Technical Tools for Ecosystem Restoration: Application in Long Island Sound

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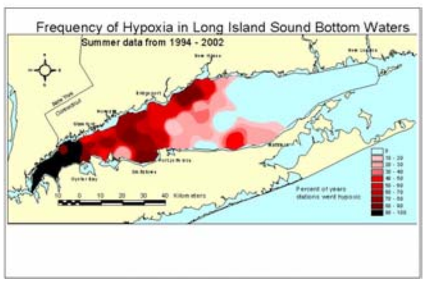
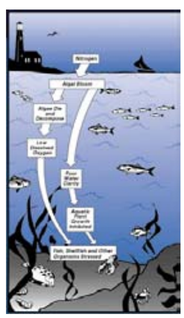
Abstract: Fifteen years of research, monitoring, modeling, and technical synthesis preceded adoption by EPA in 2001 of a CT-NY Total Maximum Daily Load (TMDL) that identified actions needed to attain water quality standards for dissolved oxygen. The TMDL establishes a 58.5 percent reduction in nitrogen loads to the Sound over a fifteen-year period ending in 2014. The TMDL incorporates flexible and innovative approaches such as "bubble" management zones and exchange ratios for reallocating waste loads to achieve water quality standards. It also highlights the importance of sources of nitrogen from outside of the New York and Connecticut portions of the watershed such as atmospheric deposition and tributary import. To date, Connecticut and New York have reduced their point source nitrogen loads by 25 percent through upgrades at wastewater treatment plants.

1. Introduction to Long Island Sound: Long Island Sound (LIS) is an estuary located in southern New England and New York State, bounded by Connecticut (CT) and New York (NY). The 16,000 sq. mi. watershed of LIS drains most of CT, small, but densely populated areas of NY and substantial portions of Massachusetts, New Hampshire and Vermont, primarily via the Connecticut River (Figure 1). Because of the high population settled around Long Island Sound, especially New York City and its expansive metropolitan area, it has often been referred to as the "Urban Sea."

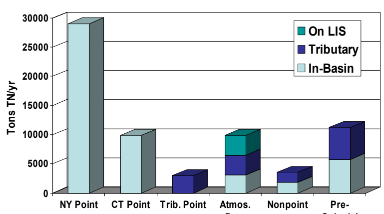
2. The Problem: Hypoxia, or low levels of dissolved oxygen, is a common summertime occurrence in Long Island Sound (LIS) bottom waters (Figure 2). Monitoring and modeling have confirmed that nitrogen is the limiting nutrient in LIS. Nitrogen loading to the Sound is at least eight times higher today than estimated for pre-Colonial times. Phytoplankton growth is stimulated to levels that are not natural to the Sound's ecosystem. The biomass from those blooms eventually adds to the carbon load in the bottom waters, either directly or cycled through living organisms such as zooplankton, fish, or shellfish. Respiration, primarily microbial decay of organic carbon, in the bottom water and sediments exceeds oxygen replenishment and DO falls to unhealthy levels. LIS hypoxia represents a classic nitrogen-driven condition in a system that is susceptible because of natural stratification processes that occur during the summer (Figure 3). Based upon the water quality impairment due to low oxygen conditions, CT and NY have included Long Island Sound on their Section 303(d) lists since 1992. It has been listed as an impaired waterbody due to low DO and a priority for TMDL development.



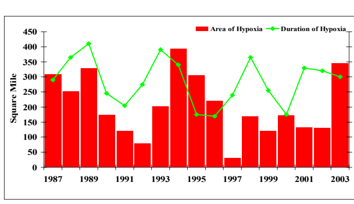


3. Understanding the Problem: To address the hypoxia problem, the Long Island Sound Study (LISS), a bi-state program sponsored by EPA and the states of CT and NY, initiated a program of research, modeling, and monitoring in 1985. The partnership involves federal, state, interstate, and local agencies, universities, environmental groups, industry, and the public to comprehensively address issues using a watershed-based approach. It was recognized early on that the complexity and potential cost of the problem would require new, flexible approaches in order for a successful program to be developed, supported, and implemented.

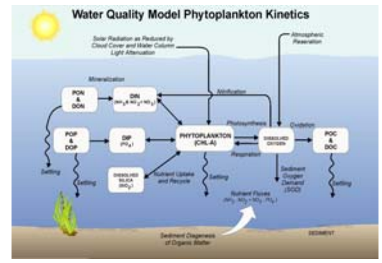
3.a. Identifying Sources: Nitrogen from sewage treatment plants dominate the load to the Sound (Figure 4). There are more than 100 municipal treatment facilities in the CT and NY portions of the watershed, discharging more than 1 billion gallons of treated effluent each day. Other sources include combined sewer overflows (CSOs), stormwater runoff, and atmospheric deposition.



