Long Island Sound Study

CCMP HYPOXIA

The Problem

During the summers of 1987-93, from half to two-thirds of the Sound's bottom waters experienced dissolved oxygen levels below 5 milligrams of oxygen per liter of water (mg/l) (Figure 2). Levels of dissolved oxygen of 5 mg/l and higher are generally accepted as being protective of the Sound's estuarine life. In 1989, a particularly bad summer, more than 500 square miles (40 percent) of the Sound's bottom waters had dissolved oxygen levels less than 3 mg/l. During most of these years, dissolved oxygen in a portion of the Sound (up to 50 square miles) fell below 1 mg/l and in 1987 anoxia, the absence of any oxygen, was recorded in a portion of the Western Narrows.

These low levels of dissolved oxygen cause significant, adverse ecological effects in the bottom water habitats of the Sound. To date, research shows that the most severe effects (such as mortality) occur when dissolved oxygen levels fall below 1.5 mg/l at any time and below 3.5 mg/l in the short-term (i.e., 4 days), but that there are probably mild effects of hypoxia when dissolved oxygen levels fall below 5 mg/l. The levels regularly observed in the Sound during late summer:

- Reduce the abundance and diversity of adult finfish;
- Reduce the growth rate of newly-settled lobsters and perhaps juvenile winter flounder;
- Can kill species that cannot move or move slowly, such as lobsters caught in pots and starfish, and early life stages of species such as bay anchovy, menhaden, cunner, tautog, and sea robin;
- May reduce the resistance to disease of lobsters and other species; and
- Diminish the habitat value of Long Island Sound.

Type following link in your browser to view map of Low Dissolved Oxygen Areas in the Sound:

http://www.longislandsoundstudy.net/pubs/maps/lodo.htm

The Cause of the Problem

Excessive discharges of nitrogen, a nutrient, are the primary cause of hypoxia. Nitrogen fuels the growth of planktonic algae. The algae die, settle to the bottom of the Sound and decay, using up oxygen in the process.

Natural stratification of the Sound's waters occurs during the summer when warmer, fresher water "floats" on the top of cooler, saltier water that is more dense. This natural stratification forms a density difference between the two layers called a pycnocline. This prevents mixing of surface and bottom waters.

Oxygen from the atmosphere and photosynthesis keep the surface layer well oxygenated, but the oxygen cannot pass through the pycnocline into the bottom layer very easily. Decaying algae and other organic material in the sediment and animal respiration in the bottom layer use up oxygen faster than it is replenished. Hypoxia develops and usually persists as long as the stratification lasts (usually one to two months in late summer).

But hypoxia in Long Island Sound is too complex to fully understand using direct observations alone. Natural variations in weather and other physical factors affect the extent and severity of

hypoxia. The Management Conference has constructed mathematical models in order to understand the relationship among natural variations, human-caused pollutant loadings to the Sound, and dissolved oxygen levels in the Sound. Work has been completed on LIS 2.0, a two-dimensional water quality model that provides the technical basis for the hypoxia management actions described in the plan. In June 1994, the Management Conference will complete work on LIS 3.0, a three-dimensional water quality model that will better define the area impacted by hypoxia. LIS 3.0 will be used as a tool to implement the plan and establish a detailed, cost-effective management program to reduce hypoxia.

LIS 2.0 provides a level of detail that allows the Management Conference to draw some clear conclusions about hypoxia in the Sound, its causes, and its solutions. Using LIS 2.0, the Management Conference has simulated water quality conditions as they were in the past, as they are today, and as they would be in the future under alternative nitrogen control scenarios. The model provided a cost-effective way of understanding the Sound and hypoxia.

- The most oxygen that can be dissolved in Long Island Sound at summer water temperatures is about 7.5 mg/l. This is known as the saturation level.
- In pre-Colonial days, natural, healthy biological activity brought dissolved oxygen levels below saturation due to the natural loadings of organic material and nitrogen, but oxygen levels probably were not below 5 mg/l.
- Under today's nutrient and organic material loading conditions, minimum dissolved oxygen levels average approximately 1.5 mg/l. These levels are associated with severe hypoxia and have been documented in the field.
- By substantially reducing nitrogen loadings to the Sound from sources within its drainage basin, the minimum dissolved oxygen levels in the bottom waters during late summer can be increased to an average of about 3.5 mg/l, thereby significantly reducing the probability and frequency of severe hypoxia and reducing the area affected by hypoxia.

