2-2009

Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States: Workshop Report

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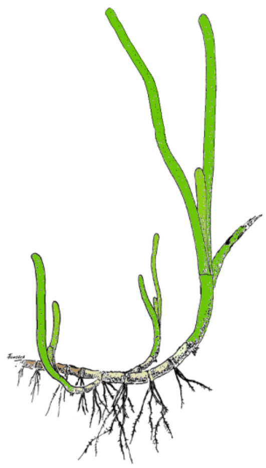
Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States

February 24-25, 2009
Portland, Maine



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Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States

Report of a Workshop Held
February 24-25, 2009
Regency Hotel, Portland Maine

Workshop Hosted By:

Gulf of Maine Council on the Marine Environment
Friends of Casco Bay
Casco Bay Estuary Partnership
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Organizing Committee:

Hilary Neckles, USGS Patuxent Wildlife Research Center, Augusta, ME
Al Hanson, Canadian Wildlife Service, Environment Canada, Sackville NB
Phil Colarusso, U.S. Environmental Protection Agency, Boston, MA
Robert Buchsbaum, Massachusetts Audubon, Wenham, MA
Fred Short, Jackson Estuarine Laboratory, University of New Hampshire, Durham NH

This report may be cited as:

Neckles, H. A., A. R. Hanson, P. Colarusso, R. N. Buchsbaum, and F. T. Short (eds.). 2009. Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States. Report of a Workshop Held February 24-25, 2009, Portland, Maine.

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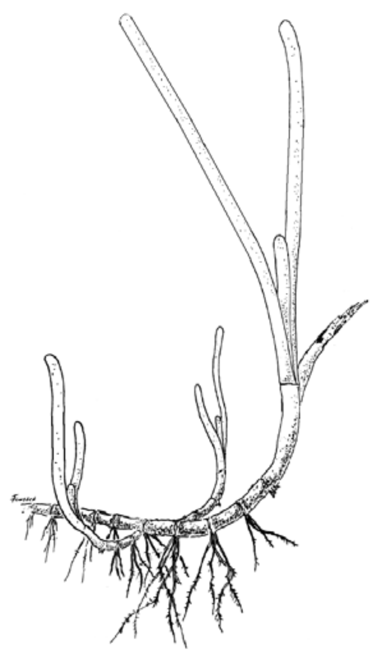


Workshop Summary

Introduction

Eelgrass (*Zostera marina L*) is the dominant seagrass occurring in eastern Canada and the northeastern United States, where it often forms extensive meadows in coastal and estuarine areas. Eelgrass beds are extremely productive and provide many valuable ecological functions and ecosystem services. They serve as critical feeding and nursery habitat for a wide variety of commercially and recreationally important fish and shellfish and as feeding areas for waterfowl and other waterbirds. Eelgrass detritus is also transported considerable distances to fuel offshore food webs. In addition, eelgrass beds stabilize bottom sediments, dampen wave energy, absorb nutrients from surrounding waters, and retain carbon through burial.

Documented declines in the distribution and abundance of eelgrass in both the United States and Canada have resulted in considerable interest in the status, trends, and conservation of this important marine resource on a regional scale. To encourage broad sharing of information on eelgrass, a workshop was convened under the auspices of the Gulf of Maine Council on the Marine Environment - Habitat Monitoring Subcommittee on February 24-25, 2009, in Portland, Maine. Workshop participants represented all sectors of eelgrass science and conservation in eastern Canada and the northeastern United States including federal, state, provincial, and municipal resource managers; researchers; members of environmental organizations; consultants; concerned citizens; students; regulators; and coastal planners and decision makers. Fred Short opened the workshop with a keynote address on eelgrass functions, values, and ecosystem services; local, regional, and global threats to eelgrass survival; and the need for enhanced policies for eelgrass protection. Ensuing presentations and discussions over the course of two days focused on eelgrass change around the region, factors controlling ecosystem change, current and emerging management issues, and regional examples of eelgrass conservation efforts.

An overview of the workshop is presented here, including a summary of the presentations and discussions, the program, abstracts of presentations, and contact information for the participants. For more detailed information, most presentations are posted on the Gulf of Maine Council website: http://www.gulfofmaine.org/council/committees/habitat_monitoring.php. We extend sincere appreciation to the many sponsors whose generous support made this workshop possible. We thank the workshop presenters and participants for their knowledge and discussions that form the basis of this report. The Organizing Committee bears responsibility for any errors in the information provided below.

Eelgrass Change Around the Region

Updates on eelgrass status and trends showed many areas of eelgrass decline throughout the northeastern United States and eastern Canada. In general, eelgrass declines have been greatest in the southern part of the region, concomitant with regional patterns of coastal development. Loss of eelgrass in this area is most frequently related to water quality degradation. For example, Chris Pickerell reported eelgrass losses of 75-90% in New York waters (Long Island Sound, Peconic Estuary and South Shore Estuary Reserve) since 1930; Charlie Costello reported a decline in 27 out of 30 Massachusetts bays and estuaries between 1994 and 2006, with several areas exhibiting more that 70% loss during this time period; and Fred Short reported 47% loss in the Great Bay Estuary, New Hampshire, between 1996 and 2006. There are southern areas that do not follow this trend, however: Sue Tuxbury reported that although over 90% of the eelgrass beds present historically in Narragansett Bay were lost by 1996, a significant increase in mapped beds has been observed since that time due to both changes in methodology and real recovery, and Tom Halavik reported that eelgrass beds in Connecticut's eastern Long Island Sound were generally stable between 2002 and 2006, although local losses have occurred. Changes in eelgrass distribution and abundance in the northern part of the region were generally less dramatic. Seth Barker reported no net change in eelgrass cover along the Maine coast between 1993 and 2005, although a substantial loss of 400 acres was detected in Penobscot Bay. Unfortunately there have not been any systematic region-wide or provincial eelgrass monitoring programs in eastern Canada, so Al Hanson summarized status and trends in Canada's five easternmost provinces based on provincial-scale inventories and local studies. Declines have been documented in several areas of New Brunswick and Nova Scotia due to disturbance from European green crabs, water quality degradation, and oyster aquaculture. Eelgrass declines have also been documented in several estuaries of Prince Edward Island. Warm summer water temperatures, nitrogen runoff from intensive agricultural development, and sediment input from the island's highly erodible soils combine to suggest poor water quality as a causal agent, but European green crabs have also been implicated in some local declines. Eelgrass beds in Newfoundland currently appear stable but European green crabs are now present in the province. In Quebec, eelgrass abundance is stable or increasing in the Gulf of St. Lawrence and St. Lawrence Estuary, but localized declines have been documented in James Bay due to discharge of fresh water during generation of hydro-electric power.

Several poster presentations provided detailed analyses of eelgrass change at local scales. John Swenarton described annual monitoring of eelgrass characteristics near Millstone Power Station in eastern Long Island Sound, from 1985 to 2007. Although considerable annual variability in eelgrass biomass was observed, both long-term declines (at two sites) and recent recovery (since 2001 at one site following municipal sewer extensions in the watershed) suggested responses to ambient nutrient levels. A shift to earlier seed production was observed at all sites correlated with an increase in ambient seawater temperature of 1.4^{o} C over the past 30 years. Steve Perrin reported a 90% loss of eelgrass cover in Taunton Bay, Maine, between 2000 and 2002. This loss of eelgrass was correlated with a severe drought in 2001 that caused unusually high salinities in the bay, which may have favored disease. Aimée Pelletier et al. described loss of 88% of the eelgrass within Kejimkujik National Park, Nova Scotia, between 1987 and 2007, with the major decline occurring between 1994 and 2000. Disturbance from European green crabs and wasting disease were implicated as causal factors.

Downward trends in eelgrass distribution and abundance in many parts of the northeastern United States and eastern Canada underscore the importance of protecting the existing eelgrass remaining and improving environmental conditions to allow for ecosystem restoration and recovery. The spatial and temporal variability in rates of eelgrass change around the region illustrate the complexity of the ecological factors controlling change as well as the technological challenges associated with change analysis. Despite the variability in observed patterns, it is clear that maintaining or improving water quality is paramount to preserving eelgrass as an integral component of nearshore ecosystems.

Protecting Habitat Functions and Values From Direct Impacts

Eelgrass provides valuable ecosystem services derived from its high productivity and associated ecological processes. Allison Schmidt reported a correlation between eelgrass habitat structure and essential ecosystem services. As described by Robert Buchsbaum, although there is considerable variability in the relationship of faunal diversity and abundance to eelgrass landscape features such as patch size and bed configuration, vegetated areas consistently show higher habitat value than unvegetated areas. This suggested that all eelgrass should be protected, regardless of structural characteristics such as shoot density or bed size.

