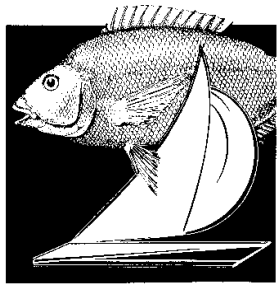

LONG ISLAND SOUND STUDY

A Partnership to Restore and Protect the Sound

2009 MONITORING, ASSESSMENT, AND RESEARCH NEEDS TO SUPPORT ATTAINMENT OF LISS GOALS AND TARGETS

THE LONG ISLAND SOUND STUDY

A Partnership to Restore and Protect the Sound

August 1, 2008

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

INTRODUCTION

The purpose of this document is to integrate science into management of Long Island Sound. The report is organized around five LISS management themes: hypoxia, toxic substances, living resources and habitat, watershed management, and interdisciplinary areas. Under each theme, the major LISS goals and targets are listed, followed by general research, monitoring, and assessment needs pertaining to that topic. Specific projects funded through the LISS base budget, LISS Enhancement Grant Program, or the Long Island Sound Research Grant Program to fulfill these needs are then summarized, along with results to date. In some cases, work supported by LISS partners is also included (e.g. Dissolved Oxygen Settlement Fund). Further synthesis of the research results to date is needed to refine priorities for future research.

I. HYPOXIA. ELIMINATE THE ADVERSE IMPACTS OF HYPOXIA RESULTING FROM HUMAN ACTIVITIES.

A. 2003 Long Island Sound Agreement Goals & Targets

1. By 2014, achieve a 58.5 percent reduction in the total enriched load of nitrogen to Long Island Sound from point and nonpoint sources within the New York and Connecticut portions of the watershed, as defined by the December 2000 document – *A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound*.

2. By 2003, establish Phase IV nitrogen reduction agreements to address atmospheric deposition and watershed management for portions of the Long Island Sound watershed outside of New York and Connecticut.

B. General Monitoring, Assessment, and Research Needs

Monitoring:

1. Propose novel monitoring programs and techniques (e.g. continuous measurements of primary productivity, respiration, nutrients, zooplankton, tracers for river water and nutrients, harmful algae, microbial pathogens, etc) to fill in gaps in the current monitoring program.

Assessment:

1. Review and assess existing monitoring data to comprehensively assess coverage and understanding of physical, chemical and biological processes.
2. Evaluate whether available water quality data exhibit trends that are consistent with the predictions of the LIS 3.0 or SWEM models and develop recommendations for improvements to the models or current monitoring efforts; i.e., analyses of available data linked to model predictions, both at regional scales (western, central, and eastern Sound) or the entire Sound.
3. Develop methods to estimate nutrient loading to all the embayments that border LIS.

4. Propose new applications of current management technologies and approaches to control nitrogen loading to Long Island Sound or to reduce the adverse impacts of nitrogen loading through alternatives to nitrogen control. Examples on nitrogen control include management of sewage treatment plant processes and innovative best management practices to control nonpoint source and storm water runoff from urban areas [also relates to watershed management section]. Examples of alternatives to nitrogen control include biomass harvesting, e.g. shellfish or macroalgae, to extract nutrients from the ecosystem.

Research:

1. Discern the response of Long Island Sound (in biological, geochemical, or physical oceanographic processes) to local nitrogen reductions (a local signal) and to ocean climate/variability (e.g., trends in temperature, winds, etc. that drive stratification). Emphasize integrated assessments of physical and biological processes involved in hypoxia.
2. Evaluate the current understanding of components of the processes that are thought to control the degree and extent of hypoxia in Long Island Sound (e.g., phytoplankton dynamics, fate of production, food web interactions, water exchange through the Sound boundaries, magnitude and rates of vertical mixing, variability of water column and benthic respiration, sedimentary geochemistry and sediment-water column fluxes, etc) using existing and, if necessary, new observations.
3. Develop new management practices to alleviate hypoxia at appropriate points of intervention for air, land, and water and evaluate their potential with respect to current management practices.

C. LISS Work to Address Needs

1. **A Biological-Physical Numerical Simulation Model for the Investigation, Prediction and Management of Oxygen Production and Consumption in Long Island Sound: Data analysis and model formulation** (UConn; PI: Goebel/Kremer; LIS 2004 Research Fund; LI-97101801; $70,578; COMPLETED): The objective of this project was to develop a simple and accurate ecosystem model of oxygen dynamics in Long Island Sound. Unlike other models, the primary productivity component of this model can be corroborated with site-specific measurements of oxygen production and consumption. The focus of these rate measurements on processes directly driving oxygen changes are especially suited to the simulation of the relationship among nitrogen loading, eutrophication, and hypoxia. Rates of primary production are fundamental to predictions of phytoplankton stocks, and primary production and phytoplankton stocks are directly related to predications of oxygen production and consumption. This model will help improve understanding of the processes that contribute to hypoxia in Long Island Sound. *Result: A simpler empirically based model reduced disagreement between observed oxygen consumption and production that is normally observed between highly parameterized models and empirical observations. However, measurements of oxygen consumption in LIS were 2-10 times larger than that calculated by the model. Inconsistencies between model output and oxygen consumption in LIS suggests previously unknown oxygen sinks or carbon sources in LIS. Incorporation of these missing sources and/or sinks into the eco-physical model is needed.*

2. **A Synthesis of Water Quality and Planktonic Resource Monitoring Data for Long Island Sound** (UConn; PI: Dam/O'Donnell; LIS 2005 Enhancements Fund; LI-97127501; $121,908; ENDS: 9/30/08): The objective of this project is to synthesize existing water quality and biological resource monitoring data into information and recommendations useful to Long Island Sound restoration management and decision-making. To meet this objective, the following tasks will be completed: 1) summarize the existing information on water quality parameters and planktonic resources in Long Island Sound; 2) statistically analyze this information for temporal trends and for spatial differences among regions of the Sound; 3) statistically examine the relationships among various water quality parameters; 4) interpret existing data in the context of the LISS management program; and 5) summarize and disseminate key findings to resource managers and the public.

3. **Application of Systemwide Eutrophication Model for Hypoxia Management** (Hudson River Foundation and HydroQual; PI: Suskowski; LIS 2001 Base Funds: $80,000; LIS 2002 Base Funds: $275,000; LIS 2003 Base Funds: $20,000. CE-98272200, CE-9829200. COMPLETED): HydroQual prepared a unit response matrix to relate nitrogen loads for different management zones to dissolved oxygen impacts in the Sound. SWEM-based management zone response regions were identified, as were the locations of critical dissolved oxygen response cells. HydroQual also completed a report documenting the degree to which dissolved oxygen response in Long Island Sound to nitrogen and carbon is linear. A series of model scenarios have been performed to assess water quality improvements against the revised water quality standards in CT and NY. This modeling work is coordinated with the concurrent work to assess nitrogen contributions from the Connecticut River that involves the states of Massachusetts, Vermont, and New Hampshire. The overall framework for the nitrogen target reassessment was approved by the Management Committee at its July 19-20, 2006 meeting. This document, "Framework for Reassessing "A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in LIS (2000)," should be referred to for details on the overall approach. *Result: Based on modeling simulations performed with SWEM, it is unlikely that water quality standards for dissolved oxygen in Long Island Sound will be achieved by the mandated Phase 3 and Phase 4 nitrogen TMDLs limits, even if credit is taken for associated, but not mandated, reductions to carbon loadings. Throughout much of Long Island Sound, currently enforceable CT and NY water quality standards for dissolved oxygen would not be met, even under pastoral loading conditions, based on model results. Accordingly, an attempt to identify targets for additional nitrogen loading reductions beyond TMDL limits to attain water quality standards was only marginally successful. An examination of ecological resource effects in the Sound however suggests that the greatest benefits to be derived have been captured by the currently mandated TMDL program. Further, potential nitrogen and carbon loading reductions beyond the current TMDL limits, but not quite as severe as a pastoral loading condition, would result in less further benefit ecological resources. A final report, "Additional SWEM Scenarios to Identify Dissolved Oxygen Responses to Load Reductions in Between TMDL and Pastoral Loadings Summary Findings Report (September 2007), is available.*

4. **Assessment of the Effects of Bottom Water Temperature and Chemical Conditions, Sediment Temperature, and Sedimentary Organic Matter (Type and Amount) on Release**

of Sulfide and Ammonia from Sediments in LIS: A laboratory study (University of New Haven; PI: Cuomo; LI-97101501; FY2004 LIS Research funding; $80,186; COMPLETED: 10/1/07): The objective of this project was to collect data on the release of sulfide and ammonia from sediments exposed to an array of environmental conditions. The researchers conducted a series of laboratory experiments in which sediment collected from western Long Island Sound was exposed to representative spring, summer and fall conditions. This research examined the fluxes of ammonia and sulfide from the sediments and any associated changes in bottom water dissolved oxygen levels, relative to certain environmental variables. *Result: Addition of fresh plankton is a significant influence on the release of both ammonia and sulfides from bottom sediments in WLIS; the influence of bioturbating organisms on sulfide and ammonia release from WLIS sediments, while not significant, is present and varies with the other conditions present; the influence of water column DO content on ammonia and sulfide release from sediments is significant but it varies with other factors; the influence of sediment locality on ammonia and sulfide release from sediments, while present, was not significant by itself; the strongest and most consistent influence on ammonia and sulfide release from sediments under experimental conditions was both water column and sediment temperature.*

5. **Connecticut River Nitrogen Attenuation Study** (NEIWPCC and USGS; FY2005 EPA Regional Applied Research Effort (RARE) funding; COMPLETED)**:** Two methods were used to measure in-stream nitrogen loss in the CT River during studies conducted in April and August 2005. A mass balance on nitrogen inputs and output for two study reaches (55 and 66 km), at spring high flow and summer low flow, was completed. In a 10.3 km subreach of the northern 66 km reach, concentrations and dissolved N_2 were also measured. The objective of the proposed work was to quantify in-stream nitrogen attenuation at the watershed scale based on sufficient measurements of nitrogen concentrations and loads at chosen locations within the Connecticut River watershed. *Result: Mass balance results showed no in-stream nitrogen loss in either reach during April 2005, and no nitrogen loss in the southern 55 km study reach during August 2005. In the northern 66 km reach during August 2005 nitrogen output was 18% less than the total nitrogen input. N_2 sampling showed similar results. The nitrogen loss measured in the northern reach in August 2005 may represent an approximate upper limit for nitrogen attenuation in the CT River. Biogeochemistry (2008) 87:311–323, Nitrogen attenuation in the Connecticut River, northeastern USA; a comparison of mass balance and N_2 production modeling approaches.*

6. **Connecticut River Nitrogen Monitoring** (NEIWPCC and USGS, [base funding in 2003-2006; COMPLETED): A key challenge in implementing the TMDL is to identify nitrogen loads and control strategies for the portion of the Connecticut River originating from upland watersheds, north of the state of Connecticut (i.e., from Vermont, New Hampshire, and Massachusetts). Meeting this challenge requires improved understanding of the magnitude and sources of nitrogen from these upland watersheds and identification of the potential effectiveness and cost of nutrient control options. NEIWPCC conducted a 3-year effort to study and model nonpoint and point source nitrogen contributions to the Connecticut River basin from Massachusetts, Vermont and New Hampshire. NEIWPCC compiled and assessed new data from the 3-year monitoring study, as well as continued to evaluate the nitrogen loading results of the New England SPARROW water quality model. *Result: Mean annual yields of total nitrogen and total nitrogen concentrations were estimated from December 2002*

to September 2005. Results published in USGS Scientific Investigations Report 2006-5144. Additional monitoring is being conducted using EPA Region 1 funds.