Understanding the components of the load of nitrogen entering the Sound is fundamental to understanding the plan (Figure 3):

- In 1990, defined as a baseline year by the Management Conference, the total nitrogen load was 90,800 tons per year.
- By 1992, the total nitrogen load had increased to 93,600 tons per year; this increase was anticipated and was a consequence of terminating ocean disposal of sewage sludge from New York City and the need to treat some of the sludge at facilities within the basin, reintroducing nitrogen to the wastestream.
- Of the 93,600 tons per year, approximately 39,900 tons are from natural sources and not subject to reductions by management activity.
- The remaining 53,700 tons of nitrogen per year are associated with human activities and have the potential to be reduced through management actions.
- 10,700 tons of nitrogen per year enter the Sound through its boundaries -- the East River in the west and The Race in the east; efforts to reduce this substantial western load will come under the auspices of the New York-New Jersey Harbor Estuary Program.
- 2,200 tons of nitrogen per year enter the Sound from direct atmospheric deposition; the Management Conference estimates that this load will be reduced to 1,540 tons of nitrogen per year through implementation of the 1990 Clean Air Act amendments.
- The remaining 40,800 tons of nitrogen per year are a result of human activity coming from point and nonpoint source discharges in the Sound's drainage basin and are the subject of the plan. Point source discharges, primarily sewage treatment plants, result in 32,400 tons of nitrogen each year and nonpoint source discharges, such as agricultural and stormwater runoff, result in 8,400 tons of nitrogen each year.

Type following link in your browser to view map of Priority Nitrogen Management Areas:

http://www.longislandsoundstudy.net/ccmp/priority.htm

The Plan to Solve the Problem
The goal of the hypoxia management plan is to eliminate adverse impacts of hypoxia resulting from human activities.

Achievement of this goal will require very large investments of capital, a long-term commitment, and the assistance of the New York-New Jersey Harbor Estuary Program. Therefore, the Management Conference has established interim targets for dissolved oxygen and has outlined a phased approach to achieving them, using what is known now to support early phases and committing to take additional steps as increased understanding of the environment will dictate in the future.

Type following link in your browser to view map of Geographic Zones for Managing Total Nitrogen Loads:

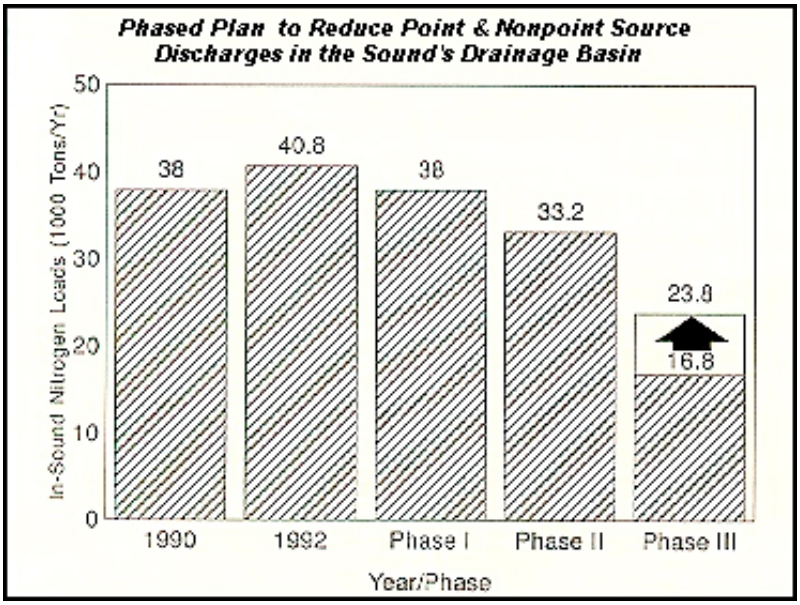
http://www.longislandsoundstudy.net/ccmp/nloads.html

Interim Dissolved Oxygen Targets
Using scientific information on the relationship between oxygen levels and ecological effects, the Management Conference has established interim target levels for oxygen that, if achieved, would minimize the adverse impacts of hypoxia. In summary, the interim dissolved oxygen targets for the bottom waters of the Sound are to:

- Maintain existing dissolved oxygen levels in waters that currently meet state standards;
- Increase dissolved oxygen levels to meet standards in those areas below the state standards but above 3.5 mg/l; and,
- Increase short-term average dissolved oxygen levels to 3.5 mg/l in those areas currently below 3.5 mg/l, ensuring that dissolved oxygen never goes below 1.5 mg/l at any time.
- There are also interim targets for the surface waters of the Sound.

Phased Approach
The Management Conference is implementing a phased approach to reducing nitrogen loadings to the Sound from point and nonpoint source discharges within the Sound's drainage basin.

- Phase I, as announced in December of 1990, froze nitrogen loadings to the Sound in critical areas at 1990 levels to prevent hypoxia from worsening.
- Phase II, as detailed in the plan, includes significant, low-cost nitrogen reductions that begin the process of reducing the severity and extent of hypoxia in the Sound.
- Phase III will present nitrogen reduction targets to meet the interim targets for dissolved oxygen, which will prevent most known lethal and sublethal effects of hypoxia on the Sound's estuarine life. Phase III also will lay out the approach for meeting the nitrogen load reduction targets.



