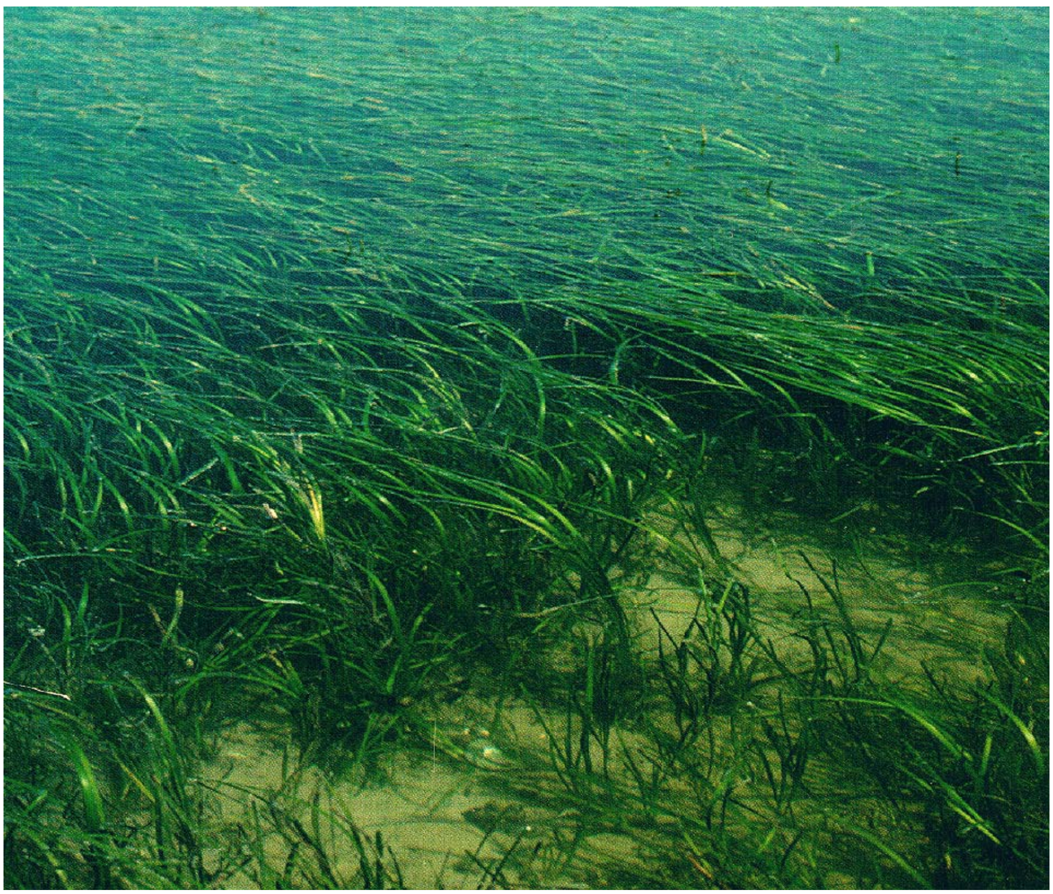
STATE OF CONNECTICUT

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Gina McCarthy, Commissioner

DEPARTMENT OF AGRICULTURE
F. Philip Prelli, Commissioner

AN ASSESSMENT OF THE IMPACTS OF COMMERCIAL AND RECREATIONAL FISHING AND OTHER ACTIVITIES TO EELGRASS IN CONNECTICUT'S WATERS AND RECOMMENDATIONS FOR MANAGEMENT



SUBMITTED IN RESPONSE TO PUBLIC ACT 01-115

January 2007

Department of Environmental Protection
Department of Agriculture

Cover Photograph: An eelgrass meadow in the shallow waters of Portsmouth Harbor, New Hampshire. Photograph courtesy of Dr. Frederick T. Short of the University of New Hampshire Seagrass Ecology Laboratory.

AN ASSESSMENT OF THE IMPACTS OF COMMERCIAL AND RECREATIONAL FISHING AND OTHER ACTIVITIES TO EELGRASS IN CONNECTICUT'S WATERS AND RECOMMENDATIONS FOR MANAGEMENT

STATE OFCONNECTICUT

M. Jodi Rell, Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Gina McCarthy, Commissioner

DEPARTMENT OF AGRICULTURE

F. Philip Prelli, Commissioner

January 2007

Contents

LIST OF TABLES IV

LIST OF FIGURES IV

LIST OF MAPS IV

ACKNOWLEDGMENTS V

EXECUTIVE SUMMARY VII

Purpose of report vii
Participants vii
Issue vii
Approach vii
Key Findings, Conclusions and Recommendations ix

INTRODUCTION 1

ASSESSMENT APPROACH AND METHODS 5

Approach 5
Methods 6
Ecological Values *6*
Distribution of Eelgrass *6*
Assessment of the Effects of Fishing Gear on Eelgrass *7*
Assessment of Other Factors Affecting Eelgrass *9*

EELGRASS: DESCRIPTION, HABITAT REQUIREMENTS, DISTRIBUTION AND ECOLOGICAL VALUES 11

Description 11
Habitat Requirements 11
The Distribution Of Eelgrass In Long Island Sound and Trends in Abundance 13
Late 1800s and Early 1990s *13*
1930 to 1980 ...... *14*
1980 to 2001 ...... *15*
2002 to 2005 ...... *18*
Monitoring Eelgrass in the Future *20*
Ecological Values of Eelgrass 20
Conclusions 25
Recommendations 26

EFFECTS OF RECREATIONAL AND COMMERCIAL FINFISH AND LOBSTER FISHING ON EELGRASS 27

Fisheries in Eastern Long Island Sound 27
State Statutes, Regulations and Policies Relevant to Eelgrass Protection 28
Assessment of Impacts by Gear Type 28
Otter trawl *28*
Trawling Activity in Eastern LIS 28
Effects of Trawling on Eelgrass 29
Assessment of Potential Impacts to Eelgrass in Eastern LIS 29
Lobster and Fish Pots *32*
Lobster and Fish Pot Activity in Eastern LIS 32
Effects of Lobster and Fish Pots on Eelgrass 32
Assessment of Potential Impacts to Eelgrass in Eastern LIS 33

Gill net *33*
Gill net Fishery in Eastern LIS 34
Effects of Gill nets on Eelgrass 34
Assessment of Potential Impacts to Eelgrass in Eastern LIS 34
Pound Net *34*
Pound Net Fishing Activity in Eastern LIS 34
Effects of Pound Nets on Eelgrass 35
Assessment of Potential Impacts to Eelgrass in Eastern LIS 35
Hook and Line (Commercial and Recreational) *35*
Hook & Line Fishing Activity in Eastern LIS 35
Assessment of Potential Impacts to Eelgrass in Eastern LIS 36
CONCLUSIONS 36
RECOMMENDATION 37

EFFECTS OF RECREATIONAL AND COMMERCIAL SHELLFISHING ON EELGRASS 39

SHELLFISHING IN EASTERN LONG ISLAND SOUND 39
STATE AND MUNICIPAL STATUTES, REGULATIONS AND POLICIES RELEVANT TO EELGRASS CONSERVATION 40
The Coastal Zone Management Act *40*
State Shellfisheries Statutes Relevant to Eelgrass Conservation. *41*
Municipal Shellfish Commission Jurisdiction, Policies and Procedures *41*
Regulation of Shellfish Aquaculture Structures *43*
THE DISTRIBUTION OF EELGRASS RELATIVE TO STATE AND MUNICIPAL SHELLFISH LEASES 44
ASSESSMENT OF IMPACTS BY GEAR TYPE 45
Oyster Dredge *45*
Oyster Dredging Activity in Eastern LIS 45
Effects of Oyster Dredges on Eelgrass 45
Assessment of Potential Impacts to Eelgrass in Eastern LIS 46
Seed Oyster Dredge *46*
Seed Oyster Dredging Activity in Eastern LIS 46
Effects of Oyster Seed Dredges on Eelgrass 47
Assessment of Potential Impacts to Eelgrass in Eastern LIS 47
Hydraulic Clam Dredge *47*
Hydraulic Clam Dredge Activity in Eastern LIS 48
Effects of Hydraulic Clam Dredges on Eelgrass 48
Assessment of Potential Impacts to Eelgrass in Eastern LIS 48
Hand Harvest Implements *49*
Hand Harvest in Eastern LIS 49
Effects of Hand Harvest on Eelgrass 50
Assessment of Potential Impacts to Eelgrass in Eastern LIS 50
Conch Pots *50*
Conch Fishing Activity in LIS 50
Assessment of Potential Impacts to Eelgrass in Eastern LIS 50
Scallop Scoop Net *51*
Scallop Scoop Net Fishing Activity in Eastern LIS 51
Assessment of Potential Impacts to Eelgrass in Eastern LIS 51
Shellfish Aquaculture Structures *51*
Shellfish Aquaculture Activity in Eastern LIS 51
Impact of Shellfish Aquaculture Structures 52
Assessment of Potential Impacts to Eelgrass in Eastern LIS 52
CONCLUSIONS 53
RECOMMENDATIONS 54

OTHER FACTORS AFFECTING THE ABUNDANCE AND DISTRIBUTION OF EELGRASS 57

REASONS FOR INCLUSION IN THIS REPORT 57
FACTORS THAT HAVE LOCALIZED EFFECTS ON EELGRASS 57
Boat Moorings and Anchorages *57*
Effects on Eelgrass 57
Assessment of Potential Impacts to Eelgrass in Eastern LIS 59
Motorized Watercraft *62*

Effects on Eelgrass 62
Assessment of Potential Impacts to Eelgrass in Eastern LIS 64
Piers, Docks and Other Structures *65*
Effects on Eelgrass 65
Assessment of Potential Impacts to Eelgrass in Eastern LIS 66
Dredging and Filling *66*
Effects on Eelgrass 66
Assessment of Potential Impacts to Eelgrass in Eastern LIS 66
Waterfowl *67*
Effects on Eelgrass 67
Assessment of Potential Impacts to Eelgrass in Eastern LIS 67
Conclusions *68*
Recommendations *68*
FACTORS THAT HAVE LONG-TERM AND LARGE-SCALE EFFECTS ON EELGRASS 70
Disease *70*
Climate *71*
Water Quality *72*
The Role of Nitrogen 72
Nitrogen Enrichment and the Distribution of Eelgrass in LIS 73
The Role of Nitrogen: Status of Research and Management in Connecticut 76
Conclusions *77*
Recommendations *78*

