Photo credits: top courtesy Theresa Hattenrath-Lehmann; center courtesy Jennifer George; bottom and large photo Barbara A. Branca

In every season, from near shore or far, under fair skies or a fast-moving front, graduate students collect samples from Long Island Sound. From top to bottom: Sea Grant Scholar Theresa Hattenrath-Lehmann and grad student Ryan Wallace study red tide in Northport Harbor; Sea Grant Scholars Laura Treible, Jennifer George and Theresa Hattenrath-Lehmann study winter productivity from aboard the *r/v Seawolf;* Sea Grant Scholar Elizabeth Suter analyzes microorganisms from the *Seawolf's* rosette sampler.

Sound Research "Gets to the Bottom" of Hypoxia, Red Tide

Since Spring 2009, the Sea Grant programs of Connecticut and New York have been tracking five funded research projects that examined some of the most serious threats to the ecological health of Long Island Sound (LIS), an Estuary of National Significance. The researchers, several of them at Stony Brook University (SBU), were awarded nearly $820,000 in research grants to address the long-term problem of LIS's low oxygen conditions (hypoxia) as well as emerging issues of red tide and the effects of climate change on the Sound's ecosystem. Recently, several researchers presented results from the two-year projects to the EPA LIS Study's Science and Technical Advisory Committee many members of which are resource managers throughout the LIS watershed.

Several projects examined hypoxia, each taking a complementary research direction, whether investigating the chemical, physical, or biological factors that contribute to the low oxygen conditions at the bottom of LIS.

Drs. Robert Wilson and **Brian Colle** along with NY Sea Grant Scholar **Sean Bratton** at SBU's School of Marine and Atmospheric Sciences (SoMAS), and **Dr. Daniel Codiga** of the University of Rhode Island have looked at the relationship between summertime storms and hypoxia. They hypothesize that these systems are a primary agent responsible for mixing bottom waters and determining oxygen levels. Using existing meteorological data, they evaluated to what extent relevant factors like wind speed, wind direction, and air pressure cause water in the Sound to either mix or stratify in layers. Results show that variation in the wind direction over the western Sound accounts for a major fraction of the variance in the duration and extent of hypoxic events. They found that high pressure patterns with winds from the east/northeast result in the highest percentage of total mixing events. These mixing events are strong determinants of fluctuations in dissolved bottom oxygen and the duration of the hypoxic event. Measurements of hypoxic event duration provide good metrics for gauging the impacts of hypoxia on living resources. However they also found that the duration and intensity of stratification events are not closely linked to those of hypoxic events.

Also at SoMAS, **Drs. Darcy Lonsdale** and **Christopher Gobler** along with NY Sea Grant Scholars **Jennifer George**, **Xiaodong Jiang** and **Laura Treible** have examined seasonal temperature differences and the effects on the Sound's food web. The spring phytoplankton bloom is an annual event in LIS and an important source of organic matter to the benthos (animals living at the bottom of LIS). The researchers hypothesized that during warm

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winters, increased zooplankton grazing might lead to a suppression of the spring bloom and thus a decline in the amount of organic matter delivered to the benthos.

They conducted two types of experiments: field observations of zooplankton grazing and controlled mesocosm (tank) experiments with varying temperatures. In the field, the research team observed that the 2010 and 2011 spring blooms occurred in early February with the peak of spring phytoplankton bloom coinciding with the lowest seawater temperature and equal temperatures from surface waters to the bottom (i.e., no stratification). Microzooplankton grazing occurred on all dates, even when seawater temperatures were approaching $0^{\circ}C$. However, in the two years of mesocosm experiments, the warmer temperature treatment resulted in fewer phytoplankton and higher zooplankton grazing. The research indicates that suppression of the spring bloom with increased winter temperature may result in less carbon at the bottom potentially improving the hypoxia problem because of decreased respiration in the benthos, but also potentially decreasing productivity of benthic fisheries.

Drs. Kamazima Lwiza and **Gordon Taylor** with NY Sea Grant Scholars **Elizabeth Suter** and **Ling Liu** have been looking at the interaction of biological and physical factors controlling dissolved oxygen. Their goals have been to determine the variability in dissolved nutrients such as nitrogen and phosphorus, and to examine the roles of phytoplankton biomass, and bacterial production and mortality on bottom water oxygen content.

