from the surface sonde's depth sensor as it is neutrally buoyant ~1 m below the sea surface.

Other synergistic activities include coordination with a SC DNR fish survey (creel and catch effort) being conducted collaboratively with CCU's marine science undergraduate students. Efforts are underway to adopt NOAA's Plankton Monitoring Network methods to further engage undergraduates in obtaining long-term time series data on phytoplankton species diversity and relative abundance by sampling from the fishing piers. The focus of this effort will be on identification of harmful algal blooms (HABs).

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LITERATURE CITED

- Diaz, R.J. and R. Rosenberg, 2008. Spreading dead zones and consequences for marine ecosystems. *Science*, 321: 926-929.
- Koepfler, E., S. Lake, E.M. Smith, J. Bennett, S. Libes. 2007. Examination of Inner Shelf Water Quality in Long Bay, South Carolina, using Dataflow. *Estuarine Research Federation Providence Rhode Island Meeting*, November 2007, abstract.
- McCoy, C., R. Viso, R. Peterson, S. Libes, B. Lewis, J. Ledoux, G. Voulgaris, E. Smith and D. Sanger (2011) Radon as an indicator of limited cross-shelf mixing and submarine groundwater discharge in a coastal embayment along the South Atlantic Bight. *Continental Shelf Research*, 31: 1306-1317.
- Sanger, D., E. Smith, G. Voulgaris, E. Koepfler, S. Libes, G. Reikerk, D. Bergquist, D. Greenfield, P. A. Wren, C. McCoy, R. Viso, R. Peterson, and D. Whitaker (accepted) Constrained Enrichment and Hypoxia Formation in Long Bay, South Carolina (USA), an Open Water Urbanized Coastline, *Marine Ecology Progress Series*.
- Sanger, D., D. Hernandez, S. Libes, G. Voulgaris, B. Van Dolah, G. Reikerk, B. Davis, E. Smith, R. Shuford, D. Porter, E. Koepfler, and J. Bennett (2010) A Case History of the Science and management Collaboration in Understanding Hypoxia Events in Long Bay, South Carolina, USA. *Environmental Management*, 46: 340-350.