7. **Connecticut River Nitrogen Reduction Strategy** (NEIWPCC; PI: Weidman; LIS Base Funding, 2002-2004; LI-98160801: $200,213; $231,752; $427,264; ENDS: 9/30/08): This project is a larger cooperative effort involving staff from NEIWPCC, the states of Connecticut, Massachusetts, New Hampshire, and Vermont, and EPA's Region 1 and Long Island Sound offices. To support the development and implementation of a Total Nitrogen Reduction Plan for the upper basin, NEIWPCC will simulate nitrogen reduction scenarios in the watershed through a cost curve analysis. The work will be accomplished through completion of an EPA-funded project to calibrate and validate the ArcView Generalized Watershed Loading Function (AVGWLF) model for the northeast region. NEIWPCC will use the AVGWLF model to simulate a series of nitrogen reduction scenarios. The scenarios will be developed from a watershed-based screening tool to rank implementation of watershed runoff management practices based on cost and performance.

8. **Development of a Long Island Sound-Specific Water Quality Index Using Cluster Analysis and Discriminant Analysis** (City College of New York; PI: Zhang; LI-97263606; LIS 2006 Research Funding; $119,217; ENDS: 8/31/08): The objective of this project is to develop a Long Island Sound-specific water quality index. The water quality index will be computed using multivariate cluster analysis and discriminant analysis of a set of individual water quality indicators. A numerical water quality index (around -1 to 1) will result, with a value close to 1 indicating good water quality (oligotrophic), a value close to -1 indicating poor water quality (eutrophic), and a slight negative value representing mesotrophic conditions (intermediate water quality). The new method will be applied to the Long Island Sound water quality data (past 15 years at ~20 stations) collected by CTDEP. Monthly water quality indices will be computed for every station, and seasonal and annual trends in the water quality indices will be examined. The outputs of this project include a new LIS-specific water quality index and an automated procedure for computing the index. The numerical water quality index will give clear indications of the trophic status of LIS waters for routine water quality assessments.

9. **Environmental Change in Long Island Sound over the Last 400 Years** (Wesleyan University; PI: Varekamp; LIS 2000 Research Funding; LI-98129501; $75,909; COMPLETED): The objective of this project was to document the environmental transition in Long Island Sound from pre-colonial times to the present day using sediment cores. The researchers constructed the levels of dissolved oxygen, the abundance of sewage effluent, turbidity, local productivity of organic carbon, the terrestrial influx of organic carbon, and the levels of toxic metal contamination in Long Island Sound over the last 400 years. Data indicated that the eutrophication of Long Island Sound began almost 200 years ago. With eutrophication, there were changes in the benthic community, with higher productivity and enhanced levels of diatom-consuming foraminifera and the occurrence of hypoxia may have been exacerbated by higher temperatures and increased water stratification. A second ecosystem shift occurred approximately 30-40 years ago, possibly as a result of the combined effect of eutrophication and increased water temperatures. This research indicates that sewage derived from humans led to the over-fertilization of the Sound, to hypoxia, and to fundamental changes in the abundance and types of animal and plant life. *Result: This study suggests*

eutrophication has been an ongoing process for close to two hundred years, possibly with the associated low oxygen conditions of the LIS bottom waters. With eutrophication came the associated changes in benthic ecosystem, with higher productivity and enhanced levels of diatom consuming foraminifera. The occurrence of hypoxia may have been exacerbated by higher temperatures and increased water stratification. A second major ecosystem shift occurred over the last 30-40 years, possibly a result of the change in population dynamics of diatoms which became silica-limited and the take over of dinoflagellates as primary producers and A. beccarii species as benthic foraminifera. Again, a combined effect of eutrophication and increased water temperatures may have played a role.

10. **LIS Eastern/Western Ferry Monitoring** (SBU and URI; 2004-2005 LIS Base Funding; LI-97286204: $98,304 & LI-97286205: $69,801 & LI-97106001: $103,087; COMPLETED) The LISS provided support for two ferry-based monitoring projects through cooperative agreements with Stony Brook University and the University of Rhode Island. These projects provided water quality data collected along the ferry transects, from Port Jefferson to Bridgeport in the western Sound and from Orient Point to New London in the eastern Sound. The observation systems acquire surface hydrography in the form of temperature, salinity, and chlorophyll fluorescence. The western site additionally captures data necessary to derive high quality estimates of surface momentum, mass and heat flux. The eastern site measures horizontally-directed currents in a vertical profile, from near the sea surface to near the seafloor, many times each minute by an acoustic Doppler current profiler (ADCP) *Result: Residual flow in eastern LIS was poorly known previously. Observed residual currents peak at about 30-60 cm/s. Eastward flow exits LIS concentrated along the north shore of Long Island near the surface. Westward flow enters LIS concentrated along the bottom near the Connecticut side. The volume of inward and outward flows in this "estuarine exchange flow" is roughly 20 times the annual-mean river inputs to LIS. These observations provide a new perspective on pathways and rates of water replenishment affecting LIS water quality. They can help validate computer simulations used in water quality management decisions. Results can be viewed at* http://www.po.gso.uri.edu/~codiga/foster/index.htm

11. **Long Island Sound Water Quality Monitoring Program** (Connecticut Department of Environmental Protection; LIS annual base funding; ~$500,000): The Connecticut Department of Environmental Protection (CTDEP) conducts the Long Island Sound Water Quality Monitoring Program. From October to May, water quality is monitored once a month by collecting samples from 18 sites by staff aboard CTDEP's Research Vessel *John Dempsey*. Bi-weekly hypoxia surveys start in mid-June and end in September with up to 48 stations being sampled during each survey. The hypoxia surveys provide a description of the extent and duration of low dissolved oxygen concentrations. *Results: Hypoxia maps are available at* http://www.ct.gov/dep/cwp/view.asp?a=2719&q=325534&depNav_GID=1654

12. **Monitoring of Bottom Water and Sediment Conditions at Critical Stations in Western Long Island Sound** (Yale University, SAIC; EPA 2001 RARE Funding; COMPLETED): Field surveys were conducted in order to obtain sediment profile images and bottom water data (dissolved oxygen, hydrogen sulphide and ammonia) from sampling stations in WLIS. The objective of these field surveys was to examine overall benthic habitat quality, as revealed by SPI photographs, bottom water chemical conditions, and benthic organisms. The data obtained

from this study was to be compared to that collected from CTDEP water quality monitoring surveys and other sources for the same time period to look for points of agreement and divergence. Finally, the data obtained in this study was to be compared to the conditions known to be in existence during the summer and fall of 1999 in order to further understand the role that hypoxia, as well as ammonia and other potentially toxic metabolites present in the bottom waters at the time, may have played in the lobster mass mortality. *Results: Releases of reduced end products (e.g. sulfide and ammonia) into overlying waters, combined with low DO levels and abnormally warm water temperatures represented multiple environmental stressors that could have stressed lobsters and contributed to susceptibility to disease. Results published in Estuaries Vol. 28, No 4. p. 529-540. 2005 and Journal of Shellfish Research, Vol. 24 No. 3 805-814. 2005.*

13. **Natural Isotopic Tracers for Anthropogenic Nitrogen in Long Island Sound** (University of Massachusetts and Wesleyan University; PI: Altabet; LI-97101301; 2004 LIS Research Fund; $125,353; COMPLETED): The objective of this project was to quantify the impact of anthropogenic nitrogen loading to Long Island Sound with respect to natural sources. Isotopic tracers were used to characterize the nitrogen sources to the Sound. This approach permits the assessment of the actual contribution of anthropogenic nitrogen to Long Island Sound's nitrogen inventory. These results will help improve understanding of the relationship between anthropogenic nitrogen loading and eutrophication. *Results: The results of this study suggest wintertime nutrient accumulation is an important phenomenon, dominant anthropogenic source is input from East River, and high historic values are due to high sewage N.*

14. **Phytoplankton Dynamics in Long Island Sound: Influence of Environmental Factors on Naturally-Occurring Assemblages** (UConn and National Marine Fisheries Service; PIs: Ward/Wikfors; LI-98161301; LIS 2002 Research Funding; $132,360; COMPLETED): The objective of this project was to determine how phytoplankton dynamics differed in Long Island Sound along an eutrophication gradient (from east to west) and with the seasons. The researchers also examined which environmental factors (i.e., nutrients, hypoxia or temperature) are the best predictors of phytoplankton assemblages. Nutrient over-loading, eutrophication and pollution can alter phytoplankton abundance and community structure. Such changes can lead to the degradation of food webs that support commercially valuable finfish species. *Results suggest that nutrient loads have a greater effect on the composition and abundance of phytoplankton in the Sound than seasonal temperatures, turbidity, dissolved oxygen or salinity.*

15. **Simulation of Long Island Sound with the System-wide Eutrophication Model (SWEM): Inter-annual Variability and Sensitivity** (UConn/DMS; PI: Dam/O'Donnell; LI-97127101; LIS 2005 Enhancement Fund; $251,164; ENDS: 9/30/08): The objectives of this project are to evaluate the effectiveness of SWEM and to identify additional studies that will improve our ability to predict the impact of management strategies on the water quality of Long Island Sound. The researchers will establish the sensitivity of SWEM to model parameters, model formulation, and inter-annual variations in weather and river discharge and will provide an independent, quantitative evaluation of the model and its utility as a management tool.