They made direct measurements of microbial biomass and activity during sampling cruises during the summers of 2009 and 2010 and also conducted statistical analyses of historical data. Respiration in bottom water samples was highest in the middle of summer 2009, including on days when hypoxia occurred. Furthermore, respiration in the very small particle-size fraction was negatively correlated with dissolved oxygen concentrations, suggesting that respiration associated with smaller particles and organisms is an important contributor to bottom water oxygen depletion. Respiration in this size fraction was also highly correlated with bacterial abundances, suggesting that bacterial respiration was one of the most important processes in depleting oxygen concentrations.

Chemical analyses indicate that nitrogen has increasingly become a limiting factor in phytoplankton blooms relative to phosphorus in LIS. There were modest decreases in dissolved inorganic nitrogen (DIN) while dissolved organic nitrogen (DON) increased, thus leaving total nitrogen relatively unchanged. Between 2002 and 2010, diatom abundances have declined in favor of nondiatom groups of phytoplankton. The researchers speculate that this is due to the Sound's changing chemistry: diatoms prefer DIN while other groups, such as dinoflagellates, prefer DON and also have a higher phosphorus requirement.

Collectively these observations are helping to create a biogeochemical numerical model to provide managers with a better understanding of hypoxia's drivers and therefore a better means of predicting hypoxic events in Long Island Sound. By specifically addressing microbial responses in the numerical model for the first time, seasonal hypoxia was modeled more accurately.

Dr. Mark Altabet of the Department of Estuarine and Ocean Science, School of Marine and Technology, University of Massachusetts, Dartmouth has been looking at the geochemistry of dissolved gases in the Sound to gain insight into oxygen exchange between surface and bottom waters. His results, to be reported at a future STAC meeting, will help the researchers put the chemical, physical and biological pieces together to create a more complete model of LIS hypoxia.

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Sound Research "Gets to the Bottom" of Hypoxia, Red Tide

Aside from the problem of LIS hypoxia, Dr. Christopher Gobler is also investigating an emerging issue: the causes and impacts of recent blooms of the red tide organism *Alexandrium fundyense* in the Sound. *A. fundyense* produce saxitoxin which may be ingested and accumulated in shellfish. The consumption of contaminated shellfish by humans or other predators, can cause paralytic shellfish poisoning (PSP) and thus presents a serious human health threat.

Gobler and his team report that from 2007 through 2011, *A. fundyense* has been detected at over 50 locations across NY and CT with the largest blooms being found in Northport Bay and other locations in NY with large nitrogen loads. Blooms in Northport persisted for up to six weeks achieving high cell densities, and forcing month-long annual closure of shellfish beds due to high saxitoxin concentrations in mussels and wild soft shell clams. Blooms have recurred annually and the researchers documented that a persistent cyst bed was established in Northport Bay in 2008 and has remained there since. In the cyst stage of *A. fundyense's* life-cycle, the cells can persist until conditions are right for them to bloom again.

In two recent journal articles, the research team reported that *A. fundyense* blooms in Northport were supported by a source of wastewater nitrogen such as septic systems or the sewage treatment plant which discharges into Northport Harbor. Also, warmer than average atmospheric temperatures in the late winter and early spring and cooler late spring temperatures can contribute to extended periods of temperatures optimal for *A. fundyense* growth and thus may have also contributed toward the large blooms. The researchers further suggest that allelopathic chemicals produced by *A. fundyense* that inhibit other algae may also aid in bloom formation. Finally, preliminary findings indicate that organic matter loading may also contribute toward bloom formation. Together all of their findings suggest that sewage-derived nitrogen loading, above average spring temperatures, organic matter loading, and the production of allelochemicals can all promote intense and toxic *A. fundyense* blooms in NY estuaries.

A portion of the funding for these projects came from two Sea Grant programs: Connecticut and New York which receive federal funding through the National Oceanic and Atmospheric Administration (NOAA). Most of the funding came from the Long Island Sound Study, a cooperative effort between the EPA's National Estuary Program and the states of Connecticut and New York to restore and protect the Sound and its ecosystems.

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