SUMMARY 81

LIST OF REFERENCES 83

LIST OF PERSONAL COMMUNICATIONS 93

MAPS SHOWING THE DISTRIBUTION OF EELGRASS IN EASTERN LONG ISLAND SOUND IN 2002 AND LOCATIONS OF EELGRASS RELATIVE TO VARIOUS REGULATORY DESIGNATIONS. 95

APPENDICES 105

Appendix I. Public Acts 01-115 and 02-50. .... *107*
Appendix II. The Value of Eelgrass as Fish and Shellfish Habitat in Long Island Sound *109*
Appendix III. Overview of Municipal Shellfish Commission Policies and Procedures Relevant to Eelgrass Conservation. *117*

List of Tables

Table 1. Fish and Invertebrate usage of eastern LIS eelgrass habitat based on regional studies and fish ecology literature. 24

Table 2. Commercial finfish and lobster fishing activity during the year 2000 by gear type between Old Saybrook and Stonington, CT (DEP Commercial Logbook Area 1). 27

Table 3. Commercial landings in the year 2000 reported by otter trawl fishermen fishing in eastern Long Island Sound. 29

Table 4. Amount of eelgrass in 2002 located within areas where bottom trawl fishing is allowed, designated shellfishing areas and designated boat anchorages and mooring areas. 31

List of Figures

Figure 1. Photograph of an eelgrass plant. 12

Figure 2. Major features of the morphology of eelgrass. 12

Figure 3. Historic occurrence of eelgrass by town. 14

Figure 4. Mooring field in Smith Cove, Niantic River (left), and a closer view showing mooring ring scars (right). 58

Figure 5. Propeller scars in submerged aquatic vegetation in Browns Bay, Virginia. 63

Figure 6. The distribution of eelgrass in Waquoit Bay, Cape Cod, Massachusetts, 1951 to 1987. 74

List of Maps

Map 1. The distribution of eelgrass from Clinton to East Lyme, June 2002. 97

Map 2. The distribution of eelgrass from East Lyme to Stonington, June 2002. 98

Map 3. The location of eelgrass from Old Saybrook to New London relative to DEP bottom trawl lines, June 2002. 99

Map 4. The location of eelgrass from New London to Stonington relative to DEP bottom trawl lines, June 2002. 100

Map 5. Location of eelgrass from Old Saybrook to New London relative to state and town designated shellfish areas, June 2002. 101

Map 6. Location of eelgrass from New London to Stonington relative to state and town designated shellfish areas, June 2002 102

Map 7. Location eelgrass relative to anchorage areas and mooring fields from Old Lyme to New London, June 2002. 103

Map 8. Location eelgrass relative to anchorage areas and mooring fields from New London to Stonington, June 2002. 104

ACKNOWLEDGMENTS

The authors would like to thank the members of municipal Shellfish Commissions and the Noank Aquaculture Cooperative, and others listed herein, who volunteered their time to share their knowledge of eelgrass and shellfishing in Connecticut's waters.

An Assessment of the Impacts of Commercial and Recreational Fishing and Other Activities to Eelgrass in Connecticut's Waters and Recommendations for Management **was prepared by the Department of Environmental Protection (DEP) and the Department of Agriculture (DA).**

The following staff contributed to the development of the report:

Ernest Beckwith, Jr., Director (retired), DEP Marine Fisheries Division

David Carey, Director, DA, Bureau of Aquaculture

Edward Parker, Bureau Chief, DEP Bureau of Natural Resources

Eric Smith, Director, DEP Marine Fisheries Division

John Volk, Director (retired), DA, Bureau of Aquaculture

Peter Aarrestad, Supervising Fisheries Biologist, DEP, Inland Fisheries Division

Min Huang, Senior Wildlife Biologist, DEP Wildlife Division

Mark Johnson (Principal report editor), Senior Fisheries Biologist, DEP, Inland Fisheries Division

Eleanor Mariani, State Boating Law Administrator, DEP Boating Division

Ron Rozsa, Supervising Environmental Analyst, DEP Office of Long Island Sound Programs

David Simpson, Supervising Fisheries Biologist, DEP Marine Fisheries Division

Harry Yamalis, Environmental Analyst, DEP Office of Long Island Sound Programs

Additional review and commentary provided by:

David Blatt, Supervising Environmental Analyst, DEP Office of Long Island Sound Programs

James Citak, Senior Environmental Analyst, DA, Bureau of Aquaculture

Peter Francis, Supervising Environmental Analyst, DEP Office of Long Island Sound Programs

Kurt Gottschall, Senior Fisheries Biologist, DEP Marine Fisheries Division

Deborah Pacileo, Senior Fisheries Biologist, DEP Marine Fisheries Division

Paul Stacey, Director, DEP Water Planning and Standards Division

EXECUTIVE SUMMARY

Purpose of report

This report was prepared pursuant to PA 01-115, *An Act Concerning Recreational Fishing in Connecticut*. This law requires the Department of Environmental Protection (DEP) in consultation with the Department of Agriculture (DA) to assess the effects of commercial and recreational fishing on eelgrass beds and submit a report with findings and recommendations to the Environment Committee of the Connecticut General Assembly.

Participants

The DEP and DA created a Report Workgroup to conduct the assessment. Participants included staff from the DEP Bureau of Natural Resources' Marine Fisheries Division, Inland Fisheries Division, and Wildlife Division; the DEP Office of Long Island Sound Programs; and the Department of Agriculture's Bureau of Aquaculture.

Issue

Eelgrass is a submerged, rooted, aquatic plant that occurs in shallow waters of Long Island Sound. It often forms large underwater meadows, commonly referred to as *beds*, which provide important habitat for life stages of many species of marine fish and shellfish. In other coastal states and countries there are documented instances of damage to eelgrass caused by certain recreational and commercial fishing and related activities. While damage caused by fishing gear has not been documented in Long Island Sound, there have been anecdotal reports of damage to eelgrass in portions of eastern Long Island Sound. Concerned that these reports might indicate that eelgrass was being extensively damaged, the legislature passed PA 05-115, which directed the DEP and DA to assess the effects of fishing gears on eelgrass in Long Island Sound and recommend action to protect eelgrass if needed.

Approach

The Report Workgroup examined information relevant to eelgrass conservation from a number of sources, including DEP and DA databases and reports, staff knowledge and experience, published and unpublished scientific literature, government reports, the Connecticut General Statutes and Regulations of Connecticut State Agencies, and municipal ordinances. In addition, discussions were held with commercial shellfish, finfish and lobster fishermen, municipal Shellfish Commission members, and recreational fishermen.

Information from these sources was utilized to: (1) delineate the current and historical occurrence and distribution of eelgrass in Connecticut's waters of Long Island Sound and Fishers Island Sound, (2) describe the functional value of eelgrass, (3) identify and describe contemporary commercial and recreational fishing activities that may occur in or adjacent to eelgrass meadows, (4) determine the extent to which eelgrass meadows may be vulnerable to damage from fishing activities, (5) estimate the potential negative effects of fishing activities on eelgrass, and (6) determine what immediate measures, if any, are needed to protect eelgrass.

In addition to examining the effects of fishing gear on eelgrass, the Report Workgroup also identified other factors affecting the abundance and distribution of eelgrass and concluded that all factors should be evaluated and compared with the effects of fishing gear. DEP Commissioner Arthur J. Rocque, Jr. conveyed the Report Workgroup's preliminary findings and concerns to the Environment Committee (Testimony to the Environment Committee, March 15, 2001, Public Hearing concerning Raised House Bill No. 592, *An Act Concerning the Protection of Connecticut's Fisheries*). Subsequently, Public Act 02-50 was approved on May 9, 2002. Section 4 states:

> The Commissioner of Environmental Protection shall adopt regulations, in accordance with chapter 54 of the general statutes, to protect and restore eelgrass, including the protection of existing eelgrass beds from degradation, the development of a restoration plan to restore eelgrass and the periodic monitoring of the effectiveness of such measures to protect and restore eelgrass.

Because PA 02-50 requires a comprehensive approach to eelgrass protection and restoration, this report considers all known factors affecting eelgrass survival and measures that may be needed to conserve and enhance eelgrass.

Key Findings, Conclusions and Recommendations

Key Findings:

- Eelgrass is an estuarine plant that grows in shallow waters of Long Island Sound, often forming expansive underwater meadows on the sea bottom. Eelgrass contributes to the productivity of Long Island Sound by producing organic matter in the form of plant material and by enhancing overall habitat diversity and complexity in the shallow water zone. Eelgrass meadows support a diverse community of microorganisms, algae and marine animals, and are utilized by some important recreational and commercial species.
- Eelgrass was once distributed along Connecticut's entire coastline, but has significantly declined in abundance and distribution over the last century. Eelgrass no longer exists in the coastal waters of western and central Long Island Sound, and is now found only in areas of eastern Long Island Sound and Fishers Island Sound between the towns of Westbrook and Stonington.
- Eelgrass appears to be more viable in areas open to the Sound compared to embayments and rivers. Eelgrass growth and survival continues to be poor in most embayments and river mouths with the notable exception of Mumford Cove, where eelgrass rebounded after a sewage outfall was removed.
- Studies in other states and countries have documented that recreational and commercial boating activities, mooring fields, and certain fishing gears and activities can cause significant damage to eelgrass. There is no information indicating that these activities are currently causing extensive damage to eelgrass in Long Island Sound; however, the eelgrass surveys conducted to date do not provide the level of detail necessary to determine if all eelgrass meadows and potential eelgrass habitat are unaffected by these activities. In addition, should eelgrass begin to recover and spread to areas occupied historically, then the level of damage resulting from these activities could increase.
- The application process administered by the Connecticut Department of Agriculture's Bureau of Aquaculture (DA/BA) for the issuance and renewal of shellfish leases in areas under the jurisdiction of the state does not take into consideration the potential effect of shellfishing activities on eelgrass.
- A high percentage (e.g. 84 percent in 2002) of CT's eelgrass is within waters where municipal shellfish commissions exercise authority over certain activities that can affect eelgrass, such as the use of dredges to cultivate oysters. The extent to which shellfish commissions review the effects of shellfishing on eelgrass varies considerably among commissions.
- The DEP has the authority to minimize damage to eelgrass caused by the construction of various structures such as docks, piers, moorings, and aquaculture structures, and from activities such as dredging.
- Studies in other states have shown that mute swans deplete eelgrass in shallow waters. It is likely that mute swans and, perhaps, resident Canada geese, have a similar effect in Connecticut's waters. The DEP is conducting research and evaluating data that will be

utilized to prepare a mute swan management plan. DEP is also evaluating the impacts of resident Canada geese.

