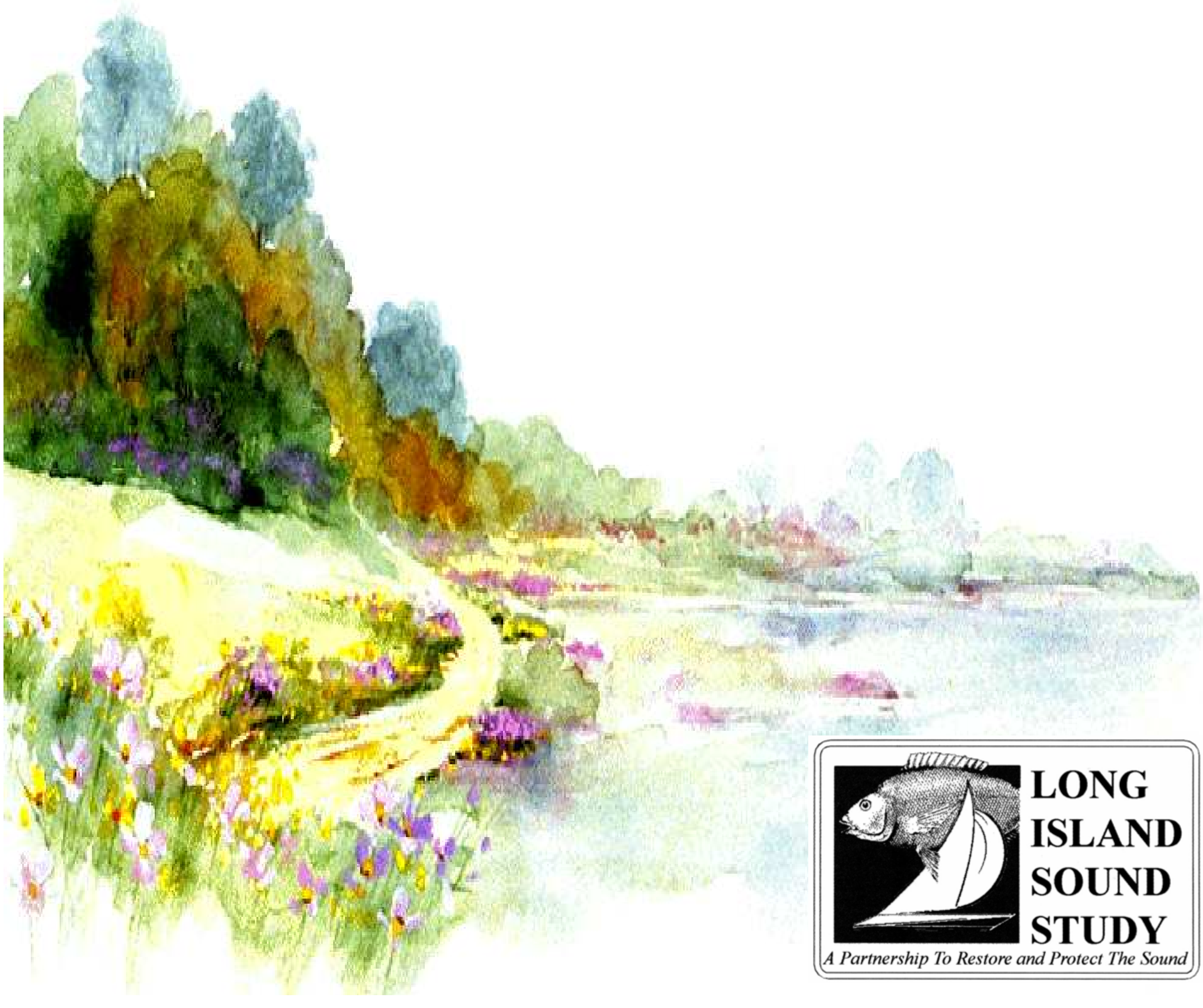
Long Island Sound
Tidal Wetland Loss Workshop
June 24 & 25, 2003
Stony Brook, N.Y.

