NUTRIENT ENRICHMENT/HYPOXIA

Introduction

Nutrient enrichment resulting in hypoxia has been identified by the LISS as the major threat to the Long Island Sound ecosystem. The nutrient enrichment/hypoxia component of the Long Island Sound Monitoring Program should be capable of yielding answers to the following questions:

- What are the major sources of nutrients to different segments of the Sound? How do they vary temporally?

- What are the chemical forms of the nutrients that are delivered to the Sound and that are present in the Sound?

- Is summertime hypoxia getting worse or better, or is it unchanged? Are there any trends in the levels of dissolved oxygen?...in the area and volume of the Sound with low dissolved oxygen levels? ...in the duration of periods of depressed oxygen levels?

- What is the trend in algal biomass? What is the trend in biomass that accumulates in the sediments?

- Have management strategies been effective?... Which ones? To what extent? Always? 90% of the time? What fraction of the time?

Background

The Management Conference is implementing a phased approach to reducing nitrogen loadings to the Sound from point and nonpoint sources 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 an aggravation of hypoxia. Phase II, as detailed in the CCMP, includes commitments for significant, low-cost actions that are expected to result in nitrogen reductions of 7,600 tons in the annual load. Most of these actions are expected to be completed by 1995-96, and will begin the process of reducing the causes of hypoxia in the Sound. Phase III will present (by December 1994) nitrogen reduction targets to meet interim targets for dissolved oxygen to prevent most known lethal and sublethal effects of hypoxia on the Sound's biota. The total required reductions that would be necessary to meet the interim dissolved oxygen targets are expected to range from 17,000 to 24,000 tons per year. It is anticipated that full implementation of Phase III actions could require up to 20 years.

The changes in dissolved oxygen expected from any of the various management strategies under consideration are modest and long-term. For example, summertime minimum dissolved oxygen levels in the bottom waters of the western Sound are expected to increase from 1.5 mg/l to 2.4 mg/l from the Phase II reductions. Because of the buildup of organic matter in the sediments, it is estimated that expected improvements in dissolved oxygen conditions might take up to five or six

years to be fully realized after achieving planned reductions in nitrogen loadings. As a result, programmatic monitoring of nitrogen control actions will be particularly important as early indicators of program effectiveness.

The large natural variability of the Long Island Sound System make it unlikely that the expected improvement in dissolved oxygen would be detected through water column monitoring alone that would be affordable and sustainable. Therefore, a diagnostic monitoring program for the nutrient enrichment component of the LIS Monitoring Program requires a combination of modeling and monitoring. The two activities not only are complementary, but are required. There are three distinct and equally important purposes for the field collection program. The data are needed to run the model and to verify it. They also are needed to develop a descriptive chronicle of how the Sound's water quality changes from season to season, from year to year, and over longer time scales. The LIS 3.0 Model will provide the quantitative framework for the eutrophication component of the LIS Monitoring Program.

There was unanimity, or near unanimity, among the participants in the two workshops that the LIS monitoring component for eutrophication should be built on existing monitoring programs. Moreover, it was agreed that with proper QA/QC, with standard methods of sampling and analysis of an agreed upon set of properties, with standard reporting, and with a sustained, long-term program, that with relatively modest modifications, the aggregate of existing state, New York City and Interstate Sanitation Commission monitoring programs should be able to answer all of the

questions listed previously. This would be a minimalist program. It is described below along with a more desirable, expanded program.

Although the anticipated changes in dissolved oxygen levels will be modest, the biological/ecological benefits of these modest changes may be much greater. They should be revealed through the Living Marine Resources component of the LIS Monitoring Program.

Minimalist Program

For a minimalist program, we recommend the following components. Changes to existing programs are in italics.

Programmatic Monitoring

The management plan highlights within tables a number of specific commitments to manage nitrogen loadings from point and nonpoint sources within the watershed. Following are the general programmatic areas for which progress must be tracked and evaluated.

- Implementation of enforceable mechanisms, e.g. permits, consent orders, that limit nitrogen discharges at point sources consistent with the 1990 *no net increase* policy and the CCMP.

- Responses of the regulated community in implementing actions to remove nitrogen including biological nutrient removal retrofits (or other process modifications) and full scale renovations to meet enforceable limits.

- Incorporation of nonpoint nitrogen control actions, including best management practices and wetlands and riparian zone protection, as high priorities for funding.