Monitoring eelgrass distribution, condition, and stressor/response relationships can help identify threats to habitat persistence and diagnose causes of habitat change. Hilary Neckles described a hierarchical framework for eelgrass monitoring: the integration of monitoring across scales offers an efficient means to identify factors that are driving changes in distribution, abundance, and ecosystem integrity. Several presentations addressed specific approaches to monitoring and assessment at different scales. A poster by Shachak Pe'eri et al. described use of hyperspectral satellite imagery for mapping eelgrass and nuisance macroalgae beds in Great Bay, New Hampshire, and Al Hanson discussed use of Quickbird satellite imagery to map eelgrass in New Brunswick and IKONOS imagery to map eelgrass in Quebec. These presentations all stressed the importance of ground-truthing when using satellite imagery for assessing eelgrass distribution. At higher resolution, a poster by Fred Short et al. described SeagrassNet, a network of sites around the globe using the same protocol for monitoring seagrass condition, and a poster by Rodgers et al. described implementation of hierarchical monitoring in Great South Bay, New York.

Human activities with direct impacts on eelgrass persist throughout the region, such as suspended-bag oyster aquaculture (described by Marc Skinner), boat moorings (Tay Evans), and shellfish dragging (John Sowles). Mechanisms to protect eelgrass from such direct impacts include gear modifications to minimize disturbance associated with specific practices and ecosystem-based management plans that balance multiple uses. Tay Evans described use of conservation moorings to reduce bottom scour, and John Sowles reported on an ecosystem management plan developed recently for Taunton Bay, Maine, that incorporates eelgrass protection as well as harvest of blue mussels by dragging. Workshop discussions highlighted the regional variation in both the types of impacts to eelgrass and the management alternatives available to safeguard ecosystem services. A combination of approaches is necessary to improve eelgrass protection. Options, not mutually exclusive, include enhancing protective regulations, increasing community awareness of eelgrass values, and forming multi-sectoral partnerships addressing diverse issues and interests in eelgrass habitat. Management plans that include eelgrass protection must consider how protected areas will be defined and delineated. Given the temporal variability in eelgrass bed structure, it may be more objective and meaningful to base conservation priorities on physical environmental characteristics that define potential eelgrass habitat than on eelgrass structural characteristics (e.g. minimum patch size or shoot density) *per se*. Research is needed to elucidate these relationships.

Various techniques exist to restore eelgrass habitat. Ryan Davis summarized the factors influencing restoration success, or the reestablishment of self-sustaining eelgrass habitat that resembles a natural system in structure and function. The most important determinant of success is location, which encompasses local factors such as light availability, sediment composition, and bathymetry, and regional factors such as shoreline configuration and landscape position. The overall success rate for restoring eelgrass beds through transplanting is about 50%. Project goals may dictate other definitions of success. For example, mitigation projects may evaluate success based on a target area planted, and community-based restoration projects may evaluate success with outreach and education metrics. Workshop participants suggested that the deciding factor in long-term eelgrass protection may indeed be increased citizen understanding of the value of eelgrass; restoration projects provide an excellent opportunity to educate stakeholders about eelgrass importance to coastal ecosystems and the difficulty involved to restore eelgrass once it has been eliminated. Poster presentations highlighted examples of successful eelgrass restoration projects in Massachusetts (Jennifer Doyle-Breen et al.) and in Maine (Casie Reed et al.). Research is needed to determine the minimum sustainable shoot density and patch size to guide restoration projects.

As the complexity and magnitude of estuarine habitat degradation continue to increase, so too do restoration needs. Ray Konisky described a multi-agency partnership for large-scale coastal and estuarine ecosystem restoration in New Hampshire. Comprehensive information on multi-habitat restoration opportunities, based on historic and current habitat distribution and site selection models, has been developed for seacoast subwatersheds. Partners share this information and collaborate to set regional restoration priorities and coordinate restoration projects. Kate Killerlain Morrison’s and Jessica Dyson’s poster described a partnership convened by The Nature Conservancy to advance eelgrass restoration in Massachusetts on a statewide scale that similarly involves multiple entities sharing information on suitability of potential restoration sites.

Eelgrass and Water Quality: Approaches to Setting Nutrient and Habitat Criteria

The most pervasive threat to eelgrass in the northeastern U.S. and Atlantic Canada is water quality degradation. Phil Colarusso summarized the components of water quality most relevant to eelgrass survival: nitrogen and phosphorus concentrations, chlorophyll *a*, suspended solids, and water clarity. Approaches to managing water quality for eelgrass protection include establishing criteria for ambient nutrient concentrations, nutrient loads, or multiple parameters affecting environmental suitability for eelgrass, and manipulating ecosystem processes (e.g. restoring shellfish beds to improve water filtration, dredging to increase flushing). A frequently cited example of seagrass recovery following wastewater treatment is in Tampa Bay, Florida, but increases in seagrass cover following water quality improvements have also been documented in three Massachusetts locations: Boston Harbor, New Bedford Harbor, and Gloucester Harbor. Given that improving water quality can reverse trends in eelgrass loss, water quality targets for estuarine management are needed.

A series of presentations addressed different approaches to setting water quality targets for eelgrass protection. First, Brian Howes described the Massachusetts Estuaries Project, a partnership between state agencies, academic institutions, and municipalities that is developing nitrogen concentration thresholds and target nitrogen loads for individual embayments in southeastern Massachusetts. Linked watershed/embayment models are being developed for each embayment. These couple land-use nitrogen loading, watershed nitrogen attenuation, and hydrodynamics of the receiving waters to yield distribution of total nitrogen throughout the estuary. Estuary-specific thresholds for total nitrogen concentration are based upon analysis of historical trends in habitat indicators (eelgrass, macroalgae, benthic communities, dissolved oxygen) and water quality, and the watershed/embayment model can then be used to analyze management strategies for meeting these nitrogen thresholds. Estuary-specific concentration thresholds are generally about 0.32 - 0.38 mg / l in these systems. Second, Paul Currier described efforts led by New Hampshire Department of Environmental Services to develop nitrogen criteria for Great Bay estuary, New Hampshire, based on eelgrass light requirements. The minimum water clarity (as K_d) for eelgrass survival in Great Bay was determined to be 0.75 m^{-1}, derived from the published minimum light requirement of 22% surface irradiance and local bathymetry and tidal range. From empirical data relating water clarity to total nitrogen concentration in Great Bay, this minimum water clarity yielded a total nitrogen threshold for eelgrass survival of 0.32 mg/l. Third, Jim Latimer and Steve Rego described development of nitrogen load – eelgrass response models for southern New England estuaries by U.S. Environmental Protection Agency – Office of Research and Development. Nitrogen load to 67 estuaries was estimated from wastewater, atmospheric, and fertilizer sources to watersheds, within-watershed nitrogen losses, and direct atmospheric deposition. Eelgrass extent within each estuary was measured from aerial photographs, and the relationship of eelgrass extent to area-normalized load of total nitrogen (kg N ha^{-1} y^{-1}) across all estuaries was analyzed for thresholds. These data suggested that 50% eelgrass loss occurs at loads above a mean threshold of 50 kg N ha^{-1} yr^{-1} and high eelgrass loss (>75%) occurs above 100 kg N ha^{-1} yr^{-1}, although factors contributing to variability in the load-response models are still being explored. Fourth, Jamie Vaudrey described a project of the Connecticut Department of Environmental Protection and University of Connecticut to develop multi-metric habitat criteria for eelgrass in Long Island Sound. Published habitat criteria from Chesapeake Bay and Long Island Sound were compared to water quality parameters, eelgrass distribution, and historical data from three study sites in Connecticut. Data from these sites fit within previously published relationships of percent eelgrass loss relative to area-normalized nitrogen load in small embayments, confirming substantial eelgrass loss in estuaries receiving greater than 50 kg N ha^{-1} y^{-1}. A minimum light requirement of 22% surface irradiance was used to predict potential eelgrass habitat in the study estuaries, and water quality metrics were evaluated in terms of eelgrass distribution and biomass patterns to establish a suite of habitat criteria.

The different methods for establishing habitat criteria to sustain eelgrass converged on quite similar water quality targets. Discussion focused on the uncertainties inherent in the derived thresholds. It is important to note that the nitrogen concentration and load thresholds derived either from a 22% minimum light requirement or by correlating water quality with eelgrass distribution are related to survival of existing beds. The water quality criteria for maximum eelgrass growth and reproduction have not been determined, nor have interactive effects of multiple, additional controlling factors (e.g. sediment grain size and organic content) on nitrogen thresholds been addressed. Determining nutrient and habitat criteria for individual embayments allows tailoring of management efforts to local conditions, but limits transferability of derived thresholds to distant locales. It may be possible to examine existing data in a regional context to estimate nitrogen thresholds for broad classes of estuaries (e.g. classified by tidal range, residence times, and other factors with known influence on eelgrass response to nutrient enrichment).