Phase I - The Nitrogen Loading Freeze
Phase I was announced in December 1990. It called for a freeze on point and nonpoint nitrogen loadings to the Sound in critical areas at 1990 levels. It committed the states and local governments to specific actions to stop a 300-year trend of ever- increasing amounts of nitrogen entering the Sound.

The states have moved aggressively to implement the freeze, seeking the full cooperation of local governments.

- Connecticut reacted quickly to obtain $15 million in state funds to ensure that the nitrogen freeze was implemented. Consent orders are in place to cap the nitrogen loads at the 15 affected facilities.
- n New York City, the New York State Department of Environmental Conservation (NYSDEC) and the city have reached full agreement on sewage treatment permit limits, freezing total nitrogen loadings at 1990 levels. The permits will be finalized shortly.
- In Westchester County, the NYSDEC has issued final permits to the four existing sewage treatment plants, freezing their aggregate load at the 1990 level. This was done with the full agreement of the county.
- On Long Island, the NYSDEC has proposed individual permits that freeze the loads from individual discharges at 1990 levels; in response, the dischargers have proposed establishment of an aggregate limit. This proposal is currently under review by the NYSDEC.

Phase I agreements to control nonpoint sources centered around three categories:

- Use of existing nonpoint source and stormwater management programs to focus on nitrogen control with the objective of freezing the loads.
- Assessing tributary loads to Long Island Sound to begin planning for their control.
- Assigning priorities for management to coastal subbasins where nitrogen loads were estimated to be the highest (Figure 4).

Phase II - Low Cost Nitrogen Reductions
Phase II includes firm commitments to reduce the annual, human-caused nitrogen load of 40,800 tons from in-basin sources by approximately 7,600 tons (or 18.6 percent). This includes complete compensation for the 2,800 tons per year increase associated with the end of ocean dumping and a 4,800 tons per year reduction from the 1990 freeze baseline.

- New York state will reduce its aggregate annual nitrogen load from 11 sewage treatment plants in New York by 25% percent (approximately 6,700 tons) at a total capital cost of $103.1 million. Five of the actions will be achieved by the end of 1995; four will be achieved by the end of 1996. The load reduction associated with centrate treatment is to

be achieved by the year 2000. The target date for achieving the load reductions associated with the upgrade of the Newtown Creek water pollution control plant in the East River is currently being negotiated by the New York City Department of Environmental Protection (NYCDEP), the NYSDEC, and the EPA. Funding for these actions is available through the State Revolving Fund.

- Connecticut will reduce its aggregate annual nitrogen load from the 15 affected treatment plants by 25 percent (approximately 900 tons) by 1995. Funding is in place for the $18.1 million expenditure with $14 million available as 100 percent grants and the balance as State Revolving Fund loans.
- Phase II activities for nonpoint nitrogen control will continue to take advantage of existing programs by focusing additional attention on nitrogen in priority coastal subbasins. The states of Connecticut and New York are formulating their Coastal Nonpoint Pollution Control programs to address coastal nitrogen sources.

The benefits of Phase II nitrogen reductions, as forecast by the LIS 2.0 model, will be substantial. Summertime minimum dissolved oxygen concentrations in the bottom waters of the western Sound will be raised on average from 1.5 mg/l to about 2.4 mg/l. The amount of estuarine habitat presently degraded will be reduced by about 10 percent. The area most severely affected by hypoxia will shrink by more than 30 percent.

However, these reductions alone will clearly not meet the interim dissolved oxygen targets nor achieve the goal for dissolved oxygen. Therefore, an additional level of nitrogen reduction will be necessary.

Phase III - Nitrogen Reduction Targets to Eliminate Severe Hypoxia
LIS 2.0 was used to begin to estimate nitrogen reductions required to meet the interim dissolved oxygen targets. Of the 40,800 tons per year total, in-basin, human-caused nitrogen load, required reductions are expected to range from 17,000 to 24,000 tons per year (or 42 percent to 59 percent). Achievement of these reductions would require the implementation of the mid- to high-level management scenarios as described in the Management Conference's 1990 Status Report and Interim Actions for Hypoxia Management. Preliminary cost estimates of these two levels of control for point sources are from $5.1 to $6.4 billion for New York state and from $900 million to $1.7 billion for Connecticut.

Cost estimates for the necessary level of control of nonpoint sources have not been developed but are expected to be substantial.

The benefit of achieving the interim targets would be the elimination of severe hypoxia. Most lethal and sublethal effects of hypoxia would be prevented and most of the severely impacted habitat area would be restored.