- Development and implementation of management zone plans for comprehensive control of all sources of nitrogen.

Inputs of Nutrients

This component of the monitoring program should document the input of various chemical forms of nutrients to LIS, from several source categories. These nutrients have been implicated in the development of eutrophication in the Sound and resulting hypoxic conditions. Figure 3 shows the amount of nitrogen contributed from different source categories.

Point Sources

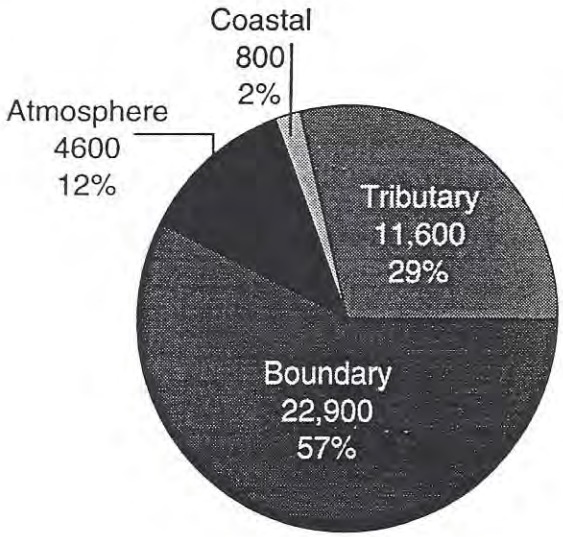
Where: Sewage treatment plants (STPs) and industrial point sources in relevant portions of the LIS watershed.

When: At least monthly.

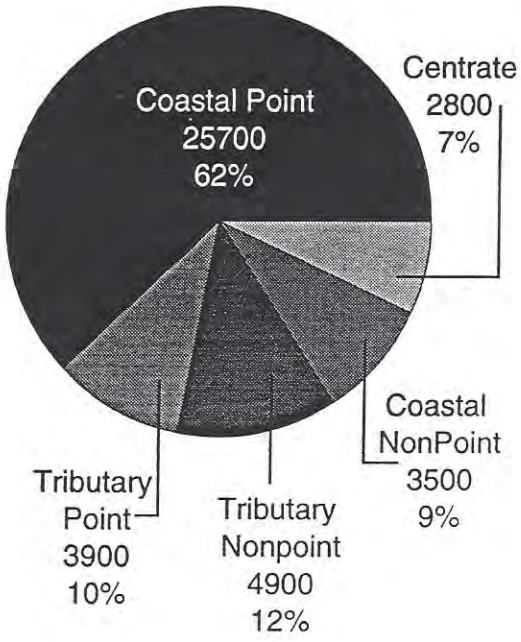
How: Discrete water effluent sampling

Data: Concentrations of major chemical species of nutrients.

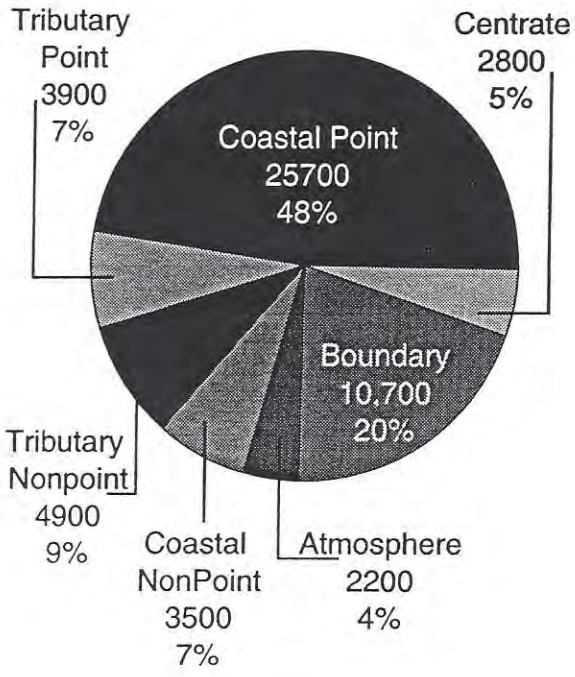
Figure 3. Nitrogen Inputs to Long Island Sound



Natural Load
39,900 Tons/Yr



In-Basin, Human-Caused Load
40,800 Tons/Yr



Human Caused Load
53,700 Tons/Yr

Who: Inputs of nutrients to LIS from sewage treatment plants (STPs) and from industrial sources are adequately characterized by existing compliance monitoring programs carried out by municipalities and industries. The LISS, through its Status Report agreements in 1990, formalized requirements for monitoring relevant point sources in the Long Island Sound basin.