Invasive Species and Climate Change

As evidenced by the emergence of European green crabs (*Carcinus maenas*) in eastern Canada, invasive species can have a marked impact on eelgrass. The presentation submitted by

David Garbary et al. reported a 95% decline in eelgrass in Antigonish Harbour, Nova Scotia between 2000 and 2001, following high densities of European green crabs in 2000. A survey of Harbour Masters throughout Nova Scotia's Gulf of St. Lawrence and Atlantic coasts revealed eelgrass declines at 31 out of 40 sites, with abundant or increasing numbers of green crabs reported. Aimée Pelletier et al. also submitted information on high densities of green crabs in an area of recent eelgrass decline in Kejimkujik National Park, Nova Scotia, along with characteristic signs of green crab disturbance (shredded bundle sheaths and live plants clipped at the base). Mary Carman and David Grunden described invasive tunicates associated with eelgrass in Massachusetts. The invasive colonial ascidian *Didemnum vexillum* is usually found on hard substrates, but in fall 2008 it was found on eelgrass in Lake Tashmoo, Martha's Vineyard, Massachusetts. Other invasive colonial ascidians were also found growing on eelgrass in this area. This is the first record of *D. vexillum* attaching to eelgrass.

Studies of structural and physiological responses to environmental factors associated with climate change can predict future climate effects on eelgrass. Ron Thom et al. presented an overview of impacts of global climate change on eelgrass based on long-term studies of eelgrass responses to temperature, light, and desiccation in the Pacific Northwest during a time of climate variation (El Nino-Southern Oscillation, Pacific Decadal Oscillation). Small variations in temperature and mean sea level were correlated with substantial changes in eelgrass density, growth, biomass, and areal extent, providing evidence for forecasting climate change impacts.

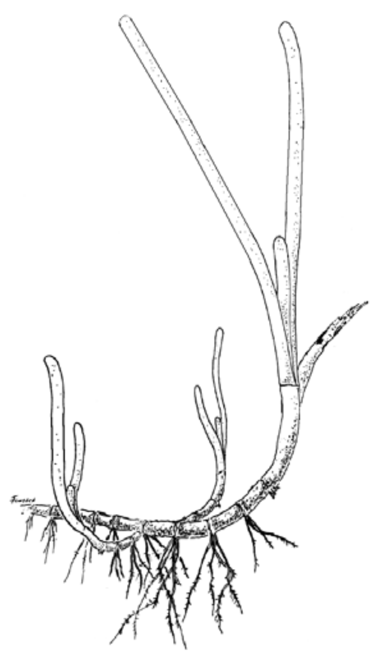
Discussions of invasive species and climate change highlighted the importance of considering emerging threats in developing management strategies to protect eelgrass. Research is needed to understand the interactions among multiple factors controlling eelgrass growth and survival and the mechanisms underlying eelgrass response. The relative importance of factors affecting eelgrass may shift with new species invasions and altered climate regimes, and new management approaches will likely be required. Integrating eelgrass monitoring, experimental studies, and modeling will improve abilities to forecast changes in eelgrass extent and condition. Restoration planning must certainly incorporate climate change predictions for factors affecting eelgrass survival. Management strategies that enhance eelgrass resilience to climate change impacts must be developed and adopted. These include conservation of areas least threatened by climate change and maintaining and improving water quality to standards sufficient to promote eelgrass recruitment and bed expansion.

Programs and Partnerships for Eelgrass Conservation

Phil Colarusso and Guy Robichaud described the regulatory framework for eelgrass conservation in the northeastern United States and Atlantic Canada, respectively. The primary tool for protecting eelgrass in the U.S. is the Clean Water Act, which protects habitat for fish and other aquatic resources and regulates discharge of dredge or fill material in vegetated shallows. Eelgrass is also subject to the "no-net-loss" of wetlands policy. In Canada, the Fisheries Act prohibits the harmful alteration, disruption or destruction of fish habitat, and the Oceans Act of 1996 promotes an ecosystem approach to integrated management of human activities affecting estuarine, coastal, and marine waters. The Department of Fisheries and Oceans has recently declared eelgrass to be an "ecologically significant species" in eastern Canada; the next steps are to develop an eelgrass management plan and means to minimize anthropogenic impacts.

In addition to federal, state, and provincial government programs to protect eelgrass, conservation efforts of citizen coalitions are equally important. Tom Irwin described the Save

Great Bay partnership, a broad-based group of stakeholders with the shared goal of protecting the Great Bay Estuary, New Hampshire. The group's efforts are focused on expanding citizens' awareness of issues concerning Great Bay and its watershed, identifying and promoting legislation and policy to improve the condition of the estuary, and developing effective communication tools to spark behavioral and policy change. A poster by Nora Beem and Fred Short described an outreach event in which school children created interpretive panels on Great Bay resources for display in local communities. This effort exemplifies public involvement in eelgrass conservation as furthered by the Save Great Bay partnership.



Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States February 24-25, 2009

Workshop Program

Tuesday, February 24, 2009

8:00 Continental Breakfast and Registration

9:30 Welcome and Introduction
Hilary Neckles, USGS Patuxent Wildlife Research Center, Augusta, ME

9:45 Keynote Address – Eelgrass: the Big Picture
Fred Short, University of New Hampshire, Jackson Estuarine Lab, Durham, NH

EELGRASS CHANGE AROUND THE REGION

10:30 State and Provincial Status and Trends Updates:

New York
Chris Pickerell, Cornell Cooperative Extension of Suffolk County, Southold, NY

Connecticut
Tom Halavik, U.S. Fish and Wildlife Service, Charlestown, RI

Rhode Island
Sue Tuxbury, NOAA Fisheries Service, Gloucester, MA

Massachusetts
Charlie Costello, Massachusetts Dept. of Environmental Protection, Boston, MA

New Hampshire
Fred Short, University of New Hampshire, Jackson Estuarine Lab, Durham, NH

Maine
Seth Barker, Maine Dept. of Marine Resources, West Boothbay Harbor, ME

Eastern Canada: Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland
Al Hanson, Canadian Wildlife Service – Environment Canada, Sackville, NB

11:30 Panel Discussion – Eelgrass Trends and Their Causal Factors

12:00 LUNCH

PROTECTING HABITAT FUNCTIONS AND VALUES FROM DIRECT IMPACTS

1:30 **Eelgrass Habitat Functions and Ecosystem Services**
Allison Schmidt, Dalhousie University, Halifax, NS

1:50 **Setting Priorities for Eelgrass Conservation and Restoration**
Robert Buchsbaum, Massachusetts Audubon, Wenham, MA

2:10 **Monitoring the Condition of Eelgrass Habitat**
Hilary Neckles, USGS Patuxent Wildlife Research Center, Augusta, ME

2:30 **Assessing Shellfish Aquaculture Impacts to Eelgrass**
Marc Skinner, Canadian Rivers Institute, Univ. of New Brunswick, Moncton, NB

2:50 **Conservation Moorings as Eelgrass Habitat Protection: A Cooperative Habitat Protection Partnership**
Tay Evans, Massachusetts Division of Marine Fisheries, Gloucester, MA

3:00 **The Taunton Bay Management Experiment - Protecting Eelgrass Amidst Conflicting Uses**
John Sowles, Maine Department of Marine Resources, West Boothbay Harbor, ME

3:30 **BREAK**

4:00 **Restoration: What Has Worked Where, and Why**
Ryan Davis, Anchor QEA, LLC, Glens Falls, NY

4:20 **Building Partnerships for Restoration**
Ray Konisky, The Nature Conservancy New Hampshire Chapter, Newmarket, NH

4:40 **Panel Discussion – Impacts to Eelgrass and Restoration Priorities**

5:15 **Adjourn for the day**

5:30 **RECEPTION**

7:00 **DINNER ON YOUR OWN IN OLD PORT**

Wednesday, February 25, 2009

7:30 Continental Breakfast

EELGRASS AND WATER QUALITY: APPROACHES TO SETTING NUTRIENT AND HABITAT CRITERIA

8:30 It's the Water Quality, Stupid!
Phil Colarusso, U.S. Environmental Protection Agency, Boston, MA

9:00 Massachusetts Estuaries Project
Brian Howes, School for Marine Science and Technology, University of Massachusetts, Dartmouth, MA

9:25 Proposed Nutrient Criteria for the Great Bay Estuary
Paul Currier, NH Department of Environmental Services, Concord, NH

9:50 Developing Nitrogen Load-Eelgrass Response Relationships for Southern New England Estuaries
James S. Latimer and Steven Rego, U.S. EPA, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI

10:15 BREAK

10:45 A Multi-metric Approach to Establishing Restoration Objectives for Eelgrass in Long Island Sound
Jamie Vaudrey, University of Connecticut, Groton, CT

