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The Breathing of the Bays

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Recommended Citation
Vaudrey, Jamie and Van_Patten (editor), Margaret (Peg) A., "The Breathing of the Bays" (2012). *Wrack Lines*. 64.
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The Breathing of the Bays

by Jamie Vaudrey

"Each day as the sun rises and retires the beautiful green bays like great creatures breathe in and out."

H.T. Odum and C.M. Hoskin, 1958.

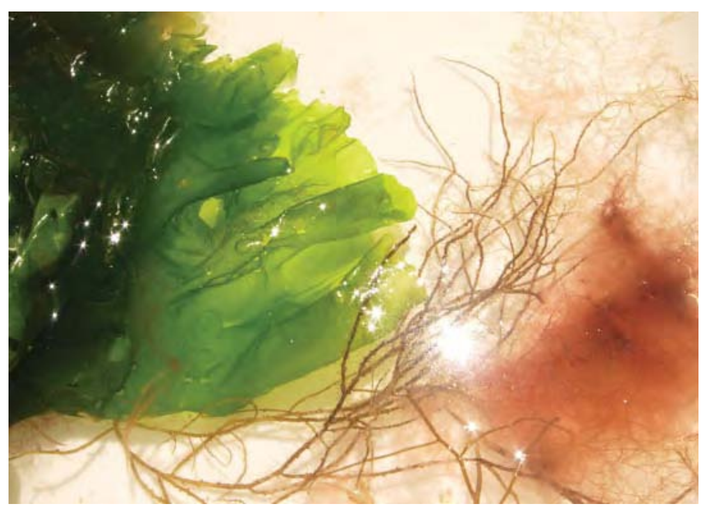
In 1958, Odum and Hoskin likened the daily rise and fall of oxygen in Texas bays to the breath drawn in and out of some great creature. This analogy can be extended even further to encompass not only our understanding of the daily oxygen cycle, but to relate how these bays may respond to our ever-increasing human population and the effects we have on coastal waters. When a creature is stressed and struggling, it may draw in a giant draught of breath and then expel this breath in a whoosh. Bays dealing with the effects of human influences can also be seen to take in a giant breath, evident through extremely high oxygen concentrations during the day. This in-drawing of breath is followed by a huge reduction in oxygen at night. This "panting" of the bays results from the production of oxygen during the day by the large amounts of primary producers, which are plants and plant-like creatures that use the sun as an energy source versus getting their energy from eating. These primary producers also require nutrients, much of which are supplied by human activities in the watershed. The primary producers and all of the creatures that feed on them respire at night, reducing the oxygen available in the water.

In an estuarine system, the water column is usually stratified, meaning that there is a distinct bottom and surface layering to the water column that inhibits mixing between the two layers. This stratification results from density differences, with the saltier denser water on the bottom. Without access to the air, the bottom layer has no way to replenish the respired oxygen, until the sun rises and the primary producers begin to generate oxygen. In systems deep enough to have no light in the bottom layer, such as the main stem of Long Island Sound, the oxygen remains low until the weather cools or a storm event is strong enough to mix the water column. Larger swings in oxygen indicate systems experiencing stress, especially when the down swing brings the oxygen so low that animals in the area find it hard to breathe.

Monitoring throughout Long Island Sound (LIS) indicates that the Western Sound experiences low oxygen, or hypoxia, in bottom waters in late summer. The extent and severity of this hypoxia vary by year. The area exhibiting hypoxia in Long Island Sound is monitored via a buoy network and biweekly cruises conducted by the Connecticut Department of Energy and Environmental Protection. While this monitoring effort provides an assessment of hypoxia in the main stem of LIS, very little is known of the hypoxic condition in the more than 70 bays scattered along the shoreline. These bays are the areas most accessible to people and are also areas that are greatly impacted by humans.

These coastal bays provide a vital service to both marine animals and humans. The bays serve as a nursery ground and source of food to many commercially, recreationally, and ecologically important species (for example, lobster, blue crab, winter flounder, etc.). The plants growing in the estuaries and the animal communities supported by those plants feed migratory and resident populations of birds. Humans enjoy many activities in these bays, including fishing, shellfishing, boating, paddling, and swimming. These areas host our marinas, yield our dinner, and provide a wide assortment of recreational outlets.