Discharges of Nutrients from Tributaries

Where: Downstream reaches of the tributaries of LIS.

When: Continuous weighted sampling (more frequent sampling when flow is higher).

How: Discrete water sampling

Data: Concentrations of major chemical species of nutrients

Who: There are 9 identified drainage basins contributing to LIS. In seven of these, there exist 11 USGS non-tidal gauging stations, which monitor 85% of the watershed. The number of variables measured by USGS is more than adequate, but the sampling frequency (11 times per year) is not adequate to detect trends. *To detect trends it is necessary to increase the USGS measuring frequency to twice/month or better, to use event/composite sampling (flow-weighted; more frequent*

sampling when the flow is higher). Moreover, it will be necessary to monitor a control watershed to factor out climate changes that influence water quality trends. A control watershed is defined as one in which no management actions are taken over the duration of the LIS Monitoring Program. At a minimum, a forested watershed should be monitored. Ideally, an urban and an agricultural watershed should also be monitored.

Atmospheric Deposition

Where: 3-4 stations around the shoreline of LIS.

When: Continuous

How: Standard methods such as those used in SEAREX.

Data: Wet and dry deposition of major chemical species of nutrients.

Who: Inputs of nutrients from the atmosphere have been estimated but have not been adequately characterized, although they are the subject of a Connecticut investigation. The University of Connecticut has a research program (funded through the spring of 1994) in which wet and dry deposition of NO3, NH4 + TDN, DIP, and SO4 are monitored in two state parks along the northern shore of the Sound. In addition, the NYSDEC Division of Air

Resources monitors wet deposition at a sampling site in Eisenhower Park, Nassau County, of NH4, NO2, NO3, HPO4, SO4. These data should be evaluated. *If the atmosphere appears to be a significant source of nitrogen, as estimates suggest, one additional station should be added in the far western Sound. It should be monitored for one year for net deposition. This station, together with the two stations already being monitored by Connecticut, would allow a determination of the relative importance of direct atmospheric deposition as a source of nutrients to the Sound. With this information it will be possible to determine whether, or not, an atmospheric component should be added to the long-term monitoring program for nutrients.*

Boundary Inputs

Where: East River and the Race

When: Same as water quality stations in receiving waters component of monitoring program (see below)

How: The concentration gradients across The Race and the quantity of flow contributed by the East River are needed to evaluate and monitor boundary conditions.

Data: Water column variables described in Exhibit A.

Who: Inputs of nutrients to the Sound across the boundaries at the two ends are not adequately characterized. *At least one additional water quality station along the longitudinal axis of the Sound is needed to the east, as an addition to the CTDEP monitoring program. Two Acoustic Doppler Current Profilers should be added: one in the East River and one in the Race. Four bottom pressure gauges should be installed and maintained on a continuing basis. Detail on each of these is provided in the section on Water Quality of receiving waters.*

CSOs

Inputs of nutrients from CSOs are not routinely monitored. Data on flows and concentrations are available, however from which one can calculate discharges of nutrients with acceptable accuracy. Nothing new is needed.

Nonpoint Sources

The following section focuses on the monitoring of nitrogen to LIS. However, the same general recommendations can be used for monitoring other nutrients and for contaminants. Nonpoint source monitoring generally includes nutrient contributions that are not captured in monitoring of point sources, e.g. atmospheric deposition, stormwater runoff, groundwater, and passage into Long Island Sound from adjacent estuarine and marine waters through the "boundaries" at The Race and the East River. However, monitoring approaches for atmospheric deposition and the boundaries have already been described. Also, tributary monitoring

assesses the combined pollutant load from all sources and areas landward of the monitoring stations. Therefore, nonpoint monitoring will focus on the runoff and groundwater transport of areas near the coast that are not assessed through tributary monitoring.

Concentrating on coastal areas will not diminish the need to monitor non-coastal areas to separate out the mix of sources that are reflected in tributary monitoring, or to better understand the relationship between land uses and nutrient loads, or even to track benefits of inland management activities. It emphasizes coastal areas in keeping with the "minimalist" philosophy, assessing a portion of the total nutrient load that would otherwise not be assessed, in concert with the other source monitoring activities described in this plan.