11:10 Panel Discussion – Criteria to Sustain Eelgrass

12:00 LUNCH

INVASIVE SPECIES AND CLIMATE CHANGE

1:00 Destruction of Eelgrass in Nova Scotia by the Invasive Green Crab, (*Carcinus maenas)*
David Garbary, Tony Miller, N. Seymour and J. Williams, St. Francis Xavier University, Antigonish, NS
and
Aimée Pelletier[1], Chris McCarthy[2] and Bill Freedman[3]
[1]School for Resource and Environmental Studies, Dalhousie University, Halifax, NS
[2]Kejimkujik National Park and National Historic Site, Maitland Bridge, NS
[3]Department of Biology, Dalhousie University, Halifax, NS

1:20 First Occurrence of the Invasive Colonial Ascidian *Didemnum vexillum* to Utilize Eelgrass *Zostera marina* as Substrate
Mary Carman, Woods Hole Oceanographic Institution, Woods Hole, MA
David Grunden, Town of Oak Bluffs Shellfish Department, Oak Bluffs, MA

1:40 Impacts of Global Climate Change on Eelgrass
Ron Thom, Pacific Northwest National Laboratory, Sequim, WA

2:00 Panel Discussion – Emerging Threats

2:30 BREAK

PROGRAMS AND PARTNERSHIPS FOR EELGRASS CONSERVATION

3:00 The Good, the Bad and the Ugly of Seagrass Protection in the Northeastern U.S.
Phil Colarusso, U.S. Environmental Protection Agency, Boston, MA

3:20 Programs and Regulations for Eelgrass Conservation in Canada
Guy Robichaud, Department of Fisheries and Oceans Canada, Moncton, NB

3:40 "Save Great Bay" Partnership: Enhancing Protection Efforts Through Better Coordination
Tom Irwin, Conservation Law Foundation, Concord, NH

4:00 Workshop Summary
Hilary Neckles, USGS Patuxent Wildlife Research Center, Augusta, ME

4:20 Group Discussion: What Are the Pressing Needs in Research and Conservation?

5:00 Adjourn Workshop

POSTERS

Elementary Student Creation of Interpretive Panels of Estuary Resources Increase Public Awareness and Enhance Experiential Education

Nora Beem and Fred Short
Dept. of Natural Resources and the Environment, University of New Hampshire, Durham NH

Eelgrass (*Zostera marina*) Restoration in Gloucester, MA

Jennifer Doyle-Breen, Nathan Henderson, Brent Courchene, and Tom Touchet
AECOM Water, Wakefield, MA

Identifying Suitable Sites for Restoration of Eelgrass (*Zostera marina*) in Massachusetts

Kate Killerlain Morrison and Jessica Dyson
The Nature Conservancy, Massachusetts Chapter, Boston, MA

A Disappearing Act? Monitoring Eelgrass (*Zostera marina*) Decline in Kejimkujik National Park, Nova Scotia, Canada

Aimée Pelletier[1], Chris McCarthy[2] and Bill Freedman[3]
[1]School for Resource and Environmental Studies, Dalhousie University, Halifax, NS
[2]Kejimkujik National Park and National Historic Site, Maitland Bridge, NS
[3]Department of Biology, Dalhousie University, Halifax, NS

Macroalgae and Eelgrass Mapping in Great Bay Estuary Using AISA Hyperspectral Imagery

Shachak Pe'eri[1], John R. Morrison[2], Frederick Short[3], Arthur Mathieson[3], Philip Trowbridge[4]
University of New Hampshire, Durham, NH: [1]Center for Coastal and Ocean Mapping, [2]Ocean Process Analysis Lab., [3]Jackson Estuary Laboratory, [4]Piscataqua Region Estuaries Partnership

Eelgrass Variability in Taunton Bay, Maine

Steve Perrin, Friends of Taunton Bay, Hancock, ME

Community Based Eelgrass Restoration at Hadley Point in Bar Harbor, Maine

Casie Reed[1], Sarah Colletti[1], Jane E. Disney[2], and George Kidder[2]
[1]College of the Atlantic, Bar Harbor, ME; [2]MDI Biological Laboratory, Salisbury Cove, ME

Assessing Estuarine Condition Through Water Quality and Seagrass Monitoring at Fire Island National Seashore, NY

Brooke Rodgers[1], Jamie Brisbin[1], Joseph Myers[1], Hilary A. Neckles[2], Blaine S. Kopp[2] and Bradley J. Peterson[1]
[1]Marine Science Research Center, Stony Brook University, Southampton, NY
[2]USGS Patuxent Wildlife Research Center, Augusta, ME

SeagrassNet: Global Monitoring Network of Seagrass Resources

Fred Short[1], Aaren Freeman[1], Giuseppe Di Carlo[1], Rob Coles[2], Miguel Fortes[3], and Evamaria Koch[4]

[1]Jackson Estuarine Laboratory, University of New Hampshire, Durham NH

[2]Northern Fisheries Centre, Queensland, Australia

[3]University of Philippines, Quezon City, Philippines

[4]Horn Point Laboratory, University of Maryland, Cambridge, MD

Long-term (1985-2007) Monitoring Studies of Eelgrass (*Zostera marina* L.) Population Dynamics in Eastern Long Island Sound

John T. Swenarton

Millstone Environmental Laboratory, Dominion Resources, Rope Ferry Rd., Waterford, CT

ABSTRACTS

Beem, N. and F. Short. Dept. of Natural Resources and the Environment, University of New Hampshire, Durham NH <fred.short@unh.edu>

Elementary Student Creation of Interpretive Panels of Estuary Resources Increase Public Awareness and Enhance Experiential Education

After participating in a hands-on marine curriculum utilizing local natural resources in the Great Bay, New Hampshire students created their own interpretive panels for display throughout the local community. The curriculum addressing the state science standards was executed as an outreach event and focused on the role of eelgrass, a marine plant, in the Great Bay Estuary. The student panels incorporate student artwork and ideas to educate the public on the importance of eelgrass while increasing their sense of stewardship for the area. Concepts displayed on these panels highlight the dependence of fish and invertebrates on eelgrass for survival.

Bradley, M.[1], K. Raposa[2], and S. Tuxbury[3]. [1]University of Rhode Island, Environmental Data Center; [2]Narragansett Bay National Estuarine Research Reserve; [3]NOAA Fisheries, Habitat Conservation Division < susan.tuxbury@noaa.gov>

Status and Trends of Eelgrass in Narragansett Bay, Rhode Island

Mapping the distribution and extent of eelgrass is a critical first step in understanding, managing, and protecting shallow-subtidal estuarine habitats. In 2006, for the first time in ten years, submerged aquatic vegetation (SAV) was mapped in Narragansett Bay and Block Island, Rhode Island. The first mapping effort in 1996 delineated 99.5 acres of eelgrass in Narragansett Bay. Results of site-specific mapping efforts and improvements in geographic information systems (GIS) and mapping technology have illustrated a need to update the 1996-Bay-wide mapping project. The overall goals of this mapping project were to 1) conduct a complete and comprehensive survey of eelgrass throughout Narragansett Bay and Block Island; 2) analyze and compare eelgrass mapping techniques (photo-interpretation of true color aerial photography vs. field-mapping methods) and 3) examine status and trends of eelgrass from 1996 to 2006. A brief overview of the mapping results will be presented for Narragansett Bay. The full copy of the report can be found at http://www.nbnerr.org/Content/2007eelgrass_Report.pdf.

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Setting Priorities for Eelgrass Conservation and Restoration

Seagrass habitats in New England and elsewhere are generally considered to be among our most valuable coastal habitats. They serve as nursery areas for commercially important fish and shellfish species, a feeding area for waterfowl and fish, and a direct source of food or detritus for coastal food webs. They also act as a stabilizer of sediments and a nutrient filter. In their assessment of biotic criteria, the Habitat Working Group of the Massachusetts Ocean Management Commission rated eelgrass meadows as high value relative to other coastal habitats. High valuation was a function of the limited area of this habitat and its vulnerability to impacts. All eelgrass meadows that were delineated as part of the Department of Environmental Protection's mapping program were given the same high value. Three issues require further investigation. First, in any survey of seagrasses some meadows or patches might be missed, particularly those at the deep end. Second is how to value potential habitat, such as areas where eelgrass meadows formerly occurred but were not recorded during more recent surveys. Third is the question of whether eelgrass meadows of different landscape characteristics might have different values, such as small patches vs. large contiguous meadows, those with high plant density v lower densities, and those near v far from other habitats such as salt marshes. A review of the literature suggests that it is very hard to generalize about the habitat value of eelgrass based on landscape functions. At a small scale where most studies have taken place, there is no consistent difference between small and large patches of seagrasses in terms of the abundance and diversity of organisms they support. This suggests that all eelgrass habitats regardless of their size and degree of patchiness should be considered of the same value.