Workshop Proceedings and Recommendations to the Management Committee of the Long Island Sound Study



LONG ISLAND SOUND STUDY

A Partnership To Restore and Protect The Sound

Acknowledgements

This workshop was made possible by a grant from the USEPA Long Island Sound Study, generous sponsorship from New York Sea Grant, the Marine Sciences Research Center of Stony Brook University, and the enthusiastic participation of all in attendance.

The success of this workshop is a testament to the dedicated professionals who gave of their time and expertise during this workshop to protect the living resources of Long Island Sound.

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Introduction

In 1999, the New York State Department of Environmental Conservation staff identified significant losses of intertidal marshes in Jamaica Bay, Queens, N.Y. These losses were occurring in spite of protective wetlands legislation and with no readily identifiable cause. A trend analysis conducted using aerial photography and historical survey charts indicated a fluctuating, but generally stable, intertidal marsh acreage between 1857 and 1924. Between 1924 and 1974 large losses were documented due to both direct dredging and filling related to land and port development, but losses averaging 10 acres per year had occurred for other reasons. The trend analysis further revealed an accelerating loss rate from 1974 to the present that appears to be unrelated to direct dredging and filling.

Department staff also began to document similar intertidal marsh losses in other New York estuaries. In particular, marshes in Long Island Sound appeared to be suffering from the same mysterious processes as those in Jamaica Bay. Staff at the Connecticut Department of Environmental Protection also observed apparent losses in the tidal portions of the rivers that drain to the Sound. This issue was brought to the attention of the Long Island Sound Study (LISS) Management Committee for further action. Funds were awarded to New York State to convene a workshop of experts in the field to address this problem.

The Workshop Format

The workshop was held on June 24 and 25, 2003 in Stony Brook, New York. Approximately 60 scientists and managers from the Long Island Sound region and from other parts of the country were invited to participate in the two-day forum. Approximately 50 people accepted the invitation and participated in the workshop. A list of attendees may be found in Appendix A.

The goal of the workshop was to create a strategy to address the issue of unexplained tidal wetland loss in the Sound that included:

- An assessment of current understanding of wetland loss processes
- A research agenda for Long Island Sound marshes
- Monitoring recommendations
- Management recommendations
- Restoration recommendations

During day one of the workshop, invited speakers presented research germane to the discussion of the issue of wetland loss in Long Island Sound. A list of speakers and the titles of their presentations appears below. Abstracts of the presentations and copies of the slides shown are attached in Appendix B.

Fred Mushacke :	Wetland Loss Trends in Long Island Sound NY
Ellen Hartig :	Salt Marsh Submergence: A Case Study in WLIS
Greg Edinger :	EPA Long Island Reference Wetland Project 1997 - 2000
Ron Rozsa :	Relative Sea Level Rise, Surface Accretion and Vegetation Change on Eastern LI Sound Salt Marshes

Scott Warren:	Relative Sea Level Rise, Surface Accretion and Vegetative Change on Eastern Long Island Sound Salt Marshes
Shimon Anisfeld :	Tidal Wetland Loss in the Quinnipiac River Estuary
Johan Varekamp :	Marsh Accretion under different rates of RSLR over the Last 1000 Years
Rich Orson :	The Paleorecord: What Historic Development during the Last Thousand Years may Mean to Present Day Wetland Losses
Alex Kolker :	Sedimentation Patterns in the Nissequogue River
Bob Wilson :	Changes in Harbor Hydrodynamics resulting from alterations in Wetland Morphology
Vivien Gornitz :	Sea Level Rise, Storms and Coastal Wetlands: A Regional Overview

Donald Cahoon of the U.S. Geological Survey gave a keynote presentation at lunch titled "Wetland Sediment Elevation Dynamics and Sea-Level Rise." A field trip to nearby Youngs Island in Stony Brook Harbor allowed participants to observe, first hand, losses typical of many areas in Long Island Sound. Appendix C contains photos of the field trip site and the analysis of losses in vegetated wetlands since 1974. Following the field trip a keynote address was given at dinner by R. Eugene Turner of Louisiana State University, titled "Disrobing at Many Shorelines." Extensive discussion was generated by the talks and field trip that carried into the next day.