Direct monitoring of nonpoint sources would require an extensive network because of the diffuse and pervasive sources of runoff. This would involve a long-term commitment to monitoring hundreds of stations year-round. Because of the variability of nonpoint loading, an attempt to establish this type of baseline would also require years of monitoring, forestalling nitrogen management actions for the foreseeable future.

Presently, few monitoring studies of nonpoint nitrogen loads exist in the area. Loading estimates have been based on transport of nitrogen past tributary monitoring stations and application of

simplified land use categories to make broad assumptions on export character. These estimates are then extrapolated to coastal areas where no monitoring has occurred. An ideal monitoring program would rest somewhere between the expansive sampling program suggested above and the minimalist system of interest. Hence, this recommended program takes advantage of ongoing tributary monitoring, special studies of small basins in the drainage, development of export coefficients based on land use, and detailed land cover mapping.

Site-Specific Studies: Site-specific monitoring is recommended in suitable areas, i.e. areas of uniform land use that drain to a single check point, to improve understanding of the interrelationships of land use and nitrogen loads, and even the attenuation afforded by natural systems such as wetlands. It is recommended that runoff coefficients be documented for the region using this approach and then extrapolated to areas that are not monitored.

Two site-specific studies are being conducted in Connecticut; Sasco Brook in Fairfield County and Fenger Brook in New London County. Those studies are documenting land uses and monitoring the pollutant loads in the basins to determine the relationship to land use. Of the two, Sasco Brook will be intensively monitored for at least the next year, including event monitoring. The basin is urbanized, a key land use in the populous Long Island Sound coastal area.

A project in Westchester County, NY, is similarly assessing nonpoint nitrogen loads from subwatersheds that are representative, in terms of land use, of other county watersheds. The information on nonpoint nitrogen loads associated with specific land uses and natural features within the subwatersheds will then be applied to the county as a whole.

Existing U.S. Geological Survey tributary stations should also be reviewed for land use/load relationships. Some drain largely forested areas, providing a "natural" load coefficient, while others may have substantial percentages of urban or agricultural land cover. However, more frequent or event monitoring would be needed at those sites to fully document nonpoint loads.

Land Cover/Land Use: Finally, extrapolation of runoff or export coefficients to other areas requires a suitable understanding of land cover or land use. While a 30m grid land cover database exists for Connecticut, it is recommended that a finer scale data base and mapping system be developed, perhaps on a 10m grid. A similar database for the New York portions of the watershed also needs to be created. Westchester County is currently updating its GIS including land use, wetlands, soil; hydrography, and related elements.

Periodic updates of land cover mapping will serve as "monitoring" of the nonpoint nutrient load to a certain extent. However, it is emphasized that nutrient loads based on land cover do not account

for natural buffering effects of wetlands and vegetated riparian areas, attenuation during transport, and benefits of installed best management practices. Those factors need to be accounted for by other means, including administrative record keeping of best management practice installation and removal efficiency of those practices.

Groundwater: Special studies of groundwater may be desirable in the future, but presently it is assumed that nutrients tranported by groundwater are captured at checkpoint monitoring stations on the tributaries to fully assess upstream contributions. Extrapolation of the documented export coefficients to the coastal zone will include groundwater contributions if this assumption is accepted.

Research: Research in the areas of land cover mapping through satellite imagery and effectiveness of best management practices in removing nutrients, particularly nitrogen, should be supported.

Water Quality Of Receiving Waters

Full Water Chemistry Stations

Another element of the eutrophication/hypoxia component of the LIS Monitoring Program is focused on describing the water chemistry of the Sound.

Where: A total of 14 stations should be established within Long Island Sound and the East River along its axis. Seven now exist as part of the CTDEP monitoring program and three

