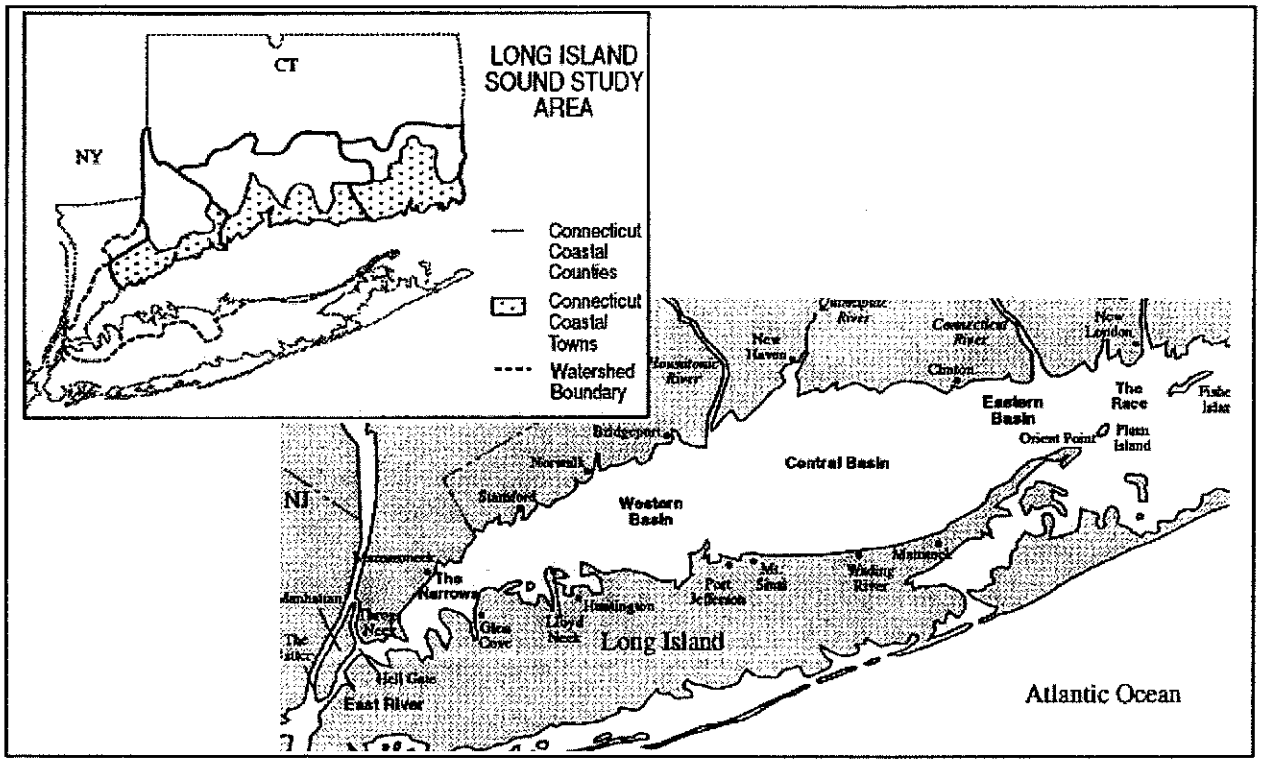
Transition from a Hypoxia-Based Monitoring Plan to an Ecosystem-Based Monitoring Plan Workshop

March 6-7, 2002



Meeting Summary

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Workshop Summary Report

A workshop entitled *Transition from a Hypoxia-Based Monitoring Plan to an Ecosystem-Based Monitoring Plan* was held at the University of Connecticut Avery Point Campus on March 6 and 7, 2002. An example of the participant invitation letters and the meeting agenda are included in Appendix A. Attendees included representatives from the U.S. Environmental Protection Agency (USEPA), National Marine Fisheries Service (NMFS), U.S. Geological Survey (USGS), various state and local agencies, universities, and other organizations performing monitoring throughout the Long Island Sound (LIS) (see Appendix B). Dr. Carlton Hunt, Battelle, facilitated the meeting with assistance from Ms. Lynn McLeod and Ms. Deb Tanis, also from Battelle.

The purpose of the workshop was to bring together individuals presently conducting monitoring, research and assessment programs in LIS. Mr. Mark Tedesco, Director of the EPA Long Island Sound Office, which coordinates the Long Island Sound Study (LISS) Management Conference, began the meeting with a presentation of background information and objectives of the workshop (Appendix C). During his presentation Mr. Tedesco spoke on LISS monitoring, conducted since 1987, which has focused on the hypoxia issues in LIS. Although this monitoring needs to continue, LISS notes that other impairments need to be addressed that the monitoring program does not focus on (*e.g.*, SAVs, HABs). Since it is important to monitor the overall health (or status) of the LIS, LISS has attempted to answer this by integrating information from other sources not meant specifically for monitoring the overall condition of LIS. LISS requested this meeting to:

- Review a conceptual framework of LIS ecosystem.
- Discuss what could be done better? What is missing?
- Identify priorities for monitoring and research.
- Prepare a report on the workshop conclusions.

While it is recognized that a tremendous amount of information is available on LIS, inclusion of additional ecosystem data on LIS can continue to improve the overall monitoring of LIS.

Mr. Joe Hall, U.S. Environmental Protection Agency (USEPA) Office of Oceans and Coastal Protection Division, who sponsored the workshop, addressed the group noting how important the workshop was to the entire National Estuary Program (NEP) and how LISS has been and continues to be a leader in the NEP.

Dr. Hunt followed Mr. Hall with a presentation on the *Conceptual Framework of Ecosystem Monitoring* (Appendix D). This presentation used the Massachusetts Water Resources Authority (MWRA) monitoring program as an example of ecosystem monitoring. The MWRA uses their monitoring program to track the effects of a new sewage outfall on the Massachusetts Bay ecosystem.

As part of the preparation for the meeting, LISS requested that Battelle update the LISS Monitoring Program Inventory, which was originally collected in 1993. Ms. McLeod presented

the results of the updated monitoring program inventory along with the objectives from the present LISS Monitoring Plan (see Appendix E). The final version of the LISS Monitoring Program Inventory is presented in Appendix F. It is noted that there are additional research and assessment programs conducted throughout LIS that are not included in the Monitoring Program Inventory.