Breakout Sessions

Day two of the workshop consisted of breakout sessions. The day was divided into three breakout sessions and a final plenary session. Each breakout session was divided into four individual groups, two in each of two discipline areas. Two groups discussed physical and hydrological factors, while two groups discussed geochemical and biological factors. Each group had a discussion leader and a student rapporteur to assist in capturing the discussion and preparing it for presentation at the final plenary session. Session one was a discussion of controls, stresses, and forcing functions of the tidal wetlands and loss mechanisms. Session two discussed the responses and impacts in the marsh to the stressors and controls identified in the first session. Session three used the findings of the first two sessions to generate recommendations for a research agenda, a monitoring program, restoration actions, and management of the issue. All of the discussion groups came together at the end of the day in a final plenary session to present the results of their discussions. The following sections represent the recommendations and consensus of the participants on moving forward in dealing with this important issue.

Breakout Session 1: Controls, Stresses, and Forcing Functions in Marsh Systems

The first breakout session discussion on forcing functions, stresses, and controls of marsh health generated lists of many potential factors in the process of marsh loss. Sediment budget and relative sea level rise (RSLR) data indicate that marshes in the Sound and nearby systems are theoretically receiving enough suspended material to allow marsh accretion to keep pace with RSLR. This has been the case in marshes in the Sound for centuries. Why it has begun to shift in the last thirty years is unknown. Discussions among scientists from the physical and biological disciplines generated a sense of uncertainty about how the physical and biological components of the marshes are interacting and what effect anthropogenic stressors are having on the marsh system.

Perhaps most importantly, the participants highlighted the need to gather baseline information on marsh health and spatial distribution on a regular schedule. This baseline data gathering should be done regardless of any specific research study, and would most appropriately be conducted by the natural resource management agencies in the Sound. The lack of these data is currently hampering efforts to determine the causes of the widespread marsh losses observed in the Sound. Understanding the causes will enable managers to define a clear course of action to prevent further loss.

Summaries of the discussions by individual breakout groups follow.

Biological and Chemical Group 1:

The group began by listing the primary stressors of marsh systems. These were nitrates, sulfides, salinity, pollutants, diseases, boat wakes, and morphological features like bulkheads. The pollutants of particular concern are herbicides, lime, creosote, and MBTE. Multiple stressors are present at most sites in the Sound and may be producing synergistic effects on the marsh. Some stressors present in the estuary at large may be exacerbated by local sources such as storm water outfalls.

Data gaps concerning the biogeochemistry of marshes in LIS, data on the marsh sediment elevations and plant composition, and marsh species variant strains hinder efforts to define the causes and effects of the stressors on the system. There is a need to identify the constituents and location of the turbidity in rivers draining to the Sound and how they have changed over time. Changes in the turbidity maximum in river systems may have led to changes in the sediment and pollutant loading to marshes.

Forcing functions were identified by the group as relative sea level rise, thermal and climate changes, increased variability of hydrological conditions, dredging, storms, and human population in the coastal zone. The thermal and climate changes can affect ambient CO_2 concentrations and increase the ice scour activity during winter. Climate changes may also increase the frequency or severity of storms and wave action.

Discussion followed on the formulation of a hypothesis that changes in the input of total nitrogen changes the sediment structure in marshes. The postulated chain of events begins with increased nitrate causing increased above-ground plant growth and relative reduction in below-ground biomass, this in turn causes peat decomposition through increased aeration of the peat, resulting in a less stable marsh. The resulting stressed marsh is more vulnerable to further stresses and forcing functions. There was also discussion about the potential for increases in nitrogen and phosphorus loading to the marsh to change the microbial activity in marsh sediments.

The importance of defining the process of marsh loss and the reality of what is happening in the marshes was also discussed. Important points that were raised included the possibility of cover type conversions from high marsh to low marsh, or from *Phragmites* to high marsh. These seemingly benign or even desirable changes could be signaling early problems in the marsh system. The extent of marsh break-up, as well as area of marsh accretion, needs to be determined through aerial photo interpretation to create an overall picture of the extent of the loss.