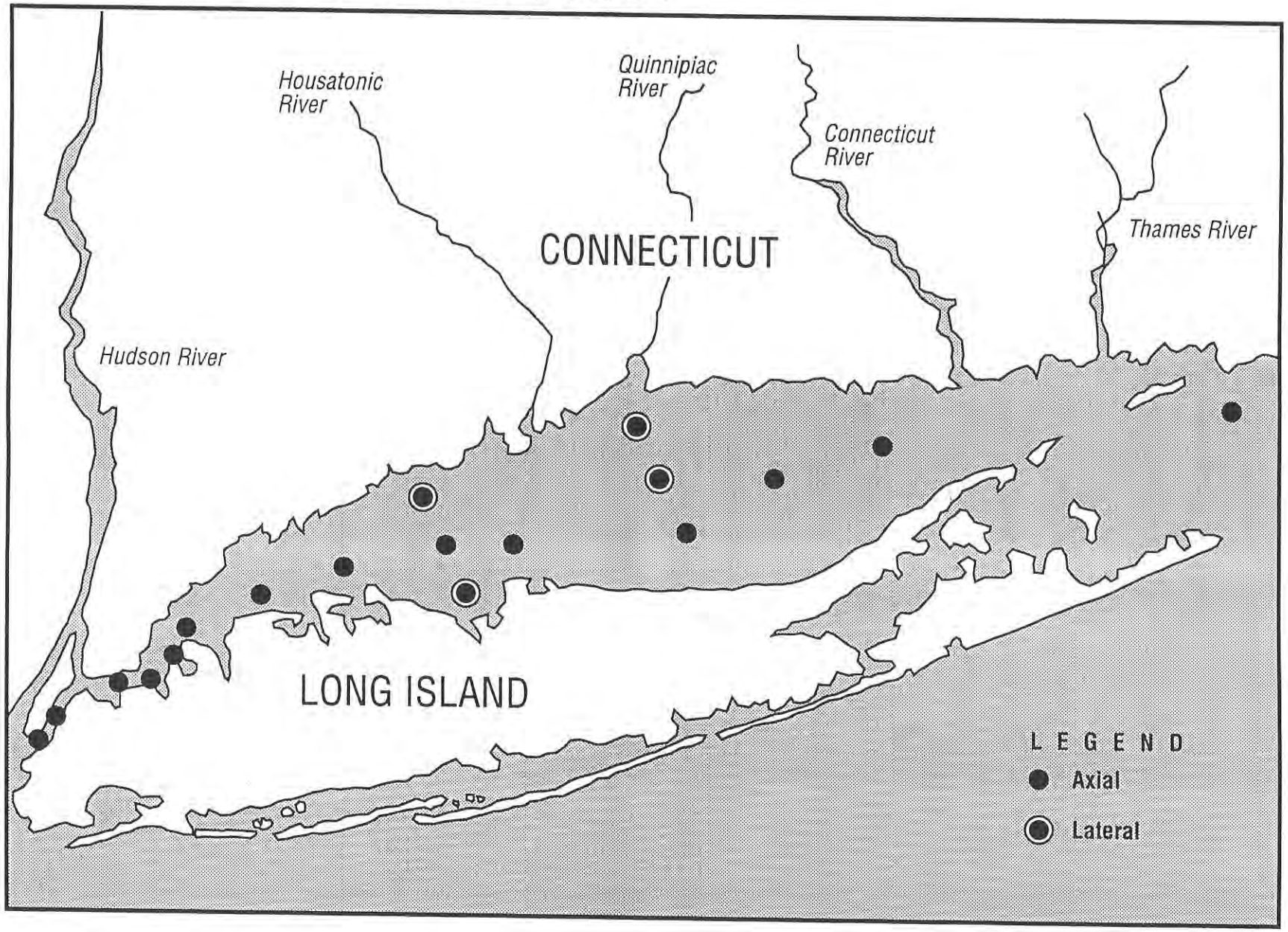
as part of the NYCDEP program. *Some would be shifted; three additional stations would be added in the Sound and one in the East River. This would bring the number of axial stations between the Battery and the Race to 14.*

Some knowledge of the lateral variability within the Sound is required for modeling and for a qualitative, or semi-quantitative, chronicle of the changing conditions of the Sound. *Four additional stations are required, which, with the axial station, will provide information along two cross-sections -- one in the western basin, one in the central basin. The stations are shown in Figure 4.*

When: These 14 axial stations and four lateral stations would be occupied monthly an average of three out of four years. During the fourth year, they would be occupied every two weeks. There must be flexibility in selecting the "fourth" year to take advantage of unusual years.

How: Use NYCDEP and CTDEP sampling programs and protocols. Temperature, conductivity and dissolved oxygen would be measured throughout the water column. All other parameters would be measured only near the surface and near the bottom.