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First occurrence of the invasive colonial ascidian *Didemnum vexillum* to utilize eelgrass *Zostera marina* as substrate

The invasive colonial ascidian *Didemnum vexillum* Kott, 2002 has adapted to utilizing eelgrass *Zostera marina* (Linnaeus, 1753) as substrate in Atlantic coastal waters at Massachusetts. Usually associated with artificial and rocky substrates, we found *D. vexillum* attached to *Z. marina* at Lake Tashmoo, Martha's Vineyard, Massachusetts in fall 2008. Several non-endemic species of ascidians including *D. vexillum* were introduced to New England in the 1980s and are now common in subtidal communities and at shellfish aquaculture sites, marinas and harbors. The bay scallop *Argopecten irradians irradians* (Lamarck, 1819), a cultured shellfish that is also placed out as part of shellfish restoration efforts on the Vineyard, is a valuable coastal resource on the Vineyard and elsewhere in New England. Eelgrass serves as a habitat for bay scallops and juvenile fish and threats to it are of concern by coastal managers and the fishing industry. We surveyed Lake Tashmoo, a protected marine pond with shellfish aquaculture operations and restored bay scallops. We found the invasive colonial ascidians *D. vexillum, Botrylloides violaceus* Okra, 1927, *Botryllus schlosseri* (Pallas, 1774), *Diplosoma listerianum* (Milne-Edwards, 1841) and the native solitary ascidian *Molgula manhattensis* (Dekay, 1843) growing on eelgrass in patches scattered throughout the mid pond area, encompassing about one fourth of the pond. These ascidians, including *D. vexillum*, were attached to the stalk and blade of live in situ eelgrass and to floating pieces of eelgrass. Rafting of ascidians on floating eelgrass blades or pieces of the plant is a recognized dispersal mechanism for some ascidians and should now be considered as a dispersal mechanism for *D. vexillum* too. *Botrylloides violaceus, B. schlosseri, D. listerianum* and *M. manhattensis* have been previously recorded as attached to eelgrass, but *D. vexillum* has not been previously recorded attached to eelgrass. Perhaps because of lack of available space, *D. vexillum* has spread to utilize eelgrass as habitable space. Other eelgrass sites in North American Atlantic and Pacific waters should be examined for epibiotic ascidians and the impact of *D. vexillum* and other invasive species of ascidians on eelgrass should be assessed.

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It's the Water Quality, Stupid!

The problem of cultural eutrophication of our coastal waters is a complex one that a multitude of state and federal agencies are attempting to address in a variety of ways. Approaches to the protection of seagrasses from over enrichment of nutrients vary widely. These approaches include development of ambient nitrogen criteria, development of nitrogen loading models to watersheds, multimetric approaches to management of water quality, and ecosystem manipulation (e.g. adding oysters/shellfish to filter water, dredging to increase water movement/flushing). Our estuaries are physically, chemically, and biologically complex and they are constantly evolving. In addition, the basic physiology, of even the most well studied species, is not completely understood. Into this arena of uncertainty, resource managers must make very difficult decisions that have real societal costs. This session will present 4 distinct approaches to water quality management and seagrass conservation.

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The Good, the Bad and the Ugly of Seagrass Protection in the Northeastern U.S.

The Clean Water Act (CWA) has been the key tool in protecting aquatic resources since its inception. The general goals of the CWA are to ensure that the waters of the US are fishable and swimmable. Implied in this goal is protection of habitat that fish and other aquatic resources rely on for critical life functions. Thus, seagrass, defined as vegetated shallows in the CWA, merits protection for its function as a nursery habitat. This talk will review seagrass regulation and management in New England over the last 20 years. The names have been changed to protect the innocent.

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Status and Trends of Eelgrass in Massachusetts

Massachusetts DEP 15-year eelgrass mapping program data has revealed significant declines in the resource throughout the state's coastline. Data suggest declines will continue into the future.

Davis, R. Anchor QEA, LLC, Glens Falls, NY <rdavis@qeallc.com>
Restoration: What Has Worked Where, and Why

Attempts to restore eelgrass habitat have been around since the mid 1940s at scales ranging from several square feet to tens of acres. Historically, the success rate for eelgrass restoration efforts is roughly 50%. A significant amount of research has been conducted to better understand the factors that contribute to the success or failure of a restoration project. Location has often been identified as the most significant factor, which has lead to the development of site selection models. These models provide a useful tool for screening large areas to prioritize test planting locations. Other factors include the source of the material, planting technique and planting density, and disturbance. In most instances, the frequency and duration of post-planting monitoring severely limits the ability to determine causal relationships between site specific conditions and success or failure. Site selection and planting techniques will be discussed, along with current research on understanding restoration success.

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Eelgrass (*Zostera marina*) Restoration in Gloucester, MA

In 2007, the City of Gloucester implemented a large scale sewer separation project designed to significantly reduce annual combined sewer overflow activations to Gloucester Harbor, MA. Due to the City's coastal setting, alternatives for selecting the location of a 550 foot stormwater outfall pipe were limited as many options involved impacts to coastal habitat including shellfish areas, salt marsh, and eelgrass (*Zostera marina*) beds. The final location was selected in consultation with USEPA and the Massachusetts Division of Marine Fisheries based on environmental, economic, and engineering considerations. The chosen route, however, traversed a 5-acre eelgrass bed and involved dredging approximately 0.5 acre of eelgrass.

The City was required to develop an eelgrass restoration program to return the function and value of the impacted eelgrass. Prior to construction, extensive SCUBA surveys were conducted to verify and map eelgrass boundaries, propose mitigation, and recommend future compliance monitoring. The restoration program involved techniques that required harvesting 32,000 eelgrass shoots from donor beds and planting them within the construction corridor. All harvesting and planting was conducted by hand with divers. A test plot was conducted in 2007, and full-scale planting occurred in 2008. Short-term survivorship results indicated that approximately 70% of transplanted shoots survived after the first two to four weeks. The 2007 test plot was evaluated 14 months after planting, and showed greater than 100% survivorship, indicating recruitment of new shoots. In addition, many planted quadrats exhibited expansion beyond the planted area, with 40 – 120 shoots located outside of the planted quadrat and encroaching on nearby planted areas. Diving efforts for the transplanting were also provided by US EPA, MA DMF and RDA Construction. The City of Gloucester, MA funded the restoration work as part of the mitigation program for the Washington Street Drain Outfall.

The restored eelgrass area will be monitored annually for three years between 2009 and 2010 to assess shoot count, bio-mass, and canopy height. The results will be compared to nearby reference beds to measure the success of transplanted eelgrass.

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Conservation Moorings as Eelgrass Habitat Protection: A Cooperative Habitat Protection Partnership

Eelgrass is vulnerable to impacts from a wide range of anthropogenic effects, including boating. One example is the direct physical disturbance caused by chain scour around a mooring. Traditional moorings, typically consisting of a heavy mushroom anchor and chain, can rip up eelgrass habitat and prevent plants from growing in the scoured area. Chain dragging can also increase water column turbidity, shading adjacent plants. Individual mooring impacts may seem small; however the cumulative effects in ever crowded mooring fields is a growing concern. New mooring technologies referred to as “conservation moorings” may serve to minimize this impact. Conservation mooring designs include a flexible rode that is kept off the bottom, minimizing scour, and may include a helical anchor to reduce direct bottom impact. Through a new National Marine Fisheries Service (NMFS) initiative, called the Cooperative Habitat Protection Partnerships (CHPPs), NMFS, EPA, Massachusetts Division of Marine Fisheries, The Nature Conservancy and local towns have partnered to promote the use of conservation moorings while simultaneously studying their effectiveness at minimizing eelgrass impacts. This CHPPs project has two main objectives; 1) to promote eelgrass habitat awareness and protection and foster stewardship by encouraging voluntary use of conservation moorings gear and, 2) to design and implement a demonstration project to study the effectiveness of the conservation mooring technology in protecting eelgrass. To date we have secured funding for an interpretive poster, outreach materials and two conservation mooring systems and are now developing a pilot study. Our standard monitoring protocols will be scalable to enable future additional sites. The potential for re-growth within mooring scars will be monitored with sampling along a transect at impact (conservation moorings replacing traditional moorings) and control (traditional moorings) sites, monitored before the conversion and after for 4 years. In addition, conservation moorings may be placed at new locations within an eelgrass bed, to study the effectiveness of these systems at preserving existing eelgrass coverage. Results will be useful to managers planning to recommend conservation moorings as a permit condition or mitigation requirement, and to the public considering a pro-active change to a conservation mooring.

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

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.