- Nitrogen loading from human sources is often linked to the loss of eelgrass in coastal waters in the U.S. and around the world.
- Available evidence indicates that increased nitrogen loading is likely to be a primary cause of the long-term eelgrass decline in Connecticut's waters and may be a key factor in understanding recent observations of eelgrass distribution and abundance, but the contributory effects of other identified stressors such as weather, climate, physical disturbance, disease and waterfowl grazing are not well understood.
- The DEP, often in partnership with other organizations, is working to expand efforts to conserve and protect eelgrass through existing educational programs, water quality programs and research on the role of nitrogen loading on eelgrass. However, current funding is not adequate to address eelgrass conservation, protection, research or monitoring.

Key Conclusions:

- Connecticut's remaining eelgrass meadows should be conserved to the greatest extent practicable.
- Recreational and commercial fishing gears do not appear to be a significant threat to eelgrass at this time; therefore, no immediate regulatory action is needed.
- Existing DEP, DA/BA and municipal shellfish programs provide the framework for addressing impacts to eelgrass. Where necessary, existing DA/BA and municipal shellfishing programs should be amended to incorporate eelgrass conservation measures and a process for assessing the effects of shellfishing on eelgrass.
- Conservation of eelgrass would be enhanced if fishermen and the general boating community were better informed of the value of eelgrass to the marine ecosystem.
- If necessary to protect eelgrass in shallow water, the impact of mute swans should be minimized in accordance with a mute swan management plan. Based upon the impact evaluation for resident Canada geese, other measures may be considered to minimize impacts due to this species.
- The effects of various fishing gears and activities, boating activities, waterfowl and mooring fields should be periodically assessed and protective measures developed as needed.
- Nitrogen loading to coastal waters appears to be associated with the long-term decline in eelgrass, and reducing loading appears to be critical to protecting the remaining eelgrass in eastern LIS embayments and tidal rivers. However, research is needed to determine the relative importance of nitrogen with respect to other identified stressors to ensure nitrogen reduction goals for eelgrass are protective.
- Restoration of eelgrass by the use of transplantation or propagation techniques should only be attempted in areas where suitable habitat and water quality conditions exist.

- A comprehensive eelgrass research and monitoring strategy is needed to provide the basis for the restoration and long-term management of eelgrass.
- Additional funding is needed to support eelgrass research, monitoring, conservation and protection.

Key Recommendations:

- Periodically re-evaluate the effects of various fishing gears and activities, boating activities, waterfowl and mooring fields to determine if significant damage is occurring in particular eelgrass meadows, and if measures are needed to protect vulnerable meadows.
- Develop procedures and regulations as needed to evaluate new state shellfish lease applications and lease renewals for effects on eelgrass.
- Work with municipal shellfish commissions to incorporate an eelgrass conservation plan into the shellfish management plans that are required to be submitted periodically to the DA/BA for review and comment.
- Continue current efforts to educate boaters and fishermen regarding the importance of eelgrass and measures they can take to minimize impacts.
- Prepare a population control management plan to minimize the impact of mute swans on eelgrass if DEP research and studies indicate adverse effects on eelgrass in Connecticut.
- Complete the resident Canada geese impact evaluation and prepare measures to minimize impacts to eelgrass as appropriate.
- Continue DEP involvement in efforts to verify and quantify the effects of nitrogen and other pollutants in concert with other likely stressors on eelgrass in localized areas such as embayments and harbors, and develop watershed water quality models to aid in the management of nitrogen loading from human sources.
- Continue to enhance DEP water management programs to: establish water quality criteria for nitrogen loading or concentration necessary for eelgrass propagation and restoration in LIS and its embayments; identify impaired waterbodies (i.e. LIS and individual embayments) based on eelgrass effects; and develop watershed management plans to establish favorable conditions for eelgrass growth.
- Develop and implement a comprehensive eelgrass research, monitoring, conservation and protection strategy.
- Develop and submit a proposal to generate funding for eelgrass research, monitoring, conservation and protection.

INTRODUCTION

Public Act 01-115, *An Act Concerning Recreational Fishing in Connecticut*, requires the Department of Environmental Protection (DEP) in consultation with the Department of Agriculture (DA) to submit a report of its findings and recommendations concerning the effects of commercial and recreational fishing on eelgrass beds[1]. The DEP and DA formed a workgroup (the Report Workgroup) to conduct the assessment. Participants included staff from the DEP Bureau of Natural Resources' Marine Fisheries Division, Inland Fisheries Division, and Wildlife Division; the DEP Office of Long Island Sound Programs; and the Department of Agriculture's Bureau of Aquaculture.

Eelgrass (*Zostera marina*) is the most abundant species of submerged aquatic vegetation (SAV) in Long Island Sound and Fishers Island Sound (collectively referred to as LIS). The plants often form large underwater meadows, also commonly referred to as eelgrass beds, in shallow nearshore waters. Eelgrass meadows are recognized as one of the most productive of coastal habitats, providing habitat for a variety of organisms and contributing to the overall productivity of the marine ecosystem by using the energy of sunlight to synthesize plant matter in the form of roots, rhizomes and plant leaves (i.e. primary productivity). When the plants die, organisms at the base of the marine foodweb – microorganisms, zooplankton and small benthic crustaceans – consume them. Eelgrass thrives in low nutrient environments, and is generally an indicator of a healthy, balanced ecosystem.

Eelgrass meadows are a structurally complex habitat that attracts various life stages of many fish and shellfish species. Young fish and smaller fish species hunt for prey amongst the plants and use the meadows as a refuge from larger predators. Among the better-known species that use eelgrass habitat are young winter flounder and tautog. Lesser-known species that spend much of their life in eelgrass include sticklebacks, pipefish and seahorse. Bay scallop prefer eelgrass habitat, which the young scallops use as attachment points and refuge from predators, and in some locations juvenile lobster and blue crabs use eelgrass habitat. Eelgrass is also an important food for overwintering waterfowl, such as Atlantic brant and black ducks.

Unfortunately, the overall distribution and abundance of eelgrass has declined significantly in LIS during the past century, as well as in the waters of other coastal states along the Atlantic coast. Eelgrass was once distributed along the length of the Connecticut and Long Island coastline, but is now restricted to eastern LIS. It is widely believed that an underlying reason for the decline is related to the amount of nitrogen entering coastal waters from human activities, a phenomenon affecting seagrasses worldwide. Other environmental stressors that may have affected eelgrass vitality are disease, habitat modification, waterfowl grazing and unfavorable

[1] The DEP and DA believe there was an error in the final drafting of Public Act 01-115. As written, the act required DEP and DA to submit a report on their findings and recommendations concerning the effects of commercial and recreational fishing on "glass eel beds." However, the DEP and DA believe that the intent of the act was to study the effects of commercial and recreational fishing on *eelgrass beds*. *Glass eel* is a term used to describe the post-larval stage of the American eel, which is translucent in appearance. Glass eels do not occur in "beds." American eels spawn in the Sargasso Sea in the southern Atlantic Ocean. After hatching, the larval eels are carried by currents to the North American coastline. By the time the larval eels first appear in the lower reaches of Connecticut's rivers and streams in early spring, they have developed into the glass eel stage and average about 2¼ inches in length.

weather conditions. Coincident with this decline, the value of eelgrass to estuarine ecosystems has become better understood. As a result, scientists, managers, the environmental community and the general public alike have become concerned about the loss of eelgrass and whether human activities may be adversely affecting the eelgrass that remains.

The Connecticut Coastal Management Act (CMA, CGS Chapter 444, Sections 22a-90 to 22a-112) establishes a single set of policies, standards and criteria to be used at all levels of government for evaluating activities that affect Connecticut's coastal zone. Eelgrass is specifically identified in Section 22a-92, Legislative Goals and Policies, as a resource " . . . to protect, enhance and allow for the natural restoration of eelgrass flats . . . " [CGS 22a-92(c)(2)(A)]. The CMA defines unacceptable adverse impacts to coastal resources as "degrading or destroying essential wildlife, finfish or shellfish habitat through significant alteration of the composition, migration patterns, distribution or breeding or other population characteristics of the natural species or significant alteration of the natural components of the habitat" [CGS Sec. 22a-93(15)(G)]. Under this definition, activities damaging or eliminating eelgrass would be considered an adverse impact due to its ecological value.

The DEP, as the lead agency responsible for administering the CMA and coordinating implementation of the CMA with all levels of government, has a strong program that protects eelgrass from a number of activities such as dredging and the construction of piers and docks. The DEP has established partnerships with other organizations (e.g. the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. Geological Service and the University of Connecticut) to conduct research and develop measures to protect and restore eelgrass. However, with few exceptions, little has been done to evaluate the effect of fishing gear on eelgrass and to integrate protective measures into fishery management plans or develop appropriate regulations. Public Act 01-115 served as a catalyst to bring together staff within DEP and DA to discuss the effects of commercial and recreational fisheries under their respective jurisdictions on eelgrass.

It is important to note that PA 01-115 did not provide funding to carry out field investigations that are necessary to fully assess the effects of fishing gears on eelgrass. Therefore, only existing information was evaluated to determine: (1) if any fishing gears are currently having a significant effect on eelgrass; (2) if the current impact is unknown, what is the potential for each activity to impact eelgrass; (3) additional information needs; and, (4) if immediate action is needed to protect eelgrass from certain activities.