In addition to programs being conducted by state and local agencies and universities, LISS requested an update on programs being conducted in the LIS area by USEPA Office of Research and Development. Dr. John F. Paul of USEPA's Atlantic Ecology Division (Narragansett, Rhode Island) discussed Environmental Monitoring and Assessment Program (EMAP) and the National Coastal Assessment (NCA) program (see Appendix G). Dr. Paul noted that in 1990-93 EMAP sampled biotic condition indicators (abundance/biomass, diversity/composition, and fish pathology/histopathology) and abiotic condition indicators (dissolved oxygen [DO], contaminant concentrations, sediment toxicity) throughout LIS. These data are available on the web site www.epa.gov/emap. Starting in 2000, the NCA core water quality, sediment quality, and biota indicators collected by the states of Connecticut and New York in LIS include: DO, salinity, temperature, depth, pH, nutrients, chlorophyll, grain size, total organic carbon, sediment chemistry, benthic community structure, sediment toxicity, fish community structure, fish external pathology, and fish tissue chemical analysis.

Dr. Hunt then gave a brief presentation on the focus, objectives, and goals of each panel, and the desired involvement of the workshop participants. The overarching goal of the workshop was to discuss what elements were needed to transition the current hypoxia-based monitoring plan into a plan that better accounted for the monitoring of the entire LIS ecosystem. To structure and facilitate the discussion, six panels were convened. All panelist presentations can be found in Appendix H.

The three panels held on the first day were (see available presentations in Appendix H):

- Water Column Trophic Interactions - J. Evan Ward (UCONN), Gary Wikfors (NMFS), Hans Dam (UCONN), Gordon Taylor (SUNY), Gerry Capriulo (St. Mary's College of California)
- Near-Shore Benthic Communities – Milan Keser (Millstone); Roman Zajac (University of New Haven), Robert Whitlach (UCONN), Carmela Cuomo (Yale University)
- Living Resources – Dave Simpson (CTDEP), Dave Conover (MSRC), Malcolm Shute (CTDOA), Harry Yamalis (CTDEP), Jason Link (NMFS)

On the morning of the second day of the workshop, Ms. Robin Miller of HydroQual, Inc. summarized the System-wide Eutrophication Model (SWEM) developed to evaluate water quality in LIS, New York Harbor, and the New York Bight (Appendix I). Her presentation gave an overview of the elements of the LIS ecosystem that are presently modeled and those that are not. In addition, she presented suggestions on additional information that might be collected to improve the model and apply it in different ways. This presentation was then followed by the remaining three panels of the workshop.

The three panels held on the second day were (see available presentations in Appendix J):

- Modeling – James Kremer (UCONN), Jim Fitzpatrick (HydroQual, Inc), Bob Wilson (SUNY), Jim O'Donnell (UCONN)

- Contaminants – Johan Varekamp (Wesleyan College), Ellen Mecray (USGS) Drew Carey (Coastal Vision), William Fitzgerald (UCONN – presented by Dr. Hunt)
- Synthesis/Next Steps – Frank Bohlen (UCONN), Larry Swanson (MSRC), Candace Oviatt (URI), John Atkin (Save The Sound), Richard Batiuk (Chesapeake Bay Program)

The panelists were charged with giving presentations that covered current monitoring and research and all panelists and the participants were charged with addressing the following questions during presentations and discussions:

- What measures of the status of Long Island Sound should be made?
- Over what time and spatial scales?
- What information will these measures provide on the ecological condition of LIS and how can this information be used?
- Is monitoring adequate to manage recreationally or commercially important living resources?
- Is monitoring of habitats adequate to support management?
- What enhancements to SWEM or new modeling initiatives are feasible and should be pursued?
- How will these enhancements aid management?

Information pertaining to these questions was offered by the panelists and participants. However, direct answers were often unachievable due to the lack of consensus among the participants and because many participants raised additional questions that need to be addressed prior to reaching definitive answers for the above questions.

The following sections will briefly summarize the presentations and discussion that followed for each panel. The last section summarizes the workshop recommendations for the next steps.

Water Column Trophic Interactions

The first panel of the workshop was focused on issues within the water column. The group was asked to focus on what measures of the rate and status of trophic interactions should be monitored and over what spatial and temporal scales.

Dr. Gordon Taylor from the State University of New York (SUNY) began the panel presentations discussing the control of hypoxia that has been the focus of most efforts within LIS. He noted that although the input of nutrients to LIS from New York City sewage treatment plants has decreased, DO concentrations have not improved. He noted that the understanding of nutrient dynamics in LIS is limited. Dr. Taylor also discussed how nutrients relate to plankton and plankton relates to DO fluctuations and indicated these relationships need further study.

Factors identified to develop a better understanding of these inter-related dynamics include:

- Stratification and limited horizontal exchange, which equate to poor ventilation
- Water temperature (physical and biotic effects)
- Magnitude of export production
    - Plankton community structure
    - Community structure controlled by multivariables (*e.g.*, nutrient speciation, light and mixing regimes, grazers)

- BOD in bottom waters – heterotopy and possible nitrification
- Episodic nutrient pulses – blooms fueled by brief discharges from runoff, stormwater and CSOs

Useful variables to monitor:

- Size-fractionated chlorophyll a concentrations as a community structure proxy
- More systematic estimates of particle flux
- Continuous bottom DO monitoring at limited sites
- Continuous physical monitoring at limited sites (stratification and currents)
- Higher resolution in BOD measurement
- Nutrient loadings
- Nutrient concentrations
- Grazer dynamics

Dr. Gerard M. Capriulo, from St. Mary's College of California, discussed the relationship between differential nutrient loadings and chemical speciation, along an east to west gradient in Long Island Sound, and resultant variations in size-fractionated chlorophyll, microbial loop, phytoplankton, microzooplankton, zooplankton and larval fish population dynamics and biomass signatures. He stated that excess nitrogen differentially stimulates (in species-specific ways) microbial loop and phytoplankton biomass and production, which in turn stimulate microcrustacean biomass/production and fecal release. Both are believed to significantly fuel hypoxia and stimulate gelatinous zooplankton production.

Dr. Capriulo noted the following research needs:

- Accurate determination of the mechanisms by which hypoxia develops (e.g., study the role of copepod biomass and fecal pellets in the development of hypoxia).
- Continued examination of spatial shifts in planktonic size-spectra, diversity, and production, and of the occurrence of toxic species.
- Assessment of the fate of western LIS "excess" biomass/production by high resolution examination of spatial and temporal patterns of larval fish, ctenophore and other gelatinous zooplankton, diversity, biomass and abundances, as well as the role of gelatinous zooplankton as sinks for larval fish and copepod production.
- Examination of alternate reasons for possible low adult and juvenile fish stocks such as: overfishing, critical habitat destruction, fish sterility due to estrogen-analog compounds and predation from coastal birds.
- The use of rate functions of key processes was suggested for improved monitoring of LIS.