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Status and Trends of Eelgrass in Eastern Canada

Although eelgrass (*Zostera marina*) has been widely recognized as an important component of coastal ecosystems in eastern Canada, regional surveys to monitor changes in eelgrass distribution and abundance do not yet exist. Important areas for eelgrass in eastern Canada include the outer Bay of Fundy, Atlantic Coast of Nova Scotia, Island of Newfoundland, Gulf of St. Lawrence, St. Lawrence River Estuary, and James Bay. An overview of current information on status and trends of eelgrass and efforts to develop cost effective monitoring programs by myself and colleagues in eastern Canada will be presented. The trends, issues and monitoring programs for eelgrass differ dramatically throughout eastern Canada. Several areas in Nova Scotia and New Brunswick have documented declines in the extent and distribution of eelgrass related to invasive species and eutrophication. On the island of Newfoundland, eelgrass appears to be stable but the European Green Crab has recently arrived. Eelgrass appears to be stable or increasing in the Gulf of St. Lawrence and St. Lawrence River Estuary in Quebec. In James Bay Quebec localized declines of eelgrass beds potentially due to hydro-electric development have been reported.

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Identifying Suitable Sites for Restoration of Eelgrass (*Zostera marina*) in Massachusetts

Despite the headway that Massachusetts has made in coastal salt marsh restoration, there currently is no broader marine restoration agenda for eelgrass (*Zostera marina*), or for any other submerged lands or seafloor habitats (e.g. shellfish reefs) in state waters. As one of the only non-profit organizations exploring on-the-ground marine restoration in Massachusetts, The Nature Conservancy is well-positioned to convene partners to conduct eelgrass restoration and to advocate for a statewide marine restoration program, endorsed by the Massachusetts Executive Office of Energy and Environmental Affairs. Through developing a shared eelgrass restoration plan, there is opportunity to leverage funding opportunities allowing restoration to be done at a large scale. These may include: (1) Ocean Resources and Waterways Trust Fund designated in the Massachusetts Oceans Act of 2008, (2) National Oceanic and Atmospheric Administration (NOAA)/TNC Community Based Partnership grant program, and/or (3) Recommendations to government agencies negotiating mitigation packages. Results of this project may also assist in identifying candidate sites for alternative mooring technologies, through the program launched by NOAA Office of Habitat Conservation, the Environmental Protection Agency and the Massachusetts Division of Marine Fisheries. In December 2008, The Nature Conservancy's Massachusetts Chapter recently became a partner on this effort. Short term project goals include: (1) to identify areas suitable for eelgrass restoration, using a combination of existing data overlays, modeled information, expert opinion and groundtruthing, and (2) to conduct test plantings in at least one site of high suitability to further ground-truth results. Long-term project goals include: (1) to encourage acceptance of identified sites as a statewide marine restoration plan, and (2) to promote the use of identified sites as priorities in mitigation packages by government agencies. To guide our work, we are convening an informal technical expert team for assistance on the following: feedback on our overall proposed approach and use of GIS, modeling and groundtruthing, information on planned eelgrass restoration activities in Massachusetts, best available data sources and identification of data limitations, information on planned data collection activities that may inform this analysis, advice on mapping anecdotal data (i.e. historic or expert recommended restoration sites), best practices for collecting water quality and other data on-site, and methods to incorporate human uses into site suitability analyses.

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Building Partnerships for Restoration

There are several regional models of estuarine restoration partnerships in the US, notably Chesapeake Bay, Delaware Bay, and San Francisco Bay. Some of these programs have been in operation for as long as 30 years and have spent upwards of $1B. Ecological progress varies by region and by habitat measure (e.g. water quality often improves but species and estuarine habitats lag behind). Still, the partnership model is an important framework for advancing complex, long-term, and wide-scale ecological restoration programs. We are in the early stages of forming a multi-agency partnership in New Hampshire called the *Partners to Restore New Hampshire's Estuaries* as a way to address degraded water quality and habitat conditions in our estuaries. While not a fiduciary entity, our group has coalesced around a shared vision for estuarine recovery based on a combination of policy change, public outreach, and direct action. Our initial work is a planning process that lays the groundwork for scaled-up restoration. As a starting point, restoration "compendiums" have been developed to show the historic and current distribution of key conservation targets (eelgrass, salt marsh, dunes, shellfish, and diadromous fish habitat). Based on compendium results, we have delineated seacoast subwatersheds into twenty focus areas, as potential sites for multi-habitat partner-driven restoration work. For each focus area, maps are developed and posted to a wiki site for data sharing and review. Partners use the wiki to post relevant information regarding opportunities, limiting factors, and regulatory designations, along with links to monitoring reports and ancillary web data sources. This information is used as the basis for discussion at quarterly meetings and to move forward on priority-setting and project coordination. We strongly believe that continued partner dialog, data-sharing, and priority planning will position us well to achieve estuarine habitat improvements on ecologically-meaningful scales in the coming years.

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Developing Nitrogen Load-Eelgrass Response Relationships for New England Estuaries

We have accumulated and analyzed eelgrass areal extent data for 67 estuaries from three New England states. To our knowledge this is the largest data set of its kind. Previous comparative studies have utilized data from a far smaller number of estuaries (ten or less) to develop empirical relationships between nitrogen inputs and eelgrass areal extent.

Cause-effect mechanisms of excess nitrogen loading on seagrass ecosystems have been published in the literature. It is thought that the dominant mechanism is the following: starting from nitrogen driven increases in phytoplankton and epiphytic growth, decreases in light result in diminished seagrass health. This progression leads to decreased density and ultimately areal extent of seagrass habitat. Based on this mechanism, we predicted, for a set of similar semi-enclosed estuaries along the New England coast, that surface area-weighted nitrogen loading rates would be inversely proportional to the extent of eelgrass (*Zostera marina*).

GIS seagrass polygon coverages were derived for the study estuaries in New England from aircraft-acquired, orthorectified digital imagery and analyzed to obtain areal extent of *Zostera* for each estuary. Nitrogen loading rates were estimated for each estuary from data on fertilizer use, atmospheric deposition rate, and human wastewater input. The data were consistent with the scientific literature showing that extent is inversely related to nitrogen inputs. However, the considerable observed variability suggests that other factors, besides nitrogen, are contributing to the magnitude of eelgrass in these small-medium sized estuaries.

Future work will include an evaluation of physical factors such as substrate type and estuarine wind regime to reduce the variance in the data. In addition, nitrogen loading threshold analysis is ongoing but appears to be similar to reported values from the literature.

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Monitoring the Condition of Eelgrass Habitat

Seagrasses are threatened by direct alterations, land-based activities, and global climate change. Monitoring can help detect threats, identify sources of problems, and suggest management solutions. However the scarcity of consistent trend data of sufficient duration, spatial extent, and resolution are often major impediments to anticipating habitat degradation before management solutions are too costly to be feasible. A hierarchical monitoring framework offers an efficient means of documenting status and trends and diagnosing causes of environmental change. This approach includes three tiers of monitoring that are integrated across spatial scales and sampling intensities. Existing mapping programs provide large-scale information on seagrass distribution (tier 1). Bay-wide surveys of condition using either low-level aerial photographs or ground-based rapid assessments characterize specific properties of large areas and identify stressor-response relationships (tier 2). High resolution measurements of seagrass condition (e.g. cover, density, biomass, shoot morphology, epiphytes, wasting disease) and environmental characteristics along depth gradients within index sites provide information on causes of change (tier 3). Spatial interpolation of tier 2 data yields snapshots of seagrass status, and use of permanent stations for tier 2 and 3 monitoring permits efficient temporal comparisons. Integration across scales permits bay-wide estimation of eelgrass biomass from easily measured parameters, extrapolation of causal relationships to bay-wide and regional scales, and the opportunity for regional assessments.

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Macroalgae and Eelgrass Mapping in Great Bay Estuary Using AISA Hyperspectral Imagery

Increases in nitrogen concentration and declining eelgrass beds in Great Bay Estuary have been observed over the last decade. These two parameters are clear indicators of impending eutrophication in New Hampshire's estuaries. The NH Department of Environmental Services (DES) in collaboration with the Piscataqua Region Estuaries Partnership adopted the assumption that eelgrass survival can be used as the target for establishing numeric water quality criteria for nutrients in NH's estuaries. One of the hypotheses put forward regarding eelgrass decline is that an eutrophication response to nutrient increases in the Great Bay Estuary has been the proliferation of nuisance macroalgae, which has reduced eelgrass area in Great Bay. To determine the extent of this effect, mapping of eelgrass and nuisance macroalgae beds using hyperspectral imagery was employed. A hyperspectral image was made by SpecTIR on August 29, 2007 using an AISA Eagle sensor. The collected dataset was then used to map eelgrass and nuisance macroalgae in the Great Bay Estuary. Here we outline the procedure for mapping macroalgae and eelgrass beds. Hyperspectral imagery was effective where known spectral signatures could be easily identified. Comprehensive eelgrass and macroalgae maps of the estuary could only be produced by combining hyperspectral imagery with ground-truth information and expert opinion. For this snapshot in time of Great Bay, nuisance macroalgae was predominantly located in areas where eelgrass formerly existed. Macroalgae mats have now replaced nearly 9% of the area formerly occupied by eelgrass in Great Bay.