16. **Water Column Oxygen Production and Consumption in Long Island Sound: Measurements and Coupled Bio-physical Modeling** (UConn; PI: Kremer; LI-98164401; LIS

2002 Research Fund; $188,277; COMPLETED): The objectives of this project were to measure water column oxygen production and consumption rates for Long Island Sound and to develop a coupled bio-physical simulation model of the Sound. The researchers directly measured plankton oxygen metabolism during the critical summer months in order to further the understanding of the processes leading to hypoxia in Long Island Sound. The model analyzed the relevant biological and physical processes that lead to eutrophication and hypoxia in the Sound. *Results: Calculations demonstrate high levels of production and phytoplankton biomass in LIS. This productivity is consistent with the nitrogen loads into cwLIS, and the level of eutrophication follows a trend shown with other systems. Autochthonous production is a plausible source of organic matter for hypoxia and anoxia in the bottom waters of the Sound. Ranges and temporal variability in daily and annual rates compare favorably to those found throughout nearby, eutrophic estuarine systems, such as Narragansett and Chesapeake Bays, despite variations in spatial distributions of production.*

17. **Western Long Island Sound Hypoxia: Isotope Tracers of the East River Nitrate Pump** (Columbia University; PI: Fairbanks; LI-98258900; LIS 2002 Research Fund; $75,004; COMPLETED): The objective of this project was to assess the contribution of discharge from the East River to hypoxia in western Long Island Sound using isotope tracers of East River water and organic particulate matter. A map of the concentration and volume of East River water in the western Sound during the development of hypoxia was produced using isotopic tracers to follow the delivery of East River-derived nitrate and phosphate to the hypoxic region. *The results of this study indicate that four small, deep basins act as "hypoxia incubators" on the seafloor of the western Sound and that these basins spread hypoxia throughout the water column. Nitrogen isotope tracers demonstrate that the organic particulates sampled in the deep basins derive their nitrogen almost entirely from wastewater effluent. Oxygen isotope measurements of water molecules indicate that tidal mixing maintains a high percentage of East River water directly overlying the site of initial hypoxia in the western Sound. Isotope data also show that the eastward spread of low oxygen waters is due to tidal and current mixing with the extremely low oxygen waters pooling in the four deep basins. The researcher recommended that managers should target abatement strategies at the four restricted basins ("hypoxia incubators") to address the immediate source of hypoxia and that a hypoxia abatement experiment should be conducted in the smallest basin using isotope and purposeful tracers.*

18. **Water Temperature Sensor Monitoring.** (NYSDEC; PI: D'Amico; LIS 2003 Base Funding; LI-97287800; $12,000) NYSDEC requested and received funding in 2003 to purchase and install water temperature sensors in key locations in Western LIS. The sensors were to be placed on buoys owned/maintained by the US Coast Guard, and were to collect data at bottom, midpoint and surface conditions.

19. **Cost-effective Strategies to Reduce Nitrogen Discharges into the Long Island Sound: Optimization of Partial Nitrification and External COD Based Denitrification at Stamford WPCA** (The Trustees of Columbia University in the City of New York, DO Fund 2007, $204,000) The project will develop and implement state of the art biological tools to remove nitrogen that enters the Long Island Sound's bays and harbors from sewage treatment plants. A high level of nitrogen reduces the amount of oxygen in water available to sustain fish

and other aquatic animals. This condition of low "dissolved" oxygen is known as hypoxia. Too much nitrogen also leads to excessive algae growth which clouds the water and blocks sunlight to marine plants that provide prime nursery and spawning habitat for juvenile finfish and shellfish. The tools piloted at the Stamford Water Pollution Control Authority will be useful to publicly owned treatment works in Connecticut and New York major point sources of nitrogen loads into local watersheds affecting water quality and the recreational, ecological and economic values of the estuary.

20. **Assessing Nitrogen Loading to Western Long Island Sound from Submarine Groundwater Discharge.** (USGS - Woods Hole Science Center, DO Fund 2007, $579,104) The project will quantify the significance of groundwater's contribution to nitrogen into the Long Island Sound. The project results will provide useful technical information to the current public dialogue about nitrogen loading from sewered and unsewered watersheds. It will compare groundwater discharge from those types of watersheds as well as other types of pollution found in groundwater (fertilizer, pesticides, air). The information generated from the study will help resource managers determine circumstances where sewers and/or other tools (e.g. filtration beds etc.) reduce nitrogen loads into local watersheds.

21. **Numerical Evaluation of Larval Survival in Long Island Sound as Influenced by Exposure to Varying Levels of Dissolved Oxygen.** (Manhattan College, DO Fund 2007, $74,654) This project will develop a tool that will improve the long-term survival of fish, shellfish and crabs by allowing resource managers to better determine and manage the amount of nutrients allowed in the open waters of the Long Island Sound. The project will look at the different amounts of dissolved oxygen required to sustain juvenile and adult fish and shellfish. Among other benefits, the project will improve our ability to pinpoint and protect important spawning habitat and to tailor nutrient reduction goals to improve propagation of fish and shellfish.

22. **Tools to Monitor the Effects of Management Actions on DO and its Interactive Effects with Sewage-derived Endocrine Disrupting Chemicals in Wastewater Affected Coastal Environments.** (The Research Foundation of SUNY, DO Fund 2007, $181,253) The project will develop an innovative approach to evaluate the effect of chemicals (including common pharmaceuticals) that increase the amount of natural and synthetic estrogens found in sediments in Jamaica Bay and Long Island Sound fish. Estrogens are now strongly believed to result in hormonal changes that increase the ratio of female to male fish and lower reproduction in fish both findings of great significance to the humans, plants and animals along the coast.

II. TOXIC SUBSTANCES. ELIMINATE TOXICITY OR BIOACCUMULATION IMPACTS ON LIVING RESOURCES BY REDUCING CONTAMINANT INPUTS AND CLEANING UP CONTAMINATED SITES, AND MANAGE RISK TO HUMANS FROM SEAFOOD CONSUMPTION.

A. 2003 Long Island Sound Agreement Goals & Targets

1. By 2004, EPA, in conjunction with the Army Corps of Engineers, will complete the Environmental Impact Statement for the designation of dredged material disposal sites in

central and western Long Island Sound and, by 2008, will complete the EIS for designation of dredged material disposal sites in eastern Long Island Sound.

2. By 2003, update the Long Island Sound Contaminants of Concern list after considering National Coastal Assessment monitoring results and other sources of data. By 2005, evaluate current contaminant monitoring and control programs and identify strategies to address priority issues.

3. By 2003, New York and Connecticut will meet to jointly review their approaches for Long Island Sound fish consumption advisories and to discuss a process to achieve the goal of consistent fish consumption advisories for Long Island Sound.

B. General Monitoring, Assessment, and Research Needs

Research**:**

1. Evaluate sources and inventories of conventional and emerging contaminants in Long Island Sound focusing on those that are (e.g., 303(d) listed impairments) or are likely to be present at concentrations where adverse effects on aquatic species or human consumers are likely.
2. Examine potential impacts of these contaminants on ecosystem function or population dynamics of key resources species.
3. Develop new management technologies and approaches to control sources of toxic substances and to remediate contaminated sediments.

C. LISS Work to Address Needs

1. **Chemical Residues in Long Island Sound Indicator Fish and Lobster: A Bi-state Update** (NYSDEC and CTDEP/DOHs: LIS base funding in 2006-2007; PI: Skinner; LI-97267505: $150,967 & LI-98246501: $168,800; ENDS: 9/30/08]: The goal of this project is to determine the current status of chemical residues in selected indicator fish species. The project was proposed in two parts, and the LISS provided funding for the Tier 1 efforts in FY2006. Tier 1 encompasses a study of striped bass and bluefish, which are recreationally and commercially important species that have historically had excessive chemical residue concentrations. This project includes the assessment of the current status of PCB and mercury concentrations in striped bass and bluefish taken from Long Island Sound and an analysis of temporal and spatial changes in PCB levels in striped bass from the Sound. These data will be used by the CT and NY Departments of Health to assess the current health advisories regarding PCB and mercury levels in fish. These data also will be useful in determining whether controls of these analytes are producing positive results and indicating whether additional controls, where feasible, may be necessary. Tier 2 of the project includes assessing the current status of PCB, mercury, cadmium, and chlorinated dioxin and furan concentrations in hepatopancreas of American lobster. The current status of PCB and mercury concentrations in weakfish taken from the Sound and in American eels taken from major tributaries or bays of the Sound would also be assessed. These data could then be used by the CT and NY Departments of Health to evaluate the current health advisories regarding PCBs, mercury, cadmium, and dioxins/furans in lobster,

weakfish, and eels.

2. **New Approaches for Assessing Mutagenic Risk of Contaminants in the Long Island Sound Environment** (Stony Brook University and Brookhaven National Laboratory; PI: McElroy; LIS 2002 Research Fund; LI-98258200; $74,453; COMPLETED): The objectives of this project were to evaluate the potential capacity of contaminants in the sediments of Long Island Sound to cause mutations in vertebrates and to determine the types of mutations induced and the classes of contaminants responsible for these mutations. The researchers collected sediment samples from the Sound and identified those samples that were mutatoxic. Eggs from a fish species that is particularly susceptible to environmental mutagens were then exposed to the mutatoxic sediments from six sites. After the eggs hatched, the fish larvae were examined to determine the mutation frequency related to the sediment samples. Mutation frequency in the fish embryos increased after exposure to sediments from only one of the LIS sites. The sediment sample from this site contained extremely high levels of polycyclic aromatic hydrocarbons (PAHs). *Results illustrate that transgenic embryos can be used to help quantify and characterize mutations induced by exposure to environmental mutagens. Data from this small-scale study also indicate that the mutagenic risk of LIS sediment contaminants to vertebrate organisms is generally low. The researchers recommended that additional work to evaluate the mutagenic risk of sediments at contaminated urban sites be conducted to substantiate their preliminary findings.*

3. **Public Scoping Meetings and Preliminary Studies in Support of a Regional Dredged Material Management Plan (DMMP) for Long Island Sound** (EPA Region 1 and US Army Corps of Engineers, New England District; LIS 2005 Base Funding, (06/07) PI: Coté; $100,000): The objective of this project is to initiate the development of a DMMP for Long Island Sound. The goal of the DMMP is to reduce the quantity of dredged material that is disposed of at open-water disposal sites by conducting a comprehensive evaluation of alternatives to open-water disposal and promoting their use. The DMMP will also evaluate and promote methods to reduce the rate of sedimentation in the Sound's harbors and potential treatment technologies for contaminated sediments. *Results: The work is ongoing but funds were used to support six public scoping meetings to get input on the development of a DMMP in November 2007.*

4. **Temporal and Spatial Changes in Copper Speciation and Toxic Metal Concentrations in Long Island Sound: Effect of Changes in Water Temperature and Dissolved Oxygen Levels** (SBU/RF; PI: Saňudo-Wilhelmy; LIS 2004 Research Fund; LI-97296600; $101,135; COMPLETED): The objective of this project was to establish the chemical speciation and vertical profiles of dissolved and particulate toxic metals in the water column in Long Island Sound. Dissolved metals undergo many changes in the estuarine environment, and this research provided valuable information regarding the temporal and spatial variations in the chemical speciation of dissolved copper in the Sound. This research will also provide resource managers with critical information regarding the distribution of toxic metals both in the water column and throughout Long Island Sound. These factors are important for evaluating the health of Long Island Sound and examining the bioavailability of metals in the water column. *Results: The results of this study showed significant amounts of labile copper throughout the Long Island Sound, with the highest levels in the western Sound near New York City. This was*

the same pattern we found for total dissolved copper. During the spring season, "toxic" copper was higher in surface waters and was probably delivered during these high-flow conditions by river runoff and sewage. In both seasons, there was evidence that microscopic algae in the surface waters were producing organic compounds to complex the dissolved copper, thereby making it less toxic. In the summer, bottom waters of the western LIS were characterized by poor water quality, very warm and depleted of oxygen. In these deep waters, "toxic" copper was greatly elevated relative to the spring season and other places within the LIS. The data showed that poor water quality resulted in increased levels of toxic copper species. The greatest influencing factor was temperature; as water temperature reached a threshold greater than about 20°C, "toxic" (labile) copper concentrations increased very rapidly. Analyses of other chemical constituents suggested that the source of this "toxic" copper was the sediments.