Dr. Hans Dam, from UCONN, presented three slides on food web interactions. He felt that in order to have an effective monitoring program of the dynamics of phytoplankton in LIS biological processes such as growth, grazing and sinking rates of phytoplankton need to be measured. He suggested that data should be collected from all three regions of the Sound: Western, Central and Eastern because the stratification of the water column is quite different in each of these regions. Dr. Dam noted that water column stratification can determine the kinds of dominant phytoplankton. This, in turn, drives grazing rates and sinking losses.

Dr. Gary Wikfors, from National Marine Fisheries Service, noted that the highest priority for development of new monitoring tools is: phytoplankton identification, net primary production,

and phytoplankton loss terms (see tables in Appendix). These along with dissolved nutrients were supported as ecologically relevant parameters. Dr. Wikfors noted that it will be important to be able to identify small changes in productivity, but capability in this area is limited at this time. He also noted that function is a process, therefore monitoring must be driven by knowledge of processes. Processes are described by rate functions, not discontinuous measurements. Therefore, product rate information is necessary for nutrients, phytoplankton, zooplankton (micro and macro), and larval fish. Dr. Wikfors suggested using predictions of models and system understanding to guide LIS monitoring and suggest higher temporal, less spatial monitoring.

Dr. J. Evan Ward, from UCONN, noted that additional monitoring of benthic-pelagic coupling issues is needed. He discussed the fact that research is showing more and more that in coastal ecosystems benthic suspension-feeding activity can have profound effects on the overlying water column, in particular, on the standing stock of phytoplankton and perhaps species assemblages. Suspension feeders (in particular bivalves) remove large quantities of suspended matter and release metabolites (remineralized material) that can be used by the phytoplankton.

A general discussion of water column interactions and monitoring took place after the panel completed their presentations. The panel presentations and the participant discussion indicate that the many and complex interactions need to be reviewed and understood to achieve conclusive answers to workshop questions.

The sense from the discussions was that "phytoplankton abundance should not always equal hypoxia" and that ecosystem interactions are very complex and interdependent. Ecological compartments suggested as important in LIS include:

- Biomass of key species (*e.g.*, gelatinous organisms)
- Export Production (feces, molts, carcasses, exuviae), particularly of microcrustaceans
- Nutrients and their chemical speciation and dynamic interactions
- N:P and N:Si ratios in the dissolved and total nutrient pool
- Ecological conditions such as
    - Stratification
    - Water Temp
    - Export of production from surface waters to bottom waters
    - Plankton community structure which may have multiple controlling factors
    - Benthic community and water column microbial dynamics
    - BOD and heterotrophic organisms affecting it
    - Pulse inputs (need to resolve spatial scales of input and influence)

All of these are believed to play a significant role in hypoxia. Because of the complex interactions among these factors, many participants felt that more research was needed before a specific indicator or suite of indicators could be selected. Participants specifically cited the need to look at N and P ratios and response of specific species to those ratios to better understand the status of the system and expected response to nutrient management. For example, brown tide toxic algae may actually thrive under decreased nitrogen concentrations and high phosphorus concentrations. Discussions indicated that research on the relation of the N to P ratio relevant to specific species survival could help determine optimum concentration levels, parameter selection, and for use in predictive modeling.

Participants agreed that studies linked to predictive models are important for understanding the interaction among nutrients, DO, and response of the ecosystem compartments. Discussions

addressed the fact that current models only represent planktonic animals (i.e., zooplankton) as single black box constants, rather than as functions, and that temporal data is not adequate to fully validate the model predictions. Discussion also addressed the need for more information on primary production.

Several suggestions were made for enhancing predictive models to improve resource managers' assessments of N inputs relative to DO response. These include:

- Focus on endpoints and rate processes for N, P, and C that affect the endpoints.
- Quantify thresholds (*e.g.*, what are acceptable conditions).
- Determine which research questions need to be resolved to provide more accurate model outputs.
- Evaluate the usefulness of existing variables with respect to system status monitoring.
- Assess what is needed to support monitoring of key variables throughout LIS.
- Measure responses in LIS to better predict system responses to change inputs.

Once confidence that the model accurately predicts these relationships is achieved, the model and the information and data gained from studies would be used to enhance understanding of: microbial loop dynamics, benthic processes, benthic/pelagic coupling, benthic index for biological integrity (multiparameter), and temporal response of community structure. Participants agreed that to generally understand the nutrient and water column dynamics and affects, it would be necessary to understand how the changes in higher trophic levels impact all parts of the ecosystem.

Some participants felt that ecosystem-based monitoring should be conducted even though all ecological interactions were not completely understood because monitoring and research can be conducted in parallel to increase system understanding. It was suggested that an adaptive management approach be used (*i.e.*, implement the monitoring plan to be based on the best current information and use information collected to adjust the plan).

One theme discussed relative to water column monitoring in an ecosystem-based program was the need to understand what portion of the "problem" is a result of human-based activities and what portion is attributable to natural processes and concentrations. This theme was repeated in many of the subsequent panels.

Near-shore Benthic Communities Panel

The second panel considered monitoring LIS benthic communities. The panel was asked to address questions similar to those requested of the water column trophic interactions panel. In many instances discussions within these two panels and the subsequent one on modeling overlapped. Although they have been individually noted here, the discussion from all three panels should be viewed from a unified perspective.

Dr. Roman Zajac from the University of New Haven was the first panelist to present information. He discussed how EMAP monitors the benthic environments of LIS and suggested that the EMAP approach to monitoring is not an effective approach in Long Island Sound. He noted that EMAP is designed to provide some general understanding of relative estuarine conditions among east coast systems, and suggested that it, however, is not an effective approach for monitoring at the scale of a specific estuary, such as Long Island Sound, because it does not incorporate the specific heterogeneity of a systems benthic landscapes and associated benthic communities. Dr.

Zajac provided examples of recent studies, which have characterized environmental heterogeneity in Long Island Sound (e.g. the special volume on LIS in the Journal of Coastal Research, 2000, Vol. 16 No. 3) and made several suggestions on improving monitoring specific to conditions and issues in LIS. A summary of his thoughts and suggestions on monitoring LIS benthic environments follows:

- A better understanding of structure and dynamics of the nearshore and offshore benthic communities of LIS is needed (the data are woefully sparse, primarily collected in the 1970s and before, and restricted spatially and temporally) and the ecological context for understanding monitoring results needs to be vastly improved through "basic" research.
- Monitoring can be effective for assessment of general trends and for localized applications (dredge disposal, energy facilities), but may not necessarily be effective for identification of suspected specific problems or development of solutions.
- Current monitoring programs, including EMAP, may not be adequate to successfully achieve any of the NEP goals.