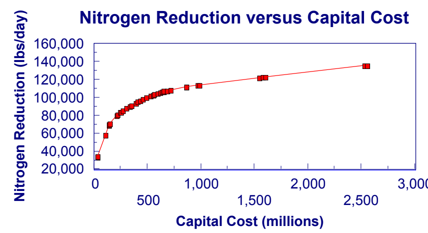
3.b. Monitoring Trends: Since 1987, the duration and areal extent of the late summer phenomenon has monitored each year (Figure 5). Hypoxia has impacted an average of 205 sq. mi. of bottom water habitat and has lasted an average of 57 days. The severity of hypoxia varies from year-to-year. In particular, weather conditions that drive nitrogen loading to the Sound and determine the strength and longevity of stratification are key to the severity of hypoxia each summer.



3.c. Developing Tools: The LISS sponsored nitrogen source and ambient water quality sampling programs to develop a coupled set of circulation and water quality models, called LIS 3.0, and to understand trends in the temporal and spatial extent of hypoxia. More than 25 water quality constituents were monitored - water quality transparency, salinity, temperature, various nutrients (nitrogen, phosphorus, and silica) and their forms, chlorophyll *a*, DO, BOD5, total organic carbon, and suspended solids among others. The model incorporates advanced physical, biological and chemical kinetics (processes) that relate nutrients and carbon-based pollutants to phytoplankton (primary productivity) dynamics and DO (Figure 6). The LIS 3.0 model was run under a range of nutrient loadings to simulate their effect on DO levels in Long Island Sound. Based on model computations, it was calculated that almost 75 percent of the DO depression at the critical location in Long Island Sound results from nutrients, with the remainder due to oxidizable carbon. Both data and modeling results indicate that nitrogen, not phosphorus, is the limiting nutrient, although the data and modeling also suggest there are short periods of time when silica limits algal growth.



3.d. Identifying Management Options: Possible levels of nitrogen control were identified. For sewage treatment plant upgrades, it became apparent that there was a level of nitrogen reduction that would maximize increases in DO levels relative to the implementation cost (Figure 7). Using this information, the LISS identified a nitrogen reduction target of 58.5 percent and compared the model-predicted DO levels that would result against the EPA marine dissolved oxygen criteria being developed to estimate some of the resulting ecological and environmental benefits. The predicted maximum area of the Sound unhealthy for aquatic life was reduced by 75 percent. The predicted duration of hypoxia was reduced by 85 percent, from more than 50 days to 6.5 days. By limiting the area and duration of unhealthy conditions, overall adverse biological effects caused by hypoxia will be greatly reduced Soundwide.



4. Implementing Solutions: CT and NY completed and EPA approved the nitrogen TMDL in 2001. The TMDL established a 58.5 percent reduction in nitrogen loads to the Sound over a fifteen-year period ending in 2014. The TMDL uses flexible and innovative approaches such as "bubble" management zones and exchange ratios for reallocating waste loads to achieve water quality standards. It also highlights the importance of sources of nitrogen from outside of the NY and CT portions of the watershed such as atmospheric deposition and tributary import.

The states of CT and NY are upgrading STPs for biological nutrient removal and working to control nonpoint source runoff. To provide flexibility in targeting cost-effective STP upgrades, NY has issued bubble permits by management zone and CT has issued a general statewide permit to its 79 dischargers. For example, using the bubble management zones and exchange ratios, New York City signed a consent agreement on actions to meet its allocation that save more than $600 million in construction costs compared to traditional approaches. CT's new nitrogen credit program will economically control and reduce point sources nitrogen loads to LIS. The nitrogen credit exchange program issued its first round of credits/debits in 2003. Facilities that surpass the 58.5 percent goal acquire and can sell weighted credits to facilities that need them. This innovative program is expected to save the state more than $200 million in wastewater treatment construction costs over the next decade.

5. Progress to Date: As of 2003, total point source nitrogen loads to the Sound have declined by 25 percent. While climate and weather conditions influence conditions for hypoxia, the maximum areal extent and duration of hypoxia each summer appears to have decreased over the last 16 years. Summer hypoxia is still a significant impairment to water quality and continues to affect critical life cycles of living marine resources.

6. Key Challenges Encountered and Lessons Learned: TMDL development and implementation involve many facets of the water programs. Revised marine dissolved oxygen criteria, water quality standards, watershed permits, compliance agreements, enforcement, modeling and monitoring, research, education and technical assistance, and water quality trading all come into play. The key challenge is reconciling the cost and time it takes to implement a program of this magnitude within the existing laws and regulations. Integration can be done, but requires flexibility, persistence, a focus on outcomes, and strong public support. Each element of water programs must be involved in *developing solutions* and *solving problems* in the broader context of improving water quality and meeting CWA objectives.