Figure 4. Proposed Minimalist Set of Water Quality Stations



Data: The suite of parameters to be measured is shown in Exhibit A. Most of the properties are now measured. *The additional parameters are: particulate organic carbon, total inorganic carbon, major phytoplankton components and hydrogen sulfide. Full characterization of BOD is also required for modeling BOD5 and BOD30 should be monitored at the routine monthly sampling frequency at axial stations.*

DO Profile Stations

Modeling and field observations demonstrate clearly that monthly sampling is not adequate to resolve temporal changes in dissolved oxygen during the summer.

Where: Central/Western LIS

When: A minimalist program clearly requires summer sampling at a higher frequency in the central and western Sound. The 18 stations occupied by ISC weekly from June to September in the East River and in the far western Sound should be continued.

The Connecticut DEP open water fishery survey carried out over the past three years (39 stations on a fortnightly basis from April-Nov.) provided valuable detail in resolving rapid

changes in dissolved oxygen during the summer. We recommend that at least some of the stations be retained for measurements of temperature, conductivity and dissolved oxygen. At present we are unable to optimize the sampling design for incorporation into a long-term monitoring program. For example, it is not clear whether, or not, an array of fixed stations would provide more information than the present randomized sampling design. This should be determined. Nevertheless, it is likely that the total number of stations could be reduced from the 39 used previously to between 10 and 20, and still provide the spatial detail desired.

How: CTD probe with Winkler verification.

Data: Dissolved Oxygen, T, S, depth.

Who: We recommend that the intensive summer DO profile surveys be continued by the Connecticut Department of Environmental Protection (DEP), by the Interstate Sanitation Commission (ISC) and by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program -- Estuaries (EMAP-E). These data should be analyzed to establish an optimal diagnostic summer sampling scheme. If these data are not adequate for this determination, we recommend that a well-designed summer experiment be conducted with

appropriate instrumentation to provide the necessary information.

Other Monitoring Activities

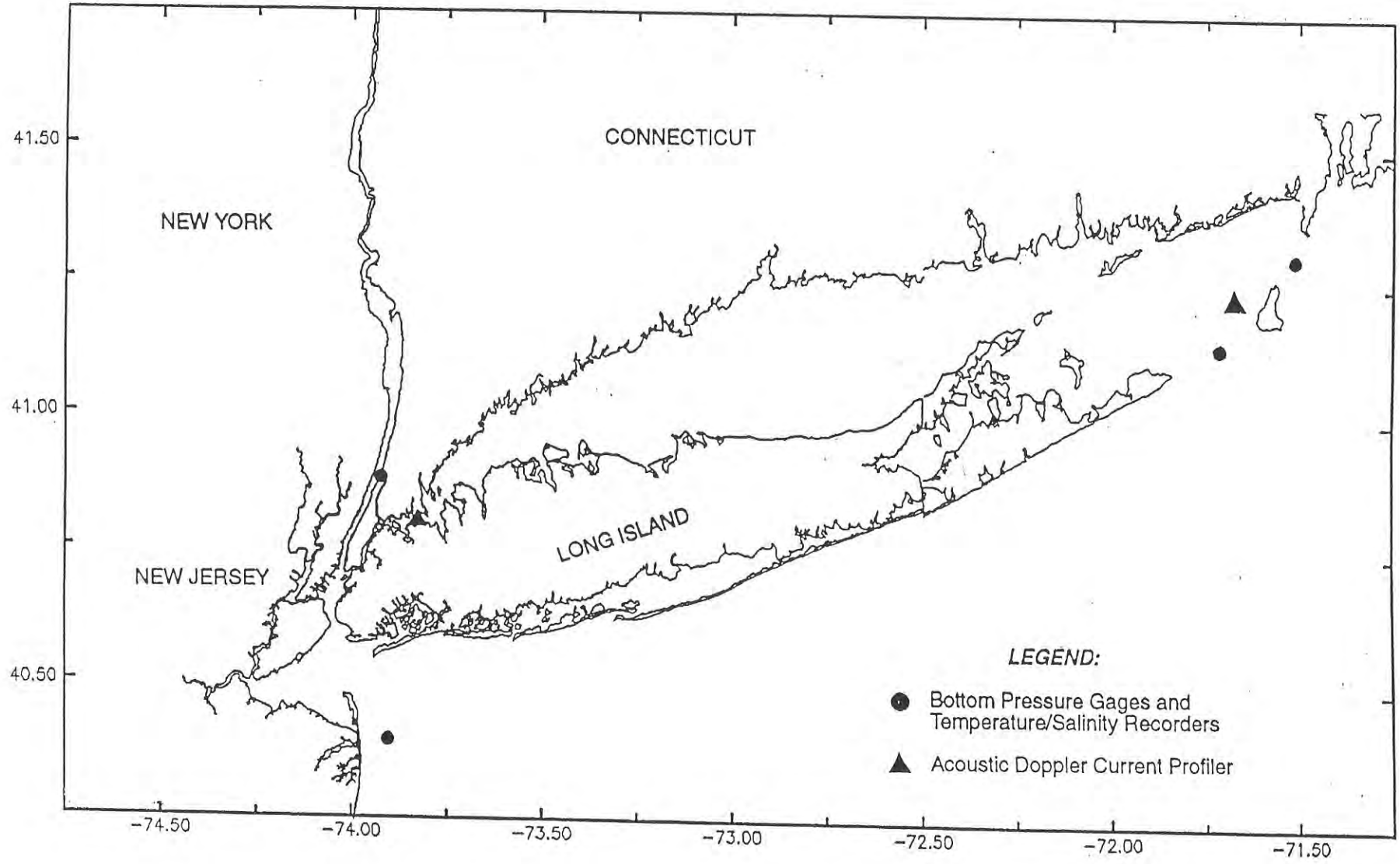
- Four bottom pressure gauges should be installed and maintained on a continuing basis. Temperature and salinity should also be continuously monitored at these stations. These data are necessary to generate the water elevations needed to drive the model. (Figure 5).