Suggestions

- Address sampling design issues in coastal assessment by incorporating a variety of benthic landscapes and associated communities in LIS.
- Select fewer but more specific areas for more intensive monitoring—some of these could be selective patch/benthic landscape types—and/or address specific issues and resources (lobster habitat areas, hypoxia, oyster / shellfish beds, conservation areas – controls, coastal erosion/marsh loss).
- Conduct more extensive research on basic benthic dynamics such as responses to disturbance and recovery in a variety of benthic habitats.
- Inventory what we know. This is laborious and problematic (*e.g.*, due to different sampling techniques), but it would likely provide a more rigorous framework for interpreting monitoring results.
- Monitor key benthic species (including invasives) and develop population models (*e.g.*, lobsters, selected polychaetes and amphipods).

Dr. Carmela Cuomo, from Yale University, discussed her findings on bottom water and sediment conditions from data collected as part of an effort to understand lobster mortality events in LIS. She noted that a greater understanding of sediment oxygen demand (SOD), very near bottom (cm scale) DO responses, and the seasonal variations of sulfides and ammonia are needed. The following ecological conditions were noted as reasons for conducting this monitoring:

- The benthic organisms of LIS, including such commercial species as lobsters and oysters, come into constant contact with the near bottom waters of LIS.
- Low DO and the presence of sulfides or ammonia are known to stress many organisms.
- Stressed organisms are more likely to experience reduced growth rates, behavioral and physiological abnormalities, and to be more susceptible to viral and bacterial pathogens.
- Monitoring the very near-bottom water conditions of LIS may make possible an additional indicator of the "health" of the benthos within LIS. Research in this area may make possible a predictive tool for characterizing the likelihood of impairment to any one particular species in a given year.

Dr. Cuomo noted the following as LIS monitoring needs:

- Near-bottom water sampling and measurement for sulfides and ammonia should be routinely conducted concurrently with DO at ½- to 1-m above bottom.
- Conduct sampling monthly from November through May; more frequently during the summer and fall; possibly weekly from August through October the time from when sulfides and ammonia have been measured in the bottom waters.
- Measurement of benthic species (both traditional and benthic imaging), sediment organic content, and sediment dissolved oxygen demand should occur at the same sites and at the same time.
- The flux of sulfides and ammonia out of the bottom should also be measured (monitored).

This monitoring could be used:

- In conjunction with temperature data, to assess the likelihood that the waters that the benthic organisms contain sulfides and/or ammonia, during any given year.
- To expand our understanding of how the sediments in an estuary contribute to the overall chemistry of the estuarine water system.
- To plan best sampling times by incorporating measurement of metals and other contaminants.

The following research was recommended by Dr. Cuomo:

- Experiments that decouple the sediment system from the water column during the late summer-early fall in LIS, to separate benthic and water column processes.
- Characterize the magnitude of the daily, seasonal, and yearly trends in release of sulfides and ammonia from LIS sediments.
- Identify and characterize the benthic communities most at risk from sulfides and ammonia.

The next panelist to present was Dr. Robert Whitlach from the University of Connecticut (UCONN). He discussed the warming of LIS waters over the past 25 years and conveyed that a shift in the benthic community structure was occurring. Dr. Whitlach suggested that a systematic approach to monitoring benthic organisms is needed. He suggested that the number of non-indigenous species present in the ecosystem could be used to identify changes in benthic communities over time throughout LIS. He noted that the less richness/diversity there is within a system, the greater the potential is for invaders to become established.

Dr. Milan Keser, from Millstone emphasized the need to synthesize existing data. He discussed the need to know more about the rocky shore intertidal and hard substrate areas of LIS. He noted that the LIS system is changing, but the reason why is not always known. For example, in Niantic, there has been a decrease in Zostera, scallops, and fish and an increase in starfish. More monitoring and modeling of the biomass and source term of the rocky shore is needed to help understand these changes.

Upon conclusion of the panelist presentations, the floor was opened to general comments from the workshop participants. Several workshop participants noted that a better understanding of the structural dynamics of the benthos and general trends in communities is needed because data in this area is sparse. In addition, the discussion suggested the context in which monitoring is

conducted needs to be improved. It was suggested that fewer, more intense studies be performed to determine the differences between landscape variations and changes due to impacts. Such studies should focus on:

- Changes in the structure of the ecosystem (communities)
- Changes in the rates of processes
- Changes in function (does benthos use productivity, lose it or store it)

Participants also suggested that a committee be established to set monitoring priorities in these areas.

Living Resources Panel

The last panel of the first day of the workshop focused on the living resources of LIS. The focus questions for this panel asked if monitoring of higher trophic levels was adequate to manage recreationally or commercially important living resources throughout LIS. In addition, the panel was asked if monitoring of LIS habitats was adequate to support management.

Living Resource panel member, Mr. Dave Simpson of Connecticut's Department of Environmental Protection (CTDEP) presented information on CTDEP's Trawl Survey begun in 1984 looking at abundance, numbers and biomass (composite), length, and age of fish caught. The Trawl Survey also measures biomass time series on macroinvertebrates (*e.g.*, lobster, squid, and crabs). One correlation presented was that species richness and abundance is sensitive to DO concentrations. Mr. Simpson noted that the CTDEP Trawl Survey is used in stock assessments supporting interstate fishery management.

Dr. David Conover, of SUNY's Marine Sciences Research Center (MSRC), was the next panel member to present. He noted that the CTDEP's Trawl Survey produces an excellent time series database of fish abundance for unobstructed bottom areas of LIS. The New York DEC beach seine surveys also give valuable fisheries data, but only on the western portion of LIS. Dr. Conover felt the primary area not being monitored adequately is the abundance of fish life-stages in the upper water column (e.g., ichthyoplankton, larval, and juvenile finfish, and pelagic species). Dr. Conover noted that perceptions of the status of living marine resources in Long Island Sound are plagued by the problem of shifting baselines. Contemporary viewpoints tend to be influenced largely by trends experienced within the lifetime of today's scientists, user groups, and the public. Historical levels of abundance (e.g., 1-3 centuries ago) more nearly reflect pristine conditions, but lack of quantitative data or other forms of "memory" of the past leads to ignorance of what were the true baseline conditions of the system. Hence, the apparent "health" of a system is a subjective judgment that continually slips over time. In addition, he felt that knowledge of trophic linkages (the food web) is a highly useful framework for summarizing our overall knowledge of an ecosystem and how it functions and changes over time: software programs such as ECOPATH and ECOSIM are readily available tools that might be useful in constructing a summary of the LIS trophic system. For example, food web studies of other aquatic systems have shown that top-down effects from predators at the higher trophic levels can lead to eutrophication, algal blooms and ultimately hypoxia. One way of the best ways to try to measure the effects of resource harvesting on abundance and community composition is by establishing no-take reserves were extraction is prohibited. For some species, the creation of reserves can potentially lead to increased yields outside the reserve. For Long Island Sound, a no-take reserve aimed at protection of lobsters would be an excellent candidate.