5. **Toxic Contamination in Long Island Sound: 2006 Update** (Yale University; PI: Enion; LI-97147501: $64,067 (2 years) COMPLETED): The objective of this project was to conduct a literature review of existing data on contaminants in Long Island Sound and to use these data to update the list of contaminants of concern. The investigators compiled data on contaminant concentrations in the water column, sediments, and biota for the period from 1994 through 2005 and compared these data to measurements collected over the previous decade. Based on this review, it was recommended that nickel, silver, tin, endosulfan, endrin, and chlorpyrifos be added to the contaminants of concern list. *Results: The researchers suggested that the occurrence and effects of manganese and dioxin-like PCBs should be further evaluated. They also recommended that a research and monitoring plan be developed to address the occurrence and effects of emerging contaminants associated with wastewater discharges, such as pharmaceuticals, musks, and flame retardants.*

6. **Trace Metals, Organic Carbon and Inorganic Nutrients in Surface Water of Long Island Sound: Sources, Cycling and Effects on Phytoplankton Growth** (SBU and Southampton College; PI: Saňudo-Wilhelmy; LI-98227701; LIS 2000 Research Fund; $91,622; COMPLETED): The objective of this project was to establish the concentration and distribution of dissolved metals and inorganic nutrients in the surface waters of Long Island Sound and to examine the relative importance of various sources (i.e., riverine inputs, sewage) of these nutrients and metals. Results: This study suggests that the East River is the most dominant external source of trace metals during low flow conditions, but the Connecticut River is the most important external force during high flow conditions. Large internal sources of copper, nickel and zinc were detected under low flow conditions, highlighting the potential importance of internal processes such as remobilization from contaminated sediments in the Sound. Additional work, such as the direct measurement of diffusive benthic fluxes, should be conducted to substantiate these preliminary findings.

III. LIVING RESOURCES AND HABITAT MANAGEMENT & CONSERVATION. ASSURE A HEALTHY ECOSYSTEM WITH BALANCED AND DIVERSE POPULATIONS OF INDIGENOUS PLANTS AND ANIMALS, MAINTAIN OR INCREASE THE ABUNDANCE AND DISTRIBUTION OF HARVESTABLE SPECIES, AND RESTORE THE ECOLOGICAL FUNCTIONS OF DEGRADED AND LOST HABITATS.

A. 2003 Long Island Sound Agreement Goals & Targets

1. By 2003, complete the mapping of eelgrass in the Long Island Sound area to determine trends. Continue to promote investigations and research into determining the impacts of nitrogen upon the degradation of aquatic habitats (i.e., loss of eelgrass, increases in macroalgae and benthic algae) in shallow embayments and bays in Long Island Sound.

2. By 2005, characterize the scope and rate of tidal wetland losses in the Sound and promote research that will determine to what degree accelerated sea level rise, sediment supply disruptions, or other factors are responsible for the loss of habitat that is critical to the Sound's birds, finfish, and overall productivity.

3. By 2004, complete research and monitoring studies into the causes of the lobster mortality event in Long Island Sound and identify any management measures that could be implemented to prevent future mortality.

4. By 2003, identify critical issues related to the management and conservation of living resources (such as fish and birds) and their habitats, and develop strategies to improve conditions, as appropriate.

5. By 2003, produce a list of the invasive species of concern in Long Island Sound.

6. Restore at least 2000 acres of habitat and 100 river miles for fish passage during the ten-year period from 1998 to 2008 and monitor these sites to confirm restoration progress over time.

7. By 2004, identify sites of outstanding and exemplary scientific, educational, or biological value.

B. General Monitoring, Assessment, and Research Needs

<u>Eelgrass</u>

Monitoring:

1. Propose monitoring programs and techniques to comprehensively assess eelgrass distribution and trends in Long Island Sound and to track the effects of pollution processes and habitat change on its distribution.
2. Deploy light meters in embayments to monitor changes in the light field. Compare the C:N in various eelgrass beds throughout LIS.
3. Monitor the habitat benefits on key living resource organisms that rely on eelgrass for recruitment and growth.

4. Quantify existing water quality conditions, particularly those parameters that are important to the growth and maintenance of Zostera (e.g., DIP, DIN, Chl A, TSS, light attenuation, benthic algae, epiphytes, CDOM, canopy height, sediment OM, etc.).

Assessment:

1. Using a Kd of 0.7/m, develop maps of potential eelgrass habitat, based on current water clarity and desired or historic water clarity. Develop maps of suitable eelgrass habitat, further considering other factors (e.g. % organics, sulfides, depth, current, sediment). Determine the current % loss of seagrass, relative to restoration target.
2. Assess nitrogen loads and trends and their effects on eelgrass health in receiving waters.
3. Calculate nitrogen-loading rates and predicted eelgrass response in LIS embayments, considering all sources and using consistent methodologies that are transferable to other embayments.

Research:

1. Perform comparative studies in embayments to evaluate where and to what degree existing nitrogen and sediment loading rates, or other factors, such as temperature, result in water quality conditions that do not support eelgrass. Validate or refine nitrogen target loads of 50 kg N ha^{-1}estuary y^{-1}.
2. Define groundwater hydrology patterns for an embayment that has experienced declines of *Zostera* including determining nitrogen concentrations (seasonal) and rates of groundwater movement.
3. Determine how long it will take for eelgrass to respond from reductions in nitrogen loads and levels from sewering or other nitrogen management efforts.

<u>Food Web Dynamics</u>

Monitoring:

1. Propose monitoring programs and techniques to comprehensively assess food web dynamics and trends in Long Island Sound and to track the effects of pollution processes and habitat change on its disruption.
2. Quantify existing habitat and water quality conditions, particularly those parameters that are important to the vitality of the LIS food web dynamics (e.g., substrate, hydrodynamics, climate related factors, water quality, energy transfer, invasive species, etc.).

Assessment:

1. Conduct a data review, synthesis, and gap analysis of key food web organisms and attributes to refine conceptual models of LIS food webs in coves, near-shore, and open waters. Determine the roles and status of the most important food web components (e.g., system filtration, nursery function, etc.). Identify critical data gaps in our present understanding of the major food web components and their potential interactions.

2. Determine how important components of the food web may have changed over time, with emphasis on those influenced primarily by anthropogenic stressors and those that can be affected by management.

Research:

1. Data Collection to Better Quantify Critical Food Web Components: Determine how changes in nutrient ratios (e.g., N/P/Si) may have affected the phytoplankton species composition and overall productivity in LIS in the past, and monitor possible future changes. Determine how nutrients (mainly nitrogen) are processed by the different components of the food web in the coves and near-shore LIS environments.
2. Determine the relative magnitude and functional group make-up of primary productivity in coves, near shore, and open water regions of LIS.
3. Determine the relative importance of different stressors (e.g., eutrophication, climate change, habitat alteration, hypoxia, fishing pressure) on food webs in LIS.
4. Determine what and how food web component(s) are driving the processing of labile organic matter in LIS.
5. Recommend research priorities to fill critical data gaps, begin to quantify the role of critical food web components, and identify management options

Tidal Wetland Loss

Monitoring:

1. Propose monitoring programs and techniques to comprehensively assess tidal wetlands distribution and trends in Long Island Sound and to track the effects of pollution processes and climate and habitat change on its distribution.
2. Monitor the habitat benefits on key living resource organisms that rely on tidal wetlands for their success.
3. Quantify existing water quality conditions, particularly those parameters that are important to the growth and maintenance of tidal wetlands (e.g., nutrients, sedimentation, etc.).

Assessment:

1. Assess condition and trends of marsh systems in the embayments and subestuaries of Long Island Sound considering issues such as fragmentation of marshes, characterization of lagoon and bay locations in Connecticut compared to New, conditions in subestuaries of LIS. Desired measures include marsh elevation, tidal hydrology, sediment accumulation rates, sediment chemistry, biomass measures, vegetation density, stem height, and others.

Research:

1. Marsh elevation and accretion rates with respect to relative sea level rise. Marshes in LIS have displayed stable rates of accretion from sediment loads, but the elevations of marshes do not appear to be rising with relative sea level. Studies of marsh elevation processes might include changes in composition of sediment supply and budget on a 300-year time

scale; changes in the communities of Foraminifera in LIS marshes over time; and/or radioisotope studies.
2. The relative importance of above vs. below-ground biomass on the health and stability of LIS marshes. Little is known about the relationship between above-ground and below-ground biomass in *Spartina alterniflora* marshes in LIS. Studies of the marsh structure with respect to this relationship may include correlations between biomass and marsh stability and health.
3. Nitrogen compounds and their effects on marsh health. Changes in the types of available and limiting nutrient compounds available to LIS marshes are hypothesized to play a role in *Spartina* marsh vigor and stability. Investigations may include greenhouse and field experiments and studies of potential synergistic effects of nitrogen and other nutrient compounds.

Species Conservation

Research:

1. Studies on the life history, population dynamics, predator-prey relationships, and behavior of diandromous fish of management concern, including river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*), American eel, and rainbow smelt, to help understand the current status of these runs, factors in the recent declines, and what management actions might result in run enhancement.
2. Determine the home range and population movement patterns of the saltmarsh sharp-tailed sparrow in Connecticut. Refine population estimates, examine connectedness among sites, and refine existing habitat use information. Examine the social cues utilized by saltmarsh sharp-tailed sparrows that attract birds to suitable habitat. Develop a technique that may improve saltmarsh restoration efforts by attracting birds to "empty" habitats through the use of these social cues.
3. Impacts of pot fisheries on impacts to diamondback terrapins and evaluate the need for terrapin excluders.

Habitat Classification and Mapping

Monitoring:

1. Monitor and map beach and island nesting habitats for terns, plovers, horseshoe crabs, herons, and diamondback terrapins.

