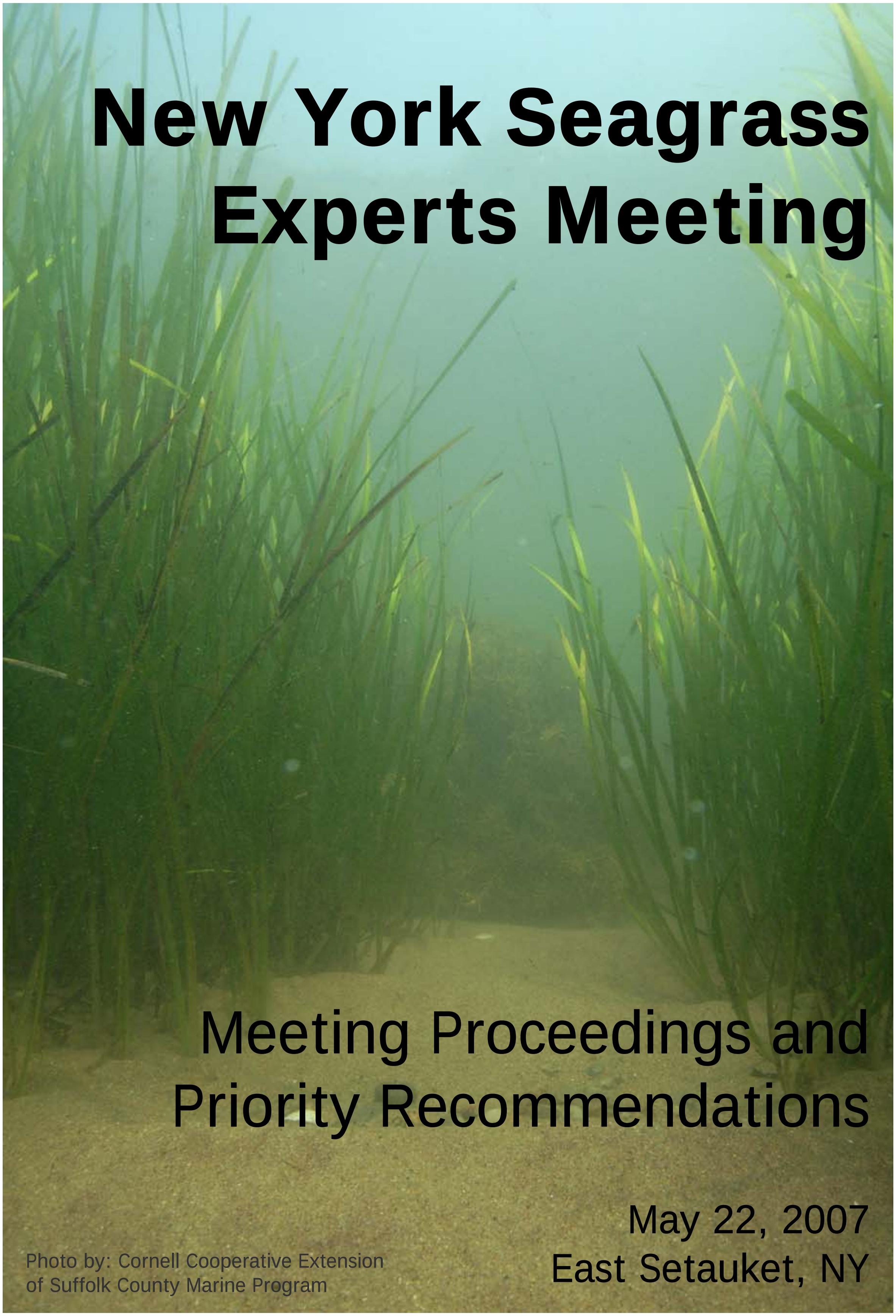

# New York Seagrass Experts Meeting

## Meeting Proceedings and Priority Recommendations

May 22, 2007
East Setauket, NY

Photo by: Cornell Cooperative Extension of Suffolk County Marine Program

## Acknowledgements

This meeting was sponsored by the New York State Department of Environmental Conservation, New York Sea Grant, Peconic Estuary Program, Cornell Cooperative Extension, The Nature Conservancy and the Long Island Sound Study.

A special thank you to members of the Steering Committee for their many months of strategic planning, and the Experts Panel for their unsurpassed dedication and enthusiasm.

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## Introduction

Seagrasses are rooted, underwater vascular plants which grow in shallow coastal waters. While several different species of seagrasses exist, the two most commonly found species in New York's coastal waters are eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritime)*. These submerged aquatic vegetation (SAV's), are considered to be some of the most productive ecosystems in the world and are biologically, ecologically and economically important. Seagrass beds stabilize benthic sediments, support nutrient cycling, oxygenate waters, improve water quality, and provide critical habitat for aquatic species (e.g., fluke, bluefish, bay scallops and hard clams). The presence of seagrass is often used as an indicator of estuarine health and high water quality.

Long Island marine waters once supported bountiful populations of seagrass. The onset of a wasting disease *(Labyrinthula zostorae)* in the early 1930's was responsible for the significant decline of eelgrass beds along the entire Atlantic seaboard. Light shading effects of Brown Tide occurrences in the 1980's further decimated eelgrass populations. Long Island seagrass populations may also continue to be impacted by nutrient enrichment, fishing and shellfishing practices, and recreational use of shallow waterways. Despite management and restoration efforts and significant improvements in water quality, populations are still declining and have not rebounded. Monitoring efforts in Long Island Sound, the Peconic Bays, and the South Shore Estuary indicate that these individual estuarine systems have each experienced separate and distinct trends. If qualitative and quantitative improvements in eelgrass beds are sought, these systems and their respective trends must be examined further.

Acknowledging the importance of seagrass and the necessity to protect and restore this valuable natural resource, Governor George Pataki enacted Chapter 404 of the Laws of 2006 on July 26, 2006, which established a New York Seagrass Task Force within the New York Department of Environmental Conservation. This Task Force is charged with examining the current state and make recommendations on means of restoring, preserving, and properly managing seagrass. Task Force meetings have since commenced in early 2008; the legislation can be found in Appendix A.

In the meantime, several representatives from various agencies and organizations decided to proceed with heightening awareness of declining seagrass trends, and drawing attention to the need of directing resources to foster an increased understanding. Consequently, a Steering Committee was formed. Members included:

Rick Balla*, United States Environmental Protection Agency/ Peconic Estuary Program*
Marci Bortman, *The Nature Conservancy*
Jerry Churchill, *Adelphi University*
Karen Chytalo*, NYS Department of Environmental Conservation, Bureau of Marine Resources*
Corey Garza, *National Oceanic and Atmospheric Administration/Long Island Sound Study*
Jack Mattice*, New York Sea Grant*
Brad Peterson, *State University of New York*
Chris Pickerell, *Cornell Cooperative Extension*
Cornelia Schlenk*, New York Sea Grant*
Laura Stephenson, *NYS Department of Environmental Conservation/Peconic Estuary Program*

This Steering Committee would organize a Seagrass Experts Meeting that would help establish a body of background information look at past and current trends, facilitate discussion between local seagrass experts, and gain insights from nationally renowned seagrass scientists and managers.

## Meeting Format

The main goal of the Seagrass Experts Meeting was to have a scientific panel of experts reach a consensus about what information gaps would be the most important to fill in order for New York to move forward most efficiently and effectively toward preserving and/or restoring seagrass habitat.

The first step was to establish a panel of seagrass experts. In an attempt to create a diverse panel, individuals were selected based on unique expertise and complementary knowledge and experience. The Steering Committee was extremely fortunate in being able to secure the interest and participation of several key, nationally-recognized seagrass experts; some located on Long Island, while others based in Alabama, Florida, Maryland, New Hampshire and North Carolina (see Figure 1). Brief biographies of Expert Panel members can be found in Appendix B. The Expert Panel was asked to attend a meeting to learn about conditions in New York, synthesis and integrate information through discussion, and then develop recommendations on research, management and monitoring priorities.

**Figure 1- Experts Panel** (L to R):
Paul Carlson (Florida Fish and Wildlife Conservation Commission), Bradley Peterson (Stony Brook University), William Dennison (University of Maryland), Kenneth Heck, Jr., (University of South Alabama), Mark Fonseca (NOAA National Ocean Service), Chris Pickerell (Cornell Cooperative Extension), A. Coolidge Churchill (Adelphi University), Fred Short (University of New Hampshire).

The next step was to identify local scientists, researchers, and managers to present the local context and set the stage for the Experts Panel's deliberations. These individuals were to address the relevant physical, biological, and chemical characteristics of Long Island Sound, the Peconic Bays, and the South Shore Estuary, as well as past and current status of seagrasses in those systems. Brief biographies of those presenters may be found in Appendix C.

The New York Seagrass Experts Meeting was held on May 22, 2007 at the New York State Department of Environmental Conservation Bureau of Marine Resources Headquarters located in East Setauket, New York. To keep the Meeting as focused and productive as possible, invitees were limited essentially to the Steering Committee, the local presenters, and the Experts Panel (see Appendix D). The agenda (see following page) began with presentations of local information to set the stage (see Appendix E for presentation abstracts and slides). Question and answer periods followed, proceeded by Expert Panel deliberations which continued late into the evening. The output of the Expert Panel deliberations was a table of priority actions (see Appendix F) which identifies:

- The ranked order of priority;
- Whether it is a research, monitoring or management activity;
- What the recommended action is;
- Tasks to be undertaken to accomplish the action;
- An estimate of the time period required; and
- An estimate of the costs involved

Expectations of the Steering Committee were well exceeded. An incredible amount of information was shared and valuable new connections between individuals made. Most importantly, priority recommendations reflect those of informed, interested, and impartial experts. Those recommended actions provide a needed, well-founded direction for New York's future efforts to preserve and restore the seagrass beds of its estuarine waters.

# AGENDA
## Seagrass Experts Meeting
## May 22$^{nd}$, 2007
## NYSDEC Bureau of Marine Resources

**8:00am** **Registration and Continental Breakfast**

**8:30am** **Welcome**
Jack Mattice, Ph.D- *Director, NY Sea Grant*

**Overview of Meeting**
Karen Chytalo- *Section Chief, Marine Habitat Protection, New York State Department of Environmental Conservation, Bureau of Marine Resources*

**8:45am** **Snapshot of Long Island Marine Waters: Physical Characteristics**
Short presentations, each followed by questions/discussion

**1. Water Quality-Nutrients, Phytoplankton** (approx 8:45-9:00am)
Chris Gobler, Ph.D.- *Associate Professor, Marine Sciences Research Center, Stony Brook University*

**2. Linking Groundwater, Pesticides and SAV's** (approx 9:00-9:15am)
Ron Paulsen- *Hydrogeologist. Suffolk County Department of Health Services, Office of Water Resources*

**3. Marine Sediment Geo-chemistry** (approx 9:15-9:30am)
Kirk Cochran, Ph.D.- *Professor, Marine Sciences Research Center, Stony Brook University*

**4. Habitat Modification & Loss of Suspension Feeders** (approx 9:30-9:45am)
Brad Peterson, Ph.D.- *Assistant Professor, Marine Sciences Research Center, Stony Brook University*

**9:55am** **Break**
Display of current and historical eelgrass maps

**10:10am** **Status, Historical Distributions, and Current Management and Research Approaches**

**1. South Shore** (approx 10:10-10:25am)
Chris Clapp- *Estuary Specialist, The Nature Conservancy*

**2. Peconic Estuary** (approx 10:25-10:40am)
Steve Schott- *Marine Botany Educator, Cornell Cooperative Extension*
Kim Petersen- *Habitat Restoration Educator, Cornell Cooperative Extension*

**3. Long Island Sound** (approx 10:40-10:55am)
Tom Halavik- *Senior Biologist, United States Fish and Wildlife Service*

**11:00am** **A Brief History of Long Island Restoration Efforts**
Chris Pickerell- *Habitat Restoration Specialist, Cornell Cooperative Extension*

**11:15am** **Introduction to Panel Discussion**
Overview of Panel Discussion and Introduction of Potential Research Questions (see Appendix G)
Karen Chytalo- *Section Chief, Marine Habitat Protection, New York State Department of Environmental Conservation, Bureau of Marine Resources*

**11:30am** **Working Lunch** (Provided)
Expert Panel will convene with facilitator to discuss presented information
Cornelia Schlenk- *Assistant Director, NY Sea Grant*

**12:15pm** **Expert Panel Questions for Speakers**

**12:35pm** **Group Discussion: Discussing Research and Monitoring Priorities**

**3:15pm** **Narrowing the Focus and Prioritizing**
Expert Panel convenes with facilitator to refine and prioritize research and monitoring agenda. Provide timeframes and estimated costs where applicable.
Cornelia Schlenk- *Assistant Director, NY Sea Grant*

**4:15pm** **Meeting Wrap Up- Next Steps**
Expert Panel will reconvene with group to present and discuss fully developed priorities

**4:45pm** **Adjourn**

# Appendix A:
# New York State
# Seagrass Task Force Legislation

# NEW YORK STATE SENATE
# INTRODUCER'S MEMORANDUM IN SUPPORT
## submitted in accordance with Senate Rule VI. Sec 1

**BILL NUMBER:** S8052

**SPONSOR:** JOHNSON¦¦¦¦¦¦¦¦¦¦¦¦¦

**TITLE OF BILL:**
An act to establish a seagrass research, monitoring and restoration task force and providing for its powers and duties; and providing for the repeal of such provisions upon expiration thereof

**PURPOSE:**
To establish a task force that will examine and make recommendations on means of restoring, preserving and properly managing seagrass.

**SUMMARY OF PROVISIONS:**
Section one establishes a seagrass research, monitoring and restoration task force. The Task force will consist of five voting members and ten non-voting members.

Sections two, three and four provide for the organization of the task force by establishing that the chairperson will be the commissioner of environmental conservation or his or her designee and requires that any vacancies on the task force be filled in the manner provided by the initial appointment.

Sections five, six and seven authorize the task force to hold public hearings and meetings to enable it to accomplish its duties; and requires that every state agency, local agency and public corporation having jurisdiction over areas of native seagrass habitat or over programs relating to the purposes and goals of this act offer full cooperation and assistance to the task force in carrying out the provisions of this act. Defines "native seagrass," as native underwater plants found in Long Island bays and estuaries including, but not limited to, eelgrass and widgeon grass.

**JUSTIFICATION:**
Long Island seagrass populations were severely decimated by wasting disease in the 1930s and again by a massive brown tide event in the 1980s. Despite the absence of these events in some areas like the Peconic Bays and Long Island Sound over the past 20 years, local seagrasses have not recovered. The intent of this legislation is to set up a task force to develop recommendations for regulations to improve seagrass protection, restoration, research and monitoring.

This task force will establish the necessary framework for reducing the impact of direct and indirect threats and restoring and properly managing seagrass into the future. Direct impacts include physical damage from boat groundings, incompatible fishing practices, docks and bulkheads, and other potentially destructive activities. Indirect impacts include water quality effects from nutrients, sedimentation and toxic contaminants.

Effective regulations for seagrass protection and restoration will depend greatly on the State's ability to understand the severity of these impacts. This task force will identify and assess severity of indirect and direct threats, develop restoration goals, recommend short-term and long-term research and monitoring and propose public outreach and education tools. Seagrass, which is designated as Essential Fish Habitat and a Habitat Area of Particular Concern for many of New York State's recreationally and commercially important marine species, is a vital component to successful and lasting restoration of Long Island finfish, shellfish, crustacean, and waterfowl populations, which has far reaching benefits for improved quality of life and economic growth opportunities for present and future generations on Long Island.

**LEGISLATIVE HISTORY**:
New bill.

**FISCAL IMPLICATIONS**:
Minimal.

**EFFECTIVE DATE**:
This act shall take effect immediately and be deemed repealed January 1, 2009.

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LAWS OF NEW YORK, 2006

CHAPTER 404

AN ACT to establish a seagrass research, monitoring and restoration task force and providing for its powers and duties; and providing for the repeal of such provisions upon expiration thereof

Became a law July 26, 2006, with the approval of the Governor.
Passed by a majority vote, three-fifths being present.

**The People of the State of New York, represented in Senate and Assembly, do enact as follows:**

Section 1. Seagrass research, monitoring and restoration task force. There is hereby established, within the department of environmental conservation a seagrass research, monitoring and restoration task force("task force") which shall consist of five voting members and ten non-voting members who shall be appointed as follows:

(a)the commissioner of environmental conservation or his or her designee;
(b)the commissioner of parks, recreation and historic preservation or his or her designee;
(c)the secretary of state or his or her designee;
(d)one member upon the recommendation of the temporary president of the senate;
(e)one member upon the recommendation of the speaker of the assembly;
(f)ten non-voting members to be selected by the department of environmental conservation representing: recreational anglers, town marine law enforcement, estuary programs, the commercial fishing industry, recreational boaters, the director of New York sea grant, local government officials, the marine resources advisory council, New York businesses and advocates for the environment.

§ 2. Task force members shall receive no compensation for their services but shall be reimbursed for actual and necessary expenses incurred in the performance of their duties.

§ 3. The chairperson of the task force shall be the commissioner of environmental conservation or his or her designee. The task force shall meet no less than four times and at other times at the call of the chairperson.

§ 4. Any vacancies on the task force shall be filled in the manner provided for in the initial appointment.

§ 5. The task force shall be authorized to hold public hearings and meetings to enable it to accomplish its duties.

§ 6. Every state agency, local agency and public corporation having jurisdiction over areas of native seagrass habitat or over programs relating to the purposes and goals of this act shall, to the fullest extent practicable, offer full cooperation and assistance to the task force in carrying out the provisions of this act.

§ 7. As used in this act, "native seagrass" shall mean native underwater plants found in Long Island bays and estuaries including, but not limited to, eelgrass (zostera marina) and widgeon grass(ruppia maritima); "native seagrass meadows" shall mean those habitats in estuarine waters vegetated with one or more species of native seagrass.

§ 8. No later than December 31, 2008, the task force shall transmit to the governor, the temporary president of the senate and the speaker of the assembly a report containing recommendations on how to accomplish the following:

(a) Recommendations on elements of a seagrass management plan including, but not limited to, regulatory and/or statutory alterations required to preserve, restore, protect and map the native seagrass population on Long Island.

(b) Recommendations on means of preserving and restoring seagrass and native seagrass meadows that will bring about a lasting restoration of finfish, shellfish, crustaceans, and waterfowl, that is compatible with an improved quality of life and economic growth for the future of the region. Such proposals shall also include any recommendations for monitoring, additional research, and public education to ensure the success of the effort.

§ 9. This act shall take effect immediately and shall expire and be deemed repealed January 1, 2009.

The Legislature of the STATE OF NEW YORK **ss:**
Pursuant to the authority vested in us by section 70-b of the Public Officers Law, we hereby jointly certify that this slip copy of this session law was printed under our direction and, in accordance with such section, is entitled to be read into evidence.

| JOSEPH L. BRUNO | SHELDON SILVER |
| --- | --- |
| **Temporary President of the Senate** | **Speaker of the Assembly** |

# Appendix B:
# Expert Panel Bios

# Brief Biographies of the Seagrass Experts Panel

**Paul Carlson** received his BA in Biology from New College in Sarasota, FL and his PhD in Ecology from UNC-Chapel Hill. After postdocs at U. Maryland Horn Point Environmental Laboratory and Harbor Branch Oceanographic Institution, he joined the Florida Marine Research Institute as a research scientist in 1984 working on seagrass, mangrove, and salt marsh habitat monitoring, assessment, and restoration. Significant projects have included seagrass mortality in Florida Bay, water quality management in mosquito control impoundments, bioturbation impacts on seagrass beds in Tampa Bay, and seagrass mapping and monitoring in Florida's Big Bend.

**A. Coolidge Churchill** earned a PhD at the University of Oregon studying marine algae under Richard Castenholz. His first and only full-time job has been at Adelphi University where he has worked for 40 years and from which he will retire in August 2007. While at Adelphi, he supervised numerous Master's theses and taught courses that run the gamut from marine biology to electron microscopy. His research work focused initially on the ecology of the marine alga *Codium fragile,* which at the time was a relative newcomer to the East coast and of some environmental concern. In the mid-1970's and supported by New York Sea Grant, he embarked on efforts to stabilize subtidal dredge spoil in Great South Bay via the transplantation of eelgrass. The potential significance of transplanting seagrasses was well appreciated at the time, but different methods were in the early stages of testing. While the results of the plantings were initially encouraging, their near total demise within 15 months reflects familiar experiences, even today, with transplant efforts. Subsequent work and also funded in part by New York Sea Grant included the study of heavy metal mobilization by eelgrass shoots, a description of anthesis and seed production in plants from Great South Bay, field studies on eelgrass seed banks, and the seasonal timing of seed germination. More recently, he has investigated the key role of dissolved oxygen in eelgrass seedling development, and together with Wyllie-Escheverria have helped to define the variation in seed size among and within eelgrass plants from different populations. He plans to continue his research on eelgrass at Adelphi after retirement.

**Dr. Bill Dennison** is a Professor of Marine Science and Vice President for Science Applications at the University of Maryland Center for Environmental Science (UMCES). Dr. Dennison's primary mission within UMCES is to coordinate the Integration and Application Network, a group of scientists committed to solving, not just studying, environmental problems. Bill rejoined UMCES in 2002 following a ten year stint at the University of Queensland in Brisbane, Australia. He originally started at UMCES (then the Center for Environmental and Estuarine Science) in 1987 as a Research Assistant Professor based at Horn Point Laboratory. In Australia, Bill worked with an active Marine Botany group at the University of Queensland. Bill obtained his academic training from Western Michigan University (B.A), the University of Alaska (M.S), The University of Chicago (Ph.D), and State University of New York at Stony Brook at Stony Brook (Postdoc). Bill began studying seagrasses for his MS in Alaska in 1978, did his PhD research in Woods Hole, and then joined Stony Brook to study Long Island seagrasses. However, the "brown tide" algal blooms changed his focus, and the seagrass research effort was confined to documenting the brown tide impacts and studying Caribbean seagrasses. Bill is currently working with an international group of seagrass scientists through the National Center for Ecological Analysis and Synthesis on global trajectories of seagrasses, building a global seagrass database, writing a series of scientific papers and producing a suite of science communication products to raise the profile of seagrasses and seagrass conservation.

**Mark S. Fonseca** is the Chief of the Applied Ecology and Restoration Research Branch of NOS/NOAA, National Centers for Coastal Ocean Science, Center for Coastal Fisheries and Habitat Research in

Beaufort, North Carolina. ***Research***: Project leader in basic and applied studies of marine and estuarine ecology with a focus on ecosystem restoration and management, as well as factors influencing seagrass ecology and faunal utilization particularly in the context of hydrodynamic and landscape processes. Duties are concentrated in the area of seagrass ecology, management and restoration. Studies have focused on exploring hydrodynamic interactions with marine ecosystems at a number of scales, developing seagrass planting techniques and management strategies for seagrasses in various parts of the world. Other studies include comparisons of planted vs. natural seagrass bed functions, light limitations of seagrasses and their population ecology. Recent investigations focus on the influence of hydrodynamic and disturbance processes in the formation and maintenance of marine landscapes, living marine resource use of contrasting landscape patterns and consequences of mitigative actions in these landscapes. Modeling research includes effects of scale on habitat characterization, GIS-based spatial modeling of habitat injury recovery and application of both spatial models and economic strategies in quantifying habitat injury assessment. Other active studies include developing GIS-based operational tools for wave exposure computation, boat wake effects on estuarine environments, a tidally corrected optical water quality model, as well as study of deepwater seagrass beds of the west Florida shelf, and evaluation of the Tortugas Ecological Reserve – coral reef ecosystem. ***Management***: Develop, transfer and assist in the implementation of management strategies for marine ecosystems, assist in damage assessment and recovery analysis as well as permit reviews and expert witness testimony for the Government. Broad discretion is given by NOAA management to define research goals and strategies, procure support, execute and publish findings.

**Kenneth L. Heck, Jr.** is a marine ecologist whose research has focused on plant-animal interactions in coastal wetlands, and on elucidating the importance of seagrass meadows and salt marshes in the production of finfish and shellfish. From 1976-1986 he was Assistant, and then Associate Curator, and also Director of the Patrick Center for Environmental Research at the Academy of Natural Sciences in Philadelphia. Since 1986 he has been a Senior Scientist at the Dauphin Island Sea Lab (DISL) and an Associate and Full Professor at the University of South Alabama (USA). He currently serves as Chair of University Programs at DISL and as Associate Director of the Alabama Center for Estuarine Studies at USA. Dr. Heck has edited two volumes of scholarly works and published more than 100 peer-reviewed articles. He has been appointed to editorial positions at the journal Systematic Zoology, Estuaries and Coasts and is currently Contributing Editor for the international journal Marine Ecology Progress Series. In addition, he regularly serves on review panels for a wide variety of federal agencies, including the National Science Foundation, the Environmental Protection Agency and NOAA Sea Grant. Dr. Heck received his B.S. in Biology from the University of West Florida (1970) and after serving in the U.S. Army obtained his M.S. (1973) and PhD (1976) in Biology from Florida State University.

**Bradley J. Peterson** received the B.S. degree in Marine Biology from the Florida Institute of Technology, Melbourne, FL, in 1989, the M.S. degree in Zoology from the University of Rhode Island in 1993, and the Ph.D. degree in Marine Science from the Dauphin Island Sea Lab / University of South Alabama in 1998. His graduate research investigated the role of suspension feeding bivalves in fertilizing seagrass productivity through their biodeposits. From 1998 to 2000, he was a Tropical Biology Post-Doctoral Scholar at the Florida International University, where he was primarily responsible for overseeing the Florida Keys National Marine Sanctuary Seagrass Status and Trends Monitoring Program. From 2000 to 2002, he was a Research Scientist at the Southeast Environmental Research Center at FIU investigating the role of the sponge communities in controlling phytoplankton blooms within Florida Bay and the concomitant effect on seagrass productivity. From 2002 to 2005, he was an Assistant Professor of Marine Science at Southampton College of Long Island University. Currently, Brad is an Assistant Professor at the Marine Sciences Research Center of Stony Brook University. His research interests include positive biological interactions, bentho-pelagic coupling, ecosystem engineering, biogeochemistry of the coastal ocean, nutrient cycling in the marine environment and ecosystem modeling.

**Chris Pickerell** is a Habitat Restoration Specialist with Cornell University Cooperative Extension of Suffolk County. Chris has 14 years experience working on the management and restoration of salt marshes and eelgrass on Long Island. His work over the last decade has included overseeing eelgrass long-term monitoring and restoration efforts in the Peconic Estuary, Long Island Sound and, most recently, in the South Shore Estuary Reserve.

**Fred Short** has been studying seagrasses for 30 years, starting in the eelgrass ponds of Rhode Island and later including work in Texas, Alaska, Florida, and throughout New England. He is the founding director of a worldwide seagrass monitoring program, SeagrassNet, which began in 2001 and now has 60 sites in 21 countries, and has traveled extensively to establish that program. He is the co-editor of Global Seagrass Research Methods (2001), the World Atlas of Seagrasses (2003) and more than 70 peer-review publications. His interests include seagrass restoration and two of his papers, particularly, address restoration issues of site selection (Short et al 2002) and success criteria (Short et al 2000). In the 1990s, Short directed a large and successful eelgrass restoration in the Great Bay Estuary on the border of New Hampshire and Maine as mitigation for a port construction project. He has conducted other eelgrass restoration projects, including New Bedford Harbor, Massachusetts and Penobscot Bay, Maine. Fred is based at the University of New Hampshire's Jackson Estuarine Laboratory, where he is a research professor. He is also the chair of UNH's largest Ph.D. program: Natural Resources and Earth Systems Science.

# Appendix C:
# Presenter Bios

## Brief Biographies of Presenters

**Tom Halavik** is the Acting Project Leader with the U. S. Fish and Wildlife Services' Southern New England / New York Bight Coastal Program. Tom has served as the Senior Fish and Wildlife Biologist for the Coastal Program for the last 15 years. Prior to that Tom worked as the Research Aquarium Manager and member of the Early Life History Investigation at the NOAA - National Marine Fisheries Service Laboratory in Narragansett, RI for 23 years. Tom has served as the Services' representative to the LISS and PEP and has been an active participant on the STAC and Habitat Restoration Workgroups. He was the principal investigator for the LISS Ecological Inventory and the Inaugural Stewardship Ecological Sites as well as the PI for the PEP's Critical Natural Resource Area designations. Tom is a USCG Licensed Captain and led the LISS Eelgrass "ground truth" efforts in 2002 and 2006.

**Kimberly Petersen** has a BS in Marine Science/Biology from the University of Tampa. She has worked for CCE's Marine Program since she began seasonally in 2003 and is now a year round staff member, working with Chris Pickerell and Steve Schott in the eelgrass restoration program. Kim also maintains the seagrassli.org website.