A final point of discussion involved the impacts of navigational dredging on nearby marshes. It is hypothesized that dredging may result in reduced inorganic material being deposited on marshes. Investigations into the importance of the inorganic components of marsh sediments are needed.

Biological and Chemical Group 2:

The group began with a general discussion of the full extent and implications of the marsh losses documented so far. Information on the spatial and temporal scale of the problem, as well as the particular characteristics of affected vs. unaffected marshes is critical to defining the problem. Measurements of hydroperiod, organic vs. inorganic soil components, micronutrient content, and basic parameters of healthy plant conditions are necessary to begin analysis of the problem. The detection of anthropogenic factors may lead to identification of reversible losses. The consistency of development in the coastal zone between 1940 and 2003 makes a good case for anthropogenic causes. Based on information gathered in the field so far, maintaining the remaining marshes is vital since revegetation of fragmented areas does not occur even in the presence of available seed banks.

The group went on to outline the controls and stresses they believe are affecting Long Island Sound marshes. The biotic factors include leaf miners and other insects, geese, crabs, burrowing action by fiddler crabs, periwinkle snails, and epiphytic organisms. Hydrologic effects include fresh water pulses, climate change, ground water quality, ground water withdrawal, and pore water characteristics. Sediment characteristics such as grain size, species composition of the peat, the bulk density of sediments, the inorganic vs. organic volume, sediment boundaries and discontinuities are all important influences on the health of the marsh.

The group discussed how biogeochemical processes in the marsh become disrupted and, in turn, cause degradation of the marsh. The majority of these processes are tied to eutrophication of the marshes and waters of the surrounding estuary. Changes in nutrient composition and nutrient levels in turn cause changes in the allocation of resources to above and below ground biomass of marsh plants, sulfite reduction in marsh plants, changes in microbial action in marsh soils, and altered denitrification. Eutrophication may also play a role in changes to the marsh epiphyte community, changing the shading effects and fouling organisms present. Changes in nutrient type and abundance also affect the above and below-ground biomass of the marsh by changing the root to shoot ratio. Eutrophication can increase biomass of macrophyte species, especially *Ulva lactuca*. Dense mats of *Ulva* become stranded on the marsh surface and can kill *Spartina alterniflora*. This can also happen with dense rafts of *Phragmites australis* stems deposited on the marsh surface.

Climatic changes in the estuary were discussed. The increase in carbon dioxide content of the atmosphere may be driving changes in the plant community. Climate changes may also be influencing the amount of ice formation and damage to the marsh during winter months.

Physical and Hydrological Group 1:

The group began by discussing the factors that control a marsh at equilibrium and what stresses upset that equilibrium. Sea level rise controls the marsh in that relative sea level rise at an appropriate rate facilitates marsh accretion, but relative sea level rise at too great a rate causes the marsh to drown. Relative sea level rise and marsh morphology drive tidal range and hydroperiod on the marshes. Sedimentation rates, bed load, relative organic and inorganic sediment fractions, and resuspension rates also influence marsh accretion.

The group then discussed the data needed to determine the root causes of marsh loss. Sedimentation characteristics need to be investigated to fully understand the implications of relative sea level rise on the marshes. Measurements of hydroperiod on the marshes provide critical information for determining the mechanisms of marsh breakup. Subsidence is an additional component that must be examined to understand the driving process of marsh loss. Both surface and ground water inflow must be examined for their impact on subsidence and marsh vegetation. Currents, wave energy, and ice scour are all erosive effects on the marsh.

Geomorphology of marshes across the Sound, including depth of peat, size of the marsh, and shape of the marsh and basin should be compared for common characteristics of fragmenting marshes. Examination of seasonal cycles of tides, variability caused by larger climate processes such as the North Atlantic Oscillation, and changes in ocean circulation need to be examined to separate seasonal variation from overall changes over time. Looking at human alterations of the system over time is also important, although the group recognized that loss is too wide spread to blame on any single type of land use. This is further supported by the documentation of losses in sub-estuaries with relatively little development.