Assessment:

1. Develop mapping products that can identify the historic location and extent of critical habitat in Long Island Sound and a strategy for utilizing historic mapping products in quantitative assessments of current habitat restoration and conservation efforts. In particular information on the historic extent and location of key habitats in Long Island Sound will be crucial in aiding current management strategies.
2. Conduct seafloor mapping consistent with bi-state strategy being developed.

Aquatic Invasive Species

Monitoring:

1. Detect new infestations and trends in known populations through the establishment of a sentinel site monitoring program. Conduct as part of an Early Detection, Monitoring, and Assessment (EDMA) plan to monitor for new introductions and follow the spread of established AIS in Long Island Sound.

Assessment:

1. Create or add to a library of voucher specimens from Long Island Sound at various life stages, as well as develop a digital archive accessible via the Internet.

C. LISS Work to Address Needs

Habitat Classification and Mapping

1. **LI Embayment Benthic Mapping** (NYSDEC; PI: D'Amico; LIS 2003 Base Fund; LI-97297800; $110,967): NYSDEC was provided funds to conduct benthic mapping of key north shore Long Island embayments. NYSDEC has contracted Stony Brook University to develop benthic maps for Port Jefferson Harbor, Huntington – Northport Bays, and Oyster Bay – Cold Spring Harbor. The side scan photography has been completed for all three embayments and benthic sampling will be conducted in Port Jefferson and Huntington – Northport Bays.

2. **Linking Seafloor Habitat Mapping Protocols to Management and Policy Needs** (UConn/DMS and National Undersea Research Center; PI: Auster; LI-97150101; LIS 2006 Research Fund; $179,027; ENDS: 04/30/08): The objective of this project is to produce a singular flexible habitat classification protocol that can be used by a range of workers focused on the Long Island Sound region. The research component of developing the habitat classification protocol will be explicitly linked to those who will implement and use the map products derived from the protocol (i.e., to insure that map products are both user-friendly and user-useful). To accomplish this task, an initial email survey of managers, policy-makers, researchers, engineers and other stakeholders (fishers, energy industry, environmentalists, coastal land developers) will be conducted to ascertain the range of habitat attributes that they deem relevant in their work. This initial survey will assist in the identification of a set of habitat attributes that are common across user groups and in the selection of a range of published marine habitat classification schemes to test with existing data. An interactive workshop with representatives of all stakeholder groups will be convened to assess the utility of the range of classification approaches tested and determine where modifications for a final protocol are needed. The final protocol and example applications will be produced as a technical document for web delivery.

Eelgrass

1. **Long Island Sound Eelgrass Survey** (USFWS; PI: Halavik; LIS2002/2004 Base Funding; $32,380; $60,123; conduct triennially). The US Fish & Wildlife Service conducted a survey of Long Island Sound to document the actual areal distribution of eelgrass in the Sound. These data suggest a possible recovery of eelgrass in the open Sound and the continuance of long-term declines in the shallow embayments, but an adequate database to assess status and trends does not exist. In June 2006, the US Fish & Wildlife Service initiated a second survey of the Sound's eelgrass beds. Aerial photography was acquired in June 2006, and these data were ground-truthed in the field in 2006, and a final report issued. *Results: The Soundwide extent of eelgrass in 2006 was 1,905 acres, compared to 1,599 acres in 2002.*

2. **Restoration Objectives for Eelgrass in Long Island Sound** (CTDEP and USGS; PI: Rozsa; LIS 2004 Base Funds: $47,000) CTDEP and USGS are working to establish restoration objectives for eelgrass beds in the coastal waters of Long Island Sound. The focus of the project is primarily on how nitrogen loading may affect eelgrass in Connecticut's coves, embayments and tidal rivers and on identifying management measures that can be taken to address this issue. The objectives of the project include the following: 1) determine relationships between typical eastern Long Island Sound watersheds, nitrogen loading and eelgrass status; 2) develop nitrogen criteria for the protection and restoration of eelgrass; and 3) assess the potential for attaining the nitrogen criteria in case study areas. The long-term goal of this effort is to implement nitrogen criteria to effect management of watershed and point discharges that achieve nitrogen levels that can sustain or lead to the restoration of eelgrass populations. Add website link.

Food Web Dynamics

1. **Food Webs in Long Island Sound: Review, Synthesis and Potential Applications** (UNH/CTDEP: PI: Zajak; FY2004 LIS Research Funding; LI-97101401; $117,545; ENDS: 08/31/08): The objective of this project is to develop conceptual and quantitative food web models for different habitats in Long Island Sound. Using these models, the researchers will assess the critical food web components in each habitat type and identify data gaps in the present understanding of major food web components and their potential interactions. These models can be used to develop simulations and analyses to evaluate the impacts of management decisions on food webs and ecosystem dynamics in Long Island Sound.

Habitat Protection

1. **GIS-based Assessment of Undeveloped Parcels in New York Coastal Counties** (Center for International Earth Science Information Network, Columbia University; PI: Gorokhovich; LIS 2006 Enhancement Grant; NEIWPCC; $76,556): The objective of this project is to assemble existing parcel data from coastal counties of New York State that will be used by LISS and NYSDEC officials in conservation of the most significant remaining unprotected and undeveloped parcels. This work will complement similar work completed for coastal Connecticut parcels. The project staff will gather digital parcel data in GIS format (primary data) from coastal counties and extract undeveloped parcels greater than five acres, publicly owned land and protected open space. Additional data collection (secondary data) will include GIS layers of LIS stewardship areas, tidal and freshwater wetlands, areas of Significant Coastal

Fish and Wildlife habitats, watercourses and water bodies. Parcel data will be analyzed, checked (aerial photos and field) and documented. This effort will help NYS DEC target land protection efforts to further open space and habitat conservation goals.

2. **Conservation Strategies for the Great Meadows Area in Stratford and Bridgeport, Connecticut.** (Audubon Connecticut, LIS Futures Fund, $57,000) Audubon Connecticut will develop a toolkit of conservation strategies to support landowners and resource managers including those at the Stewart B. McKinney National Wildlife Refuge, Long Beach and Pleasure Beach to steward the Great Meadows area one of the most important areas for birds in Connecticut hosting 270 plus species and 25% of the State's remaining undeveloped coastline.

3. **Conservation Action Plans for Long Island Stewardship Sites.** (Audubon New York, LIS Futures Fund, $64,500) Audubon New York starts phase 2 of a project working with local stakeholders to identify priority actions that further conservation at 4 Important Bird Areas (IBAs) (Lighthouse Point Park, Mamacoke Island and coves, Orient Point/Plum Island and Edith Reade Sanctuary); and to develop a transferable model for educating and engaging the public in the Long Island Sound Study Stewardship Initiative. These 4 IBAs are oasis for over 300 species of birds including: raptors, landbirds, Greater Scaup ducks, Double-crested Cormorants, Ospreys, Great Egrets, Snowy Egrets, Little Blue Herons, Black-crowned night Herons, Roseate and Common terns, Piping Plovers, American Oystercatchers and for residents of local areas who enjoy the beaches, bays and forests.

4. **Long Island Sound Stewardship Coordination** (Regional Plan Association; PI: Freudenberg; LIS 2006 Enhancement Grants; NEIWPCC: $25,204) This project will focus on one of the elements listed in the RFP for outcome 3. LIS Stewardship Coordination – identify and document threats an opportunities at inaugural stewardship sites. Under the title Task 2: Stewardship Area Research and Outreach, the original proposal describes identifying key stakeholders in Stewardship Areas and conducting interviews to determine issues including threats or opportunities with a deliverable of a publication describing threats and opportunities of Stewardship Areas. The specific objectives of the project are to assess threats in four of the inaugural stewardship areas, resulting in a GIS map and data table identifying threats for these areas, as well as a final report. Together this process and these products will serve as prototypes for assessing the threats of the remaining stewardship areas. Deliverables for the project will include a GIS layer identifying threats to stewardship areas on map (by threat, by location), a publication describing threats and opportunities at each of the chosen Stewardship Areas, and a "how-to" manual describing the processes carried out at the four sites to be used in identifying threat and mapping in other sites.

<u>Aquatic Invasive Species</u>

1. **Aquatic Nuisance Species in Long Island Sound: Fostering a Cooperative and Comprehensive Approach to Management, Research and Education** (UConn/CT Sea Grant College Program; PI: Balcom; LIS 2006 Enhancement Fund; NEIWPCC: $53,814): This project will produce an interstate Long Island Sound Aquatic Nuisance Species (ANS) Management Plan that achieves the following: 1) focuses on the prevention and control of ANS in a cost-effective, environmentally-friendly manner; 2) provides a comprehensive and

cohesive framework for management, outreach, and research addressing ANS issues in LIS; 3) facilitates interstate and inter-agency cooperation to focus limited resources on mutually-identified and agreed-upon priorities; and, 4) fosters a coordinated, rapid response effort to prevent or combat new introductions of ANS in LIS. The plan will be developed in concert with a regional working group representing state and federal agencies, industry, non-governmental organizations, universities, and marine trade organizations. The plan will be made available for public comment and submitted to the federal ANS Task Force for preliminary review before being submitted to the States of Connecticut and New York for regulatory approval and adoption. Expected outcomes include a summary of current ANS knowledge with respect to LIS, pertinent state and federal regulations and policies, existing ANS research, monitoring, and educational programs, and regional resources currently directed to ANS issues in LIS.

2. **Multi-component Evaluation to Minimize the Spread of Aquatic Invasive Seaweeds and Harmful Algal Bloom Microalgae via Live Bait Vectors in Long Island Sound** (UConn and State University of New York, Purchase; PI: Yarish; LIS 2006 Research Fund; LI-97149601; $101,756; ENDS: 08/31/08): The goal of this project is to quantify the importance of bait products and associated packing materials as vectors for the introduction of non-indigenous species and harmful algal bloom (HAB)-forming microalgae to Long Island Sound. Non-native, invasive seaweeds and HAB-forming organisms represent threats to the ecological and economic health of the Sound. Samples of bait will be examined for non-indigenous species and cultured to identify microscopic stages and HAB microalgae using molecular analysis. Specific outputs include reports of the frequency of non-native, invasive seaweeds and HAB-forming microalgae by taxon as functions of season and the location of bait product purchase. A workshop on the project's findings will be held at the end of the research to bring together relevant stakeholders.