Small coastal bays are the receiving waters for much of the nitrogen (N) and phosphorus (P) being delivered into LIS. These enclosed areas are strongly affected by the N and P entering the coastal zone and also serve to remove some of



Charles Yarish

Seaweeds grow rapidly in response to increases in N and P. They come in a variety of shapes (blades, tubes, fine filaments) and colors (green and red are shown here).

Charles Yarish

Jamie Vaudrey collecting water in order to analyze the nitrogen and phosphorus content.

the nutrients before they reach the main stem of LIS. This removal is accomplished by the use of N and P by primary producers both large and small. Most visitors to the seashore have seen the plant matter clinging to the rocks or washed up on the beach. This plant matter consists of seaweed in shades of green, red, and brown.

While seaweed is not a true plant (with roots and leaves similar to land plants), the beach visitor to the Eastern areas of LIS is likely to encounter one of our true plants capable of living in salt water: eelgrass (*Zostera marina*). These long eel-shaped blades or leaves form the above-ground portion of the plant.

In addition to the macroscopic primary producers, microscopic algae (phytoplankton) are also present in the water. All of these primary producers respond to nutrients in the water column by growing and reproducing, just as a backyard garden responds to fertilizer. When the N and P increase, the primary producers which respond fastest in shallow waters tend to be the seaweed.

These crops of fast-growing seaweed may shade slower growing seaweed and eelgrass, potentially changing the habitat characteristics to such an extent that the community of animals inhabiting the area may shift to include other types of animals. In some cases, the animals most desired by humans (for example, scallops, fish) may vacate the area. Excess nutrients entering bays accompanied by the onset of hypoxia may result in the loss of recreationally and commercially valuable species and a decrease in our ability to enjoy the area (for example, beach closures, noxious smells, fish kills).

While scientists understand the theoretical links between nutrient input, growth of the primary producers, and hypoxia, our practical knowledge of these small bays is limited. We have yet to "take the pulse" of many of these bays and translate a theoretical knowledge of processes into the practical identification of the severity and extent of hypoxia.

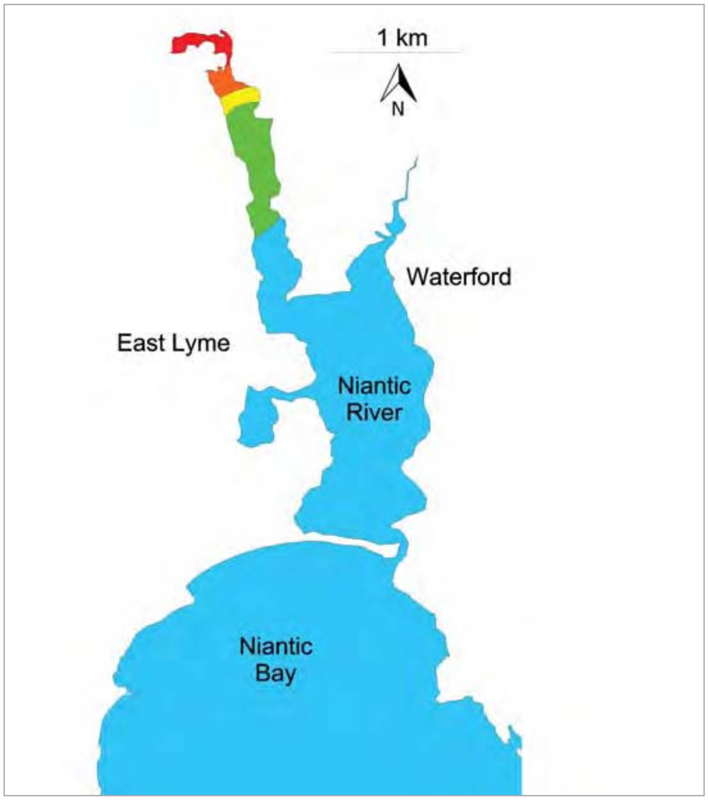
In 2011 and 2012 with funding from the Long Island Sound Study, Connecticut Sea Grant and New York Sea Grant, my colleague Charles Yarish (University of Connecticut) and I set out to sample eight bays on Long Island and along the Connecticut shore with the goal of determining if hypoxia in these bays is occurring and how widespread the problem might be. Along the Connecticut shore, sites stretched from the Stamford area in the West (Holly Pond) to Stonington Harbor in the East. Along the shore of Long Island, we sampled from Cold Spring Harbor in the West out to Mattituck Creek in the East. These sites spanned a range of sizes and a range in the amount of nutrients entering the system from the land. In some, such as Holly Pond, the watershed was highly urbanized. In others, such as Stonington Harbor and Mattituck Creek, the watershed included a mix of natural vegetation (forests, wetlands), low to moderate human development, and agricultural lands. The goal was to identify what types of estuaries may be experiencing hypoxia, based on what we know of the activities occurring in the watershed.