However, in order to proceed with such a costly enterprise in a way that obtains the greatest environmental benefits for each dollar spent, approximate Soundwide reductions must be translated into discharge- or zone-specific load reduction targets.

- Using the LIS 3.0 model, the Management Conference will identify the most beneficial and cost-effective nitrogen load reduction targets for geographic management zones established around the Sound (Figure 5).
- The states and local governments will then be given the opportunity to propose the most cost-effective mix of point and nonpoint source reduction actions to achieve these nitrogen load reduction targets within each zone.

The third phase of the plan, therefore, is to:

- Complete work on LIS 3.0 by June 1994.
- Establish LIS 3.0-based dissolved oxygen targets, and nitrogen load reduction targets by zone, by December 1994.
- Encourage and support the development of innovative, cost- effective technologies to reduce point and nonpoint sources of nitrogen.

- Complete in 1995-1997 the zone-by-zone plans to achieve the load reduction targets.
- Establish a firm timetable for achieving the load reduction targets by zone within 20 years with progress measured in five year increments; this timetable can only be met if the State Revolving Funds are adequately capitalized.
- Continue long-term implementation to ensure steady increases in dissolved oxygen and reductions in the area impacted by hypoxia.

The Management Conference has already allocated funds to complete work on LIS 3.0. Resources and staff from existing programs will be used to establish LIS 3.0-based dissolved oxygen targets and nitrogen load reduction targets. The development of zone-by-zone plans to achieve the nitrogen reduction targets has already been initiated, with over $1 million committed. To complete all the zone-by-zone plans by 1997, the Management Conference estimates that $700,000 per year for three years will be needed.

The phased plan to reduce the annual load from point and nonpoint source discharges of nitrogen is depicted in Figure 6.

Going Beyond the Interim Dissolved Oxygen Targets
Full attainment of the goal of eliminating the adverse impacts of hypoxia from human activities (not just eliminating severe hypoxia) will require additional actions beyond the scope of the Long Island Sound Study. The New York-New Jersey Harbor Estuary Program is currently considering the need for nitrogen control on a systemwide basis; nitrogen control in the Harbor could reduce the export of nitrogen and increase the export of oxygen from the Harbor to the Sound. Additionally, New York City has initiated studies to evaluate the efficacy of relocating discharges from the upper and lower East River, thereby reducing these inputs of nitrogen to Long Island Sound.

The Management Conference recommends a long-term program of monitoring and modeling to assess progress in meeting the nitrogen reduction and dissolved oxygen targets, and to assess the ecosystem's response. This program is essential to ensuring that the management actions that are implemented are benefiting the Sound as expected.

A key element of the program is the use of the LIS 3.0 model. The Management Conference recommends that LIS 3.0 be periodically recalibrated to reflect the changing conditions of the Sound, and be used to explain these changing conditions. Furthermore, the Management Conference recommends that LIS 3.0 be used to evaluate proposals to modify the management plan, as necessary.

A comprehensive hypoxia monitoring and modeling program has been proposed, building upon elements of existing programs, primarily those of the Connecticut Department of Environmental Protection (CTDEP), the NYCDEP, and the Interstate Sanitation Commission. Full implementation of the monitoring program would require additional funding of $300,000 per year. Recalibration of LIS 3.0 would cost approximately $300,000.

Costs and Funding
The Management Conference recommends increased funding of the Connecticut and New York State Revolving Fund programs. Based on the preliminary estimates, if the high-level of nitrogen control were selected, the Connecticut State Revolving Fund would need an infusion of $70 million per year in federal Clean Water Act funds and $47 million per year in state funds over 20 years to meet all statewide wastewater control needs, including Long Island Sound nitrogen control needs. The New York State Revolving Fund would need an infusion of $623 million per year in federal Clean Water Act funds and $128 million per year in state funds over 20 years to meet statewide needs, including Long Island Sound nitrogen control needs.

The Management Conference also recommends that the Congress authorize a total of $50 million under Section 119(d) of the Clean Water Act. This section of the Clean Water Act, created by the Long Island Sound Improvement Act of 1990, authorizes grants for projects that will help implement the plan. Appropriations could be spread over a period of five years. The Management

Conference would use the $50 million to fund a Long Island Sound Challenge Grant program. A significant portion of appropriated funds would be used to ensure that the Phase III nitrogen control efforts get off to a fast start with full local government cooperation. The portion of these funds allocated for nitrogen control would be used to fund cost-effective point and nonpoint source control actions not involving major capital improvements. Innovative projects would be encouraged.

And finally, the Management Conference recommends that Congress fully fund the nonpoint source control programs under Section 319 of the Clean Water Act and Section 6217 of the Coastal Zone Act Reauthorization Amendments to support additional nonpoint source management activities.