**Bradley J. Peterson** received the B.S. degree in Marine Biology from the Florida Institute of Technology, Melbourne, FL, in 1989, the M.S. degree in Zoology from the University of Rhode Island in 1993, and the Ph.D. degree in Marine Science from the Dauphin Island Sea Lab / University of South Alabama in 1998. His graduate research investigated the role of suspension feeding bivalves in fertilizing seagrass productivity through their biodeposits. From 1998 to 2000, he was a Tropical Biology Post-Doctoral Scholar at the Florida International University, where he was primarily responsible for overseeing the Florida Keys National Marine Sanctuary Seagrass Status and Trends Monitoring Program. From 2000 to 2002, he was a Research Scientist at the Southeast Environmental Research Center at FIU investigating the role of the sponge communities in controlling phytoplankton blooms within Florida Bay and the concomitant effect on seagrass productivity. From 2002 to 2005, he was an Assistant Professor of Marine Science at Southampton College of Long Island University. Currently, Brad is an Assistant Professor at the Marine Sciences Research Center of Stony Brook University. His research interests include positive biological interactions, bentho-pelagic coupling, ecosystem engineering, biogeochemistry of the coastal ocean, nutrient cycling in the marine environment and ecosystem modeling.

**Chris Pickerell** is a Habitat Restoration Specialist with Cornell University Cooperative Extension of Suffolk County. Chris has 14 years experience working on the management and restoration of salt marshes and eelgrass on Long Island. His work over the last decade has included overseeing eelgrass long-term monitoring and restoration efforts in the Peconic Estuary, Long Island Sound and, most recently, in the South Shore Estuary Reserve.

**Stephen Schott** has a BS in Botany and MS in Biology, specializing in marine botany and ecology, from the University of Rhode Island. He has been employed by Cornell Cooperative Extension since 2000, working with the wetland and eelgrass monitoring/restoration programs.

**Christopher Clapp** has been working in the Great South Bay for The Nature Conservancy since the conservancy's efforts to restore shellfish populations in Great South Bay began in 2004. He holds an MS in Marine and Environmental Sciences form Stony Brook University's Marine Science Research Center where he employed side-scan and multi-beam sonar to identify benthic habitats in Great South Bay.

**Ron Paulsen** is a Hydrogeologist with the Suffolk County Department of Health Services, Office of Water Resources. Ron has 25 years experience working on groundwater, surface water and groundwater/surface water interaction studies and investigation. Work includes investigation of various land uses (agricultural, industrial, residential) on groundwater and surface water. Several new techniques for sampling and measuring groundwater discharge have been developed in a cooperative effort with Cornell Cooperative of Suffolk and Stony Brook University. Development of an ultrasonic seepage meter and pore water sampling probes has led to new insight into the dynamic of groundwater discharge. Several studies are ongoing using these tools to characterize groundwater impacts in our local estuaries. Current work includes investigating agricultural impacts in the Peconic Estuary.

**J. Kirk Cochran** received his B.S. degree from Florida State University in 1973 and his Masters and Ph.D. degrees from Yale University in 1975 and 1979, respectively. He worked as a Research Staff Geologist in the
Department of Geology and Geophysics at Yale University and as an Assistant Scientist in the Department of Chemistry at the Woods Hole Oceanographic Institution. Past notable appointments include Dean and Director of the Marine Sciences Research Center of Stony Brook University. Currently, Kirk is a Professor at the Marine Sciences Research Center of Stony Brook University. His research interests include marine sediment geochemistry and the use of radionuclides as geochemical tracers.

**Christopher J. Gobler** is an associate professor at the School of Marine and Atmospheric Sciences (SoMAS) of Stony Brook University, as well as faculty coordinator of activities for SoMAS at Stony Brook – Southampton. Prior to his appointment at Stony Brook, he was an associate professor and program coordinator of the marine sciences program for Southampton College of Long Island University. He has been researching the bays and estuaries of Long Island for more than 15 years, having published more than 30 peer reviewed scientific articles on the subject. Gobler is best known for his work on harmful algal blooms in general, and brown tides on Long Island in particular, and is an associate editor of the international journal published by Elsevier, Harmful Algae. Gobler is a Long Island native who received a bachelor's degree in biology from the University of Delaware and his Master's and Doctorate degrees from Stony Brook University.

# Appendix D:
# List of Attendees

**List of Attendees: New York Seagrass Experts Meeting**
Tuesday May 22, 2007

**Meeting Participants** (L to R):
Front row: Jack Mattice (NY Sea Grant), Bradley Peterson (Stony Brook University), Kenneth Heck, Jr. (University of South Alabama), A. Coolidge Churchill (Adelphi University), J. Kirk Cochran (Stony Brook University), Marci Bortman (The Nature Conservancy).
Middle rows: Paul Carlson (Florida Fish and Wildlife Conservation Commission), Christopher Gobler (Stony Brook University), Tom Halavik (US Fish & Wildlife Service), Corey Garza (Long Island Sound Study Office), Chris Pickerell (Cornell Cooperative Extension), Jeffrey Fullmer (South Shore Estuary Reserve Office), Fred Short (University of New Hampshire), Karen Chytalo (NYS Dept. of Environmental Conservation), Chris Clapp (The Nature Conservancy), Carol Pesch (US EPA), Kim Petersen (Cornell Cooperative Extension), Laura Stephenson (NYS Dept. of Environmental Conservation).
Back row: Cornelia Schlenk (NY Sea Grant), Mark Fonseca (NOAA National Ocean Service), William Dennison (University of Maryland), Steve Schott (Cornell Cooperative Extension), Carl LoBue (The Nature Conservancy), Ronald Paulsen (Suffolk County Dept. of Health Services).

**List of Attendees: New York Seagrass Experts Meeting**
Tuesday May 22, 2007

| Name | Affiliation | Phone | Email |
|---|---|---|---|
| Ron Paulsen | SCDHS | 631.852.5774 | Ronald.Paulsen@suffolkcountyny.gov |
| Laura Stephenson | NYSDEC/PEP | 631.444.0871 | lbstephe@gw.dec.state.ny.us |
| Corey Garza | NOAA/LISS | 203.882.6505 | corey.garza@noaa.gov |
| Jack Mattice | NYSG | 631.632.6905 | jmattice@notes.cc.sunysb.edu |
| Carol Pesch | USEPA AED | 401.782.3081 | pesch.carol@epa.gov |
| Brad Peterson | MSRC | 631.632.5044 | bradley.peterson@stonybrook.edu |
| Mark Fonseca | NOAA | 252.728.8729 | Mark.Fonseca@noaa.gov |
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| Stephen Schott | CCE | 631.852.8660 | ss337@cornell.edu |
| Carl LoBue | TNC | 631.367.3384 | clobue@tnc.org |
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| Chris Gobler | SBU | 631.632.5043 | christopher.gobler@stonybrook.edu |
| Ken Heck | Dauphin Island Sea Lab | 251.860.2533 | kheck@disl.org |
| Paul Carlson | Florida Fish and Wildlife Research Institute | 727-896-8626 | Paul.Carlson@MyFWC.com |

SCDHS- Suffolk County Department of Health Services
NYSDEC- New York State Department of Environmental Conservation
PEP- Peconic Estuary Program
NOAA- National Oceanic and Atmospheric Administration
LISS- Long Island Sound Study
NYSG- New York Sea Grant
USEPA- United State Environmental Protection Agency
AED- Atlantic Ecology Division
MSRC- Marine Sciences Research Center (SUNY Stony Brook)
UMCES- University of Maryland Center for Environmental Science
CCE- Cornell Cooperative Extension
UNH- University of New Hampshire
TNC- The Nature Conservancy
SSER- South Shore Estuary Reserve
USFWS- United States Fish and Wildlife Service
SBU- Stony Brook University

# Appendix E:
# Presentation Abstracts and Slides

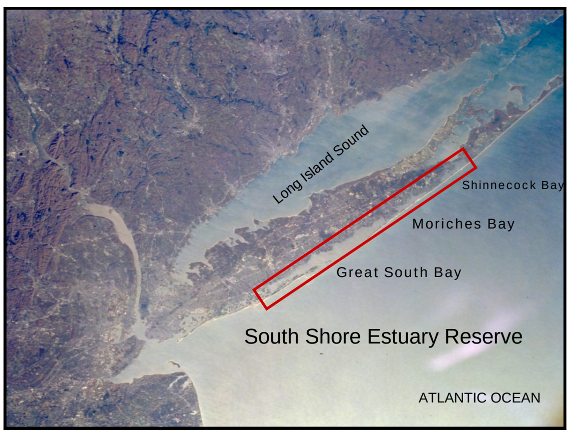
## Water Quality in Long Island's estuaries: South Shore Estuary Reserve, Peconic Estuary, and Long Island Sound

Chris Gobler, Ph.D.
*Associate Professor*
*Marine Sciences Research Center, Stony Brook University*

Long Island's primary estuaries are Long Island Sound, which is bordered by Connecticut to its north and Long Island to its south, the south shore estuary system (Great South Bay, Moriches Bay, and Shinnecock Bay), which consists of barrier island estuaries along the Island's south shore, and the Peconic Estuary, which is situated between the north and south forks of Long Island. The water quality of each estuarine system is extremely different with differing consequences for native eelgrass populations. The south shore estuaries are characterized by shallow depths (mean = 1.2 m) and gradients in water quality. Regions located near ocean inlets are cool, salty, clear, and contain low levels of algal biomass, whereas back bay regions are warmer, more fresh, and more turbid with algal biomass. While the bay bottom of inlet regions receive more than 20% of surface irradiance (the level required for robust eelgrass growth), the benthos of mid-and back-bay regions are below the 20% threshold and receive less than 1% of surface irradiance during intense algal blooms which can be common there. The Peconic Estuary contains strong gradients in depth and water clarity, with the western extreme of the estuary being shallow (2 – 3 m) but turbid and the eastern portion of the estuary being clear but deep (15 – 20m). As a consequence, Flanders Bay to the west is the only sub-estuary which likely receives > 20% of surface irradiance throughout its benthos. Eastern basins of the Peconics (Great Peconic, Little Peconic, Gardiners Bay) have levels of irradiance high enough to support eelgrass growth in their shallow, nearshore regions only. Long Island Sound also displays a strong eutrophication gradient, with high levels of phytoplankton biomass and low water quality to the west in the vicinity of New York City and clearer water to the east. Long Island Sound is also an extremely deep estuary (mean = 20 m; max = 50 m). As such, only the nearshore waters and harbors of the Sound are hospitable for eelgrass growth, with a greater likelihood of clear water and high bottom irradiance in the eastern extreme of the system.

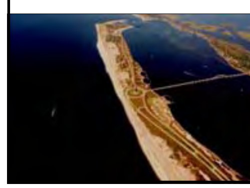
## Water quality in Long Island's estuaries: South shore estuary reserve, Peconic Estuary, and Long Island Sound

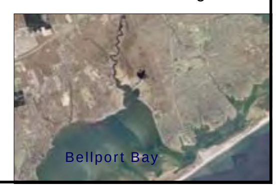
**Christopher J. Gobler**
**Marine Sciences Research Center**
**Stony Brook University**

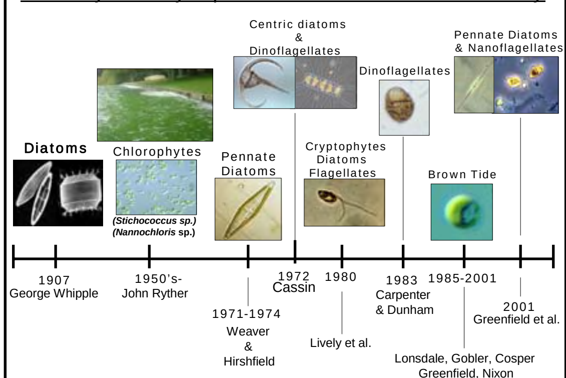

## Great South Bay

- Primary ocean influence is Fire Island Inlet.
- Average mean low water depth is 1.3 m (Wilson et al. 1991).
- Residence time is up to 96 days (Wilson et al. 1991;Conley 2000).
- Phase-shifts in algal communities: Bloom-forming 'small forms' to diatom-based mixed assemblages.



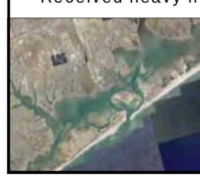



## History of Phytoplankton in Great South Bay

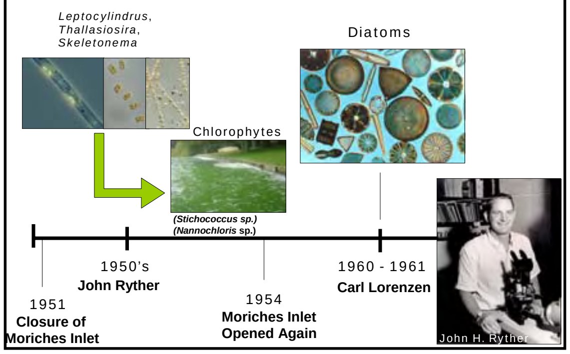



## Moriches Bay

- Connected to Great South Bay by Narrow Bay
- Smaller than GSB, similar to Shinnecock in size
- Moriches Inlet formed in 1931. Reclosed naturally in 1951.
- Reopened again in 1954 by Hurricane Edna, and made a permanent fixture with stabilizing jetties
- Received heavy input of duck farm waste



## History of Phytoplankton in Moriches Bay





## Historical Data Analysis

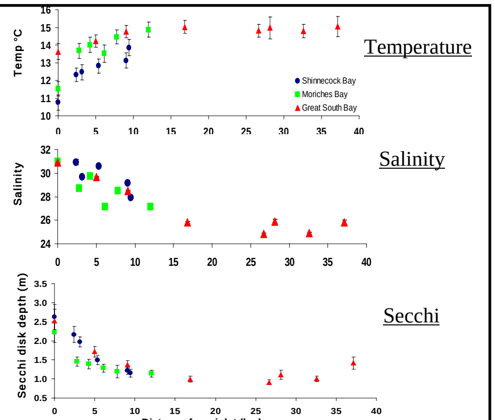
Suffolk County Department of Public Health's Water Quality Monitoring Program.

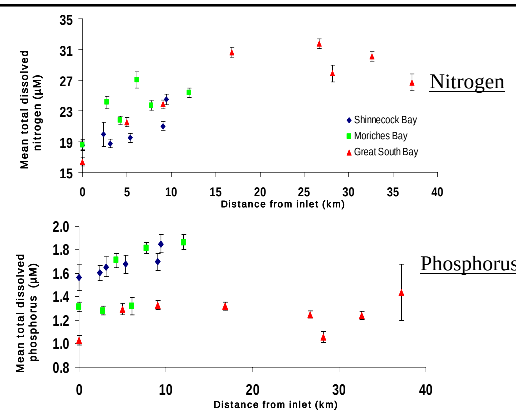
Monthly surface water samples from 1976 – 2005 (30 yrs).

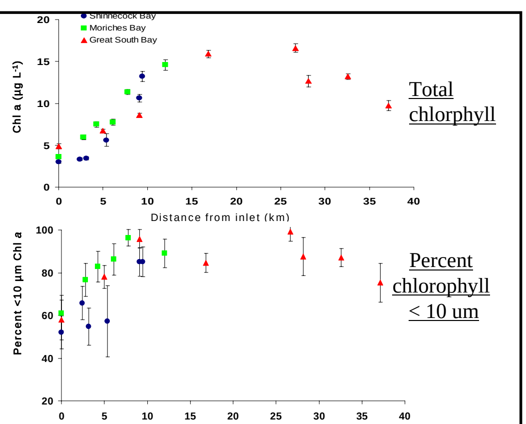
Temperature, Salinity, Turbidity

Total dissolved nitrogen & phosphorus

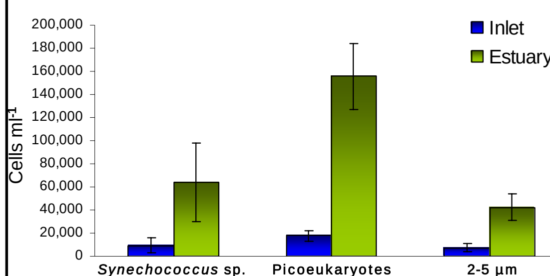
Total chlorophyll *a* & size fractionated (<10µm)



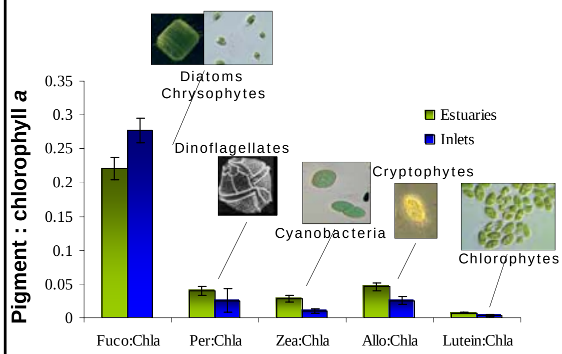




## *Synechococcus* sp., Picoeukaryotes, and 2-5 µm cells

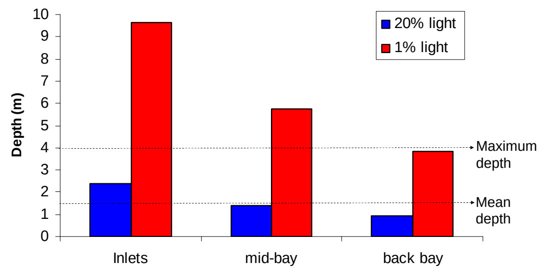


# Pigment Ratios

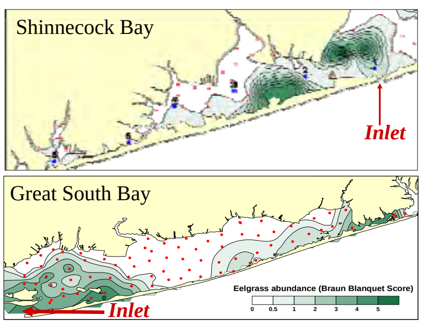



# Light in the South Shore Estuary Reserve

**Dennison et al. (1993):** Seagrasses are sensitive indicators of declining water quality because of their high light requirements (**15-25% surface irradiance**).




# Eelgrass distributions in SSER, Peterson surveys, 2004-2005

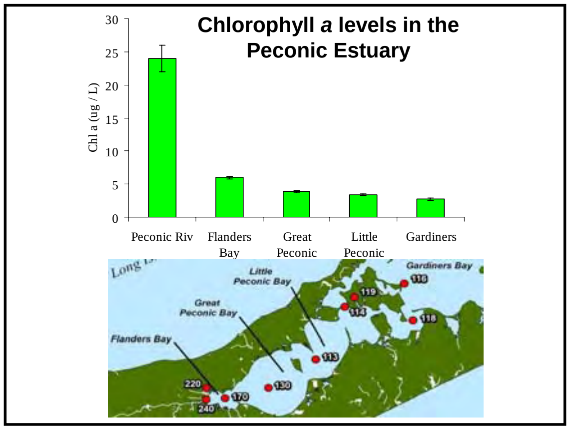


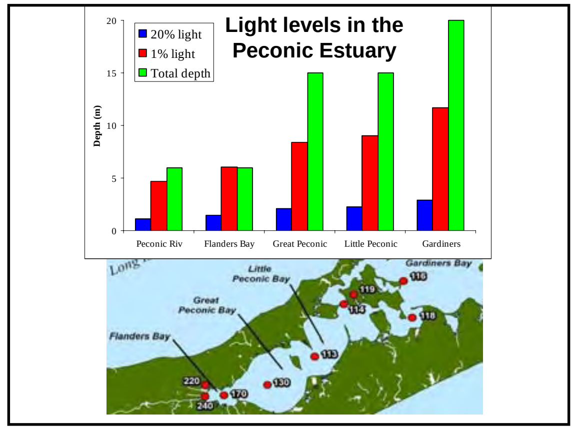


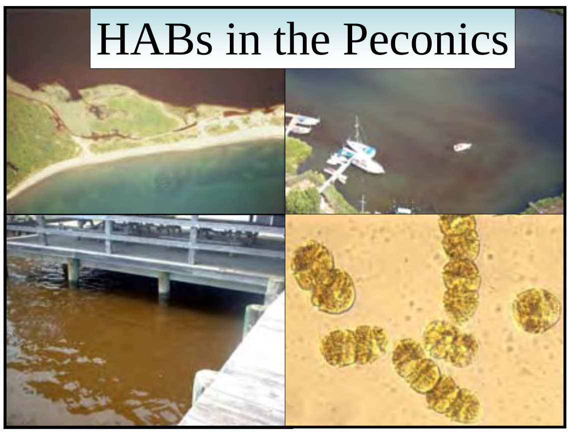
# Peconic Estuary

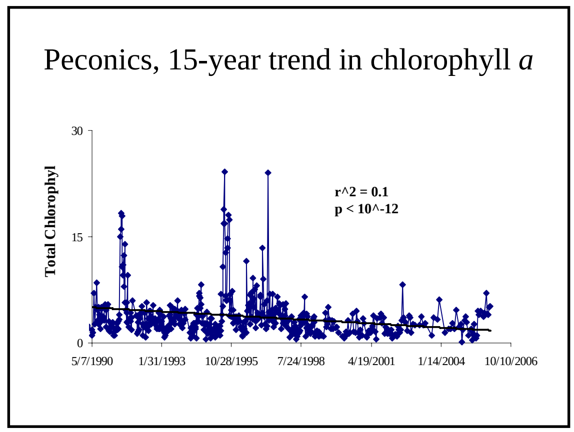

# Peconic Estuary

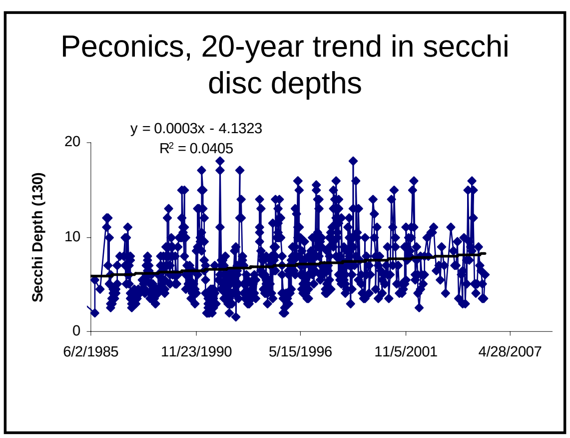
- Two month residence time of western basin
- Shallow, but more eutrophic with low water clarity / quality to the west
- Strong tidal flushing yielding high water clarity to the east; also deeper to the east

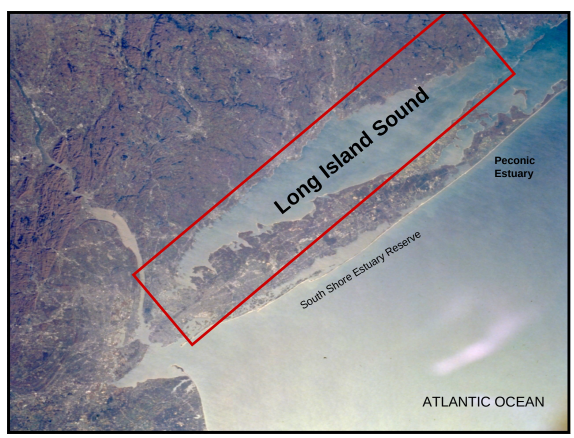

Chlorophyll *a* levels in the Peconic Estuary
Chl a (ug / L)
30
25
20
15
10
5
0
Peconic Riv
Flanders Bay
Great Peconic
Little Peconic
Gardiners
Little Peconic Bay
Great Peconic Bay
Flanders Bay
Gardiners Bay
116
119
114
118
113
130
220
170
240


Light levels in the Peconic Estuary
20% light
1% light
Total depth
Depth (m)
20
15
10
5
0
Peconic Riv
Flanders Bay
Great Peconic
Little Peconic
Gardiners
Little Peconic Bay
Great Peconic Bay
Flanders Bay
Gardiners Bay
116
119
114
118
113
130
220
170
240

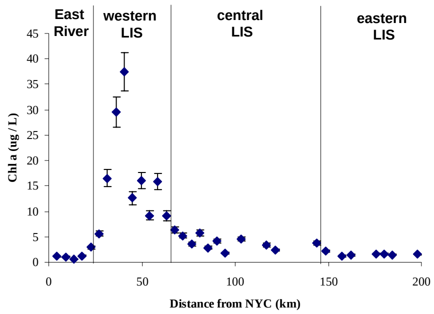

HABs in the Peconics


Peconics, 15-year trend in chlorophyll *a*
Total Chlorophyl
30
15
0
r^2 = 0.1
p < 10^-12
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006


Peconics, 20-year trend in secchi disc depths
y = 0.0003x - 4.1323
$R^2$ = 0.0405
Secchi Depth (130)
20
10
0
6/2/1985
11/23/1990
5/15/1996
11/5/2001
4/28/2007


Long Island Sound
Peconic Estuary
South Shore Estuary Reserve
ATLANTIC OCEAN

## Chlorophyll *a* in Long Island Sound




## Long Island Sound

- Mean depth = 20 meters
- Deepest = 50 meters

- Bottom of main basin < 1% light level
- Shallows of western basin also probably low light
- Higher light availability in eastern shallows

## *Conclusions*

- The South Shore Estuary Reserve has a mean depth of 1.2 m, but is likely light limited in regions away from inlets due to dense blooms of small phytoplankton and resuspension.
- The Peconic Estuary is shallow but turbid in the west, and clearer but deeper to the east.
- Peconic water clarity has increased during the past 20 years.
- Long Island Sound is a deep water estuary (20 – 40 m), with turbid waters to the west, but clearer waters to the east

## Linking Groundwater, Pesticides and SAV's

Ron Paulsen
*Hydrogeologist*
*Suffolk County Department of Health Services, Office of Water Resources*

Over the last thirty years Suffolk County Department of Health Service's Office of Water Resources has been monitoring nutrient and pesticide impacts to the ground and surface waters in Suffolk County, New York. Thousands of samples have been collected within the watershed of the Peconic Estuary over this period. In 2007 over thirty-seven different pesticides, herbicides and fungicides have been detected in groundwater in Suffolk. The ultimate fate of this pesticide-impacted groundwater is to discharge into surface water through submarine groundwater discharge (SGD). Monitoring of the near shore groundwater, offshore porewater and SGD in the Peconic Estuary has revealed that several of these pesticides and herbicides are present at levels of concern. Impacts to the phytoplankton, algae and submerged aquatic species is a distinct possibility and may explain some of the difficulties faced in restoring SAV communities and understanding the trigger mechanisms for harmful algal blooms. Although many of these pesticides have been banned decades ago in will take many years for them to be purged from the aquifer system. This passive discharge can have prolonged and significant affects on the estuary for decades to come. Currently several studies are under way in the Peconic Estuary to determine impacts of SGD on near shore environments.