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A Disappearing Act? Monitoring Eelgrass (*Zostera marina*) Decline in Kejimkujik National Park, Nova Scotia, Canada

Long-term monitoring of eelgrass (*Zostera marina*) extent and condition was initiated in Kejimkujik National Park in 2007 as part of a larger coastal ecological integrity monitoring program. A comparison of eelgrass coverage based on mapping conducted in 1987 and again in 2007-2008 indicates a loss of approximately 64 ha (~88%). A small bed (8.94 ha) fringing a tidally restricted portion of a lagoon is all that remains. Anecdotal evidence supported by the examination of aerial photo series from 1990, 1994, 2000 and 2007 suggest maximum loss occurred between 1994 and 2000. Although the original cause of eelgrass decline is unknown, monitoring data suggests that several factors are acting simultaneously and possibly cumulatively in causing continued bed decline. Swim transects of this bed conducted in 2007 followed up with trap surveys in 2008 indicate high densities of juvenile and adult European green crabs (*Carcinus maenas*). A large proportion of dislodged shoots had the characteristics signs of green crab disturbance (shredded bundle sheaths and whole, live plants sliced off at the base). Exclosure experiments are proposed for the summer of 2009 to investigate the impact of green crabs on eelgrass density and recruitment. Condition surveys detected a large proportion of shoots partially covered or knitted together with the invasive golden star tunicate (*Botryllus schlosseri*). Otherwise, epiphyte coverage was considered low and eelgrass wasting disease was not detected. Analyses conducted in 2008 indicate lagoon water quality is strongly controlled by large precipitation events which result in freshwater inputs from surrounding wetlands. Such an event, followed by a protracted period of high temperatures and calm weather precipitated rapid senescence and stagnation of the eelgrass bed in mid-July 2008—a full month earlier than the previous summer. Marginally elevated N:P ratios were observed on several occasions between May and September 2008, possibly attributable to restricted tidal flushing of the lagoon.

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Eelgrass Variability in Taunton Bay, Maine

Eelgrass coverage (acres) in [Taunton] Bay had declined about 90% between 1996 and 2002. Reports from local experts suggest that the bulk of this loss may have occurred between 2000 and 2002. Mechanisms/processes driving the decline are unknown (Slade Moore, *The Taunton Bay Assessment*, Maine Department of Maine Resources, January 30, 2004.) Some combination of the following factors may have contributed to the abrupt decline of eelgrass in the bay in 2001: 1) eelgrass dieback disease, 2) storm winds, 3) turbidity, 4) excess nutrients, 5) pollution (herbicides), 6) ice scour (the bay typically freezes in winter), 7) extreme temperatures, and 8) high salinity. Recovery since 2001 has been slow and uneven.

Containing 3,282 acres but with an entrance only 600 feet across, Taunton Bay is a mediterranean (enclosed) estuary similar to Cobscook Bay in Washington County and Bagaduce River, Skillings River, and Jordan River in Hancock County. Such estuaries are strongly influenced by runoff and human activities in the surrounding watershed. The hypothesis advanced in this poster is that lack of runoff during the drought of 2001 caused unusually high salinity levels in Taunton Bay, favoring eelgrass dieback organisms, resulting in an eelgrass decline in shallow areas of wide-ranging temperatures and salinity (high stress areas).
In 1973, eelgrass was bountiful during the year of highest snowmelt recorded in Maine. In 2000, boaters complained of dense eelgrass growth clogging their propellers. In 2001, eelgrass beds shrank and thinned conspicuously throughout the bay, and no sea lavender plants grew on their customary shores, water in the bay appeared murky, rocky shores were unusually slippery, periwinkles died by tens of thousands, and Maine had the lowest annual rainfall in 111 years.

Research by grad students at the University of Maine in Orono ruled out lack of subaqueous soil nutrients and pollution by herbicides from local blueberry barrens as factors in the dieback. Seth Barker (DMR, W. Boothbay) notes that eelgrass beds persisted during the drought at the upper end of the Taunton River channel where it opens into Taunton Bay proper, bringing cold, saline water from Frenchman Bay. This suggests that current flow, flushing, and water temperature might also be factors affecting eelgrass variability in this embayment. Eelgrass is recovering in areas receiving input from freshwater streams; but is not recovering (or is recovering more slowly) where streamflow and runoff are more limited (as around Burying Island which has no perennial or intermittent streams).

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Community Based Eelgrass Restoration at Hadley Point in Bar Harbor, Maine

Eelgrass abundance has been in decline over the past 10 years at Hadley Point in Bar Harbor, Maine. During the summers of 2007 and 2008, a diverse group of stakeholders in Frenchman Bay worked together in an effort to restore eelgrass at Hadley Point. Eelgrass was harvested from the Jordan River, located between the towns of Lamoine and Trenton, Maine. The harvested plants were then tied to grids using a method adapted from the TERFS (Transplanting Eelgrass Remotely with Frames System) method developed by Fred Short at the University of New Hampshire. Eelgrass grids were placed within the restoration area at Hadley Point and eelgrass growth was monitored for both coverage and growth rate. Water quality variables were assessed over time and restored areas were surveyed for recruitment of marine species. Within one year, eelgrass had spread within the restoration area. The growth rate of individual blades during the peak of the growth season was comparable to growth rates reported in the literature. Good water quality was sustained over the year. Preliminary studies indicate that the restored areas had recruited a diversity of marine species comparable to well-established naturally occurring eelgrass beds.

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Assessing Estuarine Condition Through Water Quality and Seagrass Monitoring at Fire Island National Seashore, NY

Seagrasses are threatened by direct alterations, land-based activities, and global climate change. Monitoring can help detect threats, identify sources of problems, and suggest management solutions. As part of the National Park Service Vital Signs Program, we used a hierarchical framework for seagrass (primarily eelgrass, *Zostera marina*) monitoring in Fire Island National Seashore, NY. The framework includes three tiers of monitoring that are integrated across spatial scales and sampling intensities. Existing mapping programs provide large-scale information on seagrass distribution (tier 1). We supplemented this with bay-wide rapid assessment of plant cover, shoot morphometry, and water depth at random sampling locations distributed throughout each system using a tessellated hexagon design (tier 2). We made detailed measurements of seagrass condition (cover, density, biomass, shoot morphology, epiphytes, wasting disease) and environmental characteristics along a depth gradient in a reference bed (tier 3).

Evaluation and monitoring of seagrass was combined with water quality and turbidity measurements through the use of a permanent sonde station. Changes in turbidity, temperature, salinity and Chlorophyll a were measured in high resolution over an extended period of time, allowing juxtaposition of water quality conditions and temporal trends in seagrass biomass and condition.

Spatial interpolation of tier 2 data yields snapshots of seagrass status and use of permanent stations for tier 2 and 3 monitoring permits efficient temporal comparisons. Integration across scales permits bay-wide estimation of eelgrass biomass from easily measured parameters and the opportunity for bay-wide assessment.

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Eelgrass Habitat Functions and Ecosystem Services

Seagrass meadows provide essential ecosystem services in coastal waters worldwide but are facing rapid global declines. Understanding the spatial and temporal patterns of the services provided by seagrass ecosystems and how these change with human impacts is essential for the proper management, conservation and recovery of these habitats. Eelgrass (*Zostera marina*) is the only seagrass species found in Atlantic Canada where it forms extensive monocultures in a range of coastal and estuarine conditions. We used large-scale field surveys to examine the spatial and temporal patterns in habitat structure (shoot density, canopy height, above and below ground biomass) as well as the regulating (carbon and nitrogen storage) and supporting (habitat/nursery provision) ecosystem services provided by eelgrass meadows. We made regional comparisons between the open Atlantic coast of Nova Scotia and the more sheltered waters of the Gulf of St. Lawrence. We also investigated seasonal changes in these services over the course of one year on the Atlantic coast as well as changes along a gradient of eutrophication in the Gulf of St. Lawrence. Overall, we found significant differences in habitat structure across regions, seasons, and the eutrophication gradient, that partly translated into changes in ecosystem services. Animal richness and abundance were found to be much higher within than outside of eelgrass beds indicating that eelgrass beds are an important coastal habitat.