Mr. Malcolm Shute, from Connecticut's Department of Agriculture (CTDOA) Department of Aquaculture, gave a brief presentation on the current programs being conducted by CTDOA. Mr. Shute was followed by Mr. Harry Yamalis of CTDEP. Mr. Yamalis gave an overview of eelgrass beds east of the Connecticut River, LIS water clarity, and anchorage areas and mooring fields over eelgrass beds in four Connecticut Harbors. In addition, he showed information on tidal wetlands loss, sedimentation-erosion in two rivers, and *Phragmites* expansion in the Connecticut River. Mr. Yamalis suggested that eelgrass beds be remapped on a regular basis and that sedimentation-erosion table monitoring be expanded to sites beyond Barn Island, reflecting the varying tide ranges along LIS. He noted that new spatial data on eelgrass beds would enable researchers to conduct trend analyses on past and future eelgrass losses or gains. In support of this monitoring, the LISS has provided funding to the U.S. Fish and Wildlife Service (USFWS) to collect data on the eastern shoreline of LIS for comparison with 1993-1994 data.

Dr. Jason Link, from the National Oceanic and Atmospheric Administration (NOAA), was the last panel member to speak during the session. He presented an overview of the National Marine Fisheries Service's (NMFS) Northeast Fisheries Science Center's (NEFSC) Bottom Trawl Survey. Key to this survey is the additional sampling that occurs beyond "counting" and weighing," particularly food habits sampling. From this data, he described a food web model that the NEFSC uses for studying the Northeast Shelf ecosystem. As an aside, he noted that many in the NEFSC have abandoned the term "ecosystem health" in favor of "ecosystem status because ecosystems go through different stages rather than dying. As complicated as food web models can be, they provide the framework for evaluating which are the most important processes within an ecosystem.

General comments made following the panel's presentations included a discussion on the importance of a research reserve. Workshop participants noted that due to the seasonal variability in the distribution of living resources throughout LIS, a research reserve would not benefit most fish species, but could potentially benefit lobsters and various benthic species depending on where it was placed. Defining key linkages to the water column processes were suggested for any research reserve. Other comments suggested other reasons for low adult and juvenile fish stocks, not just hypoxia, be evaluated. Questions were raised as to whether observed declines were a natural occurrence or impact related.

The discussion resulted in some recommendations for monitoring. These include:

- Selection of fewer areas to study in more detail
- Understand more on functional group classification before use of presence/absence index.

Also the monitoring program goals should include the element of documenting response to management actions (*e.g.*, habitat remediation or disturbances).

Modeling

Ms. Robin Miller of HydroQual Inc. gave an overview of the SWEM model. Her presentation was followed by a question and answer period on the SWEM model. After the question and answer period was completed, the modeling panel gave their input into what enhancements could be made to SWEM and what new modeling should be pursued. As part of their discussion, panelists were asked to note how these enhancements might aid management.

Dr. Robert Wilson of SUNY was the first modeling panel member to present. He noted that stratification in LIS is strongly linked to DO levels and that surface heat flux and wind stirring are

important measurements. Dr. Wilson suggested that the modelers consider assimilation of water column data in to the model as a means of improving its predictive capability.

Dr. Jim Kremer, from UCONN, suggested it is important to recognize two fundamentally different roles for modeling. And these roles dictate different goals for associated monitoring. Field data from monitoring can be used to document the status of systems and obtain a record of changes. This monitoring role is valuable even without full system understanding. In this case, models can help define what measurements need to be incorporated into monitoring, and to explore the consistency of the model, perhaps refining it over time, but the value of the monitoring does not decrease if the model is inaccurate. However, using a model as a management tool presumes that we understand much of how the system actually works. Monitoring then takes on the essential role of a way to corroborate the validity of the model. This is the position we are in now with the LIS/SWEM model. To test a model adequately, information about both rates and stocks is required. Since prior monitoring has measured only stocks, beginning to monitor rate information for processes is critical to test and eventually improve our confidence in the management model.

Dr. Jim O'Donnell, from UCONN, presented his suggestions for future modeling. He noted that present modeling inherently uses hindsight in its philosophy because complexity is assessed against model outputs that are fit to measures of status prior to performing forecasting or predictions of the future. Dr. O'Donnell presented his view that the future of modeling includes data assimilation. Moreover, he suggested models should be narrowed in scope to determine what is important and should use a correlation-based approach. He also presented his belief that models should ultimately drive technology and that models should be used to identify monitoring needs.

Mr. Jim Fitzpatrick, of HydroQual, then presented his opinions on how modeling fits to monitoring. He noted that models should focus on those parameters that cause stress by removing components of the model and that models should project the probability of an outcome. He proposed that LIS could have two models, one that projects conditions and one that projects the probability of biological response. Mr. Fitzpatrick noted that the objective of ecosystem management drives where the model goes. He suggested that a research question that could be investigated is the nitrogen/carbon levels and its relationship to hypoxia. A number of management decisions are being made by using the model rather than monitoring data.

After Mr. Fitzpatrick's presentation, a general comment session was held. The comments noted below cover those made following Ms. Miller's presentation and the Modeling panel.

Workshop participants and modeling panel members noted the following:

- Sensitivity analysis should be performed on the SWEM model to identify components that most strongly control hypoxia.
- Assess whether data assimilation techniques for temperature and salinity profile data can be performed with SWEM.
- The model should accurately incorporate stratification and surface mixing.
- The model needs to account for N:P ratio because as we reduce N we may setup conditions for harmful algal blooms.
- Use the model to partition natural variability from anthropogenic impacts.
- Explore simpler model of Nutrient-Eutrophication cycle decoupled from hydrodynamics.

- Add additional components only after they are demonstrated to have a significant role in hypoxia and that DO predictions are sensitive to their formulation in the model.