# Linking Groundwater, Pesticides & SAV's

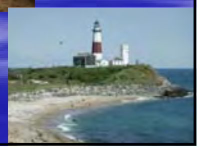

Steve Levy
Suffolk County Executive

Humayan J. Chaudhry, DO, MS.
Commissioner
Department of Health Services

Vito Minei, P.E.
Director
Division of Environmental Quality



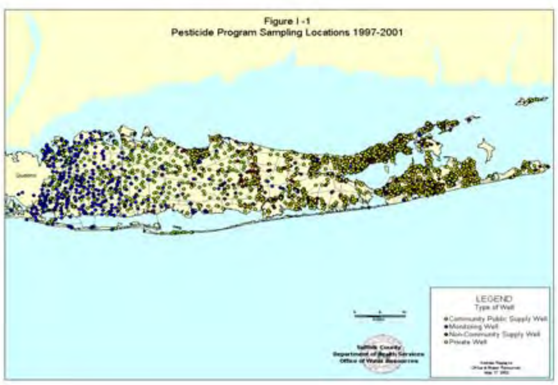
Ron Paulsen
Hydrogeologist
Office of Water Resources

## Nitrogen & Pesticide Studies

- LI 208 Study (1978)
- Status of Aldicarb contamination (1981)
  - 8,000 aldicarb samples 1979-1980
- North & South Fork Reports (1982)
  - Assessment of nitrate, aldicarb, dichloropropane
- Comprehensive Water Resources Management Study (1987)
- Nitrate & Pesticide Impacts of Agriculture (1996)
  - 20 year (1975-1994) nitrate avg 11.3 mg/L
  - Aldicarb, carbofuran, oxamyl concentrations declining
  - TCPA found in high concentrations
- NYSDEC Pesticide Monitoring Program 1999-2006

2




## 1996 Pesticide Reporting Law - SCDHS Annual Reports on Water Quality Monitoring Program to NYSDEC

1998
- 24 pesticides & metabolites identified, 8 exceed MCLs

1999
- 32 pesticides & metabolites detected, 10 exceed MCLs

2000
- 44 pesticides & metabolites detected, 12 exceed MCLs
- 3,143 public, private, & monitoring wells tested in Nassau & Suffolk
  - 25.6% contained pesticides
  - 7.8% exceed MCLs

2002
- 52 pesticides & metabolites identified, 13 exceed MCLs
- 50.6% of private wells impacted
- 90.7% of private wells exceeding MCLs impacted by agricultural chemicals

4

## Recent Monitoring Program Findings

- 63 Pesticide Related Compounds Detected

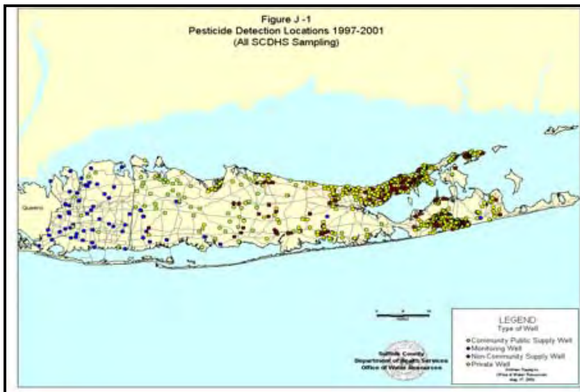
46 parent compounds
13 pesticide degradates
1 inert ingredient (DEHP)
3 pesticide impurities, i.e.,
perchlorate,
1,2,3-trichloropropane (DCP), pentachlorobenzene (PCNB fungicide)
New issues Imidachloprid & DEET

5

## Recent Monitoring Program Findings

- 15 pesticide compounds exceed MCLs
- 50% of private wells tested contain one or more pesticides
- 23% of community supply wells contained pesticides
- Co-occurrence of multiple pesticides - 15% of private wells contained 5 or more pesticide compounds

6




## Land Use Impacts

| Land Use | # Monitoring Wells |
| --- | --- |
| Residential | 16 |
| Lawn Care & Landscapers | 7 |
| Greenhouses | 33 |
| Golf Courses | 37 |
| Vineyards | 28 |
| Row Crop Agriculture | 5 |

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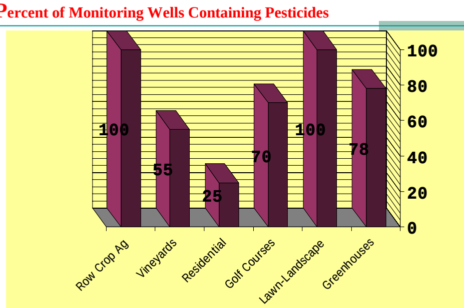
## Comparative Pesticide Impacts

**Percent of Monitoring Wells Containing Pesticides**

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## Pesticides Exceeding MCLs in LI Groundwater

- **DBCP** (banned 1979)
- **Aldicarb** (banned 1980)
- **Chlordane** (banned 1983)
- **EDB** (banned 1983)
- **Dinoseb** (banned 1986)
- **1,2 DCP** (banned 1987)
- **TCPA** (banned 1988)
- **Alachlor** (banned 1999)
- **Metolachlor** (banned 2000)
- **Cyanazine** (banned 2002)
- **Simazine** active
- **1,2,3 TCP** (contaminant)
- **DEHP** (inert ingredient)
- **Imidachloprid** **(Restricted 2004)**
- **DEET** **active**

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## Suffolk County Pesticide Monitoring Program

### Pesticide Issues

- Lack of MCLs – Only carbofuran of 10 most frequently detected chemicals has a specific MCL (UOC standard 50 ppb)
- Occurrence of multiple compounds - MCL for multiple organic compounds is 100 ppb for total POCs & UOCs (NYS Sanitary Code)
- Metabolites routinely detected in greater concentrations than parent compounds
- Alachlor & metolachlor herbicides widely applied from ~1980 through 2000 – ESA & OA metabolites were not analyzed for prior to 1999

### Nitrogen Issues

- Private wells exceeding 10 mg/L MCL – lack of access to public water
- Nitrogen discharge through stream flow and groundwater underflow to estuary – algae blooms, low dissolved oxygen

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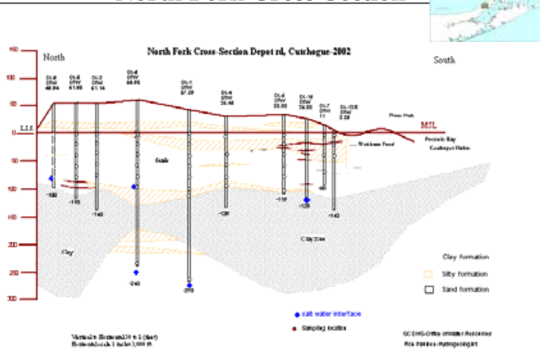
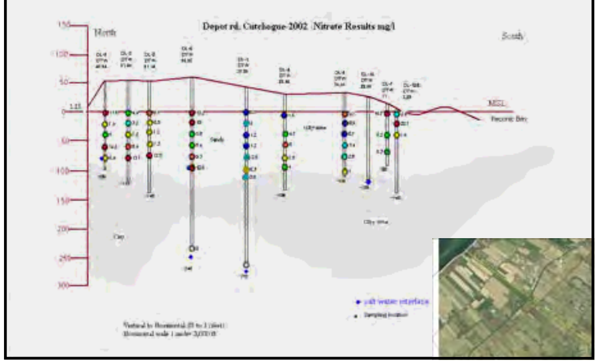
## North Fork Cross Section

12

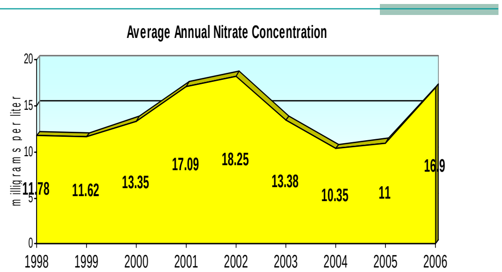
## North Fork Cross-Section




## North Fork Aquifer Cross-Section (Nitrates)




## Ag Nitrogen Monitoring 1998 - 2006

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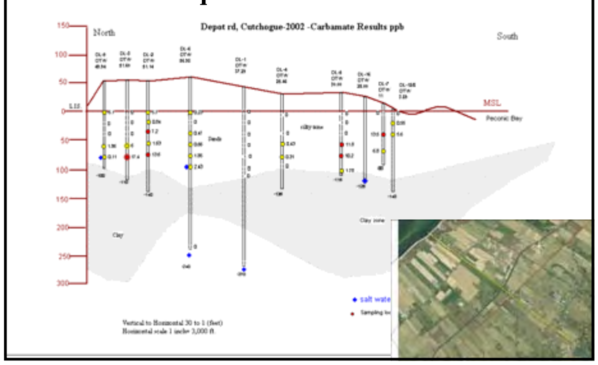
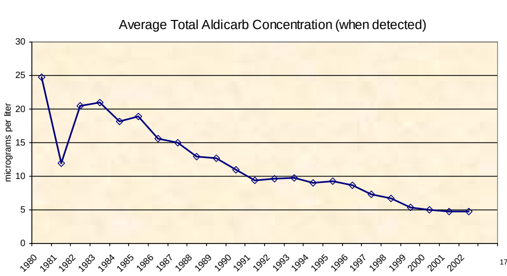
## North Fork Aquifer Cross-Section Carbamates




## Long-term Trends in Groundwater

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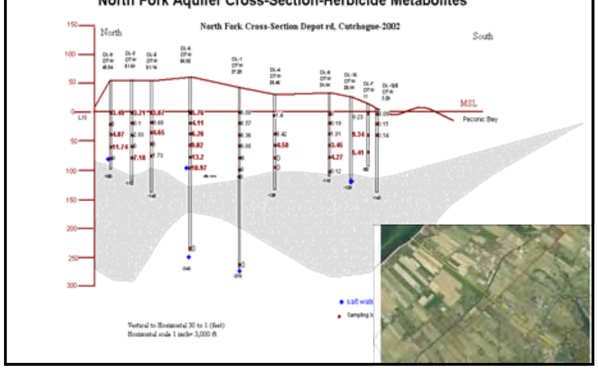
## North Fork Aquifer Cross-Section-Herbicide Metabolites



## North Fork Stream Water Quality

Pesticide monitoring at 16 creeks & streams discharging to the Peconic Estuary

| Sta. # | Stream |
|---|---|
| 200010 | Peconic River (gauge) |
| 200160 | Brushes Creek |
| 200004 | Crescent Duck Farm |
| 200170 | Deep Hole Creek |
| 200041 | Meetinghouse Creek |
| 200180 | Halls Creek |
| 200110 | Sawmill Creek |
| 200190 | Downs Creek |
| 200120 | Terry Creek |
| 200200 | West Creek |
| 200130 | Reeves Creek |
| 200210 | East Creek (Cutchogue) |
| 200140 | East Creek (S Jamesport) |
| 200230 | Pipes Creek |
| 200150 | West Drain |
| 200260 | Narrow River (south) |

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## Sampling Stations


## North Fork Stream Water Quality

- Multiple pesticides/herbicides/degradates are present in groundwater and streams discharging to Peconic Estuary
- 37 pesticide-related compounds detected in streams

| More frequently detected | Less frequently detected | |
|---|---|---|
| aldicarb sulfoxide | alachlor OA | azoxystrobin |
| aldicarb sulfone | metolachlor | chlorothalonil |
| alachlor ESA | TCPA | endosulfan sulfate |
| metolachlor ESA | simazine | deisopropylatrazine |
| metolachlor OA | dinoseb | 4,4 DDD |
| metalaxyl | | BAM |

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## Stream analyses show herbicide cocktails

(concentrations in ug/L)

| March 16, 2005 | Reeves Creek, Riverhead | Brushes Creek, Laurel |
|---|---|---|
| alachlor OA | <0.4 | 1.82 |
| alachlor ESA | 0.27 | 2.33 |
| metolachlor OA | 2.91 | 0.32 |
| metolachlor ESA | 3.41 | 0.59 |
| 2,6-dichlorobenzamide (BAM) | <0.5 | 3.38 |
| terbacil | 0.19 | <0.5 |
| dichlobenil | <0.2 | 0.5 |
| ronstar | <0.2 | 1.0 |
| metolachlor | 0.4 | <0.2 |
| metalaxyl | 0.4 | <0.2 |
| aldicarb sulfoxide | 0.71 | 0.15 |
| aldicarb sulfone | 0.5 | 0.29 |

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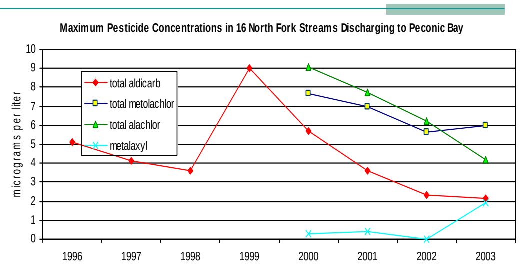
## North Fork Stream Water Quality

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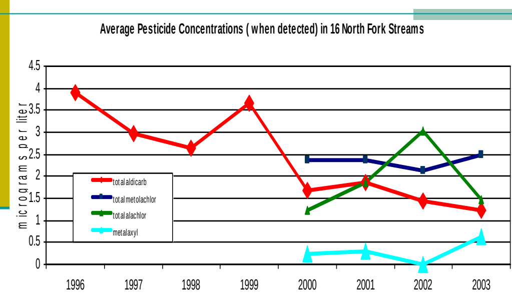
## North Fork Stream Water Quality

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## Herbicide Contaminant Issues

EPA Alachlor RED (1998)

- $EC_{50}$ for green algae is 1.64 ug/L
- No effect level is 0.35 ug/L.
- "Aquatic plants may be adversely affected by alachlor in groundwater, in places where groundwater discharges into surface water."

EPA Metolcachlor RED (1995)

- "… where groundwater discharges to surface water, metolachlor residues could present a threat to non target plants."

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## Herbicide Contaminant Issues

EPA Dichlobenil RED (1998)

- "Dichlobenil is toxic to non target terrestrial and aquatic plants."
- "potentially high acute risks to mollusks"

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## Herbicide Contaminant Issues

- What is the potential for herbicide cocktail in stream flow and groundwater underflow to alter bay ecology**?**
- Impacts on phytoplankton and eelgrass?

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## Overall Concerns

- •**Detections of pesticides increasing**
- •**Long Residual affects (Aldicarb 30 years impact)**
- •**Potential significant impacts from agricultural activities that produce concentrated waste.**
- •**Community well impacts/understanding SWAP**
- •**Affects of contaminated groundwater on surface water**
- •**Need for cooperative effort, sound management practices and monitoring**

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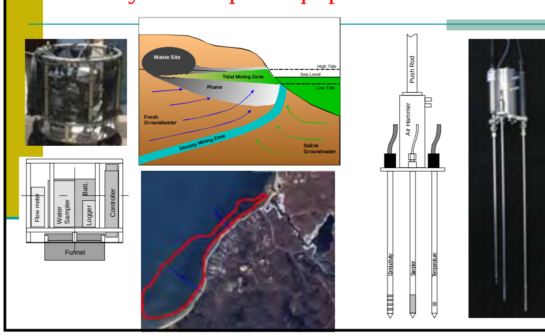
## Groundwater/Surface Water Interactions Newly Developed Equipment and Methods

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**Sediment Geochemistry Pertinent to Health of SAV**

J. Kirk Cochran, Ph.D.
*Professor*
*Marine Sciences Research Center, Stony Brook University*

Geochemical reactions occurring in the upper ~30 cm of marine sediments have implications for the health of submerged aquatic vegetation. In particular, bacterial oxidation of organic matter leads to the presence of solutes in pore water that are phytotoxic. Perhaps the most important of these is hydrogen sulfide, produced from reduction of seawater sulfate as organic matter is oxidized. Dissolved hydrogen sulfide can also be removed from pore water as reduced iron reacts with it to form solid phase iron sulfides. In addition, SAV is adapted to handle elevated sulfide in pore water, but multiple stressors (light penetration in water column, eutrophication) may occur that hamper the plant's ability to moderate the effects of sulfide. This presentation reviews the available data on sulfur geochemistry in sediments of Long Island Sound, the Peconic Bay system and Great South Bay.

# New York Sea Grant Seagrass Workshop

Sediment Geochemistry

J. Kirk Cochran
Marine Sciences Research Center

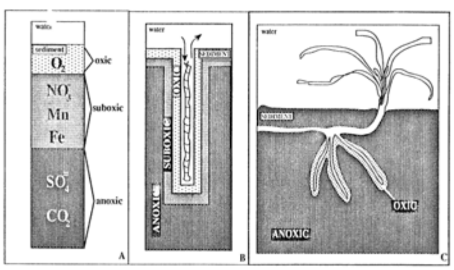
## Sediment Geochemical Issues Related to Health of SAV

- Bacterial oxidation of organic matter in sediments leads to presence of solutes in pore water that are phytotoxic (e.g. sulfide)

  **$2CH_2O+SO_4^{2-} \rightarrow H_2S + 2HCO_3^-$**

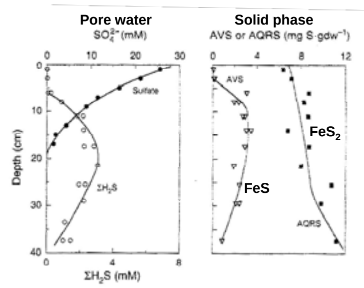
- SAV adapted to handle elevated sulfide in pore water, but must consider multiple stressors (light penetration in water column, eutrophication)

## Bacterial Oxidation of Organic Matter




Stupakopf (1993)

## Sulfide in Sediment




- Sulfide produced by sulfate reduction: $2CH_2O + SO_4^{2-} \rightarrow H_2S + 2HCO_3^-$
- $\Sigma H_2S$ represents $H_2S$, $HS^-$ and $S_o$
- $H_2S$ reacts with Fe to produce FeS and utimately, $FeS_2$

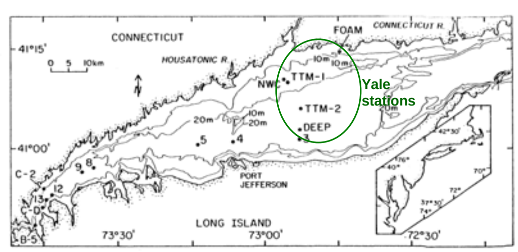
Burdige (2006)

## Sediment Geochemistry in Long Island's coastal waters

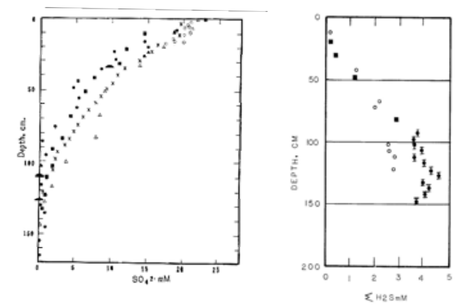
- Long Island Sound
- Peconic Bay
- South Shore Estuarine Reserve

## Long Island Sound

- Yale University (1970s)
- Long Island Sound Study (1986-7)

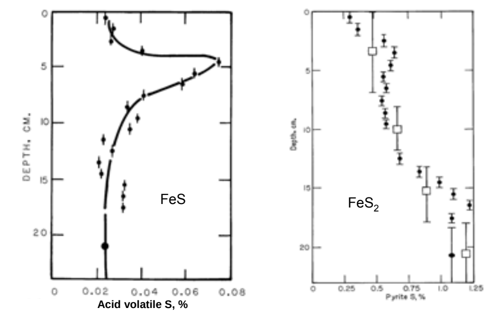


# FOAM (Friends of Anoxic Mud) Site

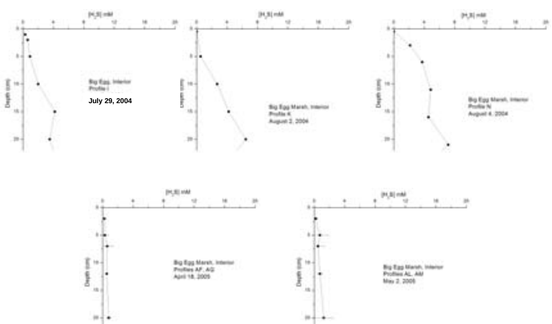


Pore Water Sulfate    Pore Water Sulfide

# Solid Phase Sulfur Pools
$Fe^{2+} + H_2S \rightarrow FeS \rightarrow FeS_2$

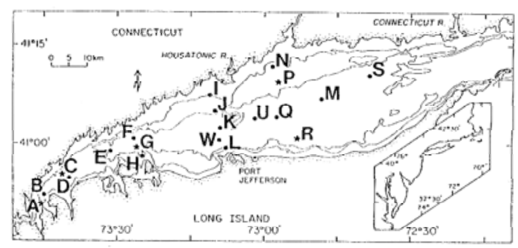



# $H_2S$ in Jamaica Bay Marshes

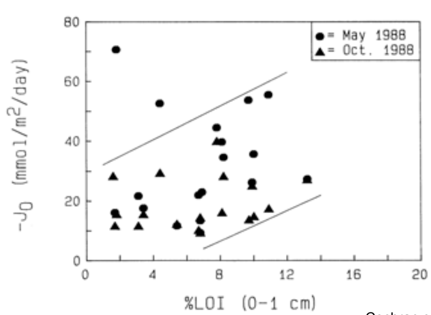



# Long Island Sound

- Long Island Sound Study (1988-89)

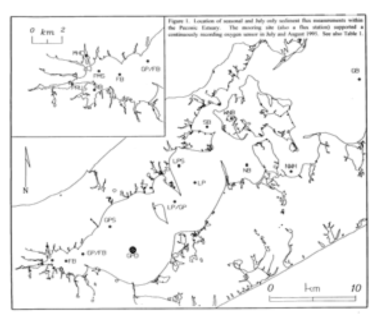



# LISS- Sediment Oxygen Fluxes




Cochran et al. (1991)

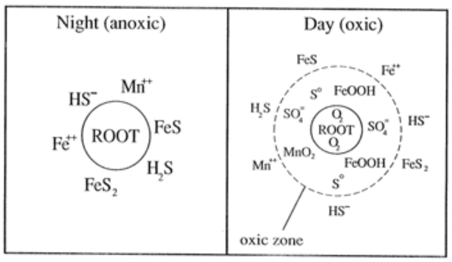
# Peconic Bays



Howes et al. (1998)

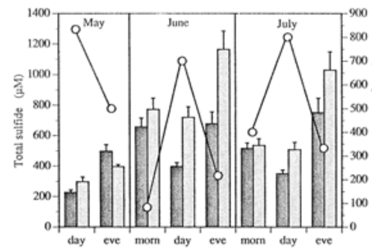
- Peconic Estuary Program (PEP)
- *Zostera* and $\Sigma H_2S$ (I. Stupakopf,1993)
- Benthic Fluxes (Howes et al.1998)
- Sediment radionuclides (accumulation, mixing: Cochran et al. 1995)

## Pore water solutes and SAV roots




Stupakopf (1993)

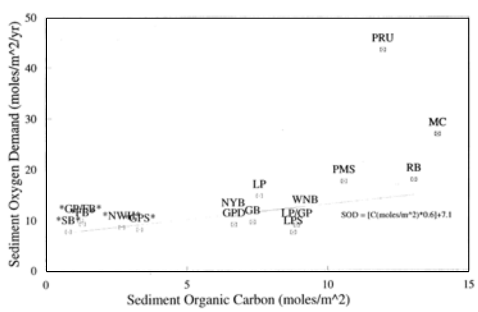
## Pore water sulfide and *Zostera*




Stupakopf (1993)

- Smith Point, Narrow Bay
- Sampled pore water (0-6 cm) inside (dark bars) patch of *Zostera* and in sediment outside (light bars) of patch
- $\Sigma H_2S$ inversely correlated with irradiance, significantly different inside vs. outside

## Peconic Bays- Sediment Oxygen Fluxes




Howes et al. (1998)

## Great South Bay

- Sampling for sediment metal distributions, basic sediment properties (Schubel et al. 1980)
- Large scale sampling of sediments for radionuclides ($^{234}Th$, $^{7}Be$, $^{210}Pb$) for sediment dynamics (Cochran et al. 2006-)

## Summary

- Large scale sediment geochemical data for Long Island's coastal waters has tended to focus on benthic fluxes
- Muddy sediments sampled most often
- Less emphasis on shallow water, coarse grained sediments
- Few data on pore water sulfide; more on sulfate, solid phase iron sulfides

## Impacts of Habitat Modification on Eelgrass Populations in New York South Shore Estuaries

Brad Peterson, Ph.D.
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Within the State of New York, there is broad recognition that action is needed to understand, protect, enhance and restore coastal ecosystems and that ecosystem-based management is the most effective approach to accomplish such action. Recently, New York passed legislation (Bill A10584B) mandating that the state begin using ecosystem-based management for its coastal and marine resources making it the second state in the U.S. to take such action. This new mandate has resource managers re-evaluating how decisions are made and what data is required to make critical regulatory choices. In an effort to understand the strength and interaction of multiple stressors on eelgrass populations in NY estuaries, the state has recently passed legislation to set up a task force to develop recommendations for regulations to improve seagrass protection, restoration, research and monitoring. The bill states *"effective regulations for seagrass protection and restoration will depend greatly on the State's ability to understand the severity of these impacts. This task force will identify and assess severity of indirect and direct threats and develop restoration goals."*

Potential stressors on eelgrass populations in NY coastal waters include habitat modification, light shading, sulfide toxicity, and increased water temperature (Fig 1). The potential consequences and mechanisms of each of these stressors on eelgrass populations will be addressed below.

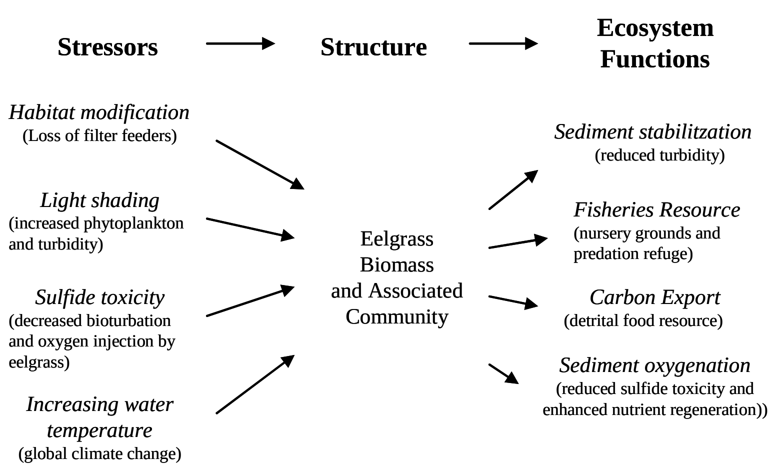


**Figure 1.** Conceptual model of NY eelgrass stressors and ecosystem functions provided by healthy eelgrass meadows.

### ***<u>Habitat modification resulting from fisheries related loss of suspension feeders</u>***

Long Island's south shore estuaries (LISSE) represent a series of contiguous barrier island estuaries including Great South Bay. LISSE have been documented as some of the most productive estuaries in the nation with regard to benthic and pelagic primary productivity and the harvest of shellfish (*1-3*). The most successful shellfishery in the LISSE has been that of the northern quahog or hard clam, *Mercenaria mercenaria*. During the 1970s, two out of every three hard clams eaten on the east coast of the United States came from LISSE and accounted for 54% of the total US hard clam harvest (*4*). These peak hard clam landings were followed by a precipitous decline in clam densities, as harvest mortalities greatly exceeded natural recruitment during the 1980s (*3*). More recent observations suggest that current settlement, growth and survival of hard clams in the LISSE are at an unprecedented low level (*5*) with recent harvest levels nearly two orders of magnitude lower than that observed in the mid 1970s. Concurrently, eelgrass coverage within LISSE has declined dramatically (Dennison et al 1989).

As "ecosystem engineers," hard clams played an important role by controlling the species diversity and abundance of phytoplankton and enhancing ecosystem stability (*6*). The benthic environment of a healthy clam bed consists of numerous individuals that create burrows, circulate water, and translocate the primary and secondary production from the water column to the benthos. It is therefore reasonable to assume that hard clams have an important influence on eelgrass abundance and survival by oxygenating the sediments, trapping seeds and supplying organic matter and nutrients to the benthos.

<u>Filter feeders enhance water clarity.</u> Chesapeake Bay represents a dramatic example of how the absence of suspension feeders has changed water clarity. There, the loss of historical oyster reefs has been implicated in phytoplankton blooms, reduced water clarity, and loss of submerged aquatic vegetation (*7-9*). Eelgrass is extremely sensitive to light levels and oysters played the central role of transforming pelagic organic matter into benthic production and keeping the water column clear (*9*). That role has been lost in many east coast estuaries, but in some areas it has been replaced by introduced filter feeders. The arrival of *Corbicula fluminea* in the Potomac River estuary improved water clarity and allowed eelgrass to reappear in areas from which it had been absent for 50 years (*10*). Similarly, *Poamocorbula amurensis* in San Francisco Bay are reducing phytoplankton and zooplankton densities (*11, 12*).

During the past quarter century, changes in LISSE microalgal communities have strongly influenced SAV communities. During the 1970's, when Long Island's hard clam fishery was the most productive in the nation (*13*), eelgrass covered 40% of LISSE (*1*). In 1985, the first brown tide bloom of the pelagophyte, *Aureococcus anophagefferens* occurred in LISSE. The annual reoccurrence of these blooms in the subsequent two decades has substantially altered the ecology of these estuaries. The negative impact of *A. anophagefferens* on eelgrass beds is well known. The severe light attenuation which occurs during brown tides reduces light levels and thus causes the destruction of eelgrass beds (*1*). It has been postulated that almost all eelgrass beds in LISSE currently subsist under subsaturating light (*14*).

<u>Benthic filter feeders fertilize estuarine sediments.</u>

In addition to improving water clarity, grazing activity of filter feeders elevate submerged aquatic vegetation growth and productivity by increasing the nutrients available to the rhizosphere (*15-18*). By removing water column particulates, suspension feedings also alter the sediment characteristics. Feces and psuedofeces produced by bivalves can increase both sediment organic content and nutrient levels in sediment pore water (Fig 2).

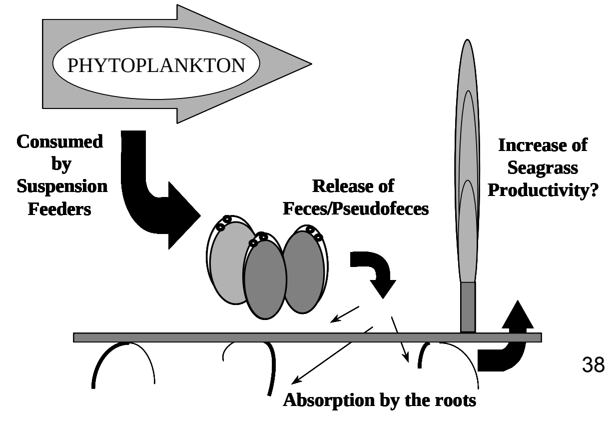


Figure 2. Conceptual model of hard clam role in elevating eelgrass productivity

Previously, Peterson and Heck (1999, 2001) found that the presence of the tulip mussel, *Modiolus americanus,* significantly increased the sediment nutrient pool and productivity of the seagrass, *Thalassia testudinum*. In addition, Reusch et al. (1994) working with the blue mussel, *Mytilus edulis,* and eelgrass, *Zostera marina,* on the west coast of the U.S. found that sediment porewater concentrations of ammonium and phosphate doubled in the presence of mussels, suggesting that the mussels fertilize eelgrass growth by the deposition of feces and pseudofeces. Similarly, Reusch and Williams (1998) demonstrated that the introduced mussel, *Musculista senhousia*, fertilized beds of *Z. marina* at moderate densities of individuals in the coastal waters off San Deigo.

Benthic filter feeders influence eelgrass recruitment, germination and seedling survival. There are three possible mechanisms by which filter feeders may influence eelgrass recruitment, germination and seedling survival. First, by providing a larger boundary layer and slowing water current speed, filter feeders may increase recruitment of floating seeds whether the seeds travel singly or within detached reproductive shoots. Seed entrapment can also be facilitated by the structure bivalves provide. Seed dispersal is limited outside *Zostera marina* beds (~80% seeds travel within 10 m of parent plants; (*19, 20*) so this effect is only important when eelgrass beds are near by or during the establishment of a new population. In addition, filter feeders might provide refuge for newly dispersed seeds from crustacean seed consumers (*21, 22*). The second mechanism by which hard clams may enhance eelgrass reproductive success is that bivalves can provide superior conditions for seed germination by filtering seawater and increasing sediment organic content. *Z. marina* seed germination is dependent on burial depth with the highest germination occurring at the anaerobic / aerobic interface (*23*). Filter feeders can act to bury and fertilize seeds at a depth that is appropriate for germination. Finally, filter feeders can increase the survival of seedlings, which have very high mortality rates (*19, 20*), by increasing light levels and nutrients and by protecting against erosion and herbivory. Despite the clear bottlenecks at these stages, there is surprisingly little information about the factors influencing eelgrass bed maintenance and formation, especially as they are related to the influence of other species interactions.