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SeagrassNet: Global Monitoring Network of Seagrass Resources

SeagrassNet is a global monitoring program that makes quarterly assessments of seagrass habitat at 98 sites in 27 countries around the globe. After a pilot program in the Western Pacific starting in 2001, SeagrassNet has expanded to Asia, Australia, North, Central and South America, Africa and Europe. SeagrassNet focuses on both monitoring and education, to understand human impacts in the coastal zone and natural variation in seagrass habitats as well as the role of global climate change on seagrasses. At each site, a SeagrassNet team of local participants (typically scientists, managers, government and NGO personnel) is trained in the monitoring protocol; the program depends on these teams to conduct the monitoring field activities, submit the data to the online database. In some cases, local teams collaborate with the SeagrassNet management to secure funding to support field activities. Worldwide, SeagrassNet teams are now a veritable United Nations of coastal monitoring.

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Assessing Oyster Aquaculture Impacts to Eelgrass

Blue mussel (*Mytilus edulis*) and American oyster (*Crassostrea virginica*) aquaculture production in Atlantic Canada have increased ten- and two-fold, respectively, over the last two decades with a combined production value of $50 million. Recent market projections have estimated a multi-fold increase in Atlantic Canadian suspended bag oyster aquaculture (SBOA) production in the coming years. However, limited data exist on the potential environmental effects of this form of aquaculture on epibenthic fauna and their habitat which, in Atlantic Canada, is often eelgrass beds (*Zostera marina*). Aerial observations of reductions in *Z. marina* distribution in SBOA areas led to the hypothesis this culture method may lead to physical disturbance of the benthos and degraded fish habitat. Field surveys in 2006 of three SBOA leases in the southern Gulf of St. Lawrence and reference stations along a distance gradient away from the leases (25, 100, and 500 m) demonstrated significantly reduced above-ground biomass, shoot density, and canopy height of *Z. marina* at SBOA leases. Subsequent field studies in 2007 expanded sample sites to 20 SBOA leases and 20 reference stations nested in 5 bays along 125 km of coast line. Results of these studies demonstrated significantly reduced *Z. marina* growth rates and above-ground biomass at SBOA leases versus reference stations. Confirmation of *Z. marina* above-ground biomass reductions in SBOA areas across a wider geographical area supports the hypothesis of a negative influence of SBOA on *Z. marina* distribution. However, decreased growth rates suggest physical destruction of beds by SBOA activity may not be the sole causal mechanism of localized *Z. marina* decline. Further analyses and field experiments examining the role of nutrient and/or light limitation in observed *Z. marina* decline are planned for 2009.

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The Taunton Bay Management Experiment – Protecting Eelgrass Amidst Conflicting Uses

Arguably the greatest challenge confronting today's natural resource managers is how to sustainably balance conflicting demands for human and ecological goods and services at multiple ecosystem levels and scales. That is the promise ecosystem-based management holds for the future. Under such a regime, it is conceptually easy to protect high value habitats and biological communities such as seagrasses. But examples of moving from concept to practice are rare. What is "disturbance?" What is "sustainable?" What is "high value?" And what constitutes "enough" to protect ecosystem functions and vulnerable populations? To test the feasibility of moving ecosystem-based management forward in Maine, a small scale management experiment was begun using a small bay in Downeast Maine. In a comprehensive marine resource management plan that includes measureable benchmarks, protection of human communities is on par with ecosystems. One of the many issues immediately confronted was how protect eelgrass habitat while also allowing the harvest blue mussels, a resource of importance to local families. Bottom drags, at present, are the only economic means of harvest and are notoriously destructive to submerged vegetation. Yet we believe this experiment has successfully balanced these apparently conflicting uses by emphasizing the use of science, community stewardship and adaptability. More importantly, however, this management experiment has provided considerable lessons that might be of interest to others who wish to practice ecosystem-based management.

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Long-term (1985-2007) Monitoring Studies of Eelgrass (Zostera marina L.) Population Dynamics in Eastern Long Island Sound

Eelgrass (*Zostera marina* L.) shoot density, proportion of seed-bearing shoots, shoot length, standing stock biomass were monitored during summer months from 1985 to 2007 at three locations in eastern Long Island Sound (LIS) near Millstone Power Station (MPS), Waterford, Connecticut, USA. While all three monitoring sites currently support healthy populations, some degree of long-term decline was detected at all three areas monitored. Two populations in Jordan Cove near the fringes of the thermal plume (<1.5 km from the MPS discharge to LIS) exhibited only slight declines in some population parameters over the 23-yr study period and thermal input from MPS to these sites was minimal (<1^{o}C above ambient conditions). By comparison, heavy eelgrass losses were documented in the Niantic River, located >2 km from the MPS thermal plume. While the causes were not always determined, nutrient loading from surface run-off and groundwater sources, and an increase in ambient seawater temperature of ~1.3^{o}C over the last 30 years may have contributed to observed declines. Short-term declines in eelgrass abundance were directly associated with fouling and overgrowth of eelgrass on three occasions: once by blue mussels and twice by blooms of green algae (*Cladophora*). Another abrupt decline was concurrent with a sharp increase in sediment silt/clay content, presence of thick mats of the red macroalga *Agardhiella* and unusually high summer seawater temperatures (>27^{o}C). Following these and other unexplained die-off events, steady recovery of the Niantic River eelgrass population has been observed, possibly related to expansion of the municipal sewage network within the watershed.

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Impact of climate change on eelgrass: lessons from the U.S. west coast

Climate variation strongly affects the abundance and distribution of eelgrass along the Pacific Coast of the U.S. The 1997-98 El Nino event caused a dramatic decline in eelgrass. However, populations recovered over the next two to four years. Our monitoring of systems coupled with experimental studies over the past three decades have shown that the primary drivers are sea temperature and mean sea level variations. Eelgrass appears to be resilient to strong climatic variation. The trajectories of predicted changes in salinity, temperature, turbidity and nutrient delivery may result in a shift in both eelgrass distribution and also fisheries and avian resource support. These changes coupled with multiple stressors in coastal systems such as overwater structures, dredging, and landuse changes could pose threats to the survival of eelgrass. Managing human-related stressors may be the most robust strategy for minimizing overall threats to this habitat.

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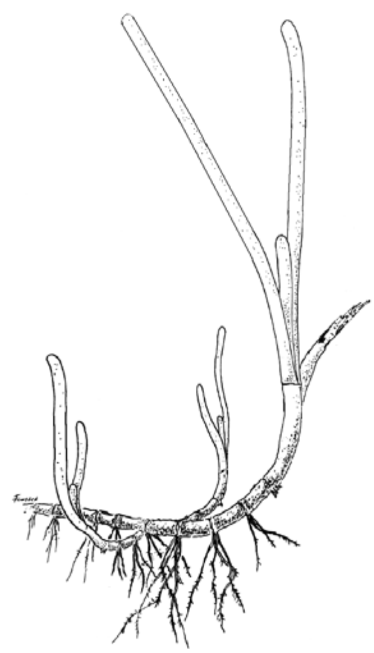
A Multi-metric Approach to Establishing Restoration Objectives for Eelgrass in Long Island Sound

Excess nitrogen delivered from the watershed has been identified as detrimental to eelgrass (*Zostera marina* L.) habitats. While low availability of nitrogen in the system is beneficial, other habitat characteristics also play a role in determining the success of eelgrass in a particular location. Restoration guidelines for submerged aquatic vegetation based on water quality and habitat-based requirements have been developed for the Chesapeake Bay region by evaluating decades of monitoring data, experimental evidence, statistical analyses of the data, and modeling efforts. These guidelines include marine and freshwater plants. This project evaluated the habitat criteria metrics from Chesapeake Bay for use in Long Island Sound, with the assumption that target values for recommended criteria would be different between the two sites. Case study sites with and without eelgrass were used to evaluate the Chesapeake Bay guidelines. For most metrics, the recommended maximum values were all lower than those for Chesapeake Bay. The primary habitat requirement for eelgrass was based on previous research indicating eelgrass needs a minimum of 22% of the light reaching the surface of the water column. The secondary habitat requirements were water quality based metrics and included nutrients, chlorophyll-*a*, and total suspended solids. An additional metric of importance in LIS is the amount of macroalgae in the system. Large amounts of macroalgae have the potential to shade eelgrass. There are also habitat constraints on the presence or potential presence of eelgrass in a location. These were related to the physical and sediment characteristics of the habitat. The physical factors (current velocity, minimum and maximum depth of distribution) helped to identify whether a certain site was suitable for eelgrass, but these factors were not likely to be changed due to mitigation efforts. The sediment characteristics should change as a result of changes in the water quality or primary producer community. The habitat constraints were used primarily as a means of explaining why *Z. marina* was not present in a location where the water quality appeared suitable. This multi-metric approach aids in identifying realistic restoration goals for eelgrass in Long Island Sound.



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