Monitoring data should be used to determine the status of the system; models should be used to predict what impacts changes would cause. The ability to assimilate monitoring data into the models to ensure they reflect more clearly what is or has been was viewed as very important. It was suggested that efforts should be shifted from understanding physical processes using the hydrodynamic model to monitoring actual physical conditions (conditions that lead to and support stratification) with assimilation of these data into the model. Scaling of physical process monitoring to areas of greatest variability and at sufficient frequency to capture pulse or key events will keep costs lower.

Ms. Miller suggested as part of her presentation that zooplankton sampling in LIS in support of modeling would be useful. Zooplankton sampling once a month over a year (annual cycle) would be helpful and would coincide with phytoplankton sampling. Carbon loading is an important part of the zooplankton component. Zooplankton data also should help address pathways to higher trophic levels. However, better communication between researchers and modelers is needed to obtain this information and determine what are the most important components

Additional monitoring suggested for improving the LIS models:

- Explore radar currents, satellite temperature and color (existing programs).
- Use data buoys with surface water, profile and bottom water logging of temperature, salinity along axis of LIS.
- Incorporate sediment trap data (type of information required was not defined), limited nutrient, chlorophyll and DO surveys (incorporate existing CTDEP program).
- Conduct bottom surveys at fixed stations to assess nutrient flux, benthic condition, and production.

Contaminants Panel

The next panel discussed contaminant monitoring throughout LIS. The panel was asked whether current contaminant assessments were adequate throughout LIS, and if additional or new indicators were advisable, to identify the risks and management responses.

Dr. Ellen Mecray, from US Geological Survey, Woods Hole Field Center, started the discussion with a presentation of data from USGS sediment sampling conducted throughout LIS,. The USGS conducted a multi-disciplinary study using sediment cores and surface sediment grabs to analyze and interpret the spatial and temporal distribution of contaminants in the Sound. The USGS has also compiled a database of historical geochemical and texture data in sediments for comparison with the current research.

The following are conclusions from Dr. Mecray's presentation:

- The multi-disciplinary approach allows for a thorough understanding of the transport, sedimentation, historical and recent contamination, and ecological changes in LIS.
- A monitoring program organized around the previous sampling efforts can build on the knowledge gained over the years.
- A monitoring program should sample in each of the sedimentary environments and should avoid highly variable urban harbors.

- Information and data from monitoring efforts should be made available to the science community for further interpretation and analysis.
- On the basis of factor analysis (using over 250 sample locations and 35 elements analyzed by USGS) , specific contaminants can be targeted and used to evaluate the overall ecological health of the Sound.

Dr. Mecray suggested that (1) future studies examine each type of sediment area, not just depositional areas; (2) Measurement of *Clostridium perfringes* (a tracer of sewage) and one representative metal, like Cu, may be possible in LIS to understand its status; and (3) Time-series sediment traps can be deployed to assess current particle-associated contaminant loadings.

Dr. Johan Varekamp of Wesleyan University presented information on environmental studies conducted by Wesleyan University, USGS, Bryn Athyn College, and the University of Massachusetts on LIS sediment cores. Using a variety of historical information and sediment cores from LIS, Mr. Varekamp and others researched the history of hypoxia in LIS looking at the last 1000, 400, and 50 year periods. This information is being used to determine under what conditions and at what times hypoxia/anoxia has occurred.

Dr. Drew Carey, from Coastal Vision discussed the need for an inexpensive assessment of bioavailability of the standing stock and flux of contaminants in the system. During his presentation, Dr. Carey noted that adequate assessments of metals in sediments have been made in LIS. Additional work is needed on metals in organisms. PAHs, PCBs, and radionuclides (pending USGS work) are needed in the sediments. Also, flux (out of sediments and into organisms) and trends for these parameters are needed. Dr. Carey noted that contaminants are not presently part of systematic monitoring or the SWEM model. Although they may not be needed for the model, a better understanding of the status of contaminant distribution and impacts would lead to greater clarity of status. He sees the goal of monitoring is to account for changes in ecosystem response to changes in anthropogenic activity. He suggested a greater understanding of the history of contaminant accumulation could provide a moving baseline unavailable for most other measures.

The last contaminant panel member, Dr. William Fitzgerald, from UCONN, provided several slides, which were presented by Dr. Carlton Hunt. The slides noted that the total mercury budget for LIS is reasonably well constrained. Levels of mercury appear to be decreasing. However, most mercury entering LIS (>75%) is anthropogenically derived. The suggestion was made that secular changes in aqueous mercury could be monitored periodically in cooperation with the CTDEP LIS Water Quality Surveys to determine status.

Dr. Fitzgerald also noted on his slides that the budget for the toxic species, methyl-mercury, is not as well constrained. Current understanding of key components (species and their interactions) of the cycle is limited. In situ production of methyl-mercury is hypothesized as the major source. Thus, mechanistic information is needed on methylation and demethylation reactions in LIS sediments and water. Since methyl-mercury bioaccumulates, food web studies are also needed. Metal speciation and reactivity is a very important part of future water quality related research in LIS as well as other coastal regions.

After all presentations were made, the discussion was opened to the workshop participants. Participants noted that there is an inadequate understanding of contaminant body burden in higher trophic levels and there is no monitoring of toxics in bottom waters. A list of priority contaminants that have a large effect on LIS should be established before expending funds to put

the data into a model. The first step for monitoring is to determine that flux is measurable and available because it is expensive to measure in sediment and tissues.

Synthesis/Next Steps Panel

The last panel of the workshop was focused on pulling together the information discussed during the previous panels along with discussing next steps towards ecosystem monitoring.

Dr. W. Frank Bohlen from the University of Connecticut led the first of the discussions during this panel. Below is a brief abstract written by Dr. Bohlen of his presentation.