***Light Shading***

Phytoplankton abundance in LISSE. The composition and productivity of phytoplankton communities within LISSE have been well studied for over 50 yrs (*2, 24-29*) during which changes in microalgal communities have strongly influenced resident eelgrass communities. In the 1950's, Ryther (1954) documented green tides of the 'small form' (2 - 4 µm) chlorophytes, *Nannochloris* sp. and *Stichococcus* sp. in Moriches Bay and Great South Bay (GSB). Blooms of these species lasted over six months each year (spring through fall) during which chlorophyte cell densities often exceeded $10^7$ cells $ml^{-1}$. Poor estuarine flushing and inputs of duck farm waste along affected bays were identified as factors promoting the green tides of the 1950's (*24, 30*). When a channel was dredged in the late 1950s and LISSE became well flushed with ocean water, the green tide blooms terminated.

During the 1970s, phytoplankton communities documented within LISSE were markedly different from those observed in the 1950s. While "small forms" or picoplankton were present at that time, they were part of a mixed assemblage of phytoplankton. For example, Weaver and Hirshfield (1976) indicated that pennate diatoms were the most abundant phytoplankter in western GSB. Similarly, Cassin's (1978) demonstrated that small phytoplankton (< 10 µm) represented a small portion (< 35%) of phytoplankton biomass across GSB and also noted an abundance of diatom species, as well as dinoflagellates. During a 1979-1980 study, Lively et al. (1981) reported that small phytoplankton comprised approximately half of the phytoplankton biomass in GSB and that diatoms, cryptophytes and flagellates were also abundant. It was also during the 1970's, when larger phytoplankton were more abundant and monospecific algal blooms were not reported, that hard clam landings and eelgrass bed coverage in LISSE reached maximal levels (40%; COSMA, 1985; Dennision et al., 1989).

Overharvesting was responsible for a tremendous decline in hard clam populations through the late 1970s and early 1980s (COSMA, 1985). Concurrently, the phytoplankton community in LISSE changed from the one described during the peak of the hard clam industry in the 1970s. In 1985, the first brown tide bloom of the pelagophyte, *Aureococcus anophagefferens* occurred in LISSE. The annual reoccurrence of these blooms in the subsequent two decades has substantially altered the ecology of these estuaries. The negative impact of *Aureococcus anophagefferens* on the growth and survival of eelgrass beds is well known (*1, 31*). The severe light attenuation which occurs during brown tides reduces benthic light levels and thus causes the destruction of eelgrass beds.

In addition to the obvious impacts of brown tide on eelgrass in LISSE, it seems those phytoplanktons which currently dominate LISSE, even when brown tide is not in bloom, may also be deleterious to eelgrass beds. While the LISSE was dominated by moderate sized phytoplankton species during the 1970s (*2, 26, 27*), recent data demonstrates that phytoplankton smaller than 5 µm now comprise the majority of phytoplankton biomass in these ecosystems. For example, during multiple studies we have undertaken in LISSE since 1998, we have found that small phytoplankton (< 5 µm) now dominate (up to 90%) of algal assemblages in LISSE such as Great South Bay, Quantuck Bay, and Mecox Bay (Fig 3). This is in stark contrast to earlier studies (*2, 26, 27*), which found a smaller percentage of "nano-phytoplankton", despite the use of a 10 µm size cut-off to define this algal group. The dominance of small phytoplankton (< 5 µm) in phytoplankton communities within multiple LISSE sites has also been observed by other investigators using flow cytometric techniques (*32*).

This abundance of small phytoplankton is likely to have a negative impact on eelgrass beds. *Zostera* typically requires 15 – 25% of incident light for maximal growth (*33*) and light penetration generally has the greatest ecological impact on the growth, distribution and biomass of eelgrass beds (*33, 34*). Moreover, almost all eelgrass beds in LISSE currently subsist under subsaturating light, and thus any change in light levels in LISSE will impact photosynthesis and biomass of existing *Zostera* populations (*14*). Since small particles tend to scatter light more than larger particles (*35*), the current abundance of picoplankton in LISSE (Fig

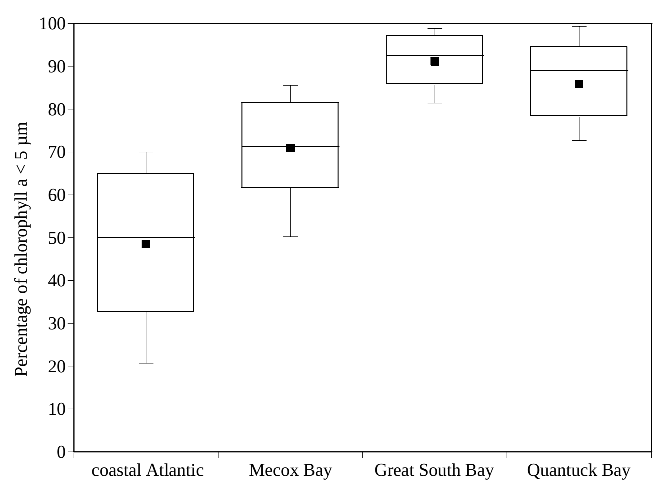


**Figure 3.** A comparison of the percentage of chlorophyll passing through a 5 µm mesh from samples collected in the coastal Atlantic Ocean (2002), Mecox Bay (2002), Great South Bay (1998 – 2002), and Quantuck Bay (1999 – 2002). Note: Mecox Bay is a temporally open estuary on the south shore of Long Island which exchanges with the Atlantic Ocean and is located 5 km east of Shinnecock Bay within LISSE.

3) has likely contributed to reduced light levels and hence reduced eelgrass distribution

The most recent change in phytoplankton community structure also does not bode well for eelgrass in Long Island estuaries. During the past three summers, harmful dinoflagellates blooms caused by *Cochlodinium* sp. have occurred in eastern Long Island waters, including Shinnecock Bay. The extremely high biomass associated with these blooms (> 100 µg chlorophyll *a* $L^{-1}$) results in a shading effect equal to or greater than brown tides (Gobler et al submitted). Moreover, these blooms have a direct lethal effect on shellfish. Bay scallops exposed to bloom densities of *Cochlodinium* sp. for one week experienced 70% mortality and a 50% decrease in growth rate relative to control treatments (Gobler et al submitted). Other filter-feeding bivalves (hard clams, oysters) also experience significantly enhanced mortality relative to control treatments (Gobler et al submitted). Clearly, these blooms will negatively impact filter feeding bivalves and as well as eelgrass.

***Sulfide Toxicity***

Recent studies have shown that sediment sulfide concentrations can also act alone or synergistically to cause chronic, sublethal or acutely lethal stress on seagrasses (*36-38*). Sulfide is produced naturally in anaerobic marine sediments by heterotrophic bacteria which use sulfate as a terminal electron acceptor in breakdown of organic matter (*39*). Because seagrass sediments typically have high organic matter content, sulfate reduction rates in seagrass sediments are higher than in unvegetated marine sediments (*36, 40*). Sulfide is also a potent cytotoxin, irreversibly binding enzymes involved in electron transport for both photosynthesis and respiration (*41*). Sulfide also causes hypoxia in seagrass roots and rhizomes by reacting with photosynthetically-produced oxygen diffusing from leaves to below-ground tissue. Marine plants and animals vary in their ability to tolerate sulfide, using a variety of avoidance strategies to exclude sulfide and accommodation strategies to detoxify sulfide (*41*). However, the tolerance limits of seagrasses can be exceeded if sulfide accumulates to toxic levels in sediment porewater. The amount of sulfide which accumulates in seagrass bed sediments depends on a number of physical and chemical characteristics. Tidal currents, wave action, and sandy sediments facilitate exchange of sediment porewater with the overlying water column, resulting in oxidation or export of sulfide produced by bacteria. In contrast, sulfide concentrations are generally higher in quiescent areas with fine grained sediments. Eelgrass may be affected by both the direct and indirect sulfide toxicity effects. The direct, cytotoxic effects will result from the reaction of sulfide with enzymes required for photosynthesis and respiration. Indirect toxicity effects are caused by hypoxia when photosynthetically-produced oxygen oxidizes sulfide which enters roots and rhizomes. Oxygen production and transport within plants is the key to resistance to hypoxia and sulfide toxicity, and eelgrass survival will depend on a balance between the plant's oxygen supply and sediment porewater sulfide (Fig 4). Any process which causes the elevation of sediment sulfide increases

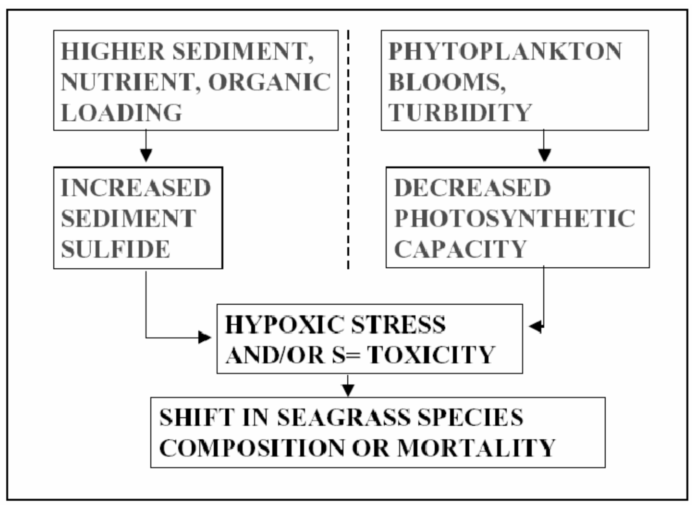


**Figure 4. Factors affecting the vulnerability of eelgrass to sulfide toxicity.**

hypoxia or sulfide toxicity in eelgrass. Sulfide toxicity can also be increased by factors which decrease eelgrass photosynthesis (e.g. reduced light levels or increased water temperature).

***Temperature***

The Intergovernmental Panel on Climate Change (IPCC) has predicted that global temperatures may rise by as much as 6 °C over the next century (*42*). Temperatures in Long Island waters have increased by 1.5°C between 1976 and 2000 (*43*), which represents typical patterns seen in the northeast US coast. Consistent with these findings, our analysis of summer (June – August) temperatures recorded by the Suffolk County Department of Health Services, Office of Ecology, in the shallow bays of eastern Long Island, have revealed that the maximum summer temperatures have steadily increased during the past two decades (Fig 5). In addition to stress on eelgrass populations caused by light limitation, sulfide toxicity, and habitat modification, higher sustained temperatures during summer months are likely to limit the productivity and recovery of this population.

Critical thermal stress has been reported in temperate seagrasses at temperatures above 25 °C (*44-46*). The effects of thermal stress on photosynthesis, productivity and morphology of seagrasses have been examined (*47-50*). Thorhaug et al. (1978) reported that at temperatures elevated 3–4 °C above ambient, seagrasses showed evidence of reduced standing crop and productivity, and that tropical species were more tolerant than temperate species, such as eelgrass, to elevated temperature. In addition to reducing photosynthesis and productivity, high temperatures have a dramatic effect on the internal oxygen balance of eelgrass. Increasing water temperatures stimulate plant respiration more than photosynthesis, and the meristems go anoxic, even in the light, at water temperatures above >25 °C. It has been hypothesized that low meristematic oxygen content resulting from increasing water temperatures may be a key factor in observed events of seagrass die-off (*51*).

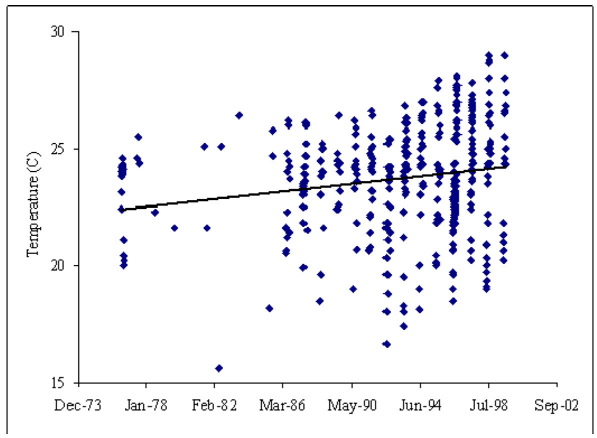

**Figure 5. June—August temperatures in Flanders Bay, NY, 1976-2000. Frequent monitoring of this system ceased after this time period.**

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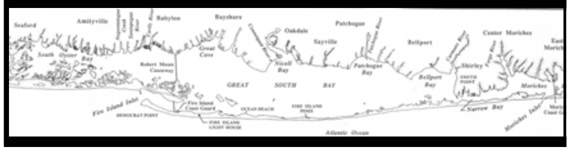
## Great South Bay

Length = 40 km
Width = 2.5 – 8 km
Ave. depth = 1.3 m
Area = 235 km$^2$
RT = 54 – 84 days

- Separated from ocean by barrier island – Fire Island (150-750 m wide)
- Direct connection to ocean through Fire Island Inlet
- Indirect connection to ocean through Jones Inlet (west) & Moriches Inlet (east)



**Stressors → Structure → Ecosystem Function**

*Habitat modification* (loss of filter feeders)
*Light Shading* (increased phytoplankton and turbidity)
*Sulfide toxicity* (decreased bioturbation and oxygen injection by eelgrass)
*Increasing water temperature* (global climate change)

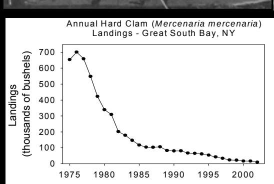
→ *Eelgrass Biomass And Associated Community* →

*Sediment stabilization* (reduced turbidity)
*Fisheries Resource* (nursery ground and predation refuge)
*Carbon Export* (detrital food resource)
*Sediment oxygenation* (reduced sulfide toxicity and enhanced nutrient regeneration)

## Fisheries related habitat modification

1. During the 1970s, 2 out of every 3 hard clams eaten on the east coast of the US came from LISSE and accounted for 54% of the total US hard clam harvest (McHugh, 1991). Population clearance rate ≈ 40% of the bay volume day$^{-1}$ and clams exerted control on plankton assembalge (Kassner, 1993)
2. These peak hard clam landings were followed by a precipitous decline in clam densities, as harvest mortalities greatly exceeded natural recruitment during the 1980s (Cosma, 1985)
3. Most recent observations suggest that current settlement, growth and survival of hard clams in the LISSE are at an unprecedented low level (NYDEC 2001) with recent harvest levels nearly two orders of magnitude lower than that observed in the mid 1970s. Under current conditions, population clearance rate < 1% of the bay volume and clams exert no control on plankton assemblage.

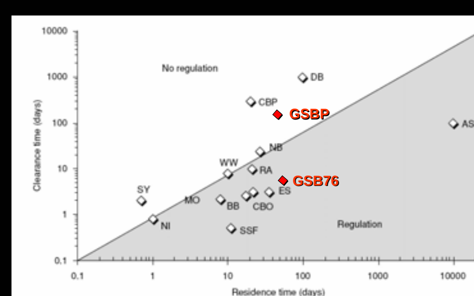
## Fisheries Related Habitat Modification




Time to filter GSB:

1976: 3 days

2005: > 3 months



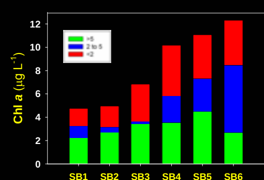

CBO: Chesapeake Bay, Past; NB: Narangasett Bay; DB: Delaware Bay; CBP: Chesapeake Bay, Present. (From Dame, 1996)

## Habitat Modification #1: Decrease in water clarity

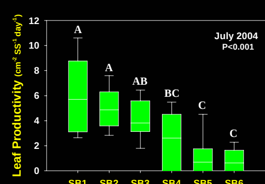
1. During the 1970's, eelgrass covered 40% of LISSE.
2. In 1985, the first brown tide bloom occurred and eelgrass coverage was reduced by 40-50% by 1988 and more restricted to Fire Island and the western region (Dennison et al. 1989).
3. It has been postulated that almost all eelgrass beds in LISSE currently subsist under sub-saturating light (Findlay 2001).

Tank without clams
Brown tide densities > 10^5

Tank with clams:
Brown tide densities < 10^4

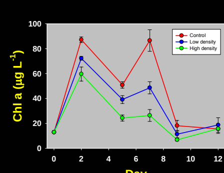


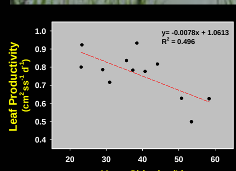


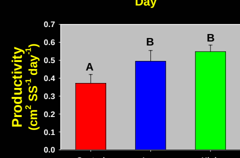

## Consequences for light scatter

1. During the 1970s, the LISSE was dominated by moderate sized phytoplankton species
2. Small phytoplankton (< 5 µm) now dominate (up to 90%) of algal assemblages in LISSE such as Great South Bay, Quantuck Bay, and Mecox Bay
3. This abundance of small phytoplankton is likely to have a negative impact on eelgrass beds since small particles tend to scatter light more than larger particles (Morel 1987)

## Mesocosm Experiment



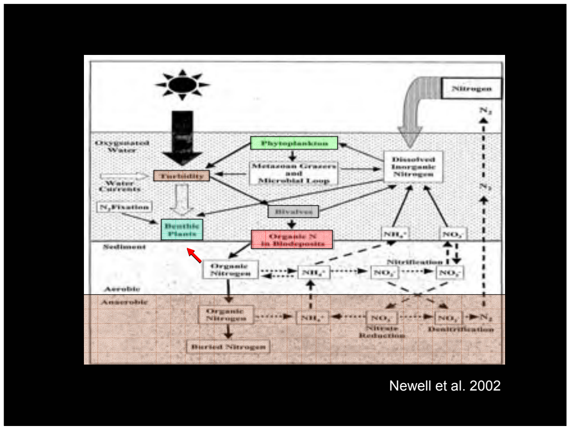



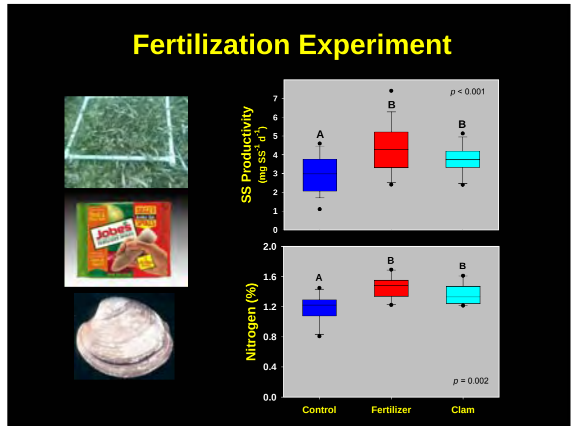



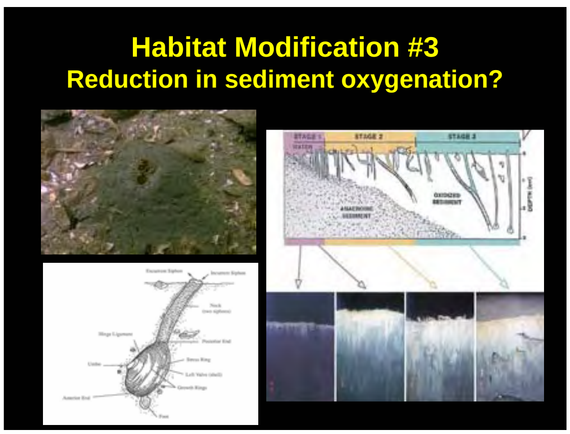

## Habitat Modification #2:

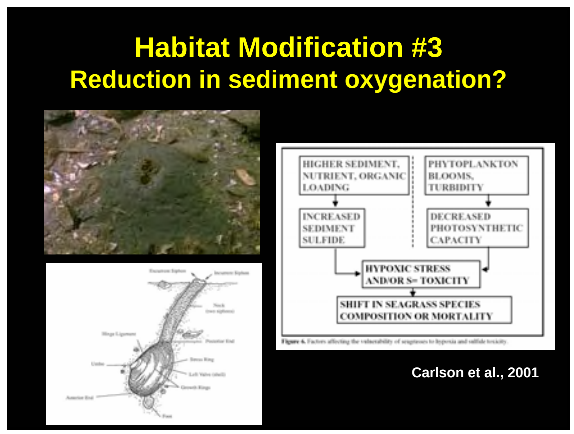
### Reduction in the translocation and burial of nutrients from the water column to the sediments

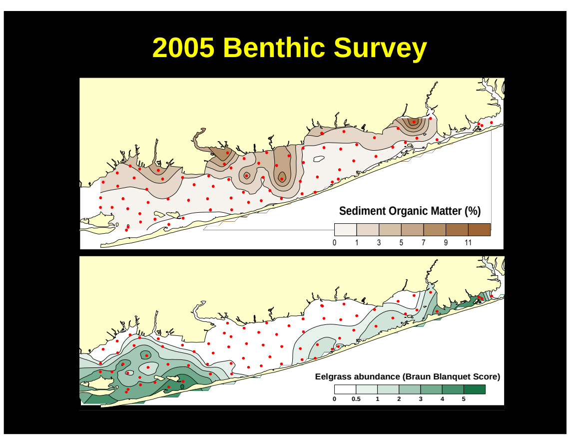
1. Suspension feeders have been repeatedly demonstrated to translocate PON, POP from the water column to the sediment.
2. These biodeposits increase sediment pore water nutrient concentrations which are available for seagrass production.
3. Eelgrass productivity in some areas of the LISSE have been demonstrated to be limited by sediment nutrient availability.

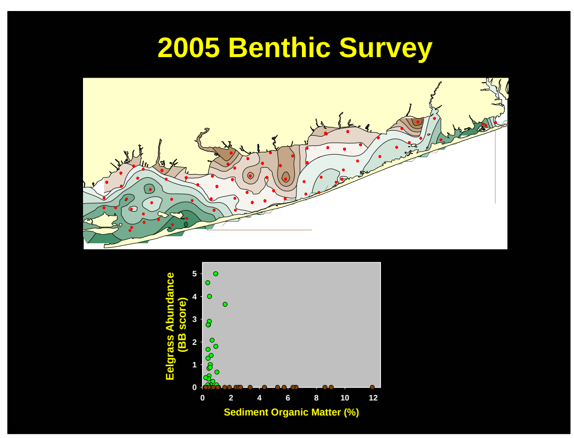

Nitrogen
Oxygenated Water
Phytoplankton
Dissolved Inorganic Nitrogen
Metazoan Grazers and Microbial Loop
Water Currents
Turbidity
N2 Fixation
Benthic Plants
Bivalves
Organic N in Biodeposits
Sediment
Organic Nitrogen
Nitrification
Aerobic
Anaerobic
Nitrate Reduction
Denitrification
Buried Nitrogen
Newell et al. 2002

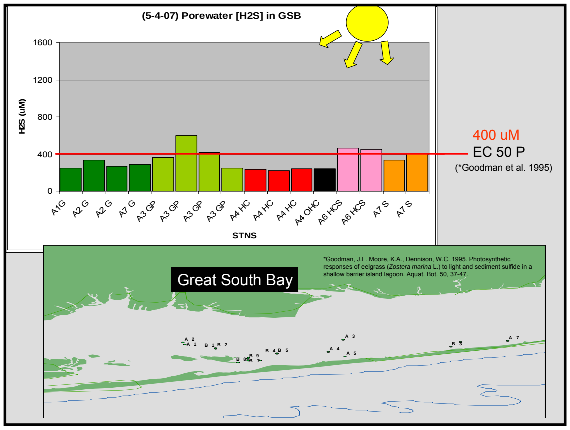

Fertilization Experiment
SS Productivity (mg SS⁻¹ d⁻¹)
p < 0.001
A
B
B
Nitrogen (%)
p = 0.002
Control
Fertilizer
Clam


Habitat Modification #3
Reduction in sediment oxygenation?
STAGE 1
STAGE 2
STAGE 3
ANAEROBIC SEDIMENT
OXIDIZED SEDIMENT
DEPTH (cm)


Habitat Modification #3
Reduction in sediment oxygenation?
HIGHER SEDIMENT, NUTRIENT, ORGANIC LOADING
PHYTOPLANKTON BLOOMS, TURBIDITY
INCREASED SEDIMENT SULFIDE
DECREASED PHOTOSYNTHETIC CAPACITY
HYPOXIC STRESS AND/OR S= TOXICITY
SHIFT IN SEAGRASS SPECIES COMPOSITION OR MORTALITY
Carlson et al., 2001


2005 Benthic Survey
Sediment Organic Matter (%)
0 1 3 5 7 9 11
Eelgrass abundance (Braun Blanquet Score)
0 0.5 1 2 3 4 5

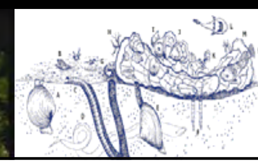

2005 Benthic Survey
Eelgrass Abundance (BB score)
Sediment Organic Matter (%)
0 2 4 6 8 10 12

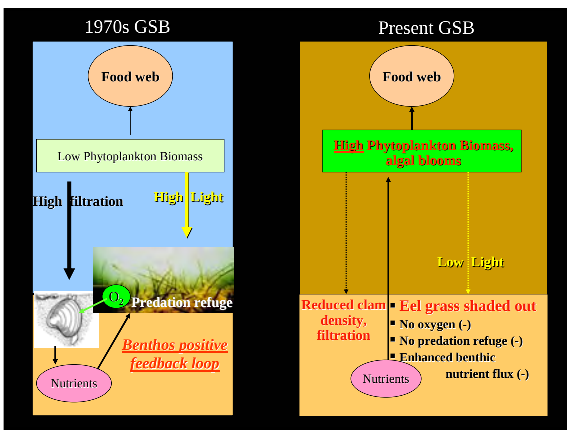


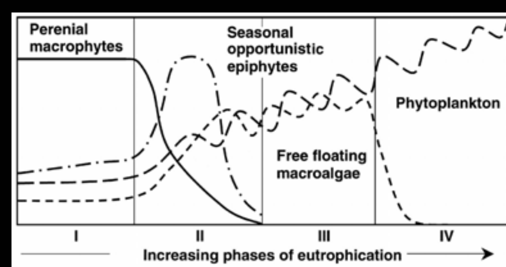

# Habitat Modification #4:

## Reduction in seed germination and survival?

1. Seed entrapment can be facilitated by the structure a mature hard clam community provides.
2. Hard clams can provide superior conditions for seed germination by increasing sediment organic content. *Zostera* seed germination is dependent on burial depth with the highest germination occurring at the anaerobic / aerobic interface (Bigley 1981). Filter feeders can act to bury and fertilize seeds at a depth that is appropriate for germination.
3. Finally, filter feeders can increase the survival of seedlings, which have very high mortality rates (Orth et al. 1994a; Ruckelshaus 1996), by increasing light levels and nutrients and by protecting against erosion and herbivory.






After Schramm, 1999

**Seagrass Distribution in Long Islands South Shore Bays**

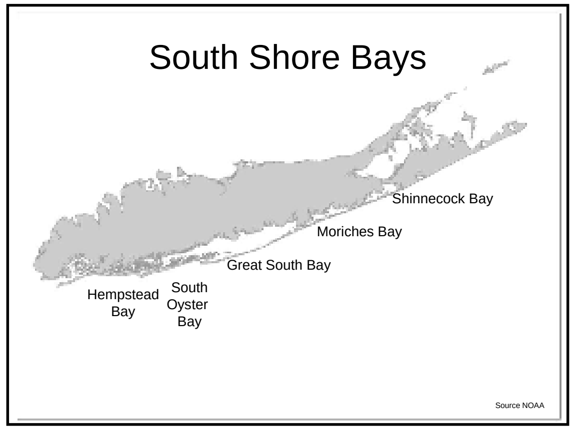
Chris Clapp
*Estuary Specialist*
*The Nature Conservancy*

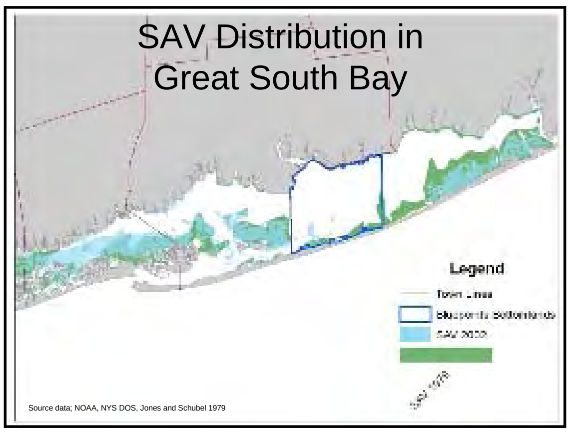
This presentation summarizes the current state of seagrass distribution in Long Islands South Shore Bays compares the relevant datasets available and presents data on what might be driving the trends in seagrass trends. The South Shore Bays include Hempstead Bay, South Oyster Bay, Great South Bay, Moriches Bay and Shinnecock Bay. Particular attention was focused upon the Great South Bay as there is more data available for this body of water.