During the preparation of this report the Report Workgroup concluded that other factors that may affect eelgrass should be addressed and compared with the effects of fishing gear. Although fishing gear may have negative effects on eelgrass, particularly within localized areas, there are other activities that may cause damage to Connecticut's eelgrass to a greater extent than fishing gear, and the role of climate variations is not well understood. As stated above, there is strong evidence that the long-term decline of seagrasses around the world is a result of nitrogen enrichment of coastal waters. While controlling the effects of fishing gear and other activities is important to protect the remaining eelgrass, water quality degradation may be the major threat to the remaining eelgrass in Connecticut's waters.

DEP Commissioner Arthur J. Rocque, Jr. conveyed the Report Workgroup's preliminary findings and concerns to the Environment Committee (Testimony to the Environment Committee, March 15, 2002, Public Hearing concerning Raised House Bill No. 592, *An Act Concerning the Protection of Connecticut's Fisheries*). Subsequently, Public Act 02-50 was approved on May 9, 2002. Section 4 states:

> The Commissioner of Environmental Protection shall adopt regulations, in accordance with chapter 54 of the general statutes, to protect and restore eelgrass, including the protection of existing eelgrass beds from degradation, the development of a restoration plan to restore eelgrass and the periodic monitoring of the effectiveness of such measures to protect and restore eelgrass.

Because PA 02-50 requires a comprehensive approach to eelgrass protection and restoration, the scope of this report has been expanded to include all known factors affecting eelgrass survival. It is hoped this initial investigation will help address PA 02-50.

The importance of eelgrass is also underscored by the recent interest in eelgrass conservation expressed by the Atlantic States Marine Fisheries Commission. Pursuant to the Commission's adoption of a Submerged Aquatic Vegetation Policy, each member state, including Connecticut, has been asked to submit a Submerged Aquatic Vegetation Conservation Plan. It is anticipated that this report will aid in the development of Connecticut's plan.

ASSESSMENT APPROACH AND METHODS

Approach

To conduct the assessment required by PA 01-115, the DA and DEP established a Report Workgroup of senior management and technical staff with experience in fish and shellfish ecology, fisheries management and coastal ecology from the following offices: DEP Office of Long Island Sound Programs (OLISP), Marine Fisheries Division (MFD), the Inland Fisheries Division (IFD), Wildlife Division (WD) and the DA Bureau of Aquaculture DA/BA).

During the initial meetings, the Report Workgroup determined that the *actual* extent of damage to eelgrass by fishing gear could not be quantified for two reasons: (1) no studies have been done in Connecticut's waters on the effects of fishing gear on eelgrass, and (2) studies to identify and quantify eelgrass damage in LIS could not be conducted due to other agency priorities, lack of dedicated funding to undertake research, and unavailability of staff needed for such an ambitious project. Therefore, the Report Workgroup turned to other sources of information – DEP and DA databases and reports, published and unpublished scientific literature, recreational fishermen, commercial fishermen and municipal shellfish commissions, Connecticut General Statutes and agency regulations – to determine the *potential* for fishing gear to damage eelgrass, and the *likelihood* of ecologically significant damage.

For each type of fishing gear, the Report Workgroup asked the following questions:

- Does the fishing gear have the potential to damage eelgrass?
- Could the nature and extent of the damage be ecologically significant?
- What is the likelihood that significant damage is currently occurring?
- Is immediate action required to protect eelgrass? If yes, what action?
- Could the amount of damage increase if the distribution of eelgrass expands?
- What additional research is needed to adequately assess damage?

In addition, the Report Workgroup asked these questions:

- What is known about how eelgrass functions as fish habitat in LIS?
- Are there other factors or activities that affect eelgrass?
- What are the reasons for the major decline of eelgrass in Connecticut's waters?
- How do all the possible factors or activities that can damage eelgrass or otherwise affect its growth and survival relate and compare to each other?
- What are the major threats to existing eelgrass and efforts to enhance eelgrass?

Again, due to the limited amount of information specific to LIS, the Report Workgroup also reviewed the published and unpublished literature to address these questions.

The characteristics of an eelgrass meadow, such as the density of eelgrass plants, patchiness, size and location, has significance relative to the overall ecological value of a meadow and the type of damage fishing gears may cause, with attendant regulatory and permitting implications. However, with the exception of some peer-reviewed articles in scientific journals, many reports use the terms *eelgrass meadow*, *eelgrass bed* and *eelgrass* interchangeably to describe a colony of eelgrass plants without reference to the characteristics of the colony. Used in this way, the terms could be describing anything from sparsely populated seabed to very dense, meadow-like growth. Therefore, given the qualitative nature of much of the data and information available, the effects of fishing gear on eelgrass meadows with various characteristics cannot be fully evaluated.

Given the inconsistencies in the literature and common usage, the term *eelgrass meadow* is defined in this report as "seabed containing eelgrass regardless of density or patchiness" unless otherwise indicated. Also, the use of *eelgrass bed* has been avoided to prevent any confusion with *shellfish bed* and *shellfish seed bed*. The term *eelgrass* is used to indicate either individual plants or meadows depending upon the context in which it is used. The term *population* is occasionally used in a subjective manner to indicate a meadow or grouping of meadows that appear to be spatially distinct from other meadows, even within geographic features such as an embayment.

Portions of both Long Island Sound and Fishers Island Sound are within Connecticut's borders. For the purposes of brevity in this report, *Long Island Sound* is defined as including Fishers Island Sound. *Eastern Long Island Sound* is defined as the waters east of the Connecticut River to Connecticut's boundary at the Pawcatuck River, thus including Fishers Island Sound. Long Island Sound will be variously abbreviated as *LIS* or *the Sound*.

Methods

Ecological Values

The ecological value of eelgrass was summarized from the considerable information available in government reports and scientific literature that describes the ecology of eelgrass along the Atlantic coast. However, very little information was available that describes how eelgrass specifically functions in LIS as fish and shellfish habitat. Therefore, studies conducted in the waters of neighboring states were used to infer what species use eelgrass in LIS and for what purposes.

Distribution of Eelgrass

A comprehensive eelgrass survey conducted by the U. S. Fish & Wildlife Service (USFWS) in June of 2002 was used as the primary dataset to generally describe the contemporary distribution of eelgrass in LIS[2]. The survey was conducted in coastal embayments and waters less than -15 ft mean low water (MLW) from Clinton Harbor to the Rhode Island border (Tiner et al. 2003). Areas west of Clinton were not surveyed because existing information indicated that eelgrass no longer existed in these areas. The USFWS followed aerial photography protocol defined by the National Oceanic and Atmospheric Administration Coastal Change Analysis Program. Potential

[2] The study was carried out under contract with the Department of Environmental Protection, and funded by an EPA Long Island Sound Study grant.

eelgrass was identified from the photographs and their position and spatial extent was georeferenced. A total of 246 sites were visited by boat to ground-truth the interpretation of the photography. If the bottom was not visible from the boat, then an underwater video camera mounted to a pole was used.

The USFWS survey data was mapped using Geographical Information System (GIS) software. The USFWS characterized eelgrass meadows as low, medium and high density; however, these determinations were somewhat qualitative since they were based on visual estimations made at a limited number of locations. Therefore, for the purposes of this report the categories were collapsed into one category defined as "seabed containing eelgrass."

Additional information from localized surveys and knowledgeable individuals was assembled to supplement the USFWS survey. Similarly, a considerable amount of information describing the historical distribution and abundance of eelgrass was acquired from the literature and DEP data and reports, and personal communications with individuals having local knowledge of eelgrass. Since no surveys comparable to the USFWS survey have been conducted, the historical information could not be quantitatively compared to the 2002 survey. The information was used, however, to understand where eelgrass existed during the 20^{th} century and to better understand the general trend of abundance and distribution in the Sound and in specific areas.

Assessment of the Effects of Fishing Gear on Eelgrass

To evaluate the effects of fishing gears, the Report Workgroup made extensive use of a report prepared by the Atlantic States Marine Fisheries Commission (ASMFC) titled *Habitat Management Series #5, Evaluating Fishing Gear Impacts to Submerged Aquatic Vegetation and Determining Mitigation Strategies* (ASMFC 2000). This report will hereafter be referred to as the *ASMFC gear impact report*. Based on a literature review, the report summarizes how fishing gears used along the Atlantic coast affect SAV, including eelgrass, and provides a framework for assessing impact.

The ASMFC gear impact report identified six principal ways that fishing gear can damage SAV.

1. <u>Leaf (frond) shearing</u> occurs when leaves are cut. The leaf cannot re-grow the section that has been sheared, but the plant can grow new leaves if the meristem, which is the portion of the stem that generates new leaves, is not damaged (undisturbed, eelgrass typically sheds and grows new leaves every three to six weeks). The effect of leaf shearing may be minimal if it does not occur often, whereas repeated leaf shearing may divert most of the plant resources to leaf replacement, possibly causing plant death.
2. <u>Seed or flower shearing</u> could prevent sexual reproduction of the plant if the seeds were not mature. Although eelgrass can propagate by both vegetative and sexual reproduction, sexual reproduction is important to maintain existing eelgrass meadows and to colonize new areas.

3. *Uprooting* results when the entire plant is uprooted or it is broken off at the rhizome below the sea bottom, but without significant disruption of the sediments. The dislodged plant cannot re-root and will die.
4. *Below seabed impacts* usually involve disruption of the sediments to the point where roots and rhizomes are dug up and chopped or crushed by the gear resulting in death of the plant.
5. *Burial* of eelgrass plants can result when sediments are dislodged by some activity or from excessive algal growth that can smother plants. Depending upon the extent and duration of burial or smothering, plants may be killed.
6. *Cumulative effects* that lead to loss of individual plants or entire meadows may result from a combination of stressors such as leaf shearing, increased turbidity and intermittent smothering or burial (each of these stressors alone might only have minimal affect).