- A rapid response capability is needed to allow the LIS Monitoring Program to take full advantage of extreme events -- natural and anthropogenic. This requires flexibility in funding and development of a management structure to decide which events may be important.

- Sediment oxygen demand and nutrient flux should be measured at three axial stations in the western and central Sound on a quarterly basis. (These observations would be combined with water column measurements, including primary productivity throughout the water column.)

- The accumulation of Chl.a in the top 3 cm of sediment should be inventoried at a network of stations throughout the Central and Western Sound at a frequency of once per month between January and June and once every two months over the remainder of the

Figure 5.


CONNECTICUT
NEW YORK
NEW JERSEY
LONG ISLAND
41.50
41.00
40.50
-74.50
-74.00
-73.50
-73.00
-72.50
-72.00
-71.50
LEGEND:
Bottom Pressure Gages and Temperature/Salinity Recorders
Acoustic Doppler Current Profiler

year. The information extracted from these data may allow detection of long-term trends in the biological response of the Sound to changes in nutrient inputs as a result of management actions.

Desirable Additions

There are a number of additional components that are highly desirable. They are enumerated below.

- Better meteorological data are needed for the model and to interpret the monitoring data. An effort should be made to obtain on a routine basis meteorological data being collected at Northeast Utilities power plants at Millstone Point (CT) and at Norwalk (CT) and at airports near the Sound in Connecticut and on Long Island. If data can not be obtained from an adequate number of sources, two meteorological stations should be added. Candidate sites are along the Connecticut coast near Millstone Point and Norwalk.

- Conduct a research project to assess whether, or not, the input of nutrients from groundwater are adequately accounted for in current estimates.

- A lower priority would be to add measurements of dissolved organic phosphorous and particulate organic phosphorous in the list of water quality variables. Ideally, one would also like to have the same forms of nutrients measured for the sources as in the receiving waters. At present this is not being done.

EXHIBIT A

WATER COLUMN VARIABLES FOR A MINIMALIST PROGRAM FOR EUTROPHICATION/HYPOXIA

(Variables Not Now Being Monitored Are In Italics)

- Temperature
- Salinity
- Dissolved Oxygen
- Light (PAR)
- Total Suspended Solids (TSS)*
- ***Particulate Organic Carbon***
- Dissolved Organic Carbon**
- ***pH***
- **Total Inorganic Carbon (TIC)**
- Chl.a
- ***Major Phytoplankton Components (Dominant types; functional taxonomic groups)***
- Total Phosphorous
- Dissolved Inorganic Phosphorous
- Particulate Organic Nitrogen
- Dissolved Organic Nitrogen
- NH_4
- $NO_2 + NO_3$
- Total Silica
- Dissolved Silica
- ***H_2S (only near the bottom and only in areas close to those where D.O. levels fall below 2 mg/1).***
- BOD5 and BOD30

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* Representative samples should be archived.

** Accuracy of methods is in dispute. This should be watched carefully.