<u>Species Conservation</u>

1. **Salt Marsh-Breeding Sparrows in Long Island Sound: Status and Productivity of a Globally Important Species.** (UConn; PI: Elphick; LIS 2002 Research Fund; LI-98161201; $102,869; COMPLETED) The main objectives of this study were to (1) assess the population size of salt marsh sharp-tailed sparrows and seaside sparrows at key coastal marshes in Connecticut in order to fully understand the global significance of this region for both sparrow species, (2) compare traditional methods for indexing population size with more complex, time consuming, methods that give absolute population sizes, in order to calibrate the traditional indices and facilitate the calculation of regional population estimates, (3) determine within and among marsh variation in sparrow abundance in order to evaluate the consequences of habitat change, marsh management, and sea-level rise, (4) obtain estimates of breeding productivity, and (5) identify suitable indicators of salt marsh health. *Results: Juncus gerardi is a good indicator of the very best saltmarsh sharp-tailed sparrow habitat, providing the resolution needed to distinguish among areas of high marsh that differ in the abundance of birds and, to a lesser extent, nests. At a grosser level, the presence of Spartina patens also indicates good areas for saltmarsh sharp-tailed sparrows, but this grass is so common that it lacks the resolution provided by J. gerardi and is therefore not as good an indicator. Marsh size, and perhaps associated landscape features, have a large effect on seasidesparrow abundance and*

are perhaps more important than local habitat features. The presence of tall vegetation, however, is also a good indicator of seaside sparrow abundance, and it is possible that interactions between vegetation height and landscape features account for discrepancies in the relationship between marsh area and seaside sparrow abundance. Areas with abundant short-form Spartina alterniflora are avoided by nesting seaside sparrows.

Tidal Wetland Loss

1. **Application of Remote Sensing Technologies for the Delineation and Assessment of Coastal Marshes and their Constituent Species** (UConn/Wesleyan University; PI: Gilmore/Civco; LIS 2004 Research Fund; LI-97101801; $70,578; COMPLETED): The objective of this project was to identify and delineate coastal marshes around Long Island Sound and distinguish various types of marsh vegetation using moderate and high resolution remote sensing satellite imagery coupled with in situ radiometry and other field data collection. The researchers identified and inventoried the current extent and condition of the Sound's coastal marshes and developed a cost-effective way to track changes in the condition of wetlands over time. *These datasets and protocols can help provide coastal resource managers, municipal officials and researchers with baseline information for current land management and for long-term monitoring of habitat changes.*

2. **Rates of Tidal Wetland Loss** (CTDEP and NYSDEC; LIS 2002 Base Funds: CTDEP; PI: Rozsa/Yamalis; $25,000; LIS 2003 Base Funds: NYSDEC; PI: Holst/Young: $27,103): The LISS provided funding to CTDEP and NYSDEC to determine the rates of tidal marsh loss in the Sound. Through an agreement with CTDEP, the USFWS completed interpretation of wetland boundaries from archival aerial photographs, taken between 1974 and 2000, of strategic coves and tidal rivers in the Connecticut portion of the western Sound. USFWS staff developed a database containing wetland polygons and acreage information, and these data were used to calculate rates of tidal wetland loss by habitat type. In New York, NYSDEC will acquire aerial infrared photography of tidal marshes and will examine wetland trends using these images and aerial photographs dating back to 1930. Aerial photography was acquired in the fall of 2005 and additional photography will be acquired in the fall of 2006. The data from the 2005 and 2006 aerial photography are directly comparable to the 1974 tidal wetland inventory and will be used to conduct a qualitative and quantitative analysis of wetland loss/gain.

3. **Surface Elevation Tables** (NYSDEC; PI: Holst/Young; LIS 2003 Base Funds: $25,908; LI-98297800): The objective of this project is to deploy SETs in Long Island marshes to monitor marsh elevation. NYSDEC is working with the Marine Sciences Research Center (MSRC) at Stony Brook University. Marshes have been selected; NYSDEC will monitor the SETs once they have been set up. Installation is expected in the spring of 2009, with help from the US Geological Survey (travel funding for USGS to be provided by The Nature Conservancy).

   The project has been expanded into a multi-faceted monitoring program that includes the following components: MSRC will be taking pore-water samples in the SET sites to measure sulfides, nitrate, nitrite, ammonia, total dissolved phosphorus, pH, and redox potential (Eh). Cores will be taken and accretion history will be determined using 210Pb. USGS will be

installing continuous monitoring stations to collect tidal elevations, water temperature, and salinity.

These New York efforts will complement CTDEP's work to deploy SETs in Connecticut marshes. With funding from the Coastal Zone Management Program, CTDEP plans to establish up to 60 new SETs in Connecticut's coastal marshes in 2008.

4. **Tidal Wetlands Loss Workshop** (NYSDEC; PI: Chytalo; LIS 2002 Base Funds: $15,000; COMPLETED): In June 2003, NYSDEC sponsored a conference for researchers to discuss and share information regarding the possible causes of tidal marsh loss in Long Island Sound. The goal of the workshop was to develop research, monitoring and management recommendations. *Results: The participants highlighted the need to gather baseline information on the health and spatial distribution of the Sound's marshes and identified priority research topics, which were included in the 2004 Research Grant Program Request for Proposals. As a result, two research grants were awarded for projects investigating possible causes and the extent of tidal wetland loss in the Sound (see Ongoing Research Projects in this section). To follow up on this conference, the LISS Habitat Restoration work group has recommended that a special session on tidal wetland loss be included at the Estuarine Research Federation November 2007 conference in Providence, RI.*

5. **Understanding the Role of Nutrient Enrichment in Tidal Marsh Loss in Long Island Sound** (Yale University; PI: Anisfeld; 2004 LIS Research Funds; LI-97100801; $125,372; COMPLETED: 03/14//08): The objective of this project is to test the hypothesis that excessive loading of nutrients (nitrogen or phosphorus) plays a role in causing tidal marsh loss. Tidal marsh loss due to drowning (i.e., loss of elevation relative to sea level and conversion of vegetated marsh to mudflat) has been observed in recent years in Long Island Sound, primarily in the western Sound. However, the mechanisms and causes of this marsh loss are poorly understood. The results of this research will help ascertain if nutrient loading is a factor in tidal marsh loss and, if so, identify which nutrient is likely responsible. *Results: N and P fertilization generally did not appear to substantially affect belowground processes, including productivity, decomposition, and soil respiration. Likewise, there was no indication that N and P fertilization affected sediment accretion or net elevation change. As a result, it is now considered unlikely that excess nutrient loading is a major contributor to marsh drowning. Also supporting this conclusion is the fact that the drowning marsh (Sherwood) had lower nutrient concentrations than the reference marsh (Hoadley).*

IV. WATERSHED MANAGEMENT. ASSURE A VIABLE LONG ISLAND SOUND WATERSHED THAT SUPPORTS VIBRANT AND HEALTHY AQUATIC LIFE, AND MINIMIZES THE NEGATIVE EFFECTS OF EROSION, SEDIMENTATION, AND FLOODING ON THE SOUND AND ITS TRIBUTARIES AND EMBAYMENTS.

A. 2003 Long Island Sound Agreement Goals & Targets

1. By 2010, Connecticut and New York will work toward a goal of having 50 percent of their respective areas in the watershed developing or implementing watershed restoration strategies.

2. By 2003, Connecticut and New York will identify the amount of impervious surface in their respective portions of the watershed, based on available land use/land cover data. Through watershed planning efforts the states will encourage municipalities to adopt limitations on impervious surfaces, with an overall goal of minimizing increases in impervious cover to a rate consistent with population change.

3. By 2004, Connecticut and New York will assess the amount of riparian forest buffer in their portions of the watershed using available land use/land cover data. Through watershed planning efforts, the states will encourage the establishment of targets to expand the percentage of riverine miles with forested buffers.

B. General Monitoring, Assessment, and Research Needs

Monitoring:

1. Monitor land use patterns and landscape features relevant to watershed functions of providing habitat and controlling water quality and quantity (e.g., land cover, buffer integrity, wetlands, population, impervious cover, etc.).

Assessment:

1. Evaluate the benefits of storm water best management practices (BMPs), such as wet ponds and wetlands, compared to the quality of storm water contributions with minimal or no BMP application.
2. Establish goals and targets for watershed feature protection based on existing conditions and trends and loading of pollutants to LIS.

Research:

1. Study the relationship between development and nutrient enrichment in small, coastal embayments and determine specific activities and sources that increase flux of nutrients to embayments.
2. Identify management practices that would help alleviate any observed impacts on LIS and its embayment and, if possible, relate trends in effects to changes in land use practices and pollutant loading.
3. Study the contributions of nutrients from ground water to Long Island Sound or its tributaries and examine the implications of ground-water travel time.
4. Identify typical unit area export rates of nitrogen from categorical land covers (urban, agricultural, forests) in the LIS watershed and how much is enrichment compared to a natural export rate.
5. Determine if forest health has been compromised by cation leaching caused by acid deposition or nitrogen saturation. Identify critical loads of nitrogen that would lead to abnormal nitrogen leaching to streams and estuaries and determine the value of forests and buffers as a nitrogen management tool.

6. Support research investigating the relationship between watershed urbanization and nitrogen processing capacity of riparian buffers.
7. In the face of atmospheric loading and potential nitrogen contributions to forested buffers and forests from adjacent urban and agricultural lands, determine the value of forests and buffers as a nitrogen management tool.

C. LISS Work to Address Needs

1. **Coastal Riparian Buffer Analysis** (UCONN/CLEAR; PI: Arnold; LIS 2005 Enhancement Funds; LI-97128801; $90,611; COMPLETED: 02/15/08): The purpose of this project is to survey Long Island Sound coastal watershed areas in New York and Connecticut to assess the condition of the Sound's riparian buffers. The project's objectives are to provide an overall picture of the Sound's riparian buffers, develop diagnostic information at the subregional watershed level that LISS and state and local managers can use to direct future efforts, and to create highly accurate information for at least one high priority basin.

2. **Connecticut River Riparian Area Mapping** (CT River Estuary Regional Planning Agency; PI: Preston; LIS 2004 Enhancements Fund; LI-97105801; $26,144; COMPLETED): This project builds upon existing GIS databases to identify and map the occurrences of riparian buffers along the main stem and major tributaries of the lower Connecticut River. This work included the creation of a linked parcel and ownership database for all properties adjacent to the river, as well as existing protected, developed, and undeveloped land. *Results: GIS maps identifying protection and restoration opportunities were developed. These maps are available to all lower Connecticut River communities. An educational brochure regarding the importance of riparian buffers was produced. Project information is posted on the Tidewater Institute website: http://www.crerpa.org/RiparianBuffers.html.*

3. **Decision Support Tool for Nitrogen Reductions** (Manhattan College; PI: Farley; LIS 2004 Enhancement Fund; LI-97286104; $80,800; COMPLETED): The goal of this project was to develop a simple modeling approach to estimate and track nonpoint source nitrogen loads in the Connecticut and New York portions of the Long Island Sound watershed. *To achieve this goal, the following tasks were completed: 1) review available tools to estimate and track nonpoint source nitrogen loads based on land use and best management practices; 2) consult with the LISS to selected the most appropriate tool; 3) verify the nitrogen mass balance for existing land uses based on previous studies and those estimated using this tool; and 4) apply the tool to demonstrate its use evaluating the effectiveness of management strategies.*

4. **Development of a Riparian Buffer Toolbox** (Columbia University; PI: Gorokhovich; LIS 2005 Enhancement Funds; LI-97269601; $34,354; COMPLETED): This project developed a "Riparian Buffer Toolbox," an online tool to provide information in support of watershed protection efforts. The PI assembled existing materials regarding the protection of riparian buffer zones and is developing a user-friendly website to display this information. *Results: The website provides municipal officials and the public with easy access to educational brochures and scientific information regarding riparian buffers, which are essential to reducing nonpoint source pollution to Long Island Sound. The website address is:*

http://www.hydroqual.com/projects/riparian.