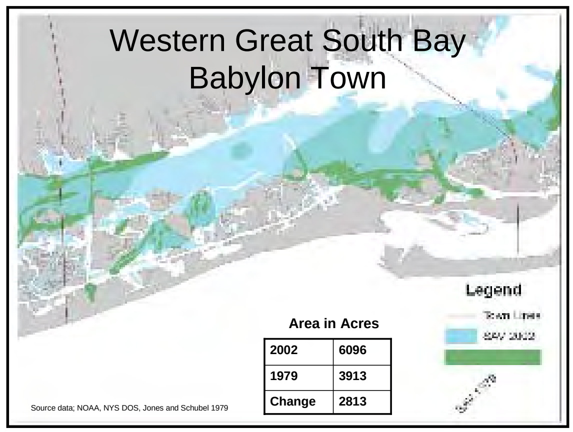
The two data sets available that illustrate seagrass distribution are Data presented includes a survey performed using discreet grab samples performed by Jones and Schubel in 1979 giving the baseline of seagrass distribution for Great South Bay from the Wantagh Parkway to the Smith Point Bridge. The second dataset was supplied by the New York Department of State Office of Coastal Services and is based upon geographically referenced aerial photos taken in 2002 and includes all of the South Shore Bays. While the methods for the two datasets are very different and cannot be directly compared for trends it is possible to get a broad perspective of change between the two datasets.

The focal point of this presentation was Great South Bay. The bay was broken into townships which also correspond to geographical regions within the bay. The data revealed that seagrasses had apparently made a resurgence (~2000 acre gain) in the western bay (Town Of Babylon) and lost acreage (~5000 acre loss) in the eastern end of the bay (Town of Brookhaven), the central part of the bay (Town of Islip) remained relatively stable. While some of the discrepancy may be due to the difference in survey methods the amount of change would likely exceed the error due to methodology.

Additional data presented included sewage district maps and the out fall plants, a 2 meter contour chart, and a draft map of shoreline hardening. This data was presented to give the expert panel some background knowledge of the system and what might be contributing to or inhibiting seagrass growth.

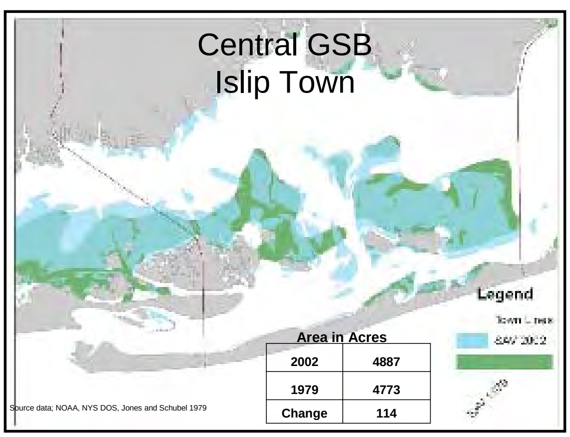



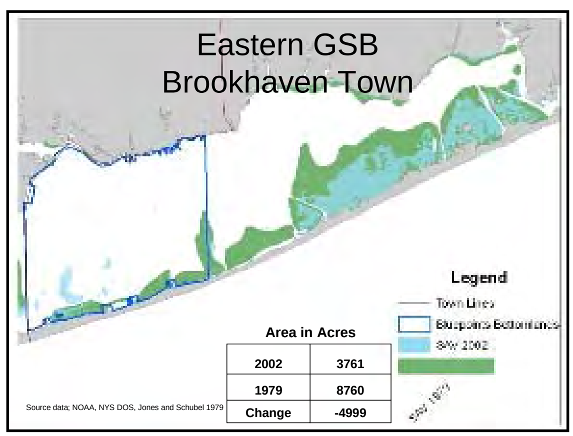

Area in Acres

| | |
|---|---|
| 2002 | 6096 |
| 1979 | 3913 |
| Change | 2813 |



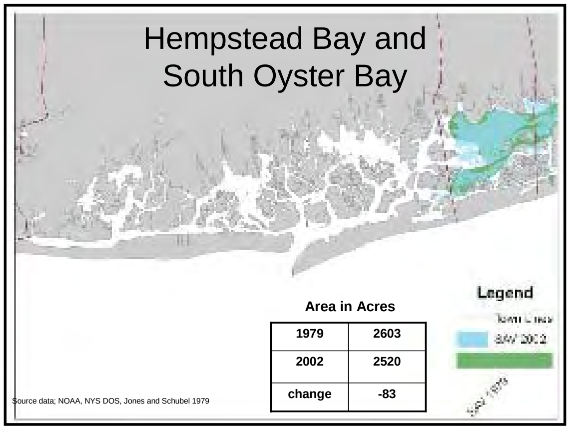

Area in Acres

| | |
|---|---|
| 2002 | 4887 |
| 1979 | 4773 |
| Change | 114 |



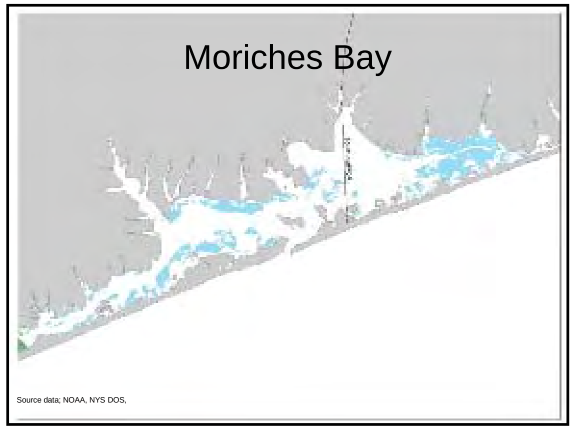

Area in Acres

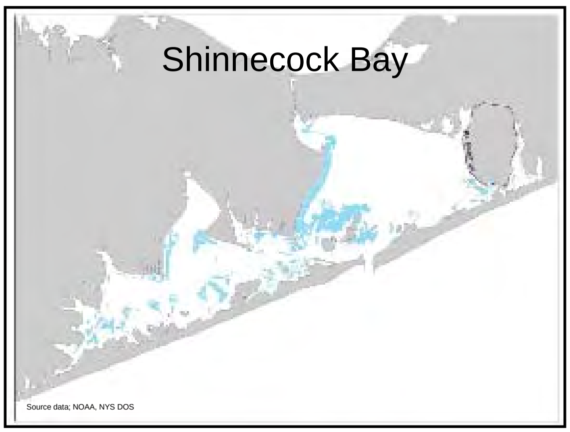
| | |
|---|---|
| 2002 | 3761 |
| 1979 | 8760 |
| Change | -4999 |

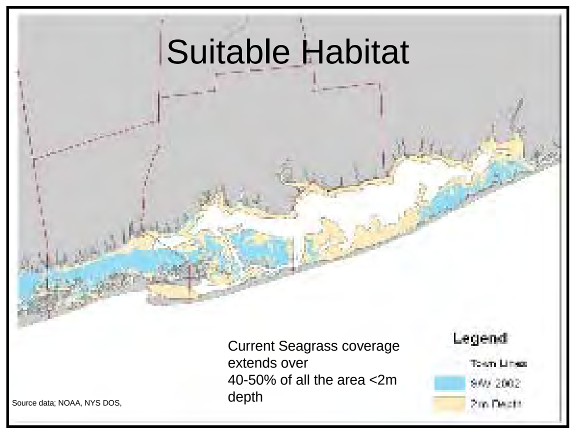


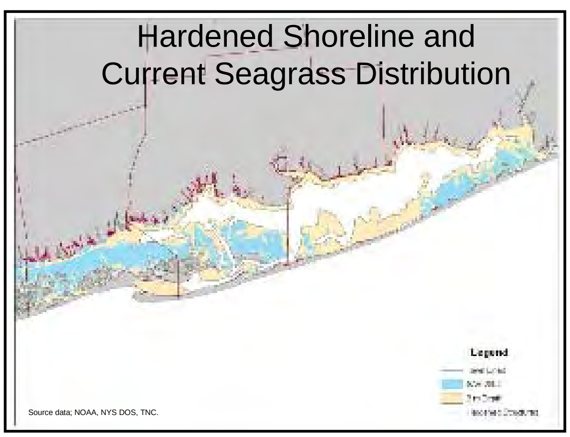

Area in Acres

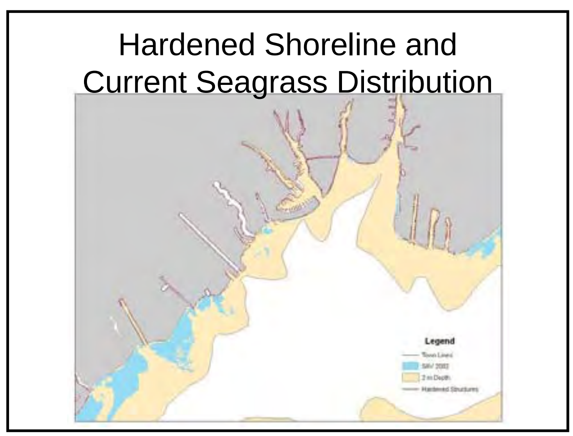
| | |
|---|---|
| 1979 | 2603 |
| 2002 | 2520 |
| change | -83 |

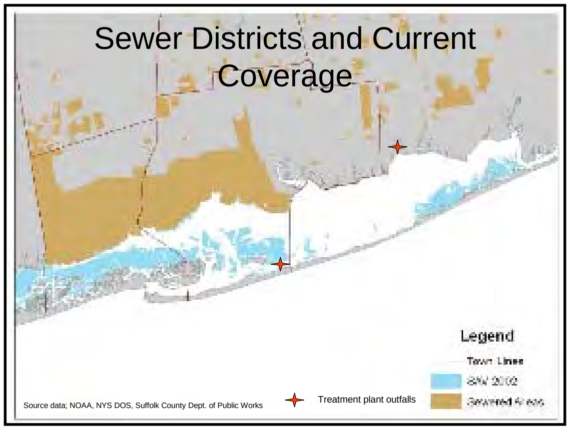


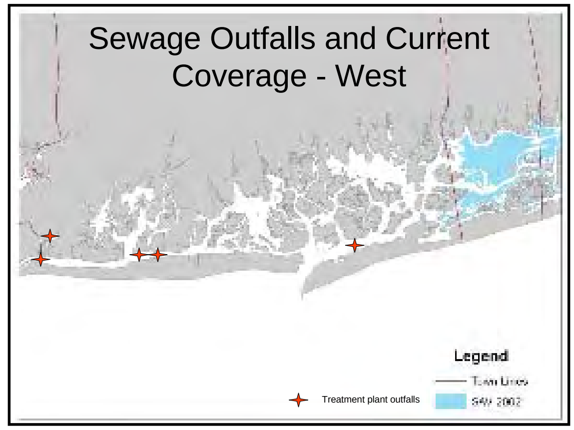




Sewer Districts and Current Coverage
Legend
Town Lines
SAV 2002
Sewered Areas
Treatment plant outfalls
Source data: NOAA, NYS DOS, Suffolk County Dept. of Public Works


Sewage Outfalls and Current Coverage - West
Legend
Town Lines
SAV 2002
Treatment plant outfalls


Nature Conservancy's Restoration Efforts


Nature Conservancy's Restoration Efforts

**Eelgrass Status in the Peconic Estuary:**
**Historic vs. Present Distribution and Current Trends**

Steve Schott
*Marine Botany Educator*
*Cornell Cooperative Extension*

Prior to the implementation of the Comprehensive Conservation and Management Program (CCMP), there was no baseline data on the health or extent of eelgrass (*Zostera marina* L.) in the Peconic Estuary. The Long-term Eelgrass Monitoring Program (LTEMP) was initiated in 1997 to provide baseline data on several eelgrass meadows in the Estuary and continue with annual monitoring to identify trends in population dynamics and areal extent of these beds over time. In support of the LTEMP and restoration efforts, historic eelgrass coverage for the Estuary was determined using 1930 aerial photographs and compared to an aerial survey conducted in 2000. In 1930, eelgrass covered approximately 8,720 acres of the Estuary, whereas, the 2000 study found only 1,552 acres of eelgrass remained. This represents an average rate of loss of almost 100 acres per year. The trend since 2000 finds that the six LTEMP reference populations have shown a relatively steady decrease in shoot density and areal extent and, currently, two of the monitoring sites no longer support eelgrass.

## Eelgrass Status in the Peconic Estuary: Historic vs. Present distribution and current trends

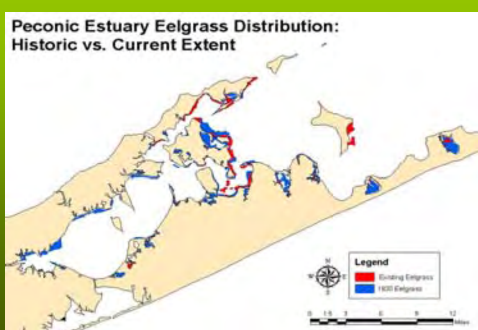
Stephen Schott
Cornell Cooperative Extension
Marine Program

## Overview

1) Distribution of Eelgrass (*Zostera marina* L.) in the Peconic Estuary
   - Historic versus Current Distribution
2) PEP Long-term Eelgrass Monitoring Program
   - Background
   - Methodology
   - Trends

## Eelgrass Distribution

Historic vs. Present: Peconic Estuary




## Eelgrass Distribution

**Summary**

- **The Peconic Estuary contained 8,720 acres of eelgrass in 1930 (This is a conservative estimate and does not include 1,990 acres of unconfirmed beds).**
- **The Tiner report (2003) calculated 1,552 total acres of eelgrass based on 2000 aerials, though that number is likely low as undocumented beds have since been identified.**
- **This represents a loss of over 80% in a 70 year period (~100 acres/year).**

## PEP Long-term Eelgrass Monitoring Program

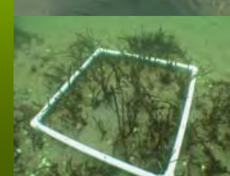
Background

- The PEP contracted Cornell Cooperative Extension, Marine Program to develop and conduct long term eelgrass monitoring in 1997
- The Program includes 6 reference beds from around the Estuary: Bullhead Bay (BB), Gardiners Bay (GB), Northwest Harbor (NWH), Orient Harbor (OH), Southold Bay (SB) and Three Mile Harbor (TMH).

## PEP Long-term Eelgrass Monitoring Program

Methodology

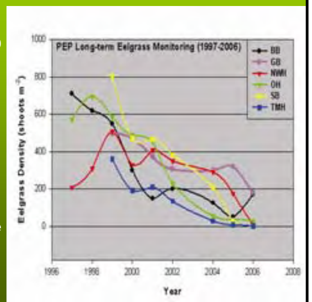
- **6 reference sites (beds), each with 6 monitoring stations**
- **Eelgrass shoot density is collected from 10 randomly placed 0.10 $m^2$ quadrats (Total of 60 quadrats per bed) at each station**
- **Percent cover of macroalgae, macroalgae species, and animals observed are recorded**



## PEP Long-term Eelgrass Monitoring Program

**Trend Analysis**

1) Overall, eelgrass shoot densities have been on a decline since 2000
2) 2002-2004 saw significant losses to several beds (75% and 78% for OH and TMH, respectively)
3) 2006 found complete loss of eelgrass for 2 of the reference sites (SB and TMH) and a significant reduction in density at 2 other sites (GB and NWH)
4) In 2006, BB showed a significant increase in shoot density from the previous year with eelgrass re-colonizing stations that were unvegetated in 2005.




## PEP Long-term Eelgrass Monitoring Program

**Summary**

- The major trend evident in the eelgrass data is the almost constant decline of eelgrass shoot densities in the six monitoring beds since 2000.
- Major declines in Bullhead Bay, Orient Harbor and Three Mile Harbor recorded in 2004 may be linked to the severe winters from 2002 through 2004. The extremely cold conditions froze the Estuary and resulted in ice scour in shallow areas and removal of eelgrass. Eelgrass decline in Southold Bay (2005) may be a result of burial by dredge spoils.
- Evidence of recovery in Bullhead Bay in 2006 indicates that extant beds may be able to reverse declining trends if/when causative pressures are relieved.

## Current Management and Research Approaches Involving Eelgrass in the Peconic Estuary

Kim Petersen
*Habitat Restoration Educator*
*Cornell Cooperative Extension*

Current Management and Research Approaches Involving Eelgrass in the Peconic Estuary includes a compilation of the following:

- Current management efforts which impact eelgrass, including local (towns bordering the Peconic Estuary) as well as state regulations.
- Proposed management actions addressed in the Peconic Estuary Program Comprehensive Conservation and Management Plan.
- Research which has taken place in the Peconic Estuary concerning or involving eelgrass.

Please see Appendix H.

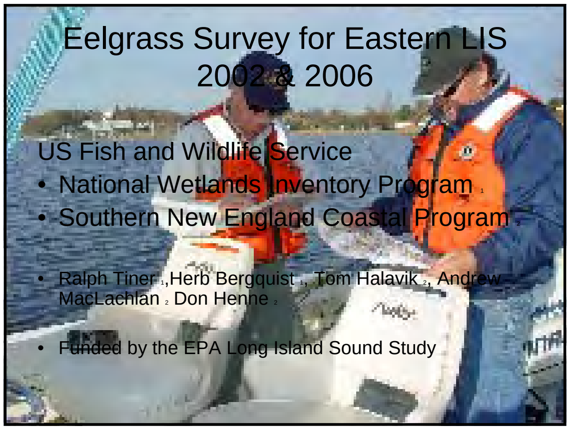
## 2006 Eelgrass Survey for Eastern Long Island Sound Connecticut and New York

Tom Halavik
*Senior Biologist*
*United States Fish and Wildlife Service*

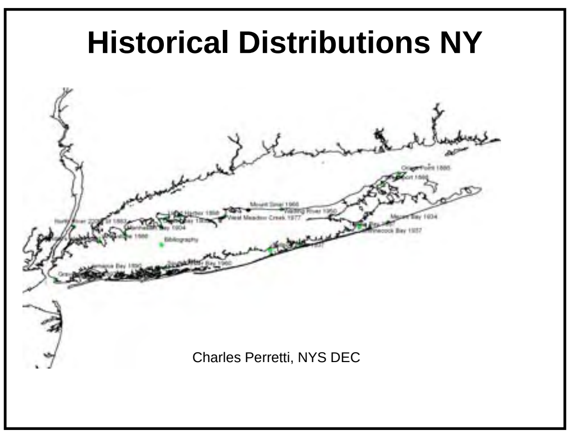
The U.S. Fish and Wildlife Service's National Wetlands Inventory Program (NWI) initiated this study in 2002 and produced a report on the distribution of eelgrass beds in the eastern portion of Long Island Sound: "Eelgrass Survey for Eastern Long Island Sound, Connecticut and New York" (Tiner, et al. 2003). This survey was intended to be the baseline study for monitoring the status of eelgrass in this area of Long Island Sound.
In 2004, the U.S. Environmental Protection Agency provided funding to update this survey in 2005. This presentation outlines the methods used in the survey, summarizes inventory results, compares the findings with the 2002 survey, and provides detailed maps showing the location of eelgrass (*Zostera marina*) beds detected during the 2006 survey.

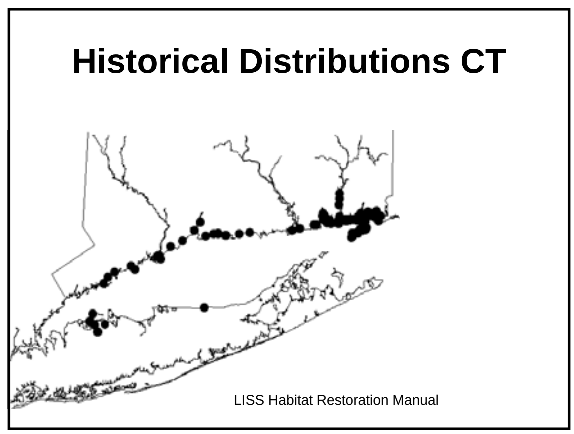
The project study area encompasses the eastern end of Long Island Sound, including Fishers Island and the North Fork of Long Island. It included all coastal embayments and near shore waters (i.e., to a depth of –15 feet at mean low water) bordering the Sound from Clinton Harbor to the Rhode Island border and including Fishers Island and the North Shore of Long Island from Southold to Orient Point and Plum Island. The 2006 survey located and mapped 1,905 acres of eelgrass beds in eastern Long Island Sound. Eelgrass beds were mostly present from Rocky Neck State Park east to the Rhode Island border and the north shore of Fishers Island. Four beds were found on the North Shore of Long Island, New York, with three in the Mulford Point area. No eelgrass was found from the Old Lyme Shores sub-basin to Clinton Harbor, except for two small beds (totaling 6.4 acres) associated with the Duck Island breakwater in the Duck Island Roads sub-basin The largest loss of eelgrass was observed in Mumford Cove where 11 acres disappeared (probably due to increased sedimentation).

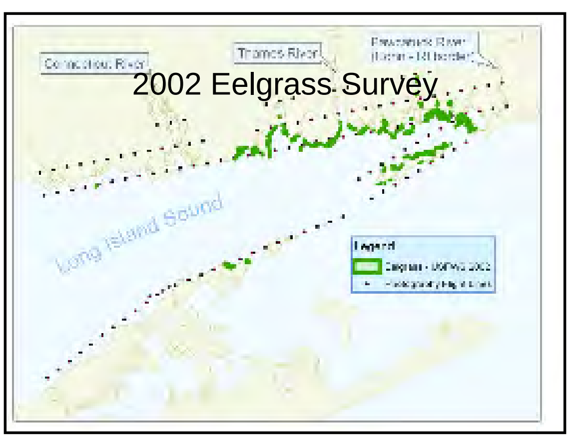
Funding for this project was provided by the U.S. Environmental Protection Agency, Office of Ecosystem Protection, Region I. Ralph Tiner was the principal investigator for U.S. Fish and Wildlife Service (Service) and was responsible for study design, coordination, and report preparation. Herb Bergquist did the bulk of the mapping work: photo interpretation, digital database construction, and GIS processing and prepared the maps and figures. The Southern New England Estuary Program (SNEP) was responsible for field review of potential eelgrass beds, with Andrew MacLachlan and Tom Halavik taking lead roles in this effort. Aerial photography was acquired and converted to digital images by James W. Sewall Company, Old Town, Maine.

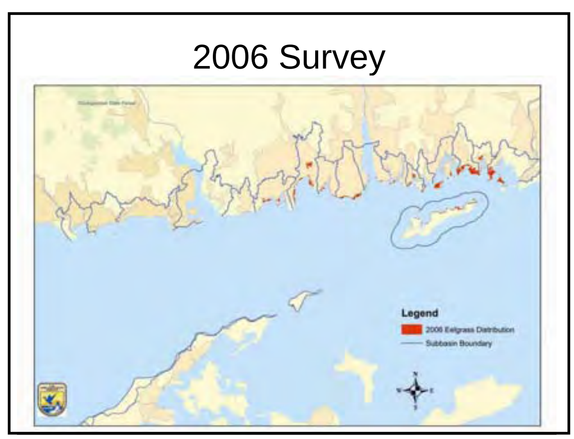

Eelgrass Survey for Eastern LIS
2002 & 2006
US Fish and Wildlife Service
• National Wetlands Inventory Program
• Southern New England Coastal Program
• Ralph Tiner ,Herb Bergquist , Tom Halavik , Andrew MacLachlan , Don Henne
• Funded by the EPA Long Island Sound Study

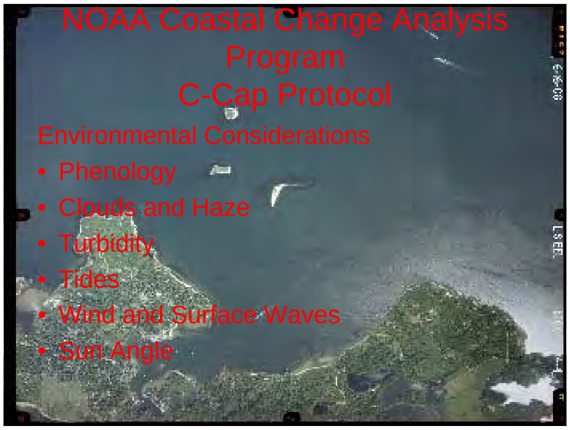

Long Island Sound
Eelgrass (Zostera marina)
Historical Distributions,
Present Status,
Current Management and
Research Approaches


Historical Distributions NY
Charles Perretti, NYS DEC


Historical Distributions CT
LISS Habitat Restoration Manual


2002 Eelgrass Survey
Connecticut River
Thames River
Long Island Sound
Legend


2006 Survey
Legend
2006 Eelgrass Distribution
Subbasin Boundary


NOAA Coastal Change Analysis Program
C-Cap Protocol
Environmental Considerations
• Phenology
• Clouds and Haze
• Turbidity
• Tides
• Wind and Surface Waves
• Sun Angle

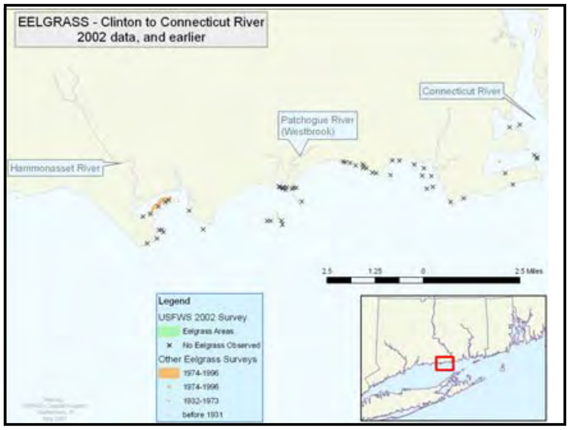

On The Water "Ground truth"
2002 Pattern Recognition

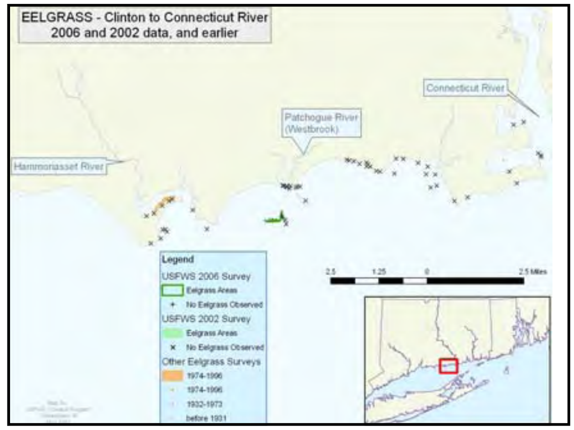

Equipment
• 2 – GPS's
• Color Sounder/Plotter
• Coastal Radar
• SeaTracker and Monitor
• 2- VHF radios

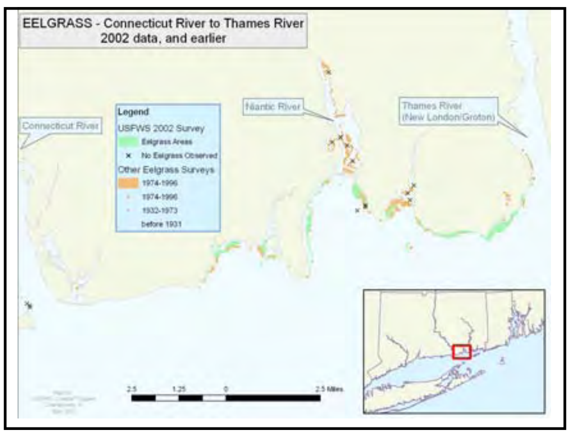

SeaViewer U/W Video
• Color Camera Specs:
• 420 Lines of Resolution
• 1.0 Lux low light sensitivity (the lower the better)
• 1/3 inch Color CCD area sensor
• 512(h) x 492(v) pick up area
• -25C to +60C Operating Temperature
• 78-degree Field of View Angle
• Operating Voltage: DC 9.6V~12V
• Power Consumption: Max 1.0 Watt
• Video out: 75ohm, 1Vp-p Composite signal
• Wide Angle Lens with Auto Focus & Gain

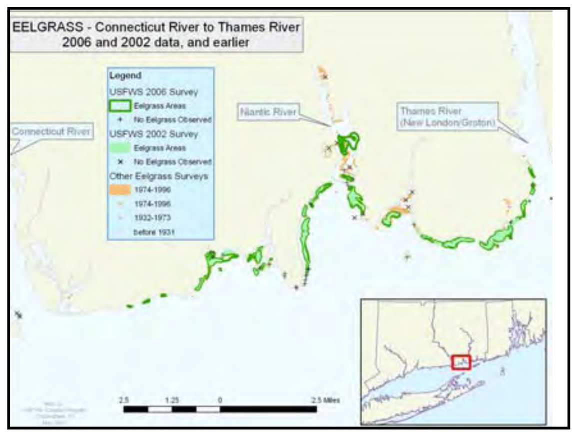

Underwater Camera with Directional Control
Capture video or stills with Sony Digital 8 TRV740I