The oxygen content of the water should be lowest just at dawn, as all of the organisms have been respiring and thus depleting the oxygen throughout the night. Once the sun rises, the primary producers begin to pump oxygen back into the water as they go about their business of photosynthesizing. We were interested in capturing any short–lived hypoxia, as well as hypoxia that might linger later into the day. So, our alarm clocks were set for 3:30 am and we headed out into the field to greet the dawn in our hunt for hypoxia.

Charles Yarish

Adam Chlus and Marissa Mackewicz preparing the benthic grab, used to collect sediment and seaweed from the bottom.

What we found mirrors the trends seen in the main stem of Long Island Sound. The lowest oxygen levels and greatest area of lower oxygen waters were seen in the Western Sound bays, where the urbanization in the watersheds is greatest. The Long Island Sound Study defines hypoxia as waters with an oxygen concentration of 3 mg/L or lower. Using this defining point, only Cold Spring Harbor evidenced widespread hypoxia. An interesting finding was that hypoxia in Cold Spring Harbor was more severe (0.5 to 2.4 mg/L) than what was seen in the main



Area and severity of hypoxia (lack of oxygen) in bottom waters of Niantic River on August 5, 2011. The color scheme follows that used by the CT DEEP for Long Island Sound hypoxia maps:

- = severe (0.0 – 0.99 mg/L),
- = moderately severe (1.0 – 1.99 mg/L
- = moderate (2.0 – 2.99 mg/L),
- = marginal (3.0 – 3.49 mg/L),
- = interim management goal (3.5 – 4.79 mg/L),
- = excellent, supportive of marine life (4.8+ mg/L).

Charles Yarish

Dawn sampling of Holly Pond. Michelle Slater, Marissa Mackewicz, and Adam Chlus preparing to launch.

stem of Long Island Sound (~4.2 mg/L) during this same time period. This indicates that the hypoxia is not derived from the main stem of Long Island Sound, but a process driven from within the bay. Only three other sites exhibited hypoxia, and the incidence of hypoxia was limited to the "head" of the estuary, or that portion furthest from Long Island Sound. These inland portions of the bays are the receiving areas for freshwater inputs. These freshwater inputs carry nutrients from the land into the bays and eventually out to Long Island Sound. That source of nutrients and the level of primary production it supports is the likeliest cause of hypoxia in these bays.

Work in these same systems will continue in the summer of 2012. By adding an additional year of sampling in the same sites, we'll begin to evaluate the inter-annual variability of hypoxia. The ultimate goal is to identify bays with a high risk of experiencing hypoxia. These sites are in need of greater efforts at nutrient reduction, which should, in turn, reduce the severity of hypoxia and improve conditions for the many valuable species of organisms that use these bays for nursery grounds and as a source of food. This will provide healthy coastal waters for human activities such as fishing, shell fishing, boating, and swimming. We need to reduce the stresses on these "great creatures," moving the panting occurring in the most belabored bays into the more natural rhythm characteristic of the breathing of the bays.

About the Author

Jamie Vaudrey is a marine ecosystems ecologist and an assistant research professor in the Department of Marine Sciences, University of Connecticut.