5. **Mapping and Monitoring Changes in Impervious Surfaces in the Long Island Sound Watershed** (UCONN CLEAR; PI: Arnold; LIS 2003 Enhancement Funds; LI-98178101; $99,006; COMPLETED): The objective of this project was to track historical changes in impervious coverage in Long Island Sound's coastal watershed over the period from 1985 to 2002. *The project provides a standardized basis by which to compare changes in impervious surface in the future, as well as an opportunity to study how these changes relate to population growth, water quality, and other factors of interest to LIS managers.*

6. **Adoption of CT River Estuary Riparian Regulations through the CT River Gateway Commission.** (Tidewater Institute, CT River Estuary Regional Planning Agency; PI: Preston; LIS 2007 Enhancement Grant; NEIWPCC: $46,714) The objective of this project is to create and facilitate the adoption of effective riparian regulations that will protect and restore riparian buffers within the eight-town Gateway Conservation Zone located in the CT River estuary. This project will build on the 2006 completed LISS-funded project, CT River Riparian Mapping, but using baseline data to inform the extent and location of estuary shoreline in need of riparian creation or restoration. Expected outputs include educational information and material, including a PowerPoint presentation to support outreach efforts that will include press, literature for local publication, and interview, in advance of individual zoning commission presentation and public hearings. Anticipated environmental benefits to LIS include increased protection for and public awareness of the values of healthy riparian buffers, particularly for water quality, but including habitat protection, benefits to air quality and scenic preservation.

7. **Simulation of the Water Quality Impacts of Urban Low Impact Development (LID).** (The Trustees of Columbia University in the City of New York, DO Fund 2007, $200,000) The project will develop reliable low impact development tools and techniques; and determine the magnitude of "usefulness" of various individual tools towards improving water quality in densely populated urban communities with a focus on the lower Bronx River. This project pushes the envelope of conventional approaches to managing urban stormwater runoff which are effective but also expensive and difficult to site. Low Impact Development (LID) is a relatively new approach in urban water quality management. LID emphasizes the community-based and broad-scale or "distributed" use of tools like roof leaders, rain barrels, rain gardens, porous pavement and rooftop detention etc. by individual citizens and municipalities to reduce runoff.

8. **Oyster Bay/Cold Spring Harbor Watershed Action Plan.** (Friends of the Bay, LIS Futures Fund, $136,000) The Friends of the Bay will develop a watershed management plan for the Oyster Bay/Cold Spring Harbor complex which addresses historic trends, environmental and land use conditions; and establishes priority actions to protect and improve the ecological integrity of the estuary. The Oyster Bay – Cold Spring Harbor Estuary is recognized by New York State as a Significant Coastal Fish and Wildlife Habitat and as an Outstanding Natural Coastal Area. The U.S. Fish and Wildlife Service recognizes the area as habitat or regional significance for restoration of anadromous fish passage. The watershed hosts the Oyster Bay

National Wildlife Refuge and the Shu Swamp Nature Preserve -- both anchor sites for the Long Island Sound Stewardship Initiative.

9. **Saugatuck River Watershed Partnership.** (The Nature Conservancy, LIS Futures Fund, $100,500) The Nature Conservancy will design fishways for two dams with a goal of opening up 1.5 miles of habitat for diadromous fish on the Aspetuck and Saugatuck Rivers. Partners include: Aquarion Water Company, Saugatuck Valley Audubon, Trout Unlimited, Southwest Conservation District, Connecticut Department of Environmental Protection, Yale School of Forestry, American Rivers among others.

V. CROSS-CUTTING AREAS

A. Long Island Sound 2003 Agreement Goals & Targets

1. Continue federal and state support and continue to build partnerships at all levels to implement the CCMP for Long Island Sound and to effect the specific elements in this Agreement.

B. General Monitoring, Assessment, and Research Needs

Monitoring:

1. Determine the utility of a comprehensive air-land-water monitoring effort that would link sources with sinks and help determine transport and cascading effects of pollutant deposition, especially nitrogen.
2. Update the LIS Monitoring Plan to support and build upon research and assessment programs.

Assessment:

1. Synthesize existing information on chemical, biological, physical, and geological aspects of the Sound to articulate what is known, identify where data gaps exist, and help inform the establishment of priorities. Evaluate the effects of climate change on the Sound as an overarching theme of the synthesis report.
2. Develop forecasting model for severity of hypoxic conditions and other water quality conditions (e.g. algal bloom).

Research:

1. Development of a Long Island Sound-specific benthic index, evaluating approaches used by NCA and others (e.g., NOAA's Assessment of Estuarine Trophic Status) and considering and quantifying natural and anthropogenic variables that affect the index. The benthic index should be coupled with the water quality monitoring data collected on behalf of the LISS by the Connecticut Department of Environmental Protection (CT DEP) (http://dep.state.ct.us/wtr/lis/monitoring/lis_page.htm), the Interstate Environmental Commission, and other local sources.

2. Develop a framework to quantify the ecosystem services provided by the aquatic resources of the LIS (there is a need to develop on the watershed side too). Various ecological components of LIS play a role in providing services to people. In order to support responsible economic development it is necessary to know what ecosystem services may be at stake in a particular development scenario. Various resources such as open water, beaches, seagrass meadows, wetlands, and soft-bottom habitats provide important services to people. More could be done to quantify the services provided by these resources. This work would be aimed at developing and implementing a framework to quantify such services for the LIS.
3. Develop Ecosystem Services Response Functions (ESRF), which are relationships between Drivers (e.g. land development), Pressures (e.g., Nitrogen loading), Stressors (e.g., hypoxic volume, water clarity), and Impact (e.g., eelgrass extent BUT put in terms of Ecosystem services such as eelgrass-derived annual lobster catch).

C. LIS Work to Address Needs

Scientific Synthesis

1. **LIS Environmental Data Synthesis** (CT Sea Grant; PI: DeGuise; LISS 2007 Base Funding; LI-97183601; $39,783, LISS 2008 Base Funding $34,760) The purpose of this effort is a systematic synthesis of information on the patterns and processes that characterize the Long Island Sound ecosystem. Throughout the synthesis emphasis will be placed on how these patterns and processes may be altered in response to global and regional change and the implications for improving ecosystem-based management of the Sound. The document would be developed for a technical audience to guide both science and management activities, but would provide the basis for brochures, fact sheets or other publications for the general public. Each section will be written by an expert or experts as a review of existing data on Long Island Sound. Lead authors, once assigned, will further develop the outline within their topic area. A proposal for a workshop to bring all contributing authors together to present the topic outlines, elaborate and expand on content, and discuss cross-cutting issues, will be submitted to EPA. Following the workshop, lead authors would prepare topic manuscripts with an honorarium provided.

Indicators

1. **Environmental Indicator Review and Assessment for Long Island Sound** (Yale University, PI: Anisfeld; FY2006 LIS Enhancement Funding; NEIWPCC: $56,811): The objectives of this study are to evaluate the scientific validity, management usefulness, and public acceptance of the way that environmental indicators are currently used by the LISS and to recommend any appropriate changes to the data collection program, the indicators used, and the interpretation and communication of those indicators. The researchers will evaluate the current suite of indicators by judging them against a clear set of criteria for what constitutes an "ideal" indicator. They will propose improvements in indicator use, including specific recommendations regarding current indicators, potential additional indicators, and improved tools for analysis, organization, and communication. Emphasis will be placed on ensuring the following: a) that sampling and interpretation are scientifically credible and defensible; b) that

indicators evaluate the entire range of stressors, including emerging threats such as climate change and personal care products; c) that indicators are organized and used in an integrated way that focuses on ecosystem endpoints and – where relevant – economic endpoints; and d) that communication with the public is both clear and accurate, and includes a discussion of uncertainties. The project will result in an improved framework for collecting, evaluating, and presenting indicators for LIS. This will give managers, scientists, stakeholders, and the general public a more accurate sense of both the health of LIS and the success of the LISS.

Appendix I: Needs Summary

I. HYPOXIA

Monitoring:

1. Propose novel monitoring programs and techniques (e.g. continuous measurements of primary productivity, respiration, nutrients, zooplankton, tracers for river water and nutrients, harmful algae, microbial pathogens, etc) to fill in gaps in the current monitoring program.

Assessment:

1. Review and assess existing monitoring data to comprehensively assess coverage and understanding of physical, chemical and biological processes.
2. Evaluate whether available water quality data exhibit trends that are consistent with the predictions of the LIS 3.0 or SWEM models and develop recommendations for improvements to the models or current monitoring efforts; i.e., analyses of available data linked to model predictions, both at regional scales (western, central, and eastern Sound) or the entire Sound.
3. Develop methods to estimate nutrient loading to all the embayments that border LIS.
4. Propose new applications of current management technologies and approaches to control nitrogen loading to Long Island Sound or to reduce the adverse impacts of nitrogen loading through alternatives to nitrogen control. Examples on nitrogen control include management of sewage treatment plant processes and innovative best management practices to control nonpoint source and storm water runoff from urban areas [also relates to watershed management section]. Examples of alternatives to nitrogen control include biomass harvesting, e.g. shellfish or macroalgae, to extract nutrients from the ecosystem.

Research:

1. Discern the response of Long Island Sound (in biological, geochemical, or physical oceanographic processes) to local nitrogen reductions (a local signal) and to ocean climate/variability (e.g., trends in temperature, winds, etc. that drive stratification). Emphasize integrated assessments of physical and biological processes involved in hypoxia.
2. Evaluate the current understanding of components of the processes that are thought to control the degree and extent of hypoxia in Long Island Sound (e.g., phytoplankton dynamics, fate of production, food web interactions, water exchange through the Sound boundaries, magnitude and rates of vertical mixing, variability of water column and benthic respiration, sedimentary geochemistry and sediment-water column fluxes, etc) using existing and, if necessary, new observations.
3. Develop new management practices to alleviate hypoxia at appropriate points of intervention for air, land, and water and evaluate their potential with respect to current management practices.

II. TOXIC SUBSTANCES

Research**:**

1. Evaluate sources and inventories of conventional and emerging contaminants in Long Island Sound focusing on those that are (e.g., 303(d) listed impairments) or are likely to be present at concentrations where adverse effects on aquatic species or human consumers are likely.
2. Examine potential impacts of these contaminants on ecosystem function or population dynamics of key resources species.
3. Develop new management technologies and approaches to control sources of toxic substances and to remediate contaminated sediments.