The group discussed the importance of changes in marsh zonation as an indicator of larger changes in the marsh. Biotic factors like bioturbation, biocementation, and grazing by geese may all factor into the efficiency of the marsh in trapping sediments.

Physical and Hydrological Group 2:

The group began by identifying sea level, sediment supply, subsurface processes, and subsidence as forcing functions. The individual mechanisms of subsidence must be identified in fragmenting marshes. These are subsurface withdrawal of water and natural gas, compaction by ice, storm surges, and surface deposition both by sediment transport and dredge spoils.

The accumulation rate in the marsh is comprised of both organic and inorganic accretion. The factors influencing organic accumulation were identified as above ground biomass, root biomass, nutrients, below-ground hydroperiod and ground water inputs, surface and sub-surface drainage, species composition of the marsh flora, and salinity. Factors influencing inorganic accretion are hydroperiod, surrounding land use and level of development in the watershed, sediment supply, and storm frequency and severity. Erosion acts as a counterbalance to all of these and is influenced by the position of the marsh in the estuary. Physical location determines the wave action, tidal currents, and amount of bank slumping that occurs in a marsh. Human activity alters several of these factors through dredging, land use changes, and on a larger scale, climate change. Marsh drainage, in particular, has been subject to human intervention. Installation of tide gates, ditches, dikes, and Open Marsh Water Management actions have altered the tidal prism and natural drainage dynamics of marshes. Non-human biotic factors such as animal grazing, bioturbation and tunneling, wrack deposition, and decomposer community alter the floristic characteristics of the marsh.

The group summarized their findings about controls in the system and the effect each one has on marshes in Long Island Sound. The conclusions are presented in descending order of importance as determined by the group.

The most important factor according to his group is relative sea level rise and its role in waterlogging marsh substrates to cause submergence. While cause and effect may not be a singular determination in the case of marsh loss, this one factor can be shown to have a direct relationship in the marshes.

The overall hydrology of the site was next in importance due to its control over accretion, subsidence, erosion, below ground biomass accumulation, and the structure of the biotic community. Examination of the underlying geomorphology of marshes and local tide information is crucial to fully understanding the role of hydrology in the loss of marshes.

Anthropogenic effects control the nutrient and contaminant inputs to the marsh, sediment distribution in the estuary, alteration of the individual hydrology and hydroperiod in marshes, disruption of the food web in the estuaries, and exacerbation of wave action on the marshes by boats and personal watercraft.

Closely allied with the hydrology of the site is the geomorphology and landscape position of the marsh in the estuary. This, in turn, influences the accretion and substrate composition of the marsh.

Finally, climate influences the primary production in the marsh and surrounding waters, the rate of decomposition in the marsh, sediment supply, salinity, and storm frequency and intensity.

Breakout Session 2: Responses and Impacts

The second set of breakout group discussions focused on the responses of marshes in Long Island Sound to the controls, stresses, and forcing functions identified in the first breakout session. Participants were given the option to remain in the same discussion group or to change to a different group. As with the first session there were two groups discussing biological and chemical responses, and two groups discussing physical and hydrological responses. All the groups approached the second session by proposing hypotheses to be tested and posing questions about the process of marsh loss.

Biological and Chemical Group 1:

Discussion began with questions about the impacts of eutrophication on the sediment structure and microbial activity in marshes. Nutrients are related to abundance of eelgrass beds in the estuary. Managers have observed larger eelgrass beds near healthier marshes. The conversion of eelgrass to macroalgal beds may be an indicator or feedback mechanism for marsh loss. The loss of eelgrass in the 1930s may be a first step in degradation followed by the currently observed losses of vegetated wetland. The group formulated the hypothesis that increased total nitrogen input modifies the sediment structure in marshes. Increased phosphorous may also play a role.

