FILLING THE GAP: DISSOLVED OXYGEN MONITORING IN NARRAGANSETT BAY

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Narragansett Bay (Rhode Island, USA) is a medium-sized (370 km²), temperate, estuary on the Atlantic coast with a 4,714 km² watershed. The salinity range is ~11-31 psu (depending on river flows), tidal range is 0.6 to 1.9 m, and average depth is 7.8 m (Bergondo et al. in press; Ely, 2002; Ries, 1990).

Over the last decade, some scientists and managers have grown increasingly concerned over the response of the Narragansett Bay ecosystem to the high level of nutrient inputs to the upper Bay. However, a prevalent view within the local scientific community has argued that most of the Bay is insensitive to nutrient impacts such as hypoxia (low oxygen below 3.0 mg l⁻¹) due to low freshwater flows (~100 m³ sec⁻¹), prevalent winds, and strong tidal currents which should keep most of the Bay well-mixed. The available oxygen data from previous upper Bay surveys were few, and did not usually occur during critical warm-water low-energy (neap tide) periods. What data that was available provided equivocal evidence of low oxygen outside of the upper tidal Providence River (Bergondo et al., 2005). In the absence of a regular ambient estuarine water quality monitoring program, water quality managers have had little recent data on dissolved oxygen levels during critical summer months with which to assess actual oxygen levels and consider the need for effective nutrient management strategies.

In 1998, the author presented circumstantial information that hypoxia and perhaps anoxia was occurring in localized areas based on fish kills, benthic community information, and sporadic limited-area oxygen data, and developed a “hypoxia-risk” map (Fig.1; Deacutis, 1999). The Narragansett Bay Estuary Program (NBEP) recognized the need for better oxygen data, and in 1999 initiated a series of seasonal overnight dissolved oxygen surveys by organizing a volunteer monitoring team dubbed “The Narragansett Bay Insomniac D.O.Strike Team” (due to the nocturnal timing of the surveys). Team volunteers were drawn from state agencies, universities, NGOs and the private sector. Vertical water column profiles of salinity, temperature, and dissolved oxygen at approximately 75 stations across the upper half of Narragansett Bay were taken monthly between midnight and 7 am on neap tides to maximize the likelihood of capturing hypoxic events. YSI multi-parameter water quality sondes (Model 6600 and 6920) with polarographic rapid pulse dissolved oxygen probes and thin rapid-response membranes were used, with readings recorded every 1.5 m after a 1 minute equilibrium period at each depth.

From 1999 to 2003, the NBEP conducted these surveys, providing data that filled a major data gap (see Prell et al., 2005). Brown University researchers collaborating with the NBEP used the data to produce oxygen distribution maps that confirmed anoxic (no
oxygen) and hypoxic (<3.0 mg l⁻¹) events occur in areas of the Providence River, where low oxygen problems associated with large sewage treatment effluent loadings are known to exist, and in Greenwich Bay, previously identified as experiencing some low oxygen issues (Granger et al, 2000). However, the surveys also identified hypoxia and even anoxia in areas of the bay once thought not to be susceptible to hypoxia, including parts of the Upper Bay, upper West passage, upper East Passage, and parts of Mount Hope Bay. The pattern of hypoxia closely matched areas shown to have shallow apparent redox potential discontinuity layer in sediment-water camera surveys performed in 1988 (Fig. 2, Deacutis et al., 2005, Valente et al., 1992).

On August 20, 2003, western Greenwich Bay experienced a severe anoxic event that killed over 1 million juvenile menhaden (Brevoortia tyrannus) along with other species. NBEP and Rhode Island Department of Environmental Management (RIDEM) staff surveyed the area, showing that anoxia occurred across most of bottom waters of this embayment. This event generated much publicity within the news media, energizing political responses from both the Governor of Rhode Island and the State Legislature. The NBEP, working with the RIDEM, was able to rapidly produce a report for the Governor and the legislators (RIDEM, 2003) which clearly identified nutrient loadings as the ultimate source causing the anoxic event, and used the previous Insomniac survey results to show that the low oxygen levels were not a unique event, having occurred in previous summers. The only unique aspect was the coincident existence of a large school of fish trapped in the area during the anoxic event in August, 2003. The NBEP has continued monitoring Greenwich Bay on neap tides in summer 2004, showing that cooler water temperature conditions in summer 2004 appear to have limited the low oxygen conditions to smaller areas with less severe hypoxia.

Local climate conditions, water temperature, and tidal energy state (weakest neap tides) appear to have a strong controlling effect on the severity and duration of these hypoxic and anoxic events. Monitoring data from a recently-developed continuous oxygen monitoring buoy system have confirmed these events, and shown that these hypoxic conditions can occur for 5-10 days (Bergondo, 2004), with some localized areas having greater event duration of >15 days (e.g., western Greenwich Bay, unpublished RIDEM data 2003). The upper areas of Narragansett Bay appear to experience intermittent stratification and hypoxia similar to the temporal pattern found in the York River, Virginia, USA (Haas, 1977).

The multi-year oxygen surveys as well as the continuous buoy monitoring data has been critical in justifying nutrient reduction strategies, and has been used to help generate support for a major clean water bond for $70 million that R.I. voters overwhelmingly passed in November 2004. Funds from this Open Space, Recreation, Bay and Watershed Protection Bond include $10.5 million to be leveraged through a revolving loan fund to implement nutrient reductions at major wastewater facilities. In addition, the state legislature passed a bill (S3040) that requires a 50% reduction in total nitrogen loadings from the major sewage treatment plants discharging directly to or just upstream of the Bay.
It is important that oxygen, chlorophyll, and other critical parameters continue to be monitored in order to follow responses of the upper Bay to the projected decreases in nitrogen loadings expected to occur within the next 3-5 years from the major sewage treatment plants. The NBEP will continue to work with state government to fully develop an adequate Bay monitoring program which includes both continuously monitored “sentinel” fixed buoy sites and areal oxygen surveys to help managers track ecosystem responses to the required nutrient reductions.

**FIGURE 1 “HYPOXIA RISK” MAP OF NARRAGANSETT BAY, RI BASED ON FISH KILLS AND LIMITED OXYGEN MEASUREMENTS IN NARRAGANSETT BAY 1986-1998. (REPRODUCED FROM DEACUTIS, 1999)**

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