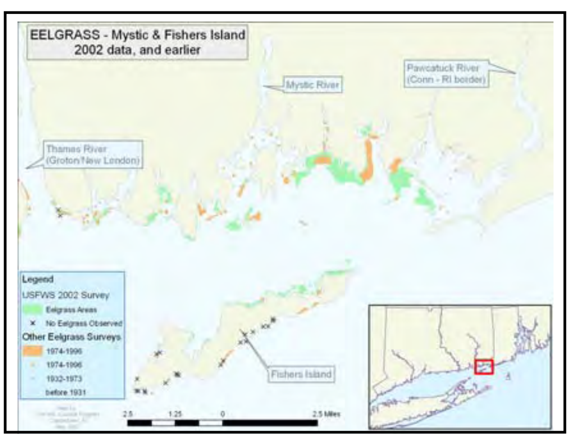

N 41 17.344
W071 57.082
Hdg: 33.3
Speed: 0.5
SEA - TRAK™ GPS Overlay
19:43:28
09-22-06

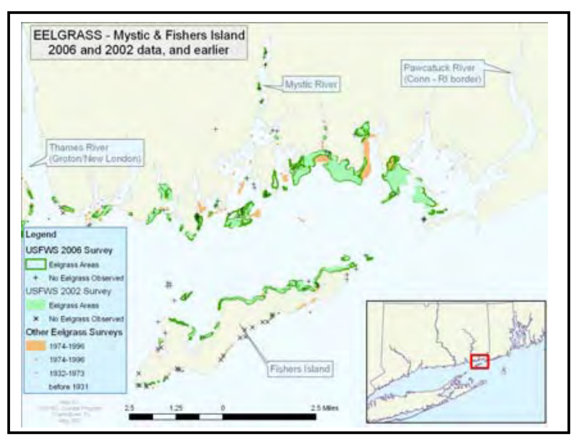

EELGRASS - Clinton to Connecticut River
2002 data, and earlier
Connecticut River
Patchogue River (Westbrook)
Hammonasset River
2.5 1.25 0 2.5 Miles
Legend
USFWS 2002 Survey
Eelgrass Areas
No Eelgrass Observed
Other Eelgrass Surveys
1974-1996
1974-1996
1932-1973
before 1931

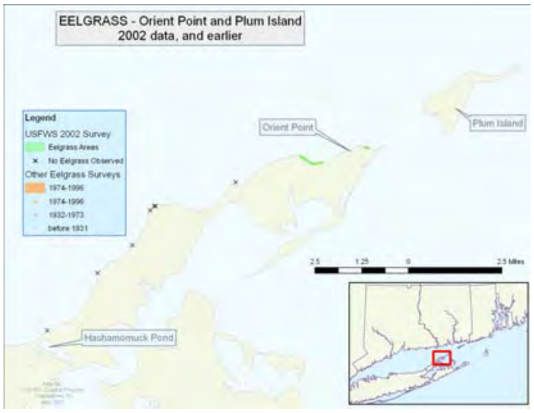

EELGRASS - Clinton to Connecticut River
2006 and 2002 data, and earlier
Connecticut River
Patchogue River (Westbrook)
Hammonasset River
Legend
USFWS 2006 Survey
Eelgrass Areas
No Eelgrass Observed
USFWS 2002 Survey
Eelgrass Areas
No Eelgrass Observed
Other Eelgrass Surveys
1974-1996
1974-1996
1932-1973
before 1931
2.5 1.25 0 2.5 Miles

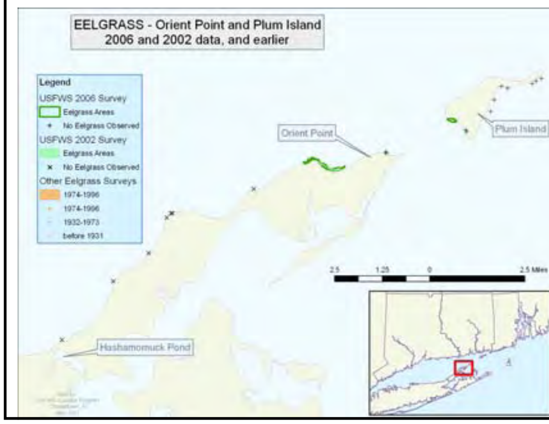

EELGRASS - Connecticut River to Thames River
2002 data, and earlier
Connecticut River
Niantic River
Thames River (New London/Groton)
Legend
USFWS 2002 Survey
Eelgrass Areas
No Eelgrass Observed
Other Eelgrass Surveys
1974-1996
1974-1996
1932-1973
before 1931
2.5 1.25 0 2.5 Miles


EELGRASS - Connecticut River to Thames River
2006 and 2002 data, and earlier
Legend
USFWS 2006 Survey
Eelgrass Areas
No Eelgrass Observed
USFWS 2002 Survey
Eelgrass Areas
No Eelgrass Observed
Other Eelgrass Surveys
1974-1996
1974-1996
1932-1973
before 1931
Niantic River
Thames River (New London/Groton)
Connecticut River
2.5 1.25 0 2.5 Miles


EELGRASS - Mystic & Fishers Island
2002 data, and earlier
Mystic River
Pawcatuck River (Conn - RI border)
Thames River (Groton/New London)
Legend
USFWS 2002 Survey
Eelgrass Areas
No Eelgrass Observed
Other Eelgrass Surveys
1974-1996
1974-1996
1932-1973
before 1931
Fishers Island
2.5 1.25 0 2.5 Miles


EELGRASS - Mystic & Fishers Island
2006 and 2002 data, and earlier
Mystic River
Pawcatuck River (Conn - RI border)
Thames River (Groton/New London)
Legend
USFWS 2006 Survey
Eelgrass Areas
No Eelgrass Observed
USFWS 2002 Survey
Eelgrass Areas
No Eelgrass Observed
Other Eelgrass Surveys
1974-1996
1974-1996
1932-1973
before 1931
Fishers Island
2.5 1.25 0 2.5 Miles




# 2002 – 2006 Comparisons
# 1,598 acres – 1,905 acres

| Acreage Change in Sub-basin | | Change # of Beds |
|---|---|---|
| Little Narragansett Bay | -2.8 | -2 |
| Stonington Harbor | +28.0 | +4 |
| Quiambog Cove | +70.7 | +6 |
| Mystic Harbor | +61.9 | -- |
| Palmer-West Cove | +0.1 | -2 |
| Mumford Cove | -11.0 | -1 |
| Paquonock River | -2.9 | -1 |
| New London Harbor | +3.9 | +1 |
| Goshen Cove | -4.9 | -- |
| Jordan Cove | -6.5 | -4 |
| Niantic Bay | +130.2 | -1 |
| Rocky Neck State Park | +7.7 | -- |
| Duck Island Roads | +5.3 | -- |
| Fishers Island, NY | +7.8 | +11 |
| North Shore, NY | +9.2 | +1 |
| Plum Island, NY | +9.5 | +1 |
| Total | +306.2 | +12 |

- Table 6. Differences in eelgrass survey results 2002-2006. + indicate gains and – losses.

# Previous and Current Studies

*TABLE 3-3. Suggested Water Quality Criteria for Eelgrass. Parameters are based upon environmental data collected at three seagrass sites in Long Island Sound over 18 months (Koch et al., 1994).*

| Parameter | LIS | Chesapeake Bay |
|---|---|---|
| Light attenuation coefficient, Kd ($m^{-1}$) | <0.7 | <1.5 |
| Total suspended solids, TSS (mg/L) | <30.0 | <15.0 |
| Chlorophyll *a*, CHLA ($\mu g\ l^{-1}$) | <5.5 | <15.0 |
| Dissolved inorganic nitrogen, DIN (mg/L) | <0.03 | <0.15 |
| Dissolved inorganic phosphorous, DIP (mg/L) | <0.02 | <0.02 |
| Sediment organic matter (%) | <3.0 | |
| Secchi depth (m) | >0.7 | >0.8 |

LISS Habitat Restoration Manual

# Previous and Current Studies

NEW ENGLAND ESTUARINE RESEARCH SOCIETY

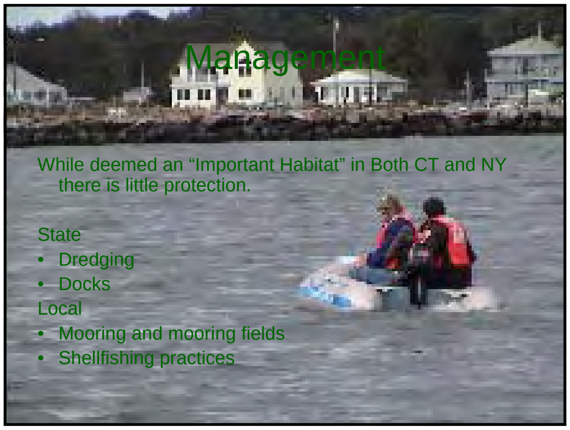
- ***ZOSTERA MARINA* BIBLIOGRAPHY FOR THE NEERS REGION**

# LISS Funded Study

Establish Restoration Objectives for Eelgrass in Long Island Sound

Prepared by:
University of Connecticut, Avery Point
and
Connecticut Department of Environmental Protection

The project will focus primarily on how nutrient loading may be affecting eelgrass in Connecticut's coves, embayments and tidal rivers and identify management measures that can be taken to restore eelgrass


Management
While deemed an "Important Habitat" in Both CT and NY there is little protection.
State
• Dredging
• Docks
Local
• Mooring and mooring fields
• Shellfishing practices

**A Brief History of Eelgrass Restoration on Long Island**

Chris Pickerell
*Habitat Restoration Specialist*
*Cornell Cooperative Extension*

INTRODUCTION

Long Island has three distinct estuaries, Long Island Sound (LIS), Peconic Estuary (PE) and the South Shore Estuary Reserve (SSER). LIS is characteristic of southern New England estuaries with a rocky high energy shoreline, the SSER is a coastal lagoon system that has extensive shallow flats characteristic of Mid-Atlantic estuaries, and the PE has characteristics of both New England and Mid-Atlantic estuaries. Table 1 provides a qualitative assessment of typical meadow characteristics for each area. Given these differences, restoration methods vary considerably between estuaries.

Table 1. Meadow characteristics for *Z. marina* growing around Long Island.

| Range | Meadow Type | Fetch | Sediment Type | *Z. marina* Depth | Temps. | Water Clarity | $1^{o}$ Stressor |
|---|---|---|---|---|---|---|---|
| Long Island Sound & Gardiners Bay | High-Energy | ≥8 miles | Sand to Rock & Cobble <OM | 0.5m to 4.5m | "Low" ≤23°C | Good | Disturbance (Waves) |
| Peconic Bay | Sheltered | ≤2 miles | Mud to Silty Sand >OM | 1m to 2m | "High" ≤30°C | Poor | Water Quality (Temp./Vis.) |
| South Shore Estuary Reserve | Shallow Lagoon | <4 miles | Mud to Sand ~OM | 0.5m to 2m | "Var" ≤28°C | ~ poor | WQ (Vis.) & Disturbance (Waves) |

Z. marina distribution in New York waters has been reduced to 10-25% of historic populations (from 1930 estimates) (Schott, pers com). In LIS and PE, eelgrass has been lost in most shallow, protected coves and harbors and retreated to deeper open waters. In the SSER, grass persists on many shallow subtidal flats. Much of the grass along the mainland shoreline in the SSER has been lost while populations ringing the north shore of the barrier island have fluctuated over the years. In some areas, meadows on these shallow sandy flat adjacent to the barrier island have expanded (e.g., parts of Shinnecock Bay).

Causes for this precipitous decline include, the wasting disease (1931), cultural eutrophication, nuisance algae blooms (i.e., "brown tide" Aureococcus anophagefferens) (1985+) and human-induced disturbance.

Extant eelgrass meadows grow subtidally in depths ranging from 0.5m to 4.5m, in mud to cobble and rock. In the early 20th century, ONE intertidal population was identified (Cold Spring Harbor), but this small meadow was lost later in the century.

There is considerable phenotypic plasticity within and between meadows depending on depth, wave exposure, light levels, bottom type, temperature and nutrient regime. Temperature appears to be a major controlling factor in these differences. Figure 1 shows a graph of typical bottom temperatures at extant meadows within each estuary. Both flowering period, and seed production can vary within and between the three estuaries (Table 2). Shoot length ranges from 20cm to 1.8meters. Epiphytic fouling varies greatly with site conditions from complete fouling with macroalgae, diatoms and or bryozoans to almost nothing. There is also a distinct seasonal shift in epiphyte and drift macroalgae assemblages with changes in water temperature and light levels.

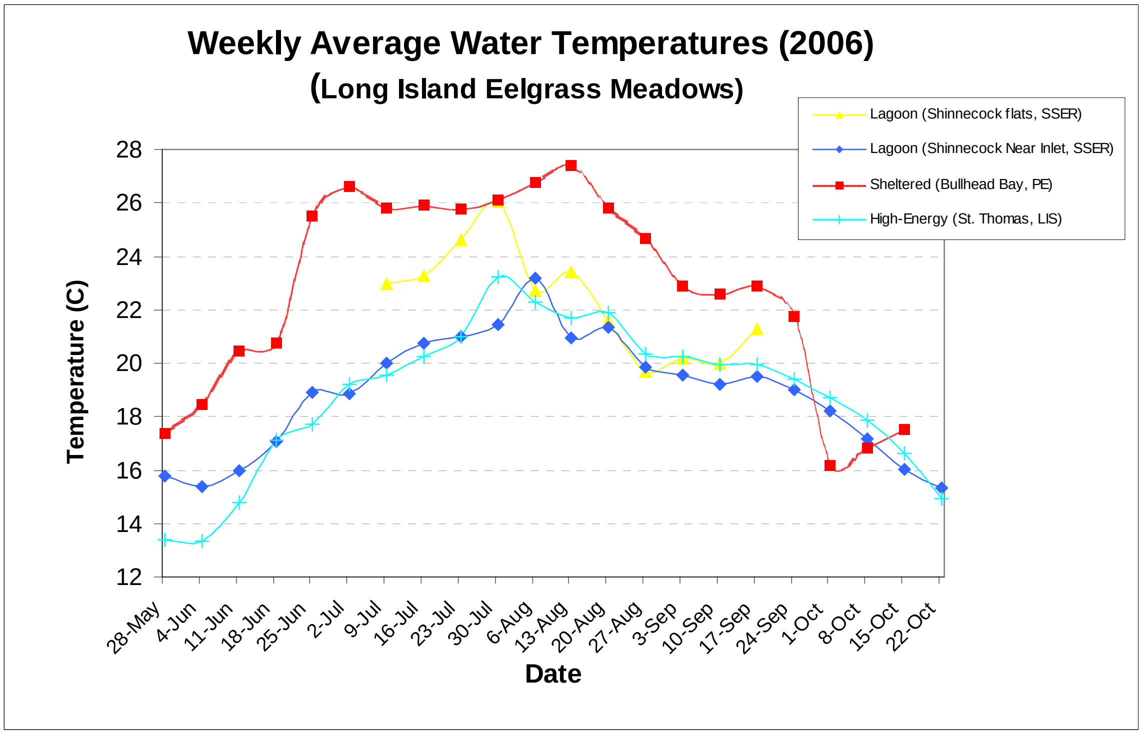



Figure 1. Weekly average water temperature (2006) for several extant eelgrass meadows around Long Island.

Table 2. Seed maturation and collection windows for eelgrass (*Z. marina*) meadows on Long Island, NY.

| Site | Estuary | Seeds per Shoot (Average) | Peak Release & Collection Window | Source/Year |
|---|---|---|---|---|
| Smith Point | South Shore | 31 | June 10-28 | Gates/1984 |
| Shinnecock Bay | South Shore | ? | June 14-30 | CCE /2006 |
| South Oyster Bay | South Shore | 52 | June 14-July 7 | Gates/1984 |
| Great South Bay | South Shore | 41 | June 26-July 2 | Churchill et al./1978 |
| | | | | |
| Bullhead Bay | Peconic | 42 | June 7-14 | CCE/2002 & 2006 |
| Hallocks Bay* | Peconic | 36 | June 24-30 | CCE/2002 |
| Noyack Creek* | Peconic | (107) | June 24-July 7 | CCE /2001& 2003 |
| Sag Harbor | Peconic | 54 | July 1-14 | CCE/2002 |
| Hay Beach Pt. | Peconic | 75 | July 21-28 | CCE/2003 |
| Orient Pt. | Peconic | 53 | July 21-Aug. 7 | CCE/2001-2006 |
| | | | | |
| Mulford Pt. | Long Island Sound | 97 | Aug. 7-14 | CCE/2003-2006 |
| Fishers Island | Long Island Sound | ~100 | Aug.14-21 | CCE/2004-2005 |

* These meadows have greatly diminished if not completely disappeared

EELGRASS RESTORATION ACTIVITIES BY DECADE

The concept that eelgrass was something of value was first realized soon after the occurrence of the wasting disease and the resultant crash of the brant goose and bay scallop populations during the 1930's. However, it wasn't until the 1970's that eelgrass restoration on Long Island really began. Prior to this, especially in Great South Bay, there was a general disregard for eelgrass as a nuisance to boaters and bathers alike. In the late 60's the Town of Hempstead commissioned a study to determine how this species could be controlled.

<u>1930's</u>

The first recorded eelgrass planting effort on Long Island occurred near Jones Beach using plantings gathered from Mecox Bay (Southampton), Virginia and Washington State. Only the Washington plants survived long enough to set seed. No follow-up monitoring was conducted.

<u>1970's</u>

The first comprehensive restoration efforts involving eelgrass were initiated in the mid 1970's by Dr. Jerry Churchill of Adelphi University. Churchill and a series of graduate students investigated the use whole plant transplantation as well as seeds in Great South Bay (SSER) and the Peconic Estuary. Other work involved testing various transplant methods for restoration. One important result of this work was the observation that <u>Z</u>. <u>marina</u> seeds could be transported via air bubbles. Dr. Churchill and his students also identified the most appropriate times to collect flowers to yield the most seeds.

<u>1980's</u>

Churchill continued work in both the SSER as well as the Peconic Estuary developing methods to use seeds for restoration. In the late 1980's Dr. Bill Dennison, working with staff from CCE conducted a small-scale test planting of seeds in the Peconic Estuary as part of a study of the effect of brown tide on local eelgrass populations.

<u>1990's</u>

With the coming of the brown tide in the mid 1980's, there was a new found interest in protecting and restoring resources in the Peconic Estuary. During the early 1990's money was made available for various "demonstration projects" to restore resources in the PE. During the period of 1994-1999, CCE and Town of East Hampton Trustees and Natural Resources Department conducted transplants at multiple sites in town waters. Seeds were not investigated during this period. Although the results of this work were mostly discouraging, it led the way to future efforts. This was the first indication that many creeks and harbors which historically supported eelgrass may no longer be able to support this species.

<u>2000's</u>

After a couple year hiatus, CCE again initiated restoration activities with funding from various sources. The first projects focused on sites within the inner estuary.

2001-2004 CCE – Seeds were investigated again as a potential restoration method. Advice was sought from Dr. Jerry Churchill (Adelphi), Dr. Robert Orth (VIMS) and Steve Granger (URI). In 2002, the first Buoy Deployed Seeding (BUDS) system was constructed and deployed in the Peconic Estuary. Although this system as well as broadcast seeding produced large numbers of seedlings, long-term survival of seedlings was poor at all sites. Similar observation were made at extant meadows where natural seedling recruitment had occurred, raising questions regarding the efficacy of using seeds as a primary restoration tool until the cause of these failures can be identified.

2002 CCE – Z. marina meadows "discovered" in Long Island Sound at Mulford Point, a very high energy site.

2003-2004 CCE – Based on observations at Mulford Pt., restoration site selection underwent a significant paradigm shift to high-energy, exposed sites along the LIS shore and points east in the Peconic Estuary.

2003- present CCE – Transplants were initiated in Long Island Sound and eastern Peconic Estuary with the first large-scale successes in the region. The "rock-planting" method was developed and high density, (unanchored plantings) were tested at several sites with suitable bottom conditions. Current work is conducted at the multiple-acre scale.

## RESTORATION TECHNIQUES

### SITE SELECTION

Early restoration work on Long Island focused on the most obvious places to plant including the shallow creeks and coves where the grass most recently grew. While some of this work in the SSER was at least initially successful, most transplant and seeding efforts eventually failed. Eventually, a Transplant Suitability Index (TSI) GIS-based model was created for the PE based on the work of Dr. Fred Short (UNH) and others. This model identified eastern portions of the Estuary as the most appropriated planting areas. Verification of this model was achieved through test plantings, but physical disturbance was a confounding factor at several sites. A similar model for Shinnecock and eastern Moriches Bays is currently under development. For LIS, a Wave Exposure Model (WEMO) is being developed in collaboration with Dr. Mark Fonseca of NOAA.

### RESTORATION METHODS

Numerous restoration methods involving transplantation of adult shoots and seeding have been attempted on Long Island over the last 70 years. See restoration summary tables for a detailed overview of restoration activities to date. The following section covers lessons learned on Long Island.

### TRANSPLANTS

Successes

Fall and winter plantings (mostly TERFS) were initially successful at most sheltered sites in the Peconic Estuary with survival through the winter and into the following summer. However, most transplants died by late summer.

Year-round plantings have been successful at high energy sites in Long Island Sound using the rock method.

Fall and winter plantings in Gardiners Bay have been mostly successful using high-density (200shoots/m2) 1m$^2$ circular plots.

Tracking of individual plots using labeled rocks has allowed for close monitoring of factors such as donor source, planting date, weather conditions, time of year and diver error at restoration sites.

Failures

Spring and summer transplants, using free-planting, the staple method and TERFS were not successful when attempted at sheltered sites within the Peconic Estuary on bottom types ranging from silty sand to sand.

SEEDS

Successes

Although the early seed work in the SSER did not result in meaningful establishment of plants, it did lead to an understanding and appreciation for the potential of using seeds for restoration and lead to development of flower harvest and handling methods.

Planting of seeds into sheltered embayments throughout the Peconic Estuary using the broadcast method and buoy deployed seeding indicated that seedling recruitment was not limiting to restoration efforts.

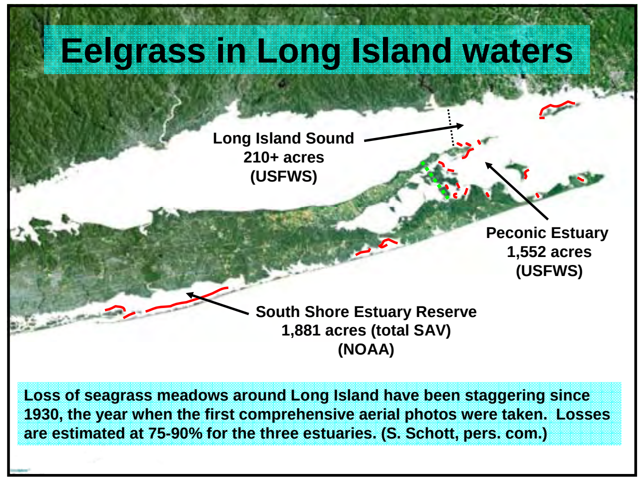
Limited success was achieved when seeding into and around existing grass at restoration sites in high-energy sites (LIS).

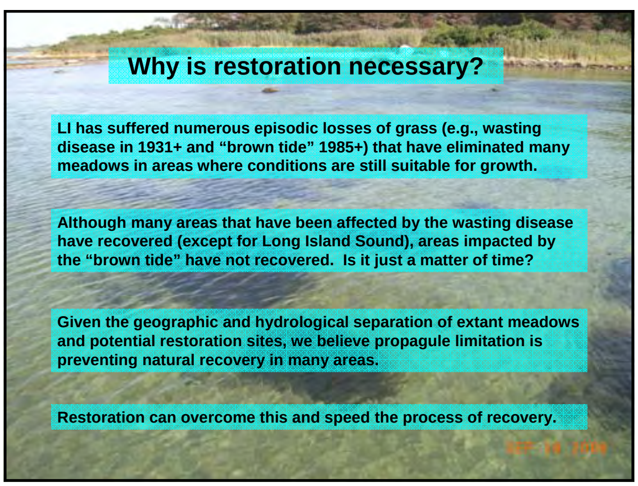
Failures

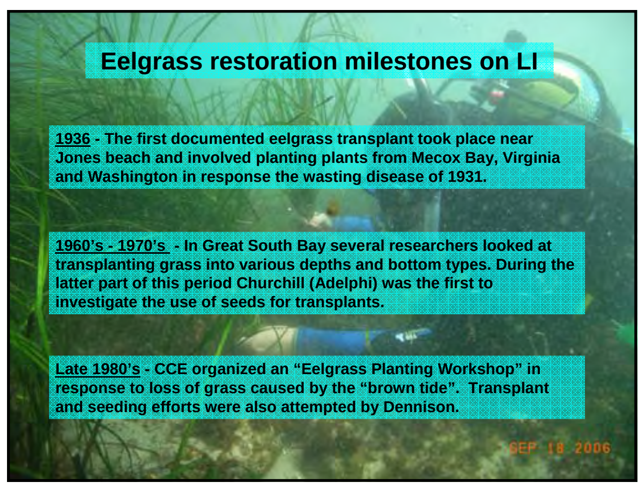
Despite all the successes of seedling establishment in various sheltered sites (e.g., harbors and creeks) throughout the Peconic Estuary, with the exception of two sites, all seeding sites suffered catastrophic losses of shoots some time during the first summer.

Seedling recruitment never occurred in any appreciable rate at high-energy, coarse-textured sediment sites unless there were adult plants nearby.


A Brief History of
Eelgrass
Restoration
on Long Island
Chris Pickerell, CCE-Marine Program
Email: cp26@cornell.edu Website: www.seagrassli.org
Long Island Eelgrass Workshop February 15, 2007


Eelgrass in Long Island waters
Long Island Sound
210+ acres
(USFWS)
Peconic Estuary
1,552 acres
(USFWS)
South Shore Estuary Reserve
1,881 acres (total SAV)
(NOAA)
Loss of seagrass meadows around Long Island have been staggering since 1930, the year when the first comprehensive aerial photos were taken. Losses are estimated at 75-90% for the three estuaries. (S. Schott, pers. com.)


Why is restoration necessary?
LI has suffered numerous episodic losses of grass (e.g., wasting disease in 1931+ and "brown tide" 1985+) that have eliminated many meadows in areas where conditions are still suitable for growth.
Although many areas that have been affected by the wasting disease have recovered (except for Long Island Sound), areas impacted by the "brown tide" have not recovered. Is it just a matter of time?
Given the geographic and hydrological separation of extant meadows and potential restoration sites, we believe propagule limitation is preventing natural recovery in many areas.
Restoration can overcome this and speed the process of recovery.


Eelgrass restoration milestones on LI
1936 - The first documented eelgrass transplant took place near Jones beach and involved planting plants from Mecox Bay, Virginia and Washington in response the wasting disease of 1931.
1960's - 1970's - In Great South Bay several researchers looked at transplanting grass into various depths and bottom types. During the latter part of this period Churchill (Adelphi) was the first to investigate the use of seeds for transplants.
Late 1980's - CCE organized an "Eelgrass Planting Workshop" in response to loss of grass caused by the "brown tide". Transplant and seeding efforts were also attempted by Dennison.

## CCE Eelgrass Planting Workshop June 1987

Almost exactly 20 years ago, the invited experts were………..



Some things never change!

## Eelgrass restoration milestones on LI

<u>1990's</u> - Town of East Hampton and CCE - Conducted multiple transplants using the staple method at several creeks and harbors.

<u>2001</u>- <u>Z. marina</u> meadows "discovered" in Long Island Sound at Mulford Point, a very high energy site. First Buoy deployed seeding line deployment.

<u>2001</u> - CCE Constructs the eelgrass culture facility on Long Island at Cedar Beach, Southold.

<u>2003</u> - CCE conducts first pilot seeding effort in Long Island Sound.

<u>2003 - present</u> - CCE begins large-scale transplants in Long Island Sound and eastern Peconic Estuary with the first large-scale successes in the region. TNC and USACOE conduct test plantings in PE and SSER. CCE refines new seeding and transplant methods (i.e., Buoy Deployed Seeding and "rock-planting"). Current work is conducted at the multiple-acre scale.

## Eelgrass Restoration Methods Used on Long Island

**<u>SEEDS</u>**
- Seed Tape ('76)
- Broadcast seeding (80's- Present)
- Buoy Deployed Seeding ('01- Present)
- Seeds placed in burlap ('05/'06)

**<u>TRANSPLANTS</u>**
- Free-Planting (FP) ('36 - Present)
- Anchored FP (90's)
- Plugs (70's - 90's)
- TERFS ('01 - Present)
- High-Density FP ('04 - Present)
- Rock-Planting ('04 - Present)

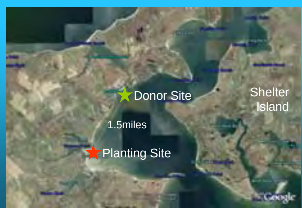
**<u>CASE STUDIES</u>**
See Handout

- TERFS ('01)
- Seeding ('01)
- Natural Seeding ('04)
- Rock-Planting ('04)

## Eelgrass Restoration: LI Case Studies

### Peconic Estuary - TERFS planting X 5

During 2001 a small-scale test planting was conducted outside of Town Creek, Southold to determine the potential for large-scale restoration. 4 TERF's were planted (61 shoots each) on 11/02/01 using plants from a nearby meadow. Survival through winter and into the following spring was excellent. During summer of 2002 the entire planting failed. Possible causes of failure include: bioturbation, high water temperatures and/or poor water clarity. Subsequent LTM at Mill Creek indicated a drastic decline in the natural meadow from ~500 shoots/m² in 2001 to almost complete loss by 2006.