The idea of sediment starvation was discussed in the context of changes in dredged material management. Dredged material was historically placed on wetlands, thereby retaining the sediments in the system. Now most dredged material is disposed of upland or offshore, potentially creating a sediment sink in the wetland. Investigating correlations between dredging activity near wetlands and extent of marsh breakup in that area should be performed. This needs to be tied to investigations of relatively intact marsh systems like the back barrier area of Fire Island near the Carmens River. The river still has natural flow patterns and the barrier beach shows some new marsh formation. The group cautioned, however, that gains of wetland in less urban areas do not necessarily balance or explain losses in more urban areas. This further highlights the need for a trend analysis of marsh loss system-wide that can be correlated to the perceived stressors in the system.

Invasive species are of great concern because little is known about their impacts on the marsh system. Asian shore crabs may affect the marsh structure. Native crabs are known to perforate the peat and perhaps boost productivity of marsh plants. Resident Canada geese create stress on the marsh by eating the young shoots of *Spartina* and depleting below-ground biomass by forcing regrowth of leaves. This could be significant when coupled with boat and personal watercraft wake erosion in marsh channels.

There is need to study the potential impacts of chemicals in the marsh system. Sewage, fertilizers, heavy metals, MBTE, petroleum hydrocarbons, and pesticides may have altered the system in subtle ways. They have great potential for disrupting the food web in marshes as in the effects of DDT on green fly larvae. Comparison of least disturbed marshes to those experiencing fragmentation is necessary to observe these effects.

Biological and Chemical Group 2:

The group began their discussions in this session by examining the role of sulfide in marsh health. The group hypothesized that changes in sulfide concentrations in the marsh change denitrification rates and patterns. Examination of the extant literature is necessary to determine what the maximum levels of sulfide should be in a northeastern marsh and examine methodology for field measurements of sulfide. Documenting variations in sulfide across marshes may be a key to determining mechanisms of marsh fragmentation. However, sulfides are just a reflection of ambient conditions, so care must be taken to identify the underlying drivers of sulfide in the marsh. Examination of air deposition, ground water input, and surface runoff contributions of sulfide is an integral part of marsh characterization of sulfide processes.

Boat wake as a degrading force in marshes was discussed in the context of boat speed, tide stage, and distance from the marsh. Development of modeling data will allow managers to demonstrate a clear negative effect on marshes if one exists. The data will also generate guidance on potential buffer zones.

Observations of documented marsh fragmentation indicate that there are some remaining areas in the system that are healthy or improving. Examination of this phenomenon within marshes and across marshes may shed some light on the fragmentation characteristics. The question of whether all the degradation is occurring at a similar elevation or position within marshes is fundamental to understanding the sequence and mechanics of marsh loss.

This group discussed Canada geese as well as other grazing waterfowl and their effect on marsh fragmentation. Brant, swans, and snow geese are all potential grazers on the marsh surface along with Canada geese.

The macronutrient requirements and ideals of *Spartina* and other marsh vegetation should be culled from the literature. Where data gaps exist, test plot experiments in the field should be conducted. This will allow better understanding of the implications of chronically eutrophic waters on the marshes. The group hypothesized that excessive nutrient species may be causing *Spartina alterniflora* to shift biomass production to vegetative growth rather than seed production. Investigations into rhizomatic growth versus sexual reproduction will shed light on this issue as well.

Physical and Hydrological Group 1:

The group began the session by discussing the effects of sediment supply on marshes. Determining what changes may have occurred in sediment supply over time is key to understanding what may be causing the marshes to drown. If marshes are unable to keep pace with relative sea level rise, then the reason for this must be determined. Sediment availability should be measured and the opportunity for sediment deposition onto the marsh must be determined. The sedimentary fractions of organic versus inorganic particles may have changed. The effects of this change are unknown, as is the separate importance of each fraction. These roles may change across marsh zones, as from high marsh to low marsh.

Determining the sequence and extent of loss is key to understanding the whole problem. Chronological examination of aerial photography sets and ground mapping of gradients from east to west and low marsh to high marsh should yield common characteristics of healthy and degraded marshes. Documenting landward migration of high marsh is important to help separate sea level rise and other hydroperiod effects like dredging and inlet alteration. Microtopography patterns in the marsh interior seem to be significant in the early stages of marsh break up. Very small depressions are the first areas to show stress. Altered drainage through ditching and ditch infilling seem to conflict with hypotheses about relative sea level rise, although the real effects of ditching may be on the fresh water flows and overall water table of the marsh. Changes in the marsh salinity have traditionally followed ditching and could be creating salt stress on the plants.