> "Experience over the past year or so as well as many of the comments received as part of this meeting indicate that significant improvements in the monitoring of Long Island Sound are possible and needed. Despite the variety of efforts over the past twenty years we are too often unable to answer fundamental questions concerning the physical, chemical and biological characteristics of the Sound. As a result the establishment of cause and effect relationships is often impossible. This fact limits effective management of the resource and erodes public confidence in the scientific establishment. Correction of this situation requires some fundamental changes in our approach to monitoring. In contrast to present protocols that are too often simply procedural future efforts must seek to understand process. Monitoring plans must focus on specific questions and be designed to test specific hypotheses. The realization of this objective requires the implementation of procedures based on close coupling between numerical models and field observations. The process begins with the structuring of a conceptual model based on the problem to be addressed, relevant historical observations, and extant understanding of the factors affecting the problem as defined. This foundation phase might be supplemented by some amount of field sampling to fill in obvious gaps and/or to provide a basis for the calibration and verification of a predictive numerical model, which serves to frame the problem being considered. Subsequent monitoring designs should employ this model to optimize station locations and to define parameters of interest and the required sampling frequency. The resultant data must be sufficient to demonstrate model reliability and to provide a basis for model alterations, as required. The process should be systematic, continuing, and thoroughly iterative with model driving monitoring and the resultant data feeding the model. Sensitivity analysis is an essential part of this process and seems to be too often neglected. The science of this process must be complemented by an administrative structure that recognizes the need for and value of this close coupling between numerical modeling and field observations. The present structure too often favors segregation of these activities. Models developed for agencies are often constructed and then used unaltered for extended periods of time without consideration of changes in understanding or redefinition of the problem of concern. Monitoring proceeds to gather data using criteria with limited sensitivity to changing model or management needs. Only by the close coupling of these activities will the full potential of both be realized and only in this way will we begin to establish a framework sufficient to allow quantitative specification of the full range of factors governing the Long Island Sound ecosystem."

Dr. Larry Swanson, from SUNY, followed with a list of considerations for moving toward a system-wide monitoring program.

- Define goals and objectives clearly.

- Focus on health versus function.
- Data from the program must be processed in a timely manner.
- Data need to be turned into information for the public and others.
- Research data also needs to be reported.
- Research Reserves could be a useful tool.
- Modeling is important and is the best tool for organizing the framework.
- Exercise the existing LISS model more to address important issues.
- Anticipate environmental problems before they happen (formulate predictions).
- Assess changing conditions.
- Keep user community informed.
- Include a means to obtain good climate data for a monitoring program.

Dr. Swanson also discussed concerns of a monitoring plan:

- Often goals can be overly optimistic.
- Responsibilities are often undefined.
- Quality control issues are generally not worked out.
- Data are not interpreted in a timely manner.
- Costs need to be controlled.

The ultimate question to keep in mind is "What does the public want to know?" including:

- Can I swim in it?
- Can I eat the fish?
- Can I drink it?
- Can I enjoy it aesthetically?

Dr. Candace Oviatt, from the University of Rhode Island presented a synopsis of central issues that could be used as an organizing framework. In a query of the workshop participants, the following key issues were suggested based on the workshop discussions:

- Hypoxia – not completely understood, studied, or predictable,
- Lobsters and living resources (commercially important),
- Global warming,
- Habitat remediation (rocky intertidal, SAVs, marshes),
- Environmental stressors,
- Bays and harbors as sources or sinks for contaminants and nutrients,
- Jellyfish (abundance, diversity), and
- Links between contaminants and biological effects and fluxes are not established.

Mr. Richard Batiuk, of the Chesapeake Bay Program, gave suggestions on how the LISS could develop more support for ecosystem monitoring through:

- Developing a clear policy commitment to goals.
- Building an infrastructure for a scientific network in the LISS policy framework.
- Developing a community model.
- Changing state standards to reflect needs.

Mr. John Atkin, from Save The Sound, discussed:

- Developing Total Maximum Daily Loads (TMDLs).
- Issuing of a general permit.
- Developing a National Status.
- Prioritizing what needs to be studied.
- Developing better predictors.
- Reinvigorating the Scientific and Technical Advisory Committee (STAC) to work with the Citizens Advisory Committee (CAC) and LISS.

General Discussion after the panel member's presentations included suggestions to:

- Validate model predictions.
- Focus on validating or falsifying the models outputs and perform sensitivity analysis as a means of understanding the importance of the ecological terms in the models.
- Focus research needs on rates and process.
- Work at separating anthropogenic from natural variances over space and time.

Mr. Mark Tedesco gave a few closing statements to the workshop participants before the meeting was concluded. Based on the meeting Mr. Tedesco noted the following:

- LISS needs to make a case that monitoring and research of LIS is valuable nationally in understanding how systems respond to nutrient enrichment and nutrient control.
- Several additional research needs were noted; but not many monitoring needs were noted.
- Partnerships within federal agencies and with federal and research institutions are needed and an infrastructure to facilitate planning and cooperation.
- Better cooperation between the federal agencies, state, local, and other groups is needed.
- Research Reserves could be possible springboards to funding (being evaluated now) and platforms to assess top-down effects on the system.
- More interactions between modelers, managers, and scientists is needed.
- Research groups are disenfranchised; a mechanism is needed to bring the research community back into the realm.

Possible next steps from the workshop included:

- Revisit and, if necessary, redefine goals and objectives of the monitoring program.
- Refocus questions and research issues – sort out and integrate.
- Develop a plan to address model sensitivity (*e.g.*, What should the model be asked to address?).
- Prepare an implementation plan.
- Develop a communication plan to incorporate new knowledge into the program quickly.
- Successful collaboration is essential. A forum is needed to facilitate collaboration. Perhaps reinstituting the STAC will assist in this effort.

The workshop was asked to identify what elements were needed to transition from the current hypoxia-based monitoring into a LIS ecosystem wide program. Several areas of monitoring appear to be robust. These include:

- Water Quality in the Central and Western Sound (not including harbors and shallow coastal areas),
- Sediment metals levels, distribution, and trends,
- Commercial and recreational fishes,
- Mapping of wetlands and sea grasses appear to be in progress, and
- Physical measurements in same areas are covered well.

Areas that appear to be poorly monitored include:

- Systematic measurements in shallow coastal areas and harbors/embayments,
- Benthic community,
- Contaminants in fish and shellfish,
- Organic contaminants in sediments,
- Rocky shore and hard substrates,
- Beach seine program in eastern and central LIS.

Appendix A

Participant Invitation Letter and Agenda

Battelle
. . . Putting Technology To Work

From: Battelle\EPA OCPD\Long Island Sound Study

Date: March 6-7, 2002

Regarding: **Transition from a Hypoxia-Based Monitoring Plan to an Ecosystem-Based Monitoring Plan**

Enclosed is logistical information for the upcoming Long Island Sound National Estuary Program (NEP) Monitoring Plan Workshop being held at the University of Connecticut=s Avery Point Campus in Groton, CT on March 6-7, 2002 for which we have you scheduled as a panelist. The workshop will begin Wednesday, March 6 with check-in from 8:00 am to 8:30 am. The meeting will conclude on Thursday, March 7 no later than 5:00 pm.

As previously discussed, the workshop will review current on-going monitoring, research, and assessment activities being conducted on Long Island Sound, how monitoring interrelates on an ecosystem-wide basis and what steps need to take place to move toward a more ecosystem-wide monitoring plan. While the format of this workshop will be informal, it is an extremely important working\planning meeting to identify ways to improve Long Island Sound monitoring. We have asked all panelists/participants to come prepared to discuss items on the agenda including any enhancements, changes, or modifications you would like to propose. Your attendance and input is very important for transitioning the focus of this monitoring plan.