Based on the available information, eelgrass is limited primarily to areas east of the Connecticut River. Therefore, information on recreational and commercial fishing activity was collected only for eastern LIS. The following information was obtained:

- Types of commercial fishing and the locations, size, intensity and seasonality of these fishing activities were identified from MFD and DA/BA catch and harvest reports, license data, staff knowledge of fishing activities, and from discussions with fishermen. Recreational fishing activity was characterized from MFD and DA/BA annual survey data, license data, staff knowledge, and from discussions with fishermen.
- Connecticut statutes, regulations and policies, and municipal ordinances and policies, were reviewed to determine if eelgrass is currently protected either directly or indirectly from fishing activities.
- The location of state shellfish leases, municipal shellfish leases and public shellfishing areas, and areas closed to particular fishing gears were mapped in relation to the location of eelgrass meadows in 2002 as determined by the USFWS survey. The total amount of eelgrass observed in these areas was determined using GIS software.

Using the above information, the potential effects of fishing gear on eelgrass in LIS was evaluated by examining: (1) the specific configuration of the gear as used in LIS as it relates to the six categories of damage described by the ASMFC gear impact report, (2) operating constraints, such as depth and obstructions that may limit where a gear can be used, (3) state and local regulatory constraints that may restrict when and where gears may be used, (4) the number of fishermen using each gear type, (5) measures of fishing effort, such as number of trips, (6) species targeted by each fishery and their likelihood of being found in eelgrass, and (7) the number of acres of eelgrass in which each gear type theoretically might be used as determined from GIS maps prepared using the USFWS 2002 eelgrass survey.

Assessment of Other Factors Affecting Eelgrass

The scope of this report was expanded to evaluate other factors or activities that may affect eelgrass, including recreational boating, mooring fields, anchorage areas, dredging, structures such as piers and docks, waterfowl feeding, disease, climate and water quality. Many of the same sources of information that were used to assess the effects of fishing gear were also used to evaluate these factors.

EELGRASS: DESCRIPTION, HABITAT REQUIREMENTS, DISTRIBUTION AND ECOLOGICAL VALUES

Description

Eelgrass (*Zostera marina)* is a submerged, rooted, grass-like plant that grows in shallow marine waters along the Atlantic coast from Nova Scotia to North Carolina (Thayer 1984). It is the most common of the two species of submerged aquatic vegetation, or SAV, found in LIS[3]. Although not a true grass, it often forms extensive underwater meadows that resemble terrestrial meadows or grasslands. Eelgrass meadows can be large and dense, or may consist of patches of eelgrass interspersed with areas of open sand, mud or rock. Eelgrass may also be found as small isolated clusters of plants dispersed on the sea bottom. Some eelgrass meadows can be found in the same area year after year, whereas others will change over time or even disappear. New meadows may form in unoccupied areas as a result of seeds being dispersed by currents.

An eelgrass plant has groups of 3-7 strap-like, dark green leaves that may each reach a length of 3 feet (Figures 1 and 2). The leaves are bound together in a sheath, or shoot, that is attached to a subterranean stem called a rhizome. The shoots produce and shed leaves on the order of every three to six weeks. Root clusters, growing from rhizome nodes, serve to anchor the plant in the sediment and are the primary sites for nutrient uptake.

Many eelgrass populations are perennial. As the rhizomes grow and extend horizontally through the sediment, new lateral shoots develop and produce clusters of leaves. This form of vegetative reproduction enables eelgrass to spread and form dense meadows that can persist year after year. The plants also reproduce sexually through flowering, pollination, and seed germination. This enables eelgrass to colonize new areas and to reoccur in areas that are subjected to stressors such as freezing and ice scouring, which may destroy the plants each winter (for a more detailed discussion, refer to Thayer et al. 1984).

Habitat Requirements

Eelgrass occupies a wide range of habitats characterized by variations in salinity, wave and current energies, nutrient content of sediments, and substrates that contain various amounts of sand, gravel, rock and mud. However, eelgrass is limited to shallow water habitats due to its dependence on relatively high levels of light.

The maximum water depth in which eelgrass can grow is related to the amount of light necessary for photosynthesis, or the use of light energy to synthesize plant tissue. It has been determined that eelgrass needs a minimum of 20 percent of the sunlight falling at the water's surface to survive and grow (see Dennison et al. 1993 for a summary). Water clarity affects how much sunlight penetrates the water column, and therefore strongly influences the distribution and abundance of eelgrass.

---

[3] Widgeon grass, *Ruppia maritima*, which is not a true seagrass, is also found in some of Connecticut's embayments, coastal streams and creeks and marsh ponds. It is relatively rare compared to eelgrass.

Water clarity in turn is determined by a number of factors, including suspended sediments, organic matter and plankton (small plants and animals) in the water column. In addition, tidal range plays an important role in regulating light penetration (Koch and Beer 1996). As tidal range increases, the maximum depth in which eelgrass plants can grow decreases.

Water clarity conditions in LIS restrict eelgrass to shallow waters, with the maximum depth of eelgrass distribution decreasing from east to west (Koch and Beer 1996). Historical records described occurrences of eelgrass in depths to -15 ft MLW in Fishers Island Sound, which has relatively clear water and a small tidal range of approximately 3 ft. In some coves and embayments, which tend to be more turbid, eelgrass grows in shallower water due to reduced light penetration. In western LIS, where eelgrass no longer exists, historical records indicate that the maximum depth eelgrass could grow in was only about -5 ft MLW. This was probably due in large part to the larger tidal range of 7 ft to 8 ft and higher turbidity levels compared to eastern LIS. It has been estimated that contemporary conditions in western LIS would limit eelgrass to areas with a maximum depth of about -3 ft MLW (Koch and Beer 1996).

Figure 1. Photograph of an eelgrass plant.

(Source: Maryland Department of Natural Resources).

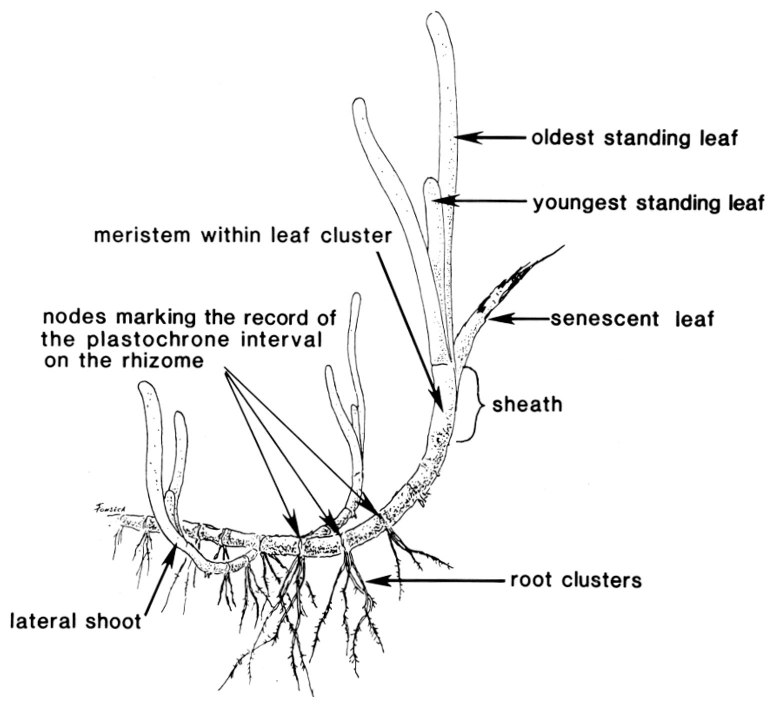


Figure 2. Major features of the morphology of eelgrass.

(From Thayer et al. 1984).

Another factor affecting the distribution of eelgrass is the level of nutrients available for plant growth. In particular, levels of nitrogen, which can be a growth-limiting factor in the marine environment[4], have been linked to distributions of eelgrass. Eelgrass thrives in low nitrogen environments, but does less well as levels increase. Some studies have indicated that high levels of nitrate may even be toxic to the plant. Therefore the presence of eelgrass is considered to be an indicator of a low nutrient environment (for a review see Duarte 1995).

The primary way nitrogen limits eelgrass growth is by stimulating the growth of phytoplankton (microscopic, single celled plants in the water column), algal epiphytes (algae growing on eelgrass) and annual forms of macroalgae (i.e. short-lived, large species of algae), which compete with eelgrass for light and space. Eelgrass can thrive under lower nutrient concentrations than these types of algae, efficiently using nitrogen from the sediments and the water column. But when nutrient concentrations increase, algae thrive and out-compete eelgrass. Water clarity, and thus the amount of light penetration, is reduced, and available light is absorbed by the various algal species. Ultimately, the eelgrass plants are shaded and cannot grow. The nitrogen levels that can cause these effects appear to be much less than the levels that may be directly toxic to the plant (for detailed discussions, see Duarte et al. 1995 and Hauxwell et al. 2003).

The Distribution Of Eelgrass In Long Island Sound and Trends in Abundance

The earliest records describing the abundance and distribution of eelgrass in LIS are from the late 1800's. Since that time the abundance of eelgrass has fluctuated, but the overall trend has been a decrease in abundance and a spatial contraction of eelgrass in LIS. The following discussion is based on a subset of the historical literature and anecdotal accounts assembled by the CT DEP Office of Long Island Sound Programs[5], and more recent information gathered by the Report Workgroup. Possible explanations for trends in eelgrass abundance are discussed in more detail in "Factors That Have Long-term, Large-scale Effects on Eelgrass: Climate, Disease, and Water Quality."

Late 1800s and Early 1990s

Historic records from 1878 through 1920 (Berzelius Society 1878, Graves et al. 1910, Nichols 1920, and various herbarium collections) indicate that eelgrass occurred all along the Connecticut coastline and was present in virtually all shoreline towns (Figure 3). For example, Graves et al. (1910) states that at the beginning of the 20th century eelgrass was "common along the coast in bays, salt rivers and creeks, growing on muddy or sandy bottoms." However, the abundance and distribution of eelgrass appears to have fluctuated considerably during the late

---

[4] Recent research is showing that the limiting role of nitrogen can be more complicated and varies by area. Other nutrients, such as phosphorus, also play a role. Also, what levels cause problems, such as hypoxia, also varies among estuaries. See Cloern (2001) for a full discussion.

[5] A more complete list of historical sources can be obtained from the CT DEP Office of Long Island Sound Programs. Contact: Ron Rozsa, Supervising Environmental Analyst.