Physical and Hydrological Group 2:

The group began with a discussion of the time scale involved in the application of stressors and the marsh response. Below ground biomass and subsidence of the marshes is a critical point of understanding that no one is investigating in the Long Island Sound system. The landscape location of the marshes needs to be correlated with the loss patterns to determine common geomorphological attributes of fragmenting marshes.

Marsh submergence occurs in response to complex processes like erosion, increased water area, substrate decomposition, hydrologic changes due to ditching, diking, and dredging, changes in sediment supply. The plants in the marsh may respond to subtly different effects of erosion, increased water area, and disruption of the wetting and drying regime. Development of a conceptual model of Long Island Sound marshes may assist in determining the relative magnitude of any one stressor. The group felt that stressors were leading to a cascade effect within fragmenting marshes.

Panel Recommendations

One overriding comment from the participants in the workgroups was that the causative factors in marsh loss are largely unknown, both in Long Island Sound and elsewhere in the country. The participants surmised that multiple factors are likely to be at work in the losses observed thus far. It is difficult to determine without careful additional investigations which degrading factors are causative, which are exacerbating the degradation, and which are symptomatic of the existing degradation process. Comparative studies of affected and unaffected marshes are critical to understanding the process of loss. It is unclear at this time what role landscape location and geomorphology of individual marsh systems play in the degradation of the marsh vegetation. The panel also felt strongly about the need for regional collaboration and coordination of research, monitoring, restoration, and management activities. The panel had several specific recommendations in each of the categories.

Research recommendations:

1. Create a conceptual model of the salt marsh system in the Sound. The creation of a conceptual model will aid in the definition of causes and effects of degrading forces on the marsh. The specific components of the model should include:
    - Identification of chemical processes in the marsh and their role in plant health and peat accumulation.
    - Identification of biological processes from bacterial activity to vertebrate gazing. Correlation of biotic data on waterfowl populations, snails, crabs, mussels, insects, molds, and parasites to marsh health whenever possible.
    - Characterization of both above and below-ground biomass and the relationship between the two and marsh health.
    - Characterization of the substrate properties in marshes, defining the organic and inorganic constituents and their relative importance in marsh accretion.
    - Identification of potential system stressors and threshold values for negative effects including:
        - chemical pollutants like MBTE, DDT, herbicides, petroleum, and others
        - physical processes like boat wakes, dredging, ditching and ditch plugging
        - hydrological factors like ground water withdrawal, alteration of surface flows through storm water redirection, changes in local hydroperiod due to bathymetric changes and shoreline hardening.

2. Conduct wide-scale investigations across gradients of several kinds. These types of comparative evaluations will help characterize what role physical location or local conditions are playing in the sequence of marsh loss. Investigations should include but not be limited to:
    - differing tidal range;
    - marshes affected vs. unaffected by loss;
    - differing salinity regimes;
    - differing marsh geomorphology, e.g. river basins vs. back barrier marshes;
    - presence or absence of alterations such as ditching and dredging; and
    - sulfate reduction processes should be detailed along with pH and sulfur profiles across marshes.

3. Conduct manipulative experiments on tidal wetlands to identify limitations in the existing system. These data can be used to validate and refine the conceptual model. Experiments should be conducted *in situ* as well as in the laboratory. Specific experiments should include:
    - manipulation of nutrient regimes, including organic and inorganic inputs of phosphorous and nitrogen;
    - manipulation of biotic communities;
    - transplantation experiments with *Spartina*; and
    - manipulation of sedimentation regimes and resultant effect on marsh health.

4. Conduct assessments of anthropogenic effects on marshes in the Sound. These results will facilitate further meaningful management recommendations to protect long term marsh health and stability. These assessments should include:
    - analysis of categories of regulated activities occurring adjacent to marshes and the relative health of those marshes;
    - human population and land use changes over time as correlated to marsh formation and loss;
    - physical studies of the erosive properties of boat and personal watercraft wakes on marsh peat; and
    - effects of proximal dredging on stability of and sediment transport to marsh islands and fringing marshes.