III. LIVING RESOURCES AND HABITAT MANAGEMENT & CONSERVATION.

A. Eelgrass

Monitoring:

1. Propose monitoring programs and techniques to comprehensively assess eelgrass distribution and trends in Long Island Sound and to track the effects of pollution processes and habitat change on its distribution.
2. Deploy light meters in embayments to monitor changes in the light field. Compare the C:N in various eelgrass beds throughout LIS.
3. Monitor the habitat benefits on key living resource organisms that rely on eelgrass for recruitment and growth.
4. Quantify existing water quality conditions, particularly those parameters that are important to the growth and maintenance of Zostera (e.g., DIP, DIN, Chl A, TSS, light attenuation, benthic algae, epiphytes, CDOM, canopy height, sediment OM, etc.).

Assessment:

1. Using a Kd of 0.7/m, develop maps of potential eelgrass habitat, based on current water clarity and desired or historic water clarity. Develop maps of suitable eelgrass habitat, further considering other factors (e.g. % organics, sulfides, depth, current, sediment). Determine the current % loss of seagrass, relative to restoration target.
2. Assess nitrogen loads and trends and their effects on eelgrass health in receiving waters.
3. Calculate nitrogen-loading rates and predicted eelgrass response in LIS embayments, considering all sources and using consistent methodologies that are transferable to other embayments.

Research:

1. Perform comparative studies in embayments to evaluate where and to what degree existing nitrogen and sediment loading rates, or other factors, such as temperature, result in water

quality conditions that do not support eelgrass. Validate or refine nitrogen target loads of 50 kg N ha^{-1}estuary y^{-1}.
2. Define groundwater hydrology patterns for an embayment that has experienced declines of *Zostera* including determining nitrogen concentrations (seasonal) and rates of groundwater movement.
3. Determine how long it will take for eelgrass to respond from reductions in nitrogen loads and levels from sewering or other nitrogen management efforts.

B. Food Web Dynamics

Monitoring:

1. Propose monitoring programs and techniques to comprehensively assess food web dynamics and trends in Long Island Sound and to track the effects of pollution processes and habitat change on its disruption.
2. Quantify existing habitat and water quality conditions, particularly those parameters that are important to the vitality of the LIS food web dynamics (e.g., substrate, hydrodynamics, climate related factors, water quality, energy transfer, invasive species, etc.).

Assessment:

1. Conduct a data review, synthesis, and gap analysis of key food web organisms and attributes to refine conceptual models of LIS food webs in coves, near-shore, and open waters. Determine the roles and status of the most important food web components (e.g., system filtration, nursery function, etc.). Identify critical data gaps in our present understanding of the major food web components and their potential interactions.
2. Determine how important components of the food web may have changed over time, with emphasis on those influenced primarily by anthropogenic stressors and those that can be affected by management.

Research:

1. Data Collection to Better Quantify Critical Food Web Components: Determine how changes in nutrient ratios (e.g., N/P/Si) may have affected the phytoplankton species composition and overall productivity in LIS in the past, and monitor possible future changes. Determine how nutrients (mainly nitrogen) are processed by the different components of the food web in the coves and near-shore LIS environments.
2. Determine the relative magnitude and functional group make-up of primary productivity in coves, near shore, and open water regions of LIS.
3. Determine the relative importance of different stressors (e.g., eutrophication, climate change, habitat alteration, hypoxia, fishing pressure) on food webs in LIS.
4. Determine what and how food web component(s) are driving the processing of labile organic matter in LIS.
5. Recommend research priorities to fill critical data gaps, begin to quantify the role of critical food web components, and identify management options

C. Tidal Wetland Loss

Monitoring:

1. Propose monitoring programs and techniques to comprehensively assess tidal wetlands distribution and trends in Long Island Sound and to track the effects of pollution processes and climate and habitat change on its distribution.
2. Monitor the habitat benefits on key living resource organisms that rely on tidal wetlands for their success.
3. Quantify existing water quality conditions, particularly those parameters that are important to the growth and maintenance of tidal wetlands (e.g., nutrients, sedimentation, etc.).

Assessment:

1. Assess condition and trends of marsh systems in the embayments and subestuaries of Long Island Sound considering issues such as fragmentation of marshes, characterization of lagoon and bay locations in Connecticut compared to New, conditions in subestuaries of LIS. Desired measures include marsh elevation, tidal hydrology, sediment accumulation rates, sediment chemistry, biomass measures, vegetation density, stem height, and others.

Research:

1. Marsh elevation and accretion rates with respect to relative sea level rise. Marshes in LIS have displayed stable rates of accretion from sediment loads, but the elevations of marshes do not appear to be rising with relative sea level. Studies of marsh elevation processes might include changes in composition of sediment supply and budget on a 300-year time scale; changes in the communities of Foraminifera in LIS marshes over time; and/or radioisotope studies.
2. The relative importance of above vs. below-ground biomass on the health and stability of LIS marshes. Little is known about the relationship between above-ground and below-ground biomass in *Spartina alterniflora* marshes in LIS. Studies of the marsh structure with respect to this relationship may include correlations between biomass and marsh stability and health.
3. Nitrogen compounds and their effects on marsh health. Changes in the types of available and limiting nutrient compounds available to LIS marshes are hypothesized to play a role in *Spartina* marsh vigor and stability. Investigations may include greenhouse and field experiments and studies of potential synergistic effects of nitrogen and other nutrient compounds.

D. Species Conservation

Research:

1. Studies on the life history, population dynamics, predator-prey relationships, and behavior of diandromous fish of management concern, including river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*), American eel, and rainbow smelt,

to help understand the current status of these runs, factors in the recent declines, and what management actions might result in run enhancement.
2. Determine the home range and population movement patterns of the saltmarsh sharp-tailed sparrow in Connecticut. Refine population estimates, examine connectedness among sites, and refine existing habitat use information. Examine the social cues utilized by saltmarsh sharp-tailed sparrows that attract birds to suitable habitat. Develop a technique that may improve saltmarsh restoration efforts by attracting birds to "empty" habitats through the use of these social cues.
3. Impacts of pot fisheries on impacts to diamondback terrapins and evaluate the need for terrapin excluders.

E. Habitat Classification and Mapping

Monitoring:

2. Monitor and map beach and island nesting habitats for terns, plovers, horseshoe crabs, herons, and diamondback terrapins.

Assessment:

1. Develop mapping products that can identify the historic location and extent of critical habitat in Long Island Sound and a strategy for utilizing historic mapping products in quantitative assessments of current habitat restoration and conservation efforts. In particular information on the historic extent and location of key habitats in Long Island Sound will be crucial in aiding current management strategies.
2. Conduct seafloor mapping consistent with bi-state strategy being developed.

F. Aquatic Invasive Species

Monitoring:

1. Detect new infestations and trends in known populations through the establishment of a sentinel site monitoring program. Conduct as part of an Early Detection, Monitoring, and Assessment (EDMA) plan to monitor for new introductions and follow the spread of established AIS in Long Island Sound.

Assessment:

1. Create or add to a library of voucher specimens from Long Island Sound at various life stages, as well as develop a digital archive accessible via the Internet.

IV. WATERSHED MANAGEMENT

Monitoring:

1. Monitor land use patterns and landscape features relevant to watershed functions of providing habitat and controlling water quality and quantity (e.g., land cover, buffer integrity, wetlands, population, impervious cover, etc.).

Assessment:

1. Evaluate the benefits of storm water best management practices (BMPs), such as wet ponds and wetlands, compared to the quality of storm water contributions with minimal or no BMP application.
2. Establish goals and targets for watershed feature protection based on existing conditions and trends and loading of pollutants to LIS.

Research:

1. Study the relationship between development and nutrient enrichment in small, coastal embayments and determine specific activities and sources that increase flux of nutrients to embayments.
2. Identify management practices that would help alleviate any observed impacts on LIS and its embayment and, if possible, relate trends in effects to changes in land use practices and pollutant loading.
3. Study the contributions of nutrients from ground water to Long Island Sound or its tributaries and examine the implications of ground-water travel time.
4. Identify typical unit area export rates of nitrogen from categorical land covers (urban, agricultural, forests) in the LIS watershed and how much is enrichment compared to a natural export rate.
5. Determine if forest health has been compromised by cation leaching caused by acid deposition or nitrogen saturation. Identify critical loads of nitrogen that would lead to abnormal nitrogen leaching to streams and estuaries and determine the value of forests and buffers as a nitrogen management tool.
6. Support research investigating the relationship between watershed urbanization and nitrogen processing capacity of riparian buffers.
7. In the face of atmospheric loading and potential nitrogen contributions to forested buffers and forests from adjacent urban and agricultural lands, determine the value of forests and buffers as a nitrogen management tool.

V. CROSS-CUTTING AREAS

Monitoring:

1. Determine the utility of a comprehensive air-land-water monitoring effort that would link sources with sinks and help determine transport and cascading effects of pollutant deposition, especially nitrogen.
2. Update the LIS Monitoring Plan to support and build upon research and assessment programs.

Assessment:

1. Synthesize existing information on chemical, biological, physical, and geological aspects of the Sound to articulate what is known, identify where data gaps exist, and help inform the establishment of priorities. Evaluate the effects of climate change on the Sound as an overarching theme of the synthesis report.
2. Develop forecasting model for severity of hypoxic conditions and other water quality conditions (e.g. algal bloom).

Research:

1. Development of a Long Island Sound-specific benthic index, evaluating approaches used by NCA and others (e.g., NOAA's Assessment of Estuarine Trophic Status) and considering and quantifying natural and anthropogenic variables that affect the index. The benthic index should be coupled with the water quality monitoring data collected on behalf of the LISS by the Connecticut Department of Environmental Protection (CT DEP) (http://dep.state.ct.us/wtr/lis/monitoring/lis_page.htm), the Interstate Environmental Commission, and other local sources.
2. Develop a framework to quantify the ecosystem services provided by the aquatic resources of the LIS (there is a need to develop on the watershed side too). Various ecological components of LIS play a role in providing services to people. In order to support responsible economic development it is necessary to know what ecosystem services may be at stake in a particular development scenario. Various resources such as open water, beaches, seagrass meadows, wetlands, and soft-bottom habitats provide important services to people. More could be done to quantify the services provided by these resources. This work would be aimed at developing and implementing a framework to quantify such services for the LIS.
3. Develop Ecosystem Services Response Functions (ESRF), which are relationships between Drivers (e.g. land development), Pressures (e.g., Nitrogen loading), Stressors (e.g., hypoxic volume, water clarity), and Impact (e.g., eelgrass extent BUT put in terms of Ecosystem services such as eelgrass-derived annual lobster catch).