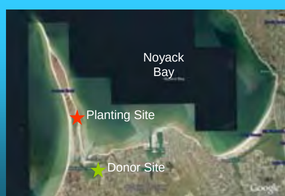



May 2002 (7 months post planting)

## Eelgrass Restoration: LI Case Studies

### Peconic Estuary - Seeding

On September 18th of 2001 the first attempts to deploy seeds using a floating cage (later to be called BuDS) took place at Jessups Cove, Southampton. Seedling recruitment the following spring was very good and seedlings grew rapidly. By mid summer all shoots were lost. Possible causes of failure include: Shellfishing, high water temperatures and/or poor water clarity. Since that time, the donor site at Noyack Creek has suffered periodic losses and recoveries in subsequent years. In some cases large numbers of adult shoots were lost and seedling recruitment was excellent only to fail in the summer.

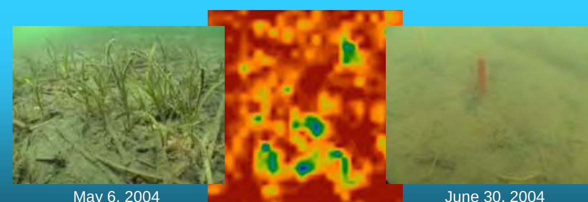



Spring 2002 (~8 months after seeding)

## Eelgrass Restoration: LI Case Studies

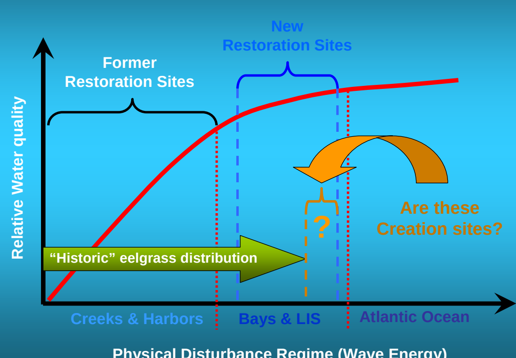
### Peconic Estuary – Natural Seedling Recruitment

In May 2004 evidence of a large-scale natural seeding event was documented using photographs and direct counts of individual shoots. Follow-up observations of the site ~55 days later indicated complete loss of ALL seedlings. Similar observations were made at another site (Bullhead Bay) in the PE that same year. The cause of these losses are unknown, but they do not appear to be linked to physical disturbance (i.e., bioturbation or shellfishing).



May 6, 2004 Contour Plot (5/6/04) June 30, 2004

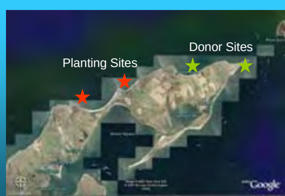
## Restoration Site Selection
## Paradigm shift ('02/'03)




## Eelgrass Restoration: LI Case Studies

### Long Island Sound – Seeding and Transplants

In October 20, 2003 the first ever seeding effort along LI's north shore was initiated. Approximately 60,000 seeds were broadcast between two sites resulting in ONE group of plants the following season. Large-scale plantings were initiated during fall of 2005 and continued into the 2006 season. The project is a success resulting in a 2-acre meadow at St. Thomas Point and a work at Terry Point is underway to create a ¾ acre meadow. Once a canopy had formed, additional seeds were broadcast at the site and there appears to have been some natural seedling recruitment. Test plots at Terry Pt. indicate a 9-fold increase in shoot density after 13months.




St. Thomas Pt. Dec. 2006

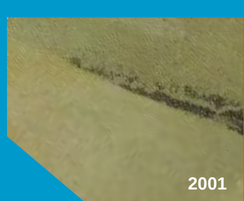
## St. Thomas Pt. Restoration Site, LIS


2 years

## Eelgrass Restoration: LI Case Studies

### Shinnecock Bay – Natural Recovery

As part of an Eelgrass and Bay Scallop Restoration planning project for the Town of Southampton we determined that one area in Shinnecock Bay has experienced considerable natural recovery from 2001 to 2007. Comparing photo graphs of the same site indicates that seeding as well as rhizome expansion have contributed to infilling at this site, resulting in a significant increase in aerial coverage at this location. Other parts of Shinnecock bay have seen a gradual decline in aerial coverage of grass. These observations





## What have we learned?

1. Each estuary is VERY different (e.g., what works in LIS will probably not work in the SSER).
2. Site selection is CRITICAL and criteria need to be refined further.
3. Transplants are labor intensive, but will work if done properly and at the right time of year.
4. Seeding has potential as a site selection screening tool and possibly in large-scale restoration, but additional work is necessary.
5. Initial success is no guarantee of long-term survival for seeds and transplants; losses typically occur during the end of the first summer.

## What have we learned?

**Site Selection is CRITICAL: "Just because it used to grow there doesn't mean it will grow there again!"**

**We have to avoid the overwhelming tendency to focus only on the most obvious areas for planting (e.g., lagoons and creeks) since they have shown to be unsuitable.**

## LI Eelgrass Restoration - Lessons Learned

**Within-site or "mesoscale" (10's of meters) variability can be considerable.**

- Sediment texture, fetch, wave exposure, depth and other abiotic factors can vary greatly within a site at the scale of 10's of meters.
- When designing pilot planting or seeding efforts spread **TEST PLOTS** across depth and bottom type changes.

Even if the entire site was covered with grass historically there may be only a small area where plantings will take (to begin the process of restoration).

## What have we learned?

**TRANSPLANTS: Labor intensive, but works when the site is suitable and the timing is correct.**

**Criteria:**

**< Temperatures**

**> Water clarity**

**> Water movement**

**< Bioturbation**

**> Grazers**

**Fall/winter planting**

## What have we learned?

**SEEDS: Seeds are a natural means of meadow recovery that may be suited for use in restoration if the site is suitable.**

**Criteria:**

**Silty Sand sediment**

**< Water movement**

**< Bioturbation**

**Summer/Fall**

## What's Next?

- Expand on current successes in LIS and eastern PE.
- Make additional attempts in middle PE.
- Expand seeding and transplant work in the SSER.

## THE END

# Appendix F:
# Research, Management, and Monitoring Priorities

# Research, Management, and Monitoring Priorities

| Ranked Order | Group Priority | ID# | Category | Action | Task | Time | Cost (w/out overhead) |
|---|---|---|---|---|---|---|---|
| 1 | High | 1 | Management | Establish a working group for coordination, and info dissemination | Define seagrass habitat, monitoring schemes, scale, indicators, leveraging efforts, take lead role in synthesis | Immediate and regular meetings | 10% total budget |
| 2 | High | 2 | Management | Synthesis of existing data, merge the datasets, IM coordinator | Follow up on May 2007 mtg, produce a report, getting GIS data layers | By end of 2007 | $80K |
| 3 | High | 5 | Monitoring | Monitoring physical conditions of the seagrass beds | Light/Temperature loggers in grass beds, use carefully chosen spatial scale. And more frequent (or continous) light sampling. | Need high resolution in summer, quarterly thereafter. | $20-30K |
| 4 | High | 16 | Management | Public education / perception | Reduce impacts to seagrasses through changes in resource use and vessel operations - potentially through waste management and regulation. Outreach with signs at boat ramps, etc. | Follow synthesis | $25K - $50K |
| 5 | High | 3 | Monitoring | New mapping of seagrass, with standardization, metadata implementation, timely reporting. Include analysis of historical aerial photos where usable to determine where seagrass existed at different times in the past. Spatial patterns of loss give clues to causes of loss-deep edge losses = light stress. | Best technique to be determined by working group (i.e., aerial photography, hyperspectral satelite data, acoustic surveys on sentiel areas). May be advantageous to do LIS, PE, SSER in same years. Develop a universal metric for defining seagrass habitat | Starting now, do every 2-3 years | $150/sq mile total (photo= 1/3 of cost; interpretation = 2/3). Groudtruthing of remote data necessary. |
| 6 | High | 6 | Monitoring | Monitor seagrass beds themselves; as examples SeagrassNet, Seagrass Watch. Frequency and design to be determined by working group. Options include fixed transects, spatially -distributed random points, fixed points. | Visual assessment for density and cover, do not count individual shoots. To be decided by working group, geared toward question being asked | Ongoing quarterly | 10-15 FTE days per quarter |
| 7 | High | 13 | Research | Need to look at multiple stressors together (e.g., light and sulfide, root penetrability of hard substrates) | E.g., manipulate organic matter in common garden experiment? Feed information inot any modeling from the synthesis section | Years 2-3 | $100K |
| 8 | High | 9 | Research | Is there a biological disturbance inhibiting persistaence, restoration, recolonization? Bioturbation, crabs, swans, lugworms, whelks, etc. | Use exlusion cages 1 ft deep and above the grass to test with and without planting | Immediate | $85K |
| 9 | Phase 1 = high Phase 2 = Low to High | 8 | Monitoring | Identify sources of light attenuation | Light attenuation parsing to guide whe to focus on. Phase 1 = regression model (color, TSS, Chl a), Gallegos model. Use secchi and WQ data. Phase 2 would be using thise and other factors to do your restoration selection | Part of Synthesis | 0 Phase 2 = $130K |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | Medium to High | 4 | Monitoring | Need bathymetry of SSER first, then PE, then LIS. If light limitation is one of the principal causes of seagrass mortality, bathymetry data will tell you where recovery is possible given incremental improvements in water clarity | 10 cm resolution, focusing in the shallow water(e.g., < 3 m in SSER). Weak green laser (3 cm accuracy) RTK (3-D GPS) unit (DOT may have) | Once | Weak green laser (lidar) $1K/sq km. Look to NOAA/ACOE for pro bono |
| 11 | Medium to High | 18 | Research | Restoration strategy including integration of landscape ecology into planning | Site selection, technique, etc. spatial modeling to predict potential recovery | Follows synthesis | 90K |
| 12 | ??? Priority depends on synthesis | 7 | Research | Is GW having a negative effect on seagrass? As a transport pathway for N and pesticides. Includes sewage/septic as affecting N (high nitrate 10uM threshold) - direct toxicity and increased phytoplankton | A) Look at SCDHS data first B) literature search about effects. C) Bioassays of chemicals - are they killing the seagrass or community (grazers) | TBD | 0 for A and B; C = $60k |
| 13 | Low to High | 17 | Research | Nitrogen budget needed for PE (mainly) and SSER to determine what the potential controlling sources may be ... integrate with synthesis work | Points to potential management jurisdictions and actions | Follows synthesis | $25K |
| 14 | Medium | 15 | Research | Epiphytic -grazer interactions - are changes in abundance or absence of grazers influencing current distribution or restoration | Indications of limitation to colonization and bed maintenance. This is examining how these grazers may facilitate survival of seagrass esp in areas where there are potentially high epiphyte loads that would reduce light availability to the plants. | 1-3 years | $50K |
| 15 | Low to High | 12 | Research | Impact of shellfishing (damage) and connection (positive feedback) between seagrass and shellfish | BPBL as a control and set up other test areas, soft vs hard bottom differences; also consider recreational impacts. - i.e. all local gear types with manipulative planting experiments | Years 2-3 | $120K |
| 16 | Medium | 14 | Research | What is the genetic diversity of seagrasses in the various estuarine systems (SSER, PE, LIS)? | Populations genetic analysis - initial screening with appropriate scale of sampling | Years 2-3 | $70K |
| 17 | Low to Medium | 11 | Research | Determine effects of physical disturbance of seagrass bed areas, including dredging, hardening, boating | BPBL could be used as a control for some disturbances, and set up other test areas | build out of information synthesis | $25K - $100K |
| 18 | Low | 10 | Monitoring | Characterize biota in seagrass beds | How have impacts to the bays influenced the function and secondary production of seagrass beds? This is about how animals USE seagrass beds and conversely, the larger community value of seagrass beds in your area | Year 3 | $50K |

| ID # | Dennison | Short | Carlson | Peterson | Pickerell | Average |
|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 1 | 1 | 1 | 1.2 |
| 2 | 2 | 3 | 2 | 2 | 2 | 2.2 |
| 3 | 3 | 9 | 4 | | 3 | 4.75 |
| 4 | | 6 | 7 | | | 6.5 |
| 5 | | 4 | 3 | 3 | 4 | 3.5 |
| 6 | 10 | 4 | 3 | 5 | 5 | 5.4 |
| 7 | 4 | 7 | 9 | 9 | 9 | 7.6 |
| 8 | 6 | 3 | 6 | 6 | | 5.25 |
| 9 | 9 | 10 | 10 | 7 | 6 | 8.4 |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | 8 | | 8 | 4 | | 6.6666667 |
| 14 | | | | | 10 | 10 |
| 15 | | | | 10 | 7 | 8.5 |
| 16 | 5 | 1 | | 8 | 2 | 4 |
| 17 | | 8 | | | | 8 |
| 18 | 7 | 5 | | | 8 | 6.6666667 |

| Sorted Average | ID# Sorted |
|---|---|
| 1.2 | 1 |
| 2.2 | 2 |
| 3.5 | 5 |
| 4 | 16 |
| 4.75 | 3 |
| 5.25 | 8 |
| 5.4 | 6 |
| 6.5 | 4 |
| 6.666666667 | 13 |
| 6.666666667 | 18 |
| 7.6 | 7 |
| 8 | 17 |
| 8.4 | 9 |
| 8.5 | 15 |
| 10 | 14 |
| | 10 |
| | 11 |
| | 12 |

| ID # | Carlson | Dennison | Short | Heck | Peterson | Fonseca | Collective Rankings |
|---|---|---|---|---|---|---|---|
| 1 | High | High | High | High | High | high | High |
| 2 | High | High | High | High | High | high | High |
| 3 | High | High | High | High | High | high | High |
| 4 | High | Medium | High | Low | medium | medium | 2-High; 3-Med; 1-Low |
| 5 | High | High | High | High | High | high | High |
| 6 | High | High | High | High | High | high | High |
| 7 | ??? | ??? | High for A and B | Low | ??? | ??? | ??? Depends on Synthesis |
| 8 | Medium | Phase 1 = High | Phase 1 = high | Low | Phase 1 = high | Phase 1 = High | Phase 1 = 4-High; 1 Low |
| 9 | High | High | High | High | High | High | High |
| 10 | Low | Low | Low | Low | Low | Low | Low |
| 11 | Medium | Medium | Medium | Low | Low | Medium | 3-Med; 2-Low |
| 12 | Low | Low | Low | High | High | Low | 2-High; 2-Low |
| 13 | High | High | High | High | High | High | High |
| 14 | Medium | Medium | Medium | Medium | Medium | Medium | Medium |
| 15 | Medium | Medium | Medium | Medium | Medium | Medium | Medium |
| 16 | High | High | Highest | High | High | High | High |
| 17 | Medium | Medium | Medium | Medium | medium | Medium | Medium |
| 18 | High | High | High | Medium | Medium | High | 3-High; 2-Medium |

| Sorted ID # | Sorted Rankings |
|---|---|
| 1 | High |
| 2 | High |
| 3 | High |
| 5 | High |
| 6 | High |
| 9 | High |
| 13 | High |
| 16 | High |
| 8 | Phase 1 = 4-High; 1 Low |
| 18 | 3-High; 2-Medium |
| 4 | 2-High; 3-Med; 1-Low |
| 7 | ??? Depends on Synthesis |
| 12 | 2-High; 2-Low |
| 14 | Medium |
| 15 | Medium |
| 17 | Medium |
| 11 | 3-Med; 2-Low |
| 10 | Low |

# Appendix G:
# Potential Research Questions

## Potential Research Questions
## Long Island Seagrass Experts Workshop
(in no particular order of importance)

Ecology

*Reproduction-Seeds*

1. What factors affect seedling recruitment in extant meadows?
2. Why is seedling survival low at some extant meadows (e.g., Peconic Estuary sites)?
3. What is the role of the seed bank in meadow maintenance and recovery?
4. How can we better predict the timing of seed release?

*Reproduction-Vegetative*

5. What factors affect lateral shoot formation?
6. What factors affect below-ground biomass allocation?

*Fauna-Grazers*

7. What is the role of *Lacuna vincta* in meadow maintenance?
8. What environmental factors control the temporal and geographic aspects of *Lacuna vincta*'s distribution?
9. What is the role/impact of mud snails on seedling and adult shoot survival?
10. What is the role of Mute swans and other waterfowl in grazing on seagrass?

*Fauna-Bioturbation*

11. What is the impact of whelk feeding on grass coverage?
12. What is the impact of crab (various sp.) burrowing and feeding activities on grass coverage?

*Genetics*

13. Could a lack in genetic diversity or some other related genetic difference be a possible cause as to the poor viability of seagrass in the Peconic Estuary as compared to other Long Island bays?

Physical Environment

14. What is the impact of increased water temperature on eelgrass distribution?
15. What is the impact of sea level rise on eelgrass distribution? Will seagrasses keep pace with Sea Level Rise? If not, what would you recommend for seagrass restoration?
16. What is the impact of groundwater/contaminants on eelgrass distribution? In particular, herbicides like atrizene, which may be used by farmers in the Peconic Estuary watershed?
17. What are the typical trends in meadow dynamics (e.g., percent cover and shoot density) in high energy environments?
18. What impact does hydrogen sulfide and ammonia toxicity in the sediments have on survival of seedlings and adult shoots?

Management and Restoration

19. How can we better refine our restoration site selection models (especially in light of Sea Level Rise)?
20. What do we know about the relationship between nitrogen and eelgrass?
21. How much nitrogen, as a load or concentration, is too much?

22. Do different forms of nitrogen affect seagrass in different ways?
23. How do different characteristics (flushing, depth, etc.) of the receiving waters affect potential water quality criteria?
24. What is our understanding of the loading from the landscape?
25. What ancillary conditions or stressors (variability of nitrogen load, seasonal effects, temperature/nitrogen interplay, other factors listed under physical environment) are important?
26. Is there a potential for water quality restoration in the range of what's needed for eelgrass?
27. How can user conflicts be resolved such that shellfishing and eelgrass restoration can co-exist?
28. How can planting methods be improved to increase success in high energy environments?
29. Is there a critical minimum size and/or density threshold for plantings to ensure survival?
30. Seagrass in the Peconic Estuary has recently disappeared from areas where it has been for decades (e.g., Hallocks Bay and Orient Harbor) although they were historically more resilient to disturbance like brown tide relative to other areas. Are there other temperate areas where there is recent, significant seagrass loss without any indication of the presence of persistent/harmful algal blooms?

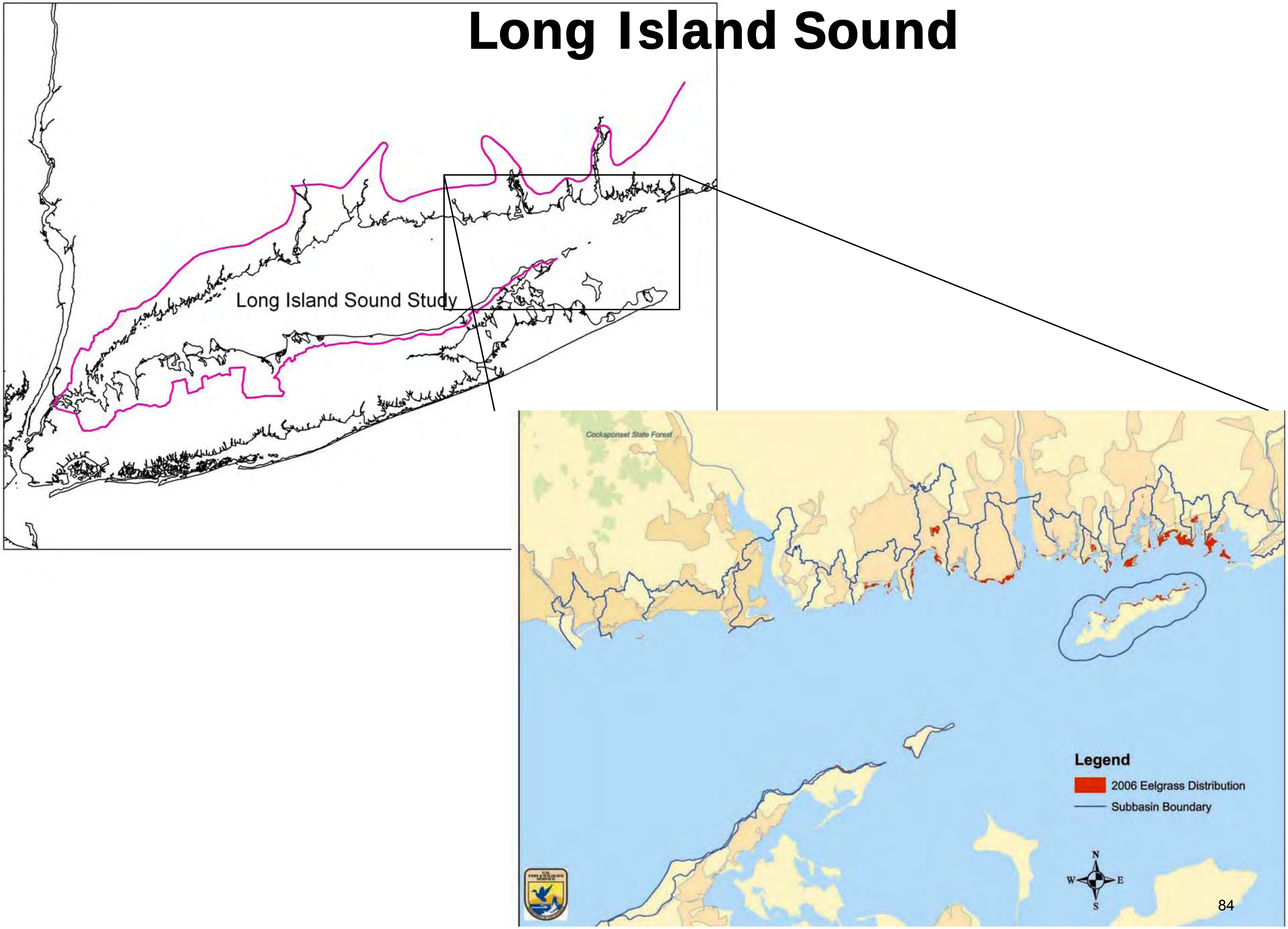
Monitoring
31. What are the best indicators of meadow health?
32. What are the most appropriate monitoring protocols (methods and timing)?
33. Is the Peconic Estuary Program Long Term Monitoring program on track?
34. What are the appropriate selection criteria for establishing new sampling stations when existing stations no longer contain seagrass?
35. How long and how often should we sample declining sites?

General
36. Why is the grass in the Peconic Estuary declining at a greater rate than other estuaries on Long Island?
37. What was the historic distribution of eelgrass along Long Island's north shore?
38. What are the specific environmental services offered by Long Island's seagrasses?
39. What fishery and shellfishery resources are dependent on Long Island's seagrasses?
40. What is the relationship between shoreline armoring and seagrass distribution?