5. Conduct studies of marsh accretion rates to better understand the local reaction of marshes to relative sea level rise. These assessments should include investigations into the changes in sediment budgets and supply on a time scale of not less than 300 years. The Foraminifera communities of sediments and radioisotopes should be characterized as markers of change in the system. The Foraminifera communities are indicators of climate changes and the radioisotopes are date and source indicators in the sediment horizon. Changes in sediment properties over time should be analyzed.

Monitoring Recommendations:

The panel strongly urged that the Long Island Sound Study initiate and maintain responsibility for basic annual monitoring of marshes around Long Island Sound. There is a need for consistent baseline monitoring irrespective of any one research investigation. The LISS needs to establish monitoring protocols and create an accessible data set for the research and management community.

1. Develop a regional marsh sampling framework coordinated by the Long Island Sound Study. The sampling should be stratified and examine geomorphology, stressor ranges, biotic condition and community, hydrology, elevation trends and accretion rates. As part of this framework, a Sound-wide system of reference marshes needs to be established for long-term study. The reference sites should include both healthy and degraded marshes, within-marsh variation measurements, tide gauges, permanent plots and transects, marker horizons, and Surface Elevation Tables. These basic investigations as critical to understanding and addressing the mechanisms of marsh loss in Long Island Sound.

2. Define the loss of marshes on both a temporal and spatial scale. The marshes in the Sound need to be re-inventoried immediately. Inventory should be conducted on a regular schedule of no less than every five years. Longer intervals are significantly less useful in defining system processes. Supplemental oblique angle videography should be taken annually to depict the elevation of marshes. Additional photography should be obtained following major storm events.

3. Use inventory information to conduct a comparative trends analysis from all available data sources. Use this information to characterize the pattern of wetland loss in as much detail as possible. Describe recurrent patterns in fragmenting and healthy marshes.

Restoration Recommendations:

The panel recommended that LISS continue funding restoration projects under the Habitat Restoration Initiative. LISS should continue act as a coordinating body for regional restoration efforts and seek new data collection on restoration project success and failure to use in the overall management decision making process.

1. Continue restoration treatments using an adaptive management strategy. Include analysis of success in marshes lost to fragmentation versus marshes lost to other more "natural" processes like sand shifts at inlets. Restoration projects should make use of coconut fiber products as wave breaks and artificial peat to combat erosion and subsidence. Dredged material should be sought to raise elevations on fragmented marshes. All projects need consistent monitoring and course corrections.

Management Recommendations:

1. Conduct a full literature search of Long Island Sound research. Use the results to determine optimal requirements for plants in LIS marshes to be incorporated into the conceptual model recommended above. Analyze what gaps exist in the data and use to prioritize further research.
2. The LISS should prioritize stable funding for marsh monitoring as an ongoing work item.
3. The LISS should continue in its coordination role among agencies and researchers to facilitate effective management of marsh loss in the Sound.
4. The LISS should continue in its coordination role among agencies and researchers to facilitate needed research as outlined above. This coordination role should extend to making data readily available to researchers and managers.
5. The LISS should continue to display leadership in bringing attention to the important issue of marsh loss, and educate the public, research community, lawmakers, and natural resource agencies about the issue both locally and on national level.
6. Monitor ongoing projects to ensure that restoration and management actions such as ditch maintenance, Open Marsh Water Management, and *Phragmites* eradication efforts are not inadvertently harming marshes over the long term.
7. Use ongoing nitrogen reduction planning to target nitrogen removal at localized sources impacting marshes.

8. Advocate "hands on" management and maintenance of marshes in public ownership. It is clearly inadequate to simply protect marshlands through acquisition.
9. Investigate policy recommendations to accommodate landward retreat of marshes. This will likely require some means of addressing shoreline hardening.

Next Steps

The panel strongly recommended a follow up forum on this topic. They advocated broader inclusion of regional and national researchers and managers. They felt that the interplay between researchers and managers in different disciplines was particularly useful.