In preparation for the meeting, Mr. Mark Tedesco and Battelle will be setting up conference calls for each panel. An e-mail will be sent to you requesting your participation. The conference call should be no longer than 1-hour. During the conference call we will discuss the focus of each panel and give each panelist a chance to ask questions prior to the meeting. Panelists will be asked to give a brief overview of their perspective on the panel subject. Although not mandatory, panelists may bring overheads or short PowerPoint presentations to assist in their talk. Please let Ms. Lynn McLeod (mcleod@battelle.org) know if you will be needing an overhead projector or any additional items. Due to the limited amount of time for each session, panelists are requested to keep their presentations to 5 minutes or less.

☐ **Agenda and Workshop Materials**

Attached please find a copy of the workshop Agenda. Additional, workshop information will be sent out ahead of time for your review prior to the meeting.

☐ **Hotel Reservations**

A block of rooms has been reserved at the New London Holiday Inn for those needing to stay overnight. The block of rooms has been reserved for March 5-7, 2002 under the **Long Island Sound NEP Workshop**. The rate reserved under this room block is $69.00 per night plus tax. Hotel reservations must be made by February 28, 2002. Payment for hotel accommodations is the responsibility of each individual attendee. The hotel can be contacted for room reservations at:

Holiday Inn, New London B Mystic, CT
I-95 & Frontage Road
New London, CT 06320
P: 800.465.4329 or 860.442.0631
F: 860.442.0130

□ **Workshop Registration Information**

Although we already know you will be attending the meeting, we would appreciate you completing the attached registration form so that we may include the correct address and association information in the List of Attendees. Please return the form to Ms. Jennyfer Smith at the following address by February 22, 2002:

Jennyfer Smith
Battelle
397 Washington Street
Duxbury, MA 02332
Fax Number 781/952-5369 or 781/934-2124

We look forward to a very productive exchange of information at the workshop! If you have any questions regarding registration or logistical information please contact Ms. Smith of Battelle at 781/952-5398. If you have any questions on your role as a panel member, please contact Mr. Tedesco at 203/977-1541 or Ms. McLeod at 781/952-5381.

CONFERENCE REGISTRATION FORM
Transition from a Hypoxia-Based Monitoring Plan to
An Ecosystem-Based Monitoring Plan

Please return the Registration Form by February 22, 2001 to:

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Battelle
397 Washington Street
Duxbury, MA 02332
Tel: 781/952-5398
Fax: 781/952-5369 or 781/934-2124

(Please Print)

Name:_____
Affiliation:_____
Title:_____
Address:_____
_____
Telephone:_____
Fax:_____
Email:_____

☐ I will attend the Long Island Sound NEP Workshop on March 6-7, 2002.
Please check each day that you will attend.

_____Wednesday, March 6, 2002
_____Thursday, March 7, 2002

☐ I will be staying at the Holiday Inn, New London B Mystic, CT. Note: Attendees are responsible for their own reservations.
Please check each night that you will be staying at the hotel.
_____Tuesday, March 5, 2002
_____Wednesday, March 6, 2002

☐ I will not be staying at the Holiday Inn, New London B Mystic, CT hotel.

Transition from a Hypoxia-Based Monitoring Plan
to an Ecosystem-Based Monitoring Plan
Workshop Agenda
March 6-7, 2002

Wednesday, March 6

8:30-9:00	Coffee and Sign-In
9:00-9:15	Introduction, Welcome, and Purpose of Workshop Purpose: Discuss transition from a hypoxia-based monitoring focus to an ecosystem-based focus. Describe meeting structure and objectives.
9:15-9:45	Conceptual Framework for Ecosystem Monitoring Purpose: Present conceptual framework of LIS ecosystem functions and interactions and lessons learned from Massachusetts Bay Monitoring Program.
9:45-10:15	Monitoring Long Island Sound: Current Programs and Products Purpose: Summarize existing monitoring. Identify elements of ecosystem that are monitored and those that are not.
10:15-10:30	Break
10:30-11:15	Monitoring Coastal Ecosystems on the National Level Purpose: Present the EMAP approach to monitoring coastal ecosystems, results, and lessons learned.
11:15-11:45	Panel Discussions: Purpose and Expected Outcomes Purpose: Review elements of ecosystem that are monitored and modeled and those that are not. Of those that are, are the spatial and temporal scales appropriate? Of those that aren=t, what parameters would provide the most managerially useful information? Over what scales should they be measured? What new technologies should be considered?
11:45-1:00	Lunch (Possible lunch time talk on the MYSound program or the LISS Environmental Indicators)
1:00-2:00	Panel on Water Column Trophic Interactions Purpose: What measures of the rate and status of trophic interactions should be monitored? Over what time and space scales? What information on ecological condition will they provide and how can this information be used?
2:00-3:15	Panel on Near-shore Benthic Communities Purpose: What measures of the rate and status of trophic interactions should be monitored? Over what time and space scales? What information on ecological condition will they provide and how can this information be used?
3:15-3:30	Break
3:30-4:45	Panel on Living Resources

Purpose: Is monitoring of higher trophic levels adequate to manage recreationally or commercially important living resources? Is monitoring of habitats (*e.g.*, SAV, tidal wetlands) adequate to support management?

Group reception.

Thursday, March 7

8:45-9:00 Coffee

9:00-9:45 Modeling Long Island Sound
Purpose: Summarize Systemwide Eutrophication Model (SWEM). Identify elements of ecosystem that are modeled and those that are not.

9:45-11:00 Panel on Modeling
Purpose: What enhancements to SWEM or new modeling initiatives are feasible and should be pursued? How will these enhancements aid management?

11:00-12:15 Panel on Contaminants
Purpose: Are current contaminant assessments adequate? Are additional or new indicators advisable to identify risks and management responses?

12:15-1:15 Lunch

1:15-2:30 Panel on Synthesis/Next Steps
Purpose: What are the practical next steps for scientists, managers, and advocates to enhancing the monitoring of the ecological system of Long Island Sound? What enhancements should be priorities? How can Long Island Sound network and collaborate with other coastal monitoring and observing initiatives?

2:30-3:00 Workshop Summary

Appendix B

List of Attendees

Transition from a Hypoxia-Based Monitoring Plan to an Ecosystem-Based Monitoring Plan
March 6-7, 2002
Avery Point, CT USA
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