# Appendix H:
# Other Supplemental Materials

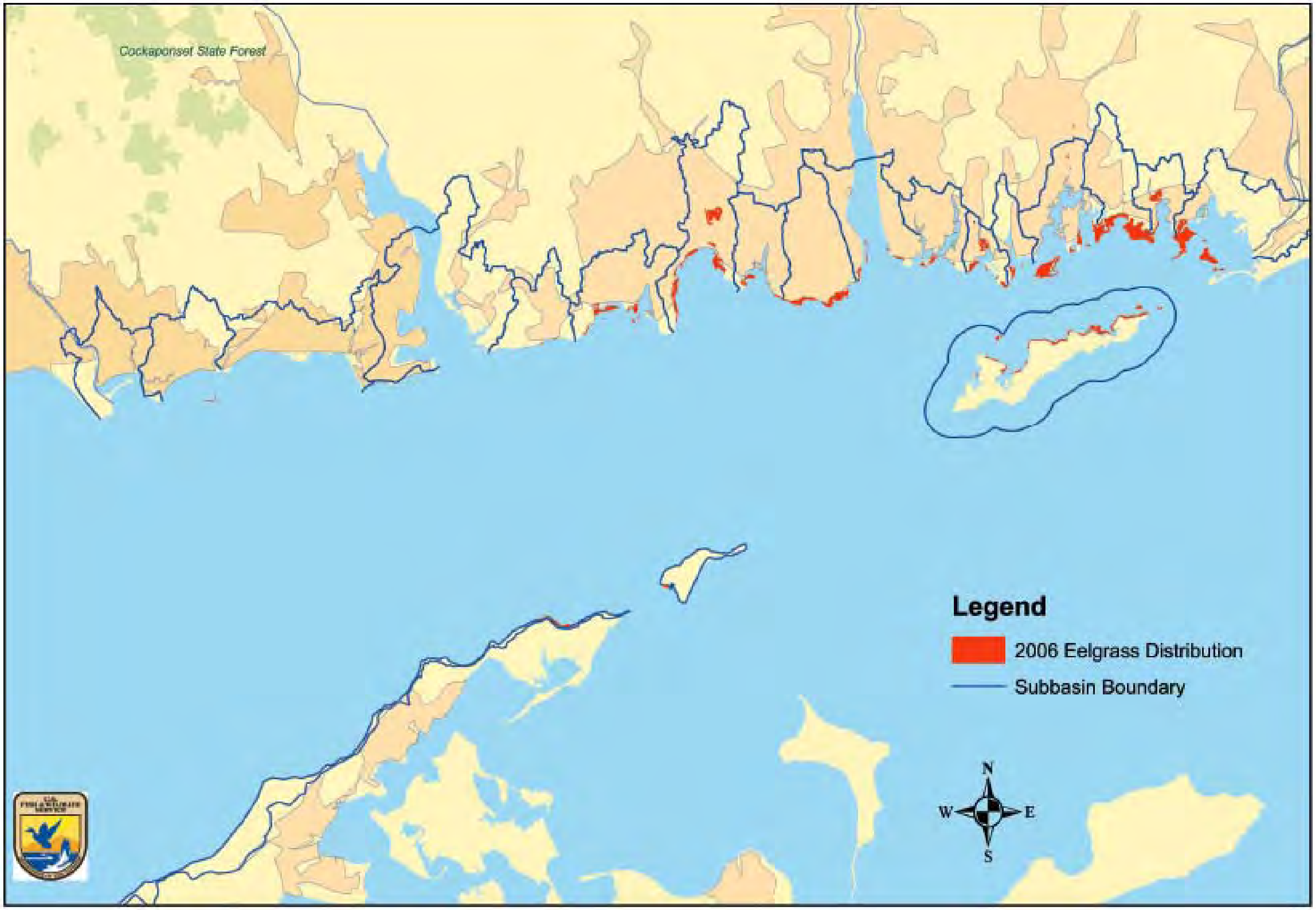
# Long Island Estuary Systems

# Long Island Sound

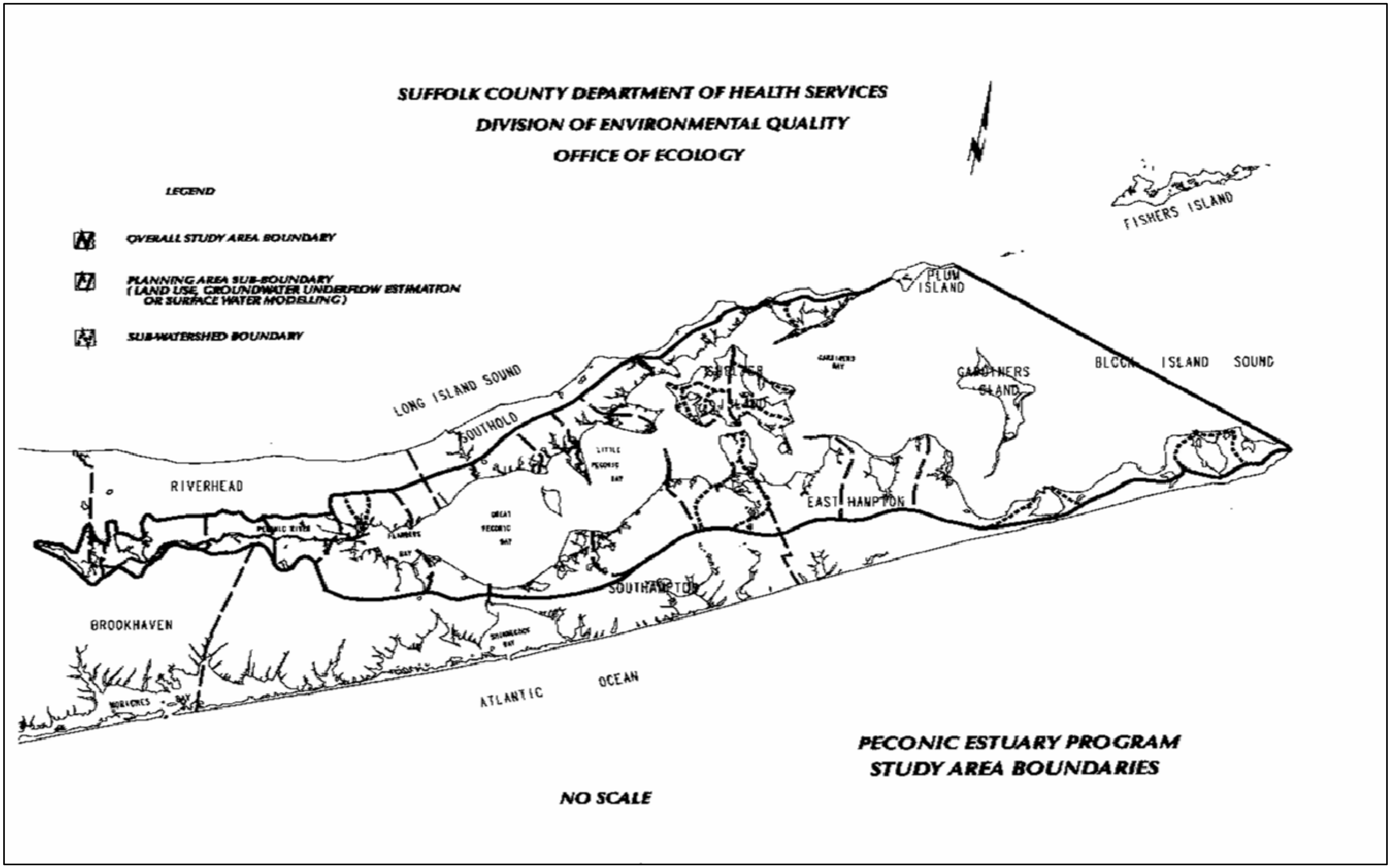


# Eastern Long Island Sound Eelgrass 2006 Inventory

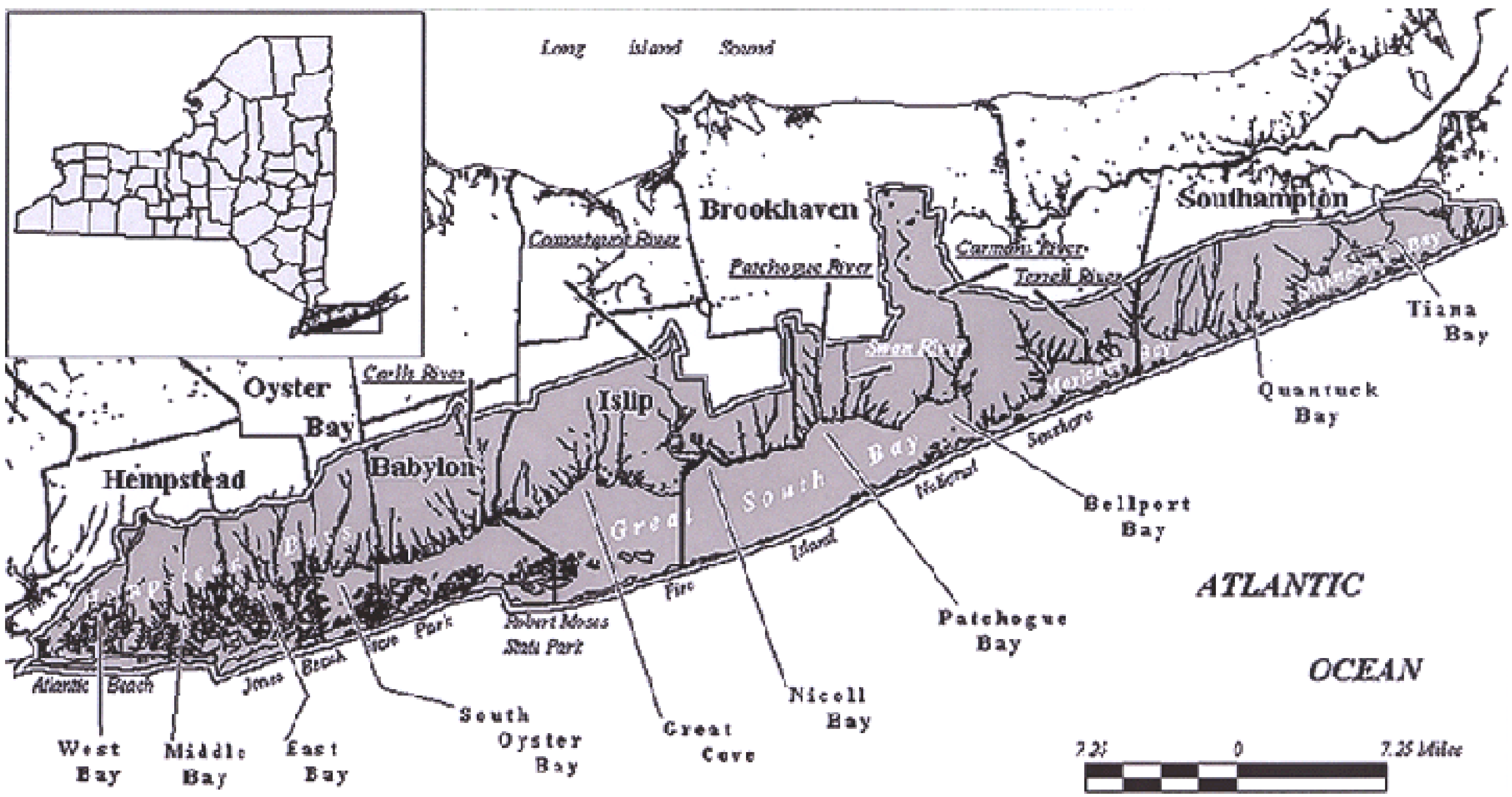
## General Eelgrass Distribution



# Peconic Estuary



# South Shore Estuary Reserve



# Research Conducted in the Peconic Estuary Regarding Eelgrass

| Timeframe | Location within Peconic Bay | Citation | Brief Description |
|---|---|---|---|
| 1934-1935 | n/a | Cottam, C. 1935. The Present Situation Regarding Eelgrass (Zostera marina). USDA Biological Survey. Leaflet BS-3. | This paper addresses the condition throughout the Atlantic including Europe post "wasting disease", mentioning that "Peconic bay conditions are still bad, although reports offer some encouragement." Contains valuable information on the history and extent of disappearance, effects of disappearance, and potential causes ("fungous disease... similar to *Labyrinthula*"). Note: Disease still present in Shinnecock and Mecox Bays, but have shown progressive betterment compared to the rest of LI bays. |
| 1936-1937 | n/a | Lynch, J. J., and C. Cottam. 1937. Status of eelgrass (Zostera marina) on the North Atlantic Coast. USDA Biological Survey. Leaflet BS-94. | Follow up of previous paper (above). Indicates no sign of eelgrass in Peconic bays yet, with reports of only a few struggling plants in the past 6 years. Note: "Shinnecock Bay has one of the best growths on the N. Atlantic coast". Details locations and morphology of eelgrass in these bays. |
| 1974 | | Thayer, G.W. and H.H. Stuart. 1974. The bay scallop makes its bed of eelgrass. Marine Fisheries Review 36 (7): 27-30. | Describes eelgrass and other seagrasses as being the preferred habitat for settling scallops. |
| July 78' and July '79 | Northwest Creek | Churchill, A.C., 1983. Field studies on seed germination and seedling development in Zostera marina. *Aquatic Botany* 16: 21-29. | The main findings were that a high percentage of seeds germinate, but a distinct seasonality exists in the time of germination. 50% of seedlings survived into autumn/winter but the remainder were lost during spring. Predation a possible factor. Stages of seedling development were classified. |
| Sept '81-Jan '83 | Northwest Creek | Bodner, P.J.Jr., 1985. A field study on seed production and sediment seed reserves in a Long Island population of *Zostera marina*. Masters Thesis, Adelphi University. | This study compared the potential seed yield of a *Zostera* meadow to the actual number of seeds recovered in the meadow sediments. Potential seed yield was high (2,125 seeds/m2), but the maximum |

| | | | |
|---|---|---|---|
| | | | number of seeds recovered was never more than 5%. |
| Summer 1984 | Northwest Creek (also Smith Point) | Churchill, A.C., Nieves, A., Brenowitz, A.H. 1985. Flotation and Dispersal of eelgrass seeds by gas bubbles. *Aquatic Botany* 4: 83-93. | Though most observations were made in Moriches, some measurements of dispersal distance and float time were recorded at NW Creek. Findings included approximately 5-13% of seeds were dispersed by flotation; dispersal distance ranged from 1-200+m and float time ranged from 0.5-40+ minutes. |
| Summers of 1985 and 1986 | Reeves Bay and New Suffolk (others in GSB) | Cosper, E. M., W.C. Dennison, E.J.Carpenter, V. Monica Bricelj, J.G. Mitchell, S.H. Kuenstner, D. Colflesh, and M. Dewey. 1987. Recurrent and persistent brown tide blooms perturb coastal marine ecosystem. Estuaries 10(4):284-290. | This study not only identified a previously undescribed microalga species making up the monospecific bloom which occurred throughout Long Island embayments during the summer months of 1985-86, but it documented the effect on local eelgrass and scallop populations. An estimated ~55% (65 km) of areas capable of supporting eelgrass growth pre-bloom became incapable of sustaining the seagrass. |
| 1988 | All L.I. Estuaries | Dennison, W.C., G.J. Marshall, and C. Wigand. 1989. Effect of "brown tide" shading on eelgrass (*Zostera marina* L.) distributions. *Coastal Estuarine Studies* **35**: 675-692. | Pre-bloom aerials from 1967 (NYS DEC) were compared to several aerial surveys conducted in 1988 for this study. No eelgrass was found in western Peconic Bays in 1988 surveys. Eelgrass in the Shelter Island area was significantly affected by brown tide, but eelgrass east of S.I. was not affected. |
| Aug 30-Sept 21, 1989 | Lake Montauk (field experiments) | Pohle, D.G., V. M. Bricelj, S. Garcia-Esquivel. 1991. The eelgrass canopy: an above-bottom refuge from benthic predators for juvenile bay scallops *Argopecten irradians*. Marine Ecology Progress Series 74; 47-59. | Both field and lab experiments revealed highly significant enhancement of scallop survival in the upper canopy (20-35cm above bottom) relative to shoot base. A highly inverse relationship between scallop size and attachment performance for 6-20mm scallops was found, and the "critical window" of vulnerability to predation for post settled scallops was discussed. |

| | | | |
|---|---|---|---|
| 1990-1993 | Lake Montauk, Napeague Harbor, Northwest Harbor, Hallock Bay | Strieb, M.D, V.M. Bricelj, and S.I. Bauer. 1995. Population biology of the mud crab, *Dyspanopeus sayi*, an important predator of juvenile bay scallops in Long Island (USA) eelgrass beds. Journal of Shellfish Research 14(2); 347-357. | Though this study was conducted mainly for implications regarding scallop predation, mud crab densities within 4 eelgrass meadows in the Peconics were found. Hallock Bay eelgrass was characterized which included canopy height, shoot density, %silt/clay, and crab densities within muddy vs. sandy substrates were compared. In Napeague Harbor, mud crabs were rare if not absent in unvegetated habitat. |
| 1990 | Northwest Harbor, Napeague Harbor, Hallock Bay | Garcia-Esquivel, Z. and V. M. Bricelj. 1993. Otogenic changes in microhabitat distribution of juvenile bay scallops, *Argopecten irradians irradians* (L.), in eelgrass beds, and their potential significance to early recruitment. The Biological Bulletin **185:** 42-55. | Though this study was conducted for implications regarding scallop recruitment and settlement, valuable density and shoot height information as well as macroalgae presence was noted. |
| August 1997 | East Hampton | Protocols for harvesting and transplanting eelgrass in the Peconic Estuary. Prepared by EEA, East Hampton Town Natural Resources Dept. and Cornell Cooperative Extension. August 1997. | Describes step by step protocols for harvesting and transplanting eelgrass using plugs and staples. Photos of each step are included. |
| Spring and Summer 2001 | Northwest Harbor, Orient Harbor, Flanders Bay | Paulsen, R., C. Smith, and D. O'Rourke. 2002. A preliminary analysis of the relationship between submarine groundwater discharge (SGD) and submerged aquatic vegetation in the Peconic Estuary. U.S. Environmental Protection Agency, Washington, D.C. | Though SGD zones were located and seepage measurements were conducted at all three locations, only the two transects in Northwest harbor were selected for water, soil, and sediment analysis. Major differences in grain size distribution between vegetated and non-vegetated transects was noted; the sediment pore water and groundwater was found to have low concentrations of nitrogen and phosphate, therefore the main source of these nutrients might have been the sediment and plant detritus. |

| *Table II. Actions and Recommendations involving Eelgrass in the CCMP (PEP, NYS, SC, EPA)* | | | | |
|---|---|---|---|---|
| **Section(s)** | **Directly/ Indirectly benefits eelgrass** | **Description** | **Details** | **Status**<br>Status:<br>R- Recommended<br>C- Commitment<br>O-Ongoing<br>N- New actions |
| HLR-7<br>(Habitat and Living Resources Management Plan) | I | Develop and implement an Estuary-wide Habitat Restoration Plan (HRP) | 7.1-7.7 Complete! | ***Complete☺** |
| HLR-8 | **D** | Develop and implement specific restoration projects | 8.3 Quantitative goal for eelgrass restoration complete! Plan for **eelgrass** is **no net decrease; 10% increase in 10 yrs.** | ***Complete☺** |
| HLR-6 | **D** | Evaluate current policies preserving **eelgrass**/ develop ways to increase protection for all extant **eelgrass** | **6.1 Priority** Evaluate current protection; develop increased protection. 6.2 Monitor existing; protect extant; restore degraded. 6.3 Evaluate effects of dredging, anchor dragging, prop scarring; 6.4 hold workshop☺ | All R except our monitoring program c/o |
| HLR-1 | **D** | Use CNRA's (critical natural resource areas) to develop and implement management strategies to protect high quality habitats and concentrations of species of special emphasis | 1.8 Examine possibility of establishing marine reserves (e.g. **eelgrass beds**) within CNRA's | R |
| HLR-4 | **D** | Promote non-destructive (to **eelgrass** and salt marshes) methods of shellfish harvesting | 4.1 Determine methods of harvesting shellfish that are most compatible with **eelgrass** establishment and growth. Develop recommendations for methods, frequency, timing etc. allowing recovery of **eelgrass** and enhancement of shellfish productivity | R |
| HLR-3 | **D** | Assess the impacts of dredging activities on habitat and natural resources and develop recommendations and guidelines for reducing impacts. | **3.2 Priority** Assess navigational dredging in creeks and embayments for damages or impacts to **eelgrass beds** and other habitats; develop permit conditions to minimize impacts; Determine if dredging impairs water quality precluding restoration of **eelgrass.**<br>**3.1 Priority** "dredging summit"; analyze impacts including on benthic communities | Both R |

| Section(s) | Directly or Indirectly affected | Description | Details | Status |
|---|---|---|---|---|
| HLR-5 | I | Impliment, enforce, incourage continuation of wetland policies and regulations | 5.1 Ensure continued protection through implementation and enforcement of current regulations<br>Enhancement recommended | C/O;<br><br>R |
| HLR-12 | **D** | Foster sustainable recreational and commercial finfish and shellfish uses in the PE that are compatible with biodiversity protection | **12.2 Priority** I.D., protect, and restore key shellfish and finfish spawning, nursery, and feeding habitats to enhance stocks and incorporate into essential fish work conducted under ASMFC (Atlantic States Marine Fisheries Commission) | R |
| HLR-14 | I | Protect Sea Turtles and Marine Mammals | 14.1 Review areas identified as turtle feeding areas, consider what restrictions could protect these spp. and their food sources. | Enhance existing programs-R |
| HLR-16 | **both** | Develop and implement a living resource research, monitoring, and assessment program | 16.3 Support research on interaction bet. **eelgrass** and dominant macroalgae species in the PE to determine impacts on eelgrass distribution and abundance<br>16.5 Perform research on ecology of food sources of sea turtles to eval. importance of PE to them and potential threats to these endangered and threatened spp.<br>16.7 Determine effects of dredging on benthic communities and recovery time of these communities.<br>16.8 Evaluate progress of **eelgrass** restoration goals | R |
| HLR- 2 | **I** | Manage Shoreline Stabilization, Docks, Piers, and Flow Restriction Structures to Reduce or Prevent Additional Hardening and Encourage Restoration of Hardened Shorelines to a Natural State. | 2.1 Quantify and map all hardened shoreline, docks and piers, and flow-restriction structures in the Peconic Estuary and assess the overall impacts of stabilization structures on natural resources.<br>2.2 review existing regulations for shoreline hardening structures at all levels of government, encourage consistent policies and strength regulations where appropriate. | |

| | | | | |
|---|---|---|---|---|
| | | | **2.3 Priority** Establish and enforce a policy of *no net increase* of hardened shoreline in the Peconic Estuary and, if possible, a net decrease in hardened shoreline.<br>**2.4 Priority** Develop a variety of financial incentives and programs to encourage property owners to remove or modify hardened shoreline structures | |
| B-1 (Brown Tide Management Plan) | I | Ensure cont'd brown tide monitoring, research, coordination, and info. sharing | 1.1-1.7 Continue existing efforts. | C/O |
| N-1 (Nutrients Management Plan) | I | Continue to use and refine water quality standards and guidelines | **1.2 Priority** Integrate monitoring, modeling, and research data to evaluate the use of recommended 0.4 mg/l total nitrogen guideline for the shallow waters of the estuary to optimize **eelgrass habitats**. | C/N |
| N-4 | | Control Point Source Discharges from STPs and Other Dischargers | 4-**Priority** "" (same as description) | |
| N-5 | I<br>I | *N-5. Implement Nonpoint Source Control Plans | N-5.1 Ensure that the Section 6217(g) management measures of CZARA are appropriately implemented, in support of the overall nitrogen management plan<br>*N-5.2 Investigate feasible implementation mechanisms and develop a plan to prevent increases and encourage decreases in nitrogen in groundwater underflow due to domestic fertilizer use.<br>*N-5.3 Investigate feasible implementation mechanisms and develop a plan to prevent increases and encourage decreases in nitrogen in groundwater underflow due to on-site disposal systems (sanitary systems).<br>*N-5.4 Develop a regional implementation plan for agricultural nitrogen load reductions which would include promoting agricultural best management practices, expanding agricultural environmental management (AEM) strategies, and promoting | R<br>C/O |

| | | | | |
|---|---|---|---|---|
| | | | organic farming among other initiatives.<br>N-5.5 Manage stormwater runoff on a Subwatershed basis to control nitrogen inputs | |
| CLPP-7 (Critical Lands Protection Plan) | | Develop a strategy for the management of underwater lands which conserves and enhances the region's natural resources. | 7.1 "" (same as description) | |
| T(1-8) (Toxics management plan) | I | Review historical monitoring data and conduct new monitoring studies where needed to further characterize sources, landings, and impacts of toxic contaminants; ensure dredged material is placed in a way as to reduce toxic impacts associated with contaminated sediments; explore management strategies emphasizing the elimination or reduction of toxics. | 1.1- Include toxics in the PEP long-term monitoring plan<br>**1.5 Priority** Identify toxics present at low levels that individually or cumulatively may be affecting aquatic resources.<br>8.1and 8.2- Ensure that all permits and applications are protective of Peconic ecosystem and its food chains.<br>6.6 Develop model guidelines for use of treated wood in the marine environment | |

## TABLE I. LOCAL MANAGEMENT AFFECTING EELGRASS

| Responsible Entity | Chapter in Code | Section/Article | Direct/ Indirect Impact | Details |
|---|---|---|---|---|
| Town of Southold | **219** -Shellfish and other Marine Resources | 219-20: Vegetation removal prohibited | **D/I** | • No wetland vegetation of any kind can be removed or soil placed thereon during shellfishing activities |
| | | 219-16: Culling shellfish and restoration of underwater lands | **I** | • Bottom must be returned to previous state upon taking of shellfish |
| | **275** (formally 97) - Wetlands and Shoreline | 275-2: Definitions | **I** | • Basically same as DEC wetlands regs. , but up to 5ft depth @mlw; 100 ft from wetland boundary |
| | | 275-11: Construction and Operation standards | **D** | • Dredging in or close to seagrass is prohibited<br>• Whether or not seagrasses (**including eelgrass and widgeon grass**) will be damaged or prevented from growth is considered before permitting dock placement |
| | | | **I** | • Use of lumber treated with CCA, creosote, penta products or homemade wood preservatives prohibited<br>• No new bulkheads in creeks and bays unless low-sill<br>• No new jetties or groins unless results in a total net decrease in the subject area |
| | **Mooring and Anchoring Draft Chapter 34 (new chapter)** Dec 11,2006 | 34-15: Moorings in Designated Mooring Areas created by the Town<br><br>34-14 (A,C): Mooring Assignments: General rules for Town waters | **D** | • In designating mooring areas, the Town Board shall ensure town mooring areas avoid **eelgrass** beds.<br>• Boatyard, Marina, Yacht club, and riparian moorings only allowed based on considerations including locations of seagrass meadows. |

| TABLE II. LOCAL MANAGEMENT AFFECTING EELGRASS cont'd | | | | |
|---|---|---|---|---|
| **Responsible Entity** | **Chapter in Code** | **Section/Article** | **Direct/ Indirect Impact** | **Details** |
| **Town of Easthampton** | 255- Zoning | **255-1-20**: Definitions | **I** | • "Lands lying within or beneath tidal waters shall also be deemed to be "tidal wetlands," regardless of the type or amount of vegetation growing thereon or the absence of the same."<br>• All underwater lands are included in wetland definition, no max depth |
| | | **255-5-50**: Special Permit Uses: Specific standards and safeguards | **I** | • "No permit shall issue for any structure which would unduly interfere with…marine life or habitat or which would destroy other than minimal practicable areas of existing wetland vegetation… |
| | | | **D** | • Dock permit issuance will consider "whether the dock will result in the destruction of beds of eelgrass or shellfish." |
| | | | **I** | • Use of wood treated with CCA, ACQ, or creosote will be allowed for coastal structures "unless it can be shown that no reasonable alternative material will serve the purpose" |
| | | | **I** | • No new docks unless floating and seasonally removed; coastal erosion structures only permitted if "imminent, rapid or sudden loss of the property, or a substantial portion thereof, to erosion caused by rain, current, wind, wave or storm tidal action", and structures shall be minimum necessary. |
| | | **255-4-20**: Natural resources special permit; regulations | **I** | • Like DEC wetland regs, but w/in 150ft of wetland boundary |

| TABLE II. LOCAL MANAGEMENT AFFECTING EELGRASS cont'd | | | | |
|---|---|---|---|---|
| **Responsible Entity** | **Chapter in Code** | **Section/Article** | **Direct/ Indirect Impact** | **Details** |
| **Town of Southampton** | Shellfish Permits and Regulation Article II (not in Town Code) | Section 8E. Soft Clams | **D** | • "Churning over or through submerged **eelgrass** beds is strictly prohibited" Regulated by bay constables |
| | **278** - Shellfish | 278-8 ,9: Escallops and Hard Clams | **I** | • Scallops and crabs may be harvested with a dredge only if same as DEC requirements for scallops<br>• No plant life (or hard clams) may be removed by mechanical means |
| | **330** - Zoning | 330-40: Tidal Wetland Regulations | **I** | • Bulkheading prohibited unless in Waterfront Business District or to protect the natural environment from erosion, silting etc. |
| | **111**-Beaches, Parks and Waterways | 111-28: Removal of Beach Grass | ? | • "No person shall remove, impair, damage or destroy any beach grasses or wetlands vegetation of any kind nor place spoil thereon in any other area of the Town of Southampton without prior written approval by the Director of Natural Resources of the Town of Southampton and the Board of Trustees." |
| | **325**-Wetlands | 325-3: Definitions | **I** | • Tidal wetland definition includes "All lands lying in the area inundated by tidal action and/or peak lunar tides", "all estuaries", "littoral zones", though no depth limit specified<br>• Same regulated activities as DEC except **200ft** from wetland boundary |
| **Town of Riverhead** | 47-Bays and Creeks | 47-21: Docks, basins and ramps | **D** | • The potential for destruction of **eelgrass** or shellfish beds is considered by the Conservation Advisory Counsel before issuing a dock permit |
| | | | **I** | • No commercial copper quat (ACQ), pentachlorophenol, or creosote treated wood may be used for shoreline structures. CCA can only be used for pilings. |
| | | Article II- Shellfish | **I** | • Same as Southampton Town regs |

| TABLE II. LOCAL MANAGEMENT AFFECTING EELGRASS cont'd | | | | |
|---|---|---|---|---|
| **Responsible Entity** | **Chapter in Code** | **Section/Article** | **Direct/ Indirect Impact** | **Details** |
| **Town of Riverhead cont'd** | 107-Tidal and Freshwater Wetlands | 107-3,4 –Definitions and Regulations | I | • Littoral zone (up to 6ft at mlw) included in tidal wetlands definition.<br>• Same wetland regs. as DEC except **150ft** from wetland boundary. |
| **Town of Shelter Island** | 129-Wetlands | 129-3: General guidelines to activities within regulated area. | I | • "The depositing or removal of the natural products of wetlands during recreational or commercial fishing, shellfishing or aquaculture is allowed so long as there is no undue disturbance of the wetlands." |
| | | | I | • No new bulkheads will be allowed unless property is in imminent peril of destruction from erosion and that other measures are not viable. |
| | | 129-8: Definitions | I | • Wetlands def. includes "all lands generally covered or intermittently covered with, or which border on, tidal waters, or lands lying beneath tidal water such as…littoral zones", though no depth mentioned.<br>• Same regulated activities as DEC; **100ft** from wetland boundary |
| | 108-Shellfish | 108-5: Regulations | I | • No churning for soft clams<br>• Same scallop, hard clam regs. as DEC |

| TABLE II. STATE MANAGEMENT IMPACTING EELGRASS | | | | |
|---|---|---|---|---|
| **Responsible Entity** | **Chapter in Code** | **Section/Article** | **Direct/ Indirect Impact** | **Details** |
| | | | | |
| **NYS DEC** | **6NYC RR Part 661**-Tidal Wetlands Land Use Regulations (Statutory authority: Environmental Conservation Law, §§ 1-0101, 3-0301, 25-0302) | 661.4 (hh)-Tidal Wetlands classifications | I | • Littoral zone included in tidal wetland definition (up to 6ft depth @mlw) |
| | | 661.4(ee)- Regulated Activity | I | • Any form of dredging or dumping of aggregates<br>• The erection of any structures whether or not changing the ebb and flow of the tide<br>• Any other activity which may substantially impair or alter the natural condition of the tidal wetland area |
| | | 661.5 Uses | n/a | ***No permit necessary for depositing or removing the natural products of a tidal wetland (or adjacent area) in the process of recreational or commercial fishing, shellfishing, aquaculture, hunting or trapping, including the erection and maintenance of temporary hides or blinds. |
| | **6 NYCRR Part 46**-Public Use of State-Owned Tidal Wetlands | 46.7 Prohibited Activities | **D** | • Removal of naturally occurring or introduced flora, whether living or dead, except for specifically permitted research or educational activities |
| | | | I | • Disposal of any solid, liquid or toxic waste material. |
| | 6 NYCRR Part 49-Shellfish Management-Gear restrictions | Soft clams | n/a | • No mechanical means except churning by propeller allowed below low tide |
| | Protection of Waters | Article 15 of the ECL. Part 608 | I | • Requires a permit before construction, reconstruction or expansion of a dock, wharf, groin, mooring or any other structure, in or above waters in state-owned underwater lands. |

# Long Island Estuary Systems: Snapshot

| | | | Peconic Estuary | South Shore Estuary | Long Island Sound |
|---|---|---|---|---|---|
| **Watershed Land Acres** | | | 125,783 acres | 208,640 acres | 10,764,800 acres |
| **Surface Water Acres** | | | 158,056 acres | 110,080 acres | 844,800 acres |
| **Watershed Population** | | | 100,000 winter; 280,000 summer | 1,500,000 | 8,500,000 |
| **Flushing Times** | | | 56 days Western; 22 days Eastern | | |
| **Average Depth** | | | 4.7 m | 1-3 m | 19.2 m |
| **Secchi Depth (ft)*** | | | | | |
| | winter | mean | 9.2 | 4.1 | |
| | | min | 2.0 | 1.0 | |
| | | max | 25.0 | 11.0 | |
| | | | | | |
| | sum | mean | 7.1 | 3.8 | |
| | | min | 2.0 | 1.0 | |
| | | max | 15.0 | 15.0 | |
| **Surface Water Temperature (C)*** | | | | | 32F winter; 73F summer |
| | winter | mean | 3.2 | 3.4 | |
| | | min | < 0.1 | < 0.1 | |
| | | max | 11.0 | 10.3 | |
| | sum | mean | 22.4 | 23.8 | |
| | | min | 15.3 | 16.9 | |
| | | max | 27.8 | 27.8 | |
| **Total Nitrogen (mg/L)*** | | | | | |
| | winter | mean | 0.21 | 0.37 | |
| | | min | < 0.05 | < 0.05 | |
| | | max | 0.80 | 2.20 | |
| | | | | | |
| | sum | mean | 0.28 | 0.41 | |
| | | min | < 0.05 | < 0.05 | |
| | | max | 1.40 | 1.10 | |
| **Basin Morphology** | | | 2 Separate: Peconic Bay and Gardiner's Bay | Interconnected coastal bays | Eastern and Western Basins |
| **Circulation** | | | Classic estuary; FW riverine and tidal influence | Inlet-fed and small rivers | NYC metro area FW inputs; Western tidal |
| **Eelgrass Acres** | | | | | |
| | Historic | | 1930: 8,720 | | |
| | Current | | 2001: 1,552 | | 2006: 1,905 |

*Peconic mainstem stations (Flanders, Great Peconic, Little Peconic, Noyac Bay, Shelter Island Sound, Orient Harbor, NW Harbor, Gardiners Bay) 2000-2005;
Great South Bay/South Shore Estuary open bay sites (no ocean or inlet) 2000-2005.