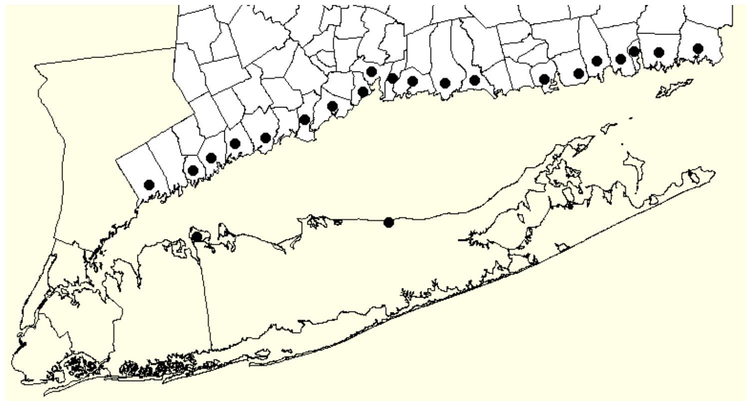


Figure 3. Historic occurrence of eelgrass by town.

A dot indicates that at least one historical record exists that describes one or more occurrences of eelgrass within a town's waters.

1800s and early 1900s, with periods of low abundance in New England in 1894, 1908, 1915 and 1930. Similar fluctuations were observed in the eastern North Atlantic coasts of Europe (Rasmussen 1977; Orth and Moore 1983). The reasons for these fluctuations were generally attributed to variations in climate (e.g. Martin 1954; Rasmussen 1977).

1930 to 1980

Beginning in 1931, a widespread die-off of eelgrass occurred all along the Atlantic Ocean in both Europe and North America (Thayer et al. 1984; Costa, 1988). During the summer of 1931, eelgrass leaves became somewhat darkened, broke from the roots, and washed ashore in great windrows from New England to North Carolina (Cottam 1935). By 1933 it was estimated that at least 90 percent of Atlantic coast eelgrass died. Losses in some areas were even higher; for example, there were estimates of less than 0.1 percent of the original population remaining in Buzzards Bay, Massachusetts. Although the reasons for this widespread decline were never definitely determined, it was generally believed that a pathogenic organism was primarily responsible.

After the dramatic decline of eelgrass in the early 1930s, populations rebounded in eastern LIS. There were reports of full recovery in the eastern portion of LIS by the 1950s and continuing into the 1970s (e.g. see Knight and Lawton 1974, McGill 1974). In some areas eelgrass became so abundant that it was considered a nuisance. For example, eelgrass in the Niantic River was so abundant that it was believed water circulation in certain parts of the river was reduced to the point where water quality became impaired. Targeted blasting was evaluated as means to selectively remove eelgrass and thereby promote water circulation (Ludwig 1977). This method was also evaluated for clearing eelgrass in the vicinity of swimming beaches (Swenarton, personal communication). And residents of Jordan Cove became concerned with the increasing abundance of eelgrass because it was washing up on their waterfront. This concern prompted the Northeast Utilities Company to conduct a study to determine whether the thermal plume from the

Millstone Nuclear Power Station was responsible for the increase, which turned out not to be the case (Knight and Lawton 1974).

In contrast to the recovery in eastern LIS, the recovery of eelgrass in western LIS was spotty and ultimately unsuccessful. Attempts were made to aid the recovery by transplanting eelgrass from Niantic Harbor to areas further west, such as Hotchkiss Grove Beach in Branford and the Norwalk River, Norwalk (Addy and Johnson 1947). Addy and Johnson also reported an attempt in Huntington Harbor, N.Y. The effort at Hotchkiss Grove Beach reportedly had some success[6], whereas efforts further west failed. In 1954, Cottam and Munro (1954) reported "Though eelgrass is perhaps less abundant in this state (i.e. Connecticut) than along most of the New England coast, the plant has shown encouraging improvement. In a few coves and bays, notably Stonington Harbor, Mystic, Poquonock, and Niantic Rivers, it is now regarded as abundant. Yet, in some adjacent areas beds are scarce or even nonexistent. Eelgrass is said to be practically absent near New Haven, Milford Harbor, Southport, and Rowayton. Reestablishment on Long Island's north shore is noticeably poorer than that on adjoining coastal areas."

1980 to 2001

From 1993 to 1995, researchers at the University of Connecticut attempted to map the distribution of eelgrass in LIS (Yarish in prep[7]). The researchers compiled a list of potential eelgrass sites from historical information, anecdotal accounts and a set of false-color infrared aerial photographs of the coastline taken by the DEP Office of Long Island Sound Programs in 1990. From 1993 to 1995 they field checked the sites by boat and SCUBA to determine if eelgrass was present. Due to the limitations of the methodology the survey is not a complete inventory, but it does provide a good overview of the distribution of eelgrass in LIS at that time. Most of the eelgrass observed was east of the Connecticut River. West of the river, eelgrass was only reported in Clinton Harbor and in an area near Duck Island, Westbrook. There have been no reports of eelgrass west of Clinton Harbor since this study was conducted[8].

Although eelgrass had rebounded in the eastern part of LIS, declines were again observed in many coves and embayments, apparently starting sometime in the 1980s and continuing through the 1990s[9]. In Clinton Harbor, "extensive" eelgrass meadows were reported in the 1980s in the

---

[6] This transplant effort was conducted by Bud Beckley, Wildlife Biologist with the CT Board of Fisheries and Game. In testimony related to a permit application in 1982, he stated he had been planting eelgrass in this location over a 30 year period (CT DEP OLISP permit files). He stated the eelgrass was sprouting continuously.

[7] This survey was part of a study funded by a CT DEP LIS Research Fund grant to investigate various aspects of eelgrass ecology in LIS. The final report is in preparation. The principal investigator, Dr. Charles Yarish, provided the results of the survey for use in this report. His pending report will be referred to as "Yarish in prep" or "Yarish."

[8] The last time eelgrass was reported west of Clinton Harbor was in 1982 near Hotchkiss Grove Beach, Branford (Mike Ludwig personal communication). This population was the result of the transplant effort conducted by Bud Beckley, Wildlife Biologist with the CT Board of Fisheries and Game.

[9] Declines were also observed at this time along the Atlantic coast such as Chesapeake Bay (e.g. see Orth and Moore 1983, Koch and Beer 1996).

inner harbor on the north side of Cedar Island[10], and eelgrass was observed along the flanks of the channel in the outer harbor[11]. An eelgrass survey of the inner harbor in 1990 estimated 23 ha of eelgrass on both sides of the channel in the inner harbor (Randall et al. 1999). It appears that the majority of the eelgrass was of very low density[12]. In 1995 Yarish observed ee1grass along the north side of Cedar Island, but he described the plants as reduced in stature and had poorly developed root systems and brittle rhizomes (Yarish in prep). The eelgrass along the navigation channel in the outer harbor declined steadily, and appears to have disappeared by 1995 (Penny Howell and Dave Molnar personal communication).

In the Niantic River, the abundance of eelgrass declined significantly in the 1980s to the point where eelgrass was almost non-existent in the fall of 1988 (Short 1988). Since that time eelgrass has not recovered to 1970s levels. Subsequent surveys of the Niantic River conducted by the Millstone Environmental Laboratory have shown that abundance fluctuates widely from year to year, and abundance even fluctuates considerably within a year due to die-offs of entire meadows (DNC 2005). In addition, the distribution of eelgrass has contracted over the last 20 years to the middle and lower parts of the river. The last time eelgrass was reported in Smith Cove was 1989, and eelgrass was last reported in the upper eastern arm (a.k.a. the Back River) by Yarish in 1994. A small meadow was consistently reported by the Millstone Environmental Laboratory from 1987 to 1995 at Sandy Point in the northern part of the river, but has not been observed since.

Similar declines have occurred in Pine Island Bay, lower Poquonock River, West Cove, outer Mystic Harbor and Beebe Cove. Two members of the Groton Shellfish Commission, Ed Martin and Roger Sherman, were aware of thriving eelgrass populations in these areas in the 1980s (Ed Martin and Roger Sherman personal communication). Around 1990 some of these populations began to decline. By 2000 they were aware that eelgrass was gone from the Poquonock River and a large portion of Pine Island Bay, and the meadows in West Cove and Mystic Harbor were considerably reduced. In the early 1990s Yarish did not report eelgrass in the Poquonnock River, Beebe Cove or West Cove. In 2001 a Stonington Shellfish Commission member surveyed of one of the meadows in outer Mystic Harbor, which was the largest meadow described by the Groton commissioners, and found only sparse eelgrass (Alan Banister, personal communication). He did, however, find denser eelgrass further to the east in Stonington waters in approximately the same area where Yarish reported eelgrass in 1993.

In the early 2000s, the Groton Shellfish Commission members were aware that eelgrass was no longer in Beebe Cove but were uncertain as to when it disappeared. Yarish did not report eelgrass during the 1993-1995 survey; however Connecticut College professor Scott Warren

---

[10] From DEP permit files. Observations reported in: Materials in Support of Permit Applications Submitted to the United States Army Corps of Engineers and the CT DEP, February 1988, Cedar Island Marina Expansion. Vol. 3.

[11] Marine Fisheries Division staff established a juvenile winter flounder sampling site in this area in 1988. The site is sampled annually.

[12] Eelgrass was assigned to three density categories: high, medium and low. Of the 23 ha of eelgrass, 11 ha were low density, 5.5 ha were medium and 6.5 ha were high density. The high category was defined as $\geq$ 41 shoots/sq. m, which encompasses densities that are considered low by most researchers. For example, see Deegan et al. 1997, which defines low density as <100 shoots/sq. m and high as 500-1,000 shoots/sq. m.

observed abundant eelgrass in the cove in 1997. He observed very little eelgrass in 1999, and none in 2002 (Scott Warren, personal communication).

In contrast to the declines, the Groton commissioners were aware of two eelgrass populations that appear to have remained relatively stable during the 1980s and 1990s: one off Shennecosset Beach at the mouth of the Thames River and another in LIS south of Bushy Point Beach.

Similar patterns in distribution and abundance have been observed in Stonington waters. At Williams Beach in upper Mystic Harbor, Connecticut College professor Paul Fell started routine seine sampling for finfish with his students in 1983. He observed that eelgrass was very abundant in the general area through the mid 1990s (this observation contrasts with that reported by Yarish in 1993, who only reported a small population in this area). Some time in the late 1990s he noticed eelgrass was declining, and became interested in documenting how the fish community might change in response to this major habitat shift (Scott Warren, personal communication).

Declines have occurred in Stonington Harbor and Little Narragansett Bay (LNB). Stonington Shellfish Commission member Alan Banister has observed changes in Stonington Harbor and Little Narragansett Bay (LNB). In Stonington Harbor, an extensive meadow along the length of the west side of the harbor was reported in 1991[13] and 1993 (Yarish in prep). Stonington Shellfish Commission member Alan Banister began observing this meadow in 1998. In subsequent years he observed this meadow contract from north to south to less than half its original size.

In LNB in the late 1980s Alan Banister was aware of four populations: a large meadow in lower Wequetequock Cove, a smaller meadow on the east side of Elihu Island, a sparse population on the eastern side of Barn Island and a population north of Napatree Point. Connecticut College professor Scott Warren was also aware of the population near Napatree Point in the 1970s and 1980s, which he described as flourishing. These populations began to decline in the 1990s and three had disappeared by 1996. In 1998 Alan Banister conducted a systematic survey of eelgrass in LNB and only found the population north of Napatree Point, which he described as small and sparse (a small population previously mapped by Yarish in 1993 near the Barn Island state boat launch was also not observed). This population was not found in 2001.

During his work on salt marshes at Barn Island, Scott Warren observed changes in the wrack line[14] on the marsh just to the east of the state boat launch that suggested a major ecological change had occurred in LNB. He recalls in the mid to late 1970s that the wrack line was composed primarily of eelgrass, which was present in large quantities. Over a period of about a decade, the composition of the wrack line changed to various macroalgae, with Cladophora dominant. By the early 1990s eelgrass was rarely found in the wrack line. Assuming the eelgrass in the wrack line originated in LNB, these observations suggest that eelgrass was abundant in LNB and declined significantly.

---

[13] John Swenarton, Environmental Biologist, Millstone Environmental Laboratory, personal communication with Dr. Juliana Barrett, Ecologist, with The Nature Conservancy, 1991. Dr. Barrett gathered and reported information on the distribution of eelgrass to the CT DEP as part of a plant community classification project.

[14] A wrack line is a string of debris left stranded by the high tide.

2002 to 2005

In 2002 the USFWS conducted a survey of eelgrass in LIS (Tiner et al. 2003). Despite some limitations, the survey provided a good estimate of the distribution of eelgrass as well as the best estimate of the spatial extent of eelgrass to date (refer to Methods for a description of the methodology). Since there was no evidence that eelgrass existed further west than Clinton Harbor, the survey was conducted between Clinton Harbor and the Connecticut/Rhode Island border. The westernmost observation of eelgrass was near Duck Island, Westbrook. As with the Yarish survey, eelgrass was found primarily east of the Connecticut River (Maps 1 and 2). Most of the eelgrass was along the coastline, particularly along coastline exposed to LIS. It was estimated that 1,235 acres of seabed contained eelgrass.

The USFWS survey documented eelgrass in depths ranging from 4.5 ft to 16.0 ft. Adjusting for the tide stage at the time of observation, it appears that the maximum depth in which eelgrass was observed was about 18 ft deep at mean high water (MHW), or about 15 ft deep at mean low water (MLW). This agrees well with historical records of eelgrass distribution. However, in the fall of 2001, Mohegan Aquaculture LLC documented eelgrass on a shellfish lease south of Stonington Harbor in depths slightly greater than -20 ft MLW[15] (Peter Francis personal communication). Based on the extensive spatial coverage of the USFWS survey it is reasonable to conclude that most eelgrass occurs in depths less than -15 ft MLW, but the information provided by Mohegan Aquaculture LLC indicates there may be locations where eelgrass can grow in deeper water. In addition, there are some shallow offshore areas, such as Noyes shoal, where eelgrass has been reported by various fishermen but was not detected by the survey.

In addition to the USFWS 2002 survey, the Millstone Environmental Laboratory improved the quality of their survey of the Niantic River and Jordan Cove, and some municipal shellfish commissions have become more interested in observing and documenting the locations of eelgrass. Although this information cannot be quantitatively compared with previous surveys and anecdotal accounts, some interesting observations can be made.

It appears that the declining trend observed in many embayments has continued. In Clinton Harbor, where it appears eelgrass was declining through the 1990s, no eelgrass was observed in 2002. The USFWS 2002 survey did not report eelgrass in Beebe Cove, and there have been no other reports of eelgrass in the cove since Scott Warren last observed it in 2000. Very little eelgrass was observed in Mystic Harbor where it once flourished, although small populations were recorded by the 2002 survey in the northern part of the Mystic River in the vicinity of Williams Beach.

In the Niantic River, very little eelgrass was observed in the USFWS 2002 survey; however, this contrasts with the survey conducted by the Millstone Environmental Laboratory, which observed significantly more eelgrass during that year (DNC 2005). Evidently the meadows were not visible on the aerial photographs. The reasons for this have not yet been definitively determined,

[15] DEP OLSIP and the U.S. Army Corps of Engineers required this survey as part of an environmental review of an application for the deployment of aquaculture structures. The data presentation was not adequate to determine the exact maximum depth in which eelgrass was observed, but 20 ft MLW is a reasonable approximation.

but this error indicates that the USFWS survey has certain limitations and so the data must be interpreted accordingly.

Based on the Millstone Environmental Laboratory survey it does not appear that eelgrass has continued to decline in the Niantic River, but abundance is still reduced compared to earlier periods and continues to fluctuate considerably from year to year (DNC 2005). In nearby Jordan Cove, a similar contraction appears to have taken place toward the outer parts of the cove open to the Sound. The Millstone Environmental Laboratory last recorded eelgrass in the inner cove in 1985.

The USFWS observed two small areas of eelgrass in Quiambog Cove in 2002. Some historical information is available for the cove, but it is not possible to say there has been a trend in abundance. Eelgrass was relatively abundant in the cove from 1975 to 1997 (Matson 1982 referenced by Crawford 1989). Considerably less eelgrass was reported in 1985, but the researcher noted it was difficult to compare abundance to the earlier survey because "beds could thrive and disappear over very short periods of time" (Welsh et al. 1985 referenced by Crawford 1989). Apparently a similar situation to that of the Niantic River was observed where a "thick and luxurious" meadow observed in June had disappeared by August.

In Stonington Harbor, the once large meadow on the western side of the harbor has continued to contract. The 2002 USFWS survey confirmed the observations made by Alan Banister. Mr. Banister has continued to monitor the meadow and has observed the meadow continued to contract from 2003 to 2005 to a fraction of its size in the early 1990s. And finally, no eelgrass was observed in LNB by the USFWS in 2002, or by any other observers through 2005.

The trend of eelgrass abundance in Mumford Cove appears to be a significant exception to the general decline observed in most coves and embayments. The USFWS survey observed abundant eelgrass in Mumford Cove in 2002, which contrasts with previous years when eelgrass was either non-existent or in low abundance. Researchers at the University of Connecticut summarized the available information on ecological changes in the cove between 1988 and 1992, and conducted additional investigations in 1999 and 2002 (James Kremer, personal communication). Some eelgrass seedlings, as well as another species of SAV (widgeon grass, *Ruppia maritima*), were observed in the cove in 1988 and 1989, but these did not appear to develop into meadows. Limited eelgrass and widgeon grass were again observed in 1992, as well as by Yarish in 1993. A modest expansion of eelgrass and widgeon grass was observed in 1999. Then, in 2002, a dramatic expansion of eelgrass occurred, with approximately 48 acres observed by the USFWS. Abundant eelgrass has been observed in subsequent years (Ed Martin personal communication).

The USFWS 2002 survey also observed eelgrass in some surprising places. A small population of eelgrass was observed in the upper reach of the Mystic River. No historical information about eelgrass in this location was available to put this occurrence in context. In addition to these, the 2002 survey mapped a significant population of eelgrass in the northernmost portion of Stonington Harbor, north of the Route 1 causeway. Eelgrass was also observed here in 1991 (John Swenarton, personal communication with Juliana Barrett).

In 2002, the USFWS observed that the majority of eelgrass was along open coastlines. Very little historical information for eelgrass in these areas is available to put the 2002 survey in context. The best available information was collected by Yarish from 1993 to 1995. Although the 2002 survey recorded considerably more eelgrass than Yarish in these areas, the two surveys cannot be compared quantitatively due to differences in survey methodology. Considering that Yarish probably underestimated the size and number of meadows relative to the 2002 survey, there does not appear to be a major change in abundance or distribution during this time period. It appears that eelgrass populations along open coastlines and offshore areas are relatively stable, whereas the abundance of eelgrass in the majority of coves and embayments is declining or fluctuating at low levels.

Monitoring Eelgrass in the Future

Although the USFWS 2002 survey provided valuable information about the distribution of eelgrass, it was only funded as a one-year project. The Report Workgroup determined that a long-term eelgrass monitoring program is needed to track the abundance and distribution of eelgrass over time. A monitoring program is essential for determining what factors affect eelgrass distribution, what measures are needed to protect, enhance, and restore eelgrass, and for assessing the effects of such measures.

The USFWS survey employs a cost-effective methodology that provides a reasonable estimate of the distribution of eelgrass over a broad area. However, the 2002 survey was not without error, as was demonstrated by comparing the USFWS 2002 survey with the survey conducted by the Millstone Environmental Laboratory. Stonington Shellfish Commission member Alan Banister also observed eelgrass in places not recorded by the survey. And as previously mentioned, the survey did not record eelgrass in some shallow offshore areas and in deeper water.

Despite some problems, the USFWS survey can serve as the core of a long-term monitoring program. Improvements can be made over time to increase data quality and specificity, such as by increasing the number of ground-truthing stations and monitoring particular eelgrass meadows in finer detail. The survey could involve interested parties, such as municipal shellfish commissions, to collect this additional data.

Members of the Report Workgroup requested that the Environmental Protection Agency's Long Island Sound Study (LISS) consider funding the USFWS survey on a long-term basis. In 2004 the LISS approved the funding for the USFWS survey, with the next survey scheduled for June 2006. Additional funding, from LISS or other sources, may be needed to fund improvements to the survey.

Ecological Values of Eelgrass

Eelgrass performs a number of important ecological functions. Eelgrass meadows, by virtue of their structural complexity, provide habitat for a diverse community of microorganisms, algae and marine animals. Eelgrass plants contribute to the overall productivity of the marine ecosystem by using the energy of sunlight to produce organic matter in the form of roots, rhizomes and plant leaves (i.e. primary productivity). Leaf production can be prolific, with new ones produced and old ones shed every 3 to 6 weeks. A few invertebrate animals graze the plants, but most of the organic matter enters the base of the marine foodweb when the plants die and are consumed by microorganisms, zooplankton and small benthic crustaceans. Other important ecological functions are: sediment stabilization, which reduces turbidity and retains nutrients in the sediments; protecting shorelines from erosion by slowing currents and dampening wave energy; chemical and nutrient absorption and recycling; oxygenation of the water column; and assimilation of certain contaminants (for a full discussion, see Thayer et al. 1984).

Along with other species of marine seagrasses and perennial macroalgae (e.g. species of rockweed and kelp), eelgrass occupies an important position in the marine foodweb of oligotrophic[16] estuaries with low nutrient supplies. These plants contribute considerably to the primary productivity of the marine ecosystem and play an important role in nutrient cycling. Compared to phytoplankton and annual forms of macroalgae, they tend to be slow growing, long-lived, decompose slowly and are lightly grazed by marine animals. Eelgrass in particular thrives under low nutrient conditions and efficiently cycles nutrients that are derived primarily from the sediments. Nutrients are released slowly to the marine environment as plant leaves die, breakdown, and are used by microorganisms, zooplankton and benthic animals such as crabs and amphipods. These processes set up a relatively stable ecosystem (see Duarte 1995 for a review).

This system contrasts with a eutrophic system (very productive and typically supplied by high level of nutrients), which tends to be dominated by species of phytoplankton and macroalgae that are fast growing, short-lived and heavily grazed. These plants derive most of their nutrients from the water column and cycle them rapidly as they grow and die. Under these conditions, population growth tends to be a boom and bust cycle. While these events do occur naturally and are an important part of marine ecosystems, such cycles can become the dominant feature of estuaries receiving excessive nutrients from human sources, resulting in regularly occurring problems such as depressed oxygen conditions in the water column and in the sediments. Such conditions can lead to the loss of eelgrass, which may in turn feed this cycle – eelgrass stabilizes sediments, and the loss of eelgrass can result in frequent sediment resuspension, reducing water clarity and releasing nutrients to the water column that can be used by phytoplankton (see Duarte 1995 for a review).

Eelgrass meadows support a rich assemblage of marine invertebrates. Examples are various species of marine worms, crustaceans (e.g. barnacles, crabs, shrimp, copepods, amphipods) hydroids, bryozoans and mollusks (e.g. mussels, snails and clams). Some spend their lives attached to eelgrass leaves, while others live within the sediment or on the sea bottom. A few feed directly on eelgrass plants, while others feed on the algae coating the leaves or on the plant matter produced when the leaves die. Together they form a complex web of predators and prey. The invertebrates in turn attract large numbers of fish (see Thayer et al. 1984, but especially Lipson and Lipson [1984] for an excellent description of the biological community of eelgrass meadows in the Chesapeake Bay).

[16] A system is oligotrophic if it has a relatively low supply of organic carbon. Since nutrients are one of the keys to increasing the supply of organic carbon by stimulating plants to grow and reproduce (i.e. by photosynthesis), oligotrophic estuaries typically have a low supply of nutrients in the system. This contrasts with a eutrophic system, which has a large supply of organic carbon and nutrients.

Eelgrass meadows are widely recognized as important fish habitat (e.g. ASMFC 1997a and ASMFC 2000). A number of studies have shown that the total abundance of fishes and diversity of fish species in eelgrass meadows is higher than in adjacent, non-vegetated habitats, and abundance and diversity tends to increase with increasing plant density (e.g. Thayer et al 1984, Heck et al. 1989, Able and Kaiser 1991, Wyda et al. 2002). The structural complexity created by eelgrass plants provides protection from predators, a plentiful food supply in the form of the many invertebrate species living among the plants, settling areas for larval fishes and invertebrates, and opportunities for species that are habitat specialists (i.e. adapted to life in a particular habitat).

The importance of eelgrass to a few species, such as bay scallop, is well understood, but in general very little research has been done to document what species of fish and shellfish use eelgrass habitats of LIS and the overall importance of eelgrass habitat to Connecticut's fisheries. However, research has been conducted in neighboring coastal states, and this information can be used to infer what other species use eelgrass habitat and for what purposes (Table 1; Appendix II).

Although there are no fish and shellfish species in LIS that are truly dependent upon eelgrass for their survival, eelgrass habitat is utilized by a variety of species for feeding and protection from predators (Table 1; Appendix II). Most fishes using eelgrass extensively are young-of year[17], juveniles or the adults of species that are small in size. By virtue of the complex habitat that eelgrass plants create, and the diverse assemblage of algae and invertebrates they support, eelgrass habitat creates additional feeding opportunities, provides refuge from predators, and creates additional niches that can be occupied by habitat specialists. The value of eelgrass habitat is increased when it is part of a mosaic of habitat types in the nearshore zone (e.g. macroalgae communities, rock/reef, open bottom). The result is a net increase of the overall productivity and diversity of the LIS ecosystem.

There are number of habitat specialists that utilize eelgrass throughout their life history. In LIS, these are pipefish, lined seahorse and several species of sticklebacks. Grubby, a small short-lived member of the sculpin family, can be found in a variety of habitats but appears to prefer eelgrass habitat when available. Eelgrass is a preferred habitat of the bay scallop, which uses eelgrass as a settling substrate for the larval stage and protection from predators. A number of other benthic tending species use eelgrass habitat during their juvenile phase for food and refuge, such as the recreationally and commercially valuable tautog and winter flounder, and perhaps lobster and blue crab. Several prolific, schooling species that feed on plankton and small crustaceans are often found near or within eelgrass, including Atlantic silverside and Atlantic menhaden. Adults of larger, predatory species (e.g. striped bass) frequent eelgrass meadows in search of food. Eelgrass is an important component in the marine food web that supports fishes. Small crustaceans consume eelgrass detritus and are in turn prey for a variety of fishes, and eelgrass detritus may be a component in the diet of Atlantic menhaden and blue crab (for additional detail, see Appendix II).

[17] *Young-of-year* refers to the first year of life. Another commonly used term is *age 0*. The term *juvenile* may also refer to the first year, but generally it means that a fish is immature.

A number of waterfowl feed on eelgrass. Eelgrass is an important food source for waterfowl such as Atlantic brant (*Branta bernicla hrota*), black duck (*Anas rubripes*), canvasback duck (*Aythya valisineria*) and Canada goose (*Branta canadensis*). Waterfowl consume the nutritious seeds and tubers, as well as rootstalks. Atlantic brant and ducks rely upon eelgrass leaves and seeds as a principal food source in the winter and spring migratory period. The introduced mute swan (*Cygnus olor*) also feeds extensively on eelgrass. Mute swan and non-migratory Canada goose often feed on eelgrass year-round.

Table 1. Fish and Invertebrate usage of eastern LIS eelgrass habitat based on regional studies and fish ecology literature.

The species listed in this table are a selected list of species observed in fish habitat utilization studies conducted in embayments of the mid-Atlantic Bight and Gulf of Maine (see Appendix II) that likely use LIS eelgrass habitat. In addition, several species are included that were not observed in these studies because other information indicates they use eelgrass habitat. Usage of eelgrass habitat in LIS was inferred and ranked based on the results of these studies, general fish ecology literature, and fish ecology literature specific to LIS. The level of usage was ranked as high, medium or low based on the overall importance of eelgrass habitat for each species. The primary life stages (Y = young-of-year, J = juvenile, A = adult) using the habitat were identified, as was the type of usage (F = feeding, R = refuge, S = spawning).

Fish	Usage	life stage	type of usage	comments
four-spined stickleback	high	Y, J, A	F, R, S	eggs laid in nest
northern pipefish	high	Y, J, A	F, R, S	eggs reared in male's brood pouch
lined seahorse	high	Y, J, A	F, R	status of breeding population unknown
three-spined stickleback	med	Y, J, A	F, R, S	eggs laid in nest
grubby	med	Y, J, A	F, R, S	
Atlantic silverside	med	Y, J, A	F, R	
tautog	med	Y, J	F, R	adults may feed in eelgrass
winter flounder	med	Y, J, A	F, R	primarily age 0, found in low to medium density eelgrass or near edges
Atlantic tomcod	med	Y, J, A	F, R	commonly observed, low numbers
oyster toadfish	med	Y, J	F, R	
rainbow smelt	low	Y, J, A	F, R	commonly observed, low numbers
nine-spined stickleback	low	Y, J, A	F, R, S	found only in CT and RI studies
mummichog	low	Y, J, A	F, R	proximity to salt marsh may be important
sheepshead minnow	low	Y, J, A	F, R	proximity to salt marsh may be important
bluefish	low	Y, J, A	F	age 0 fish observed in one study; probably feed near eelgrass
striped bass	low	J, A	F, R	only observed in one study, probably feed near eelgrass
summer flounder	low	J, A	F, R	not observed in any studies, probably feed near eelgrass
weakfish	low	J, A	F, R	not observed in any studies, more common in southern seagrasses
scup	low	Y	F, R	
black sea bass	low	Y	F, R	
cunner	low	Y, J	F, R	
northern puffer	low	Y, J, A	F, R	
Atlantic menhaden	low	Y, J, A	R	may consume eelgrass detritus, as well as zooplankton that feed on detritus
bay anchovy	low	Y, J, A	R	may have eelgrass detritus connection
Atlantic herring	low	Y	R	may have eelgrass detritus connection
American eel	low	Y, J	F, R	
alewife	low	Y	F, R	
blueback herring	low	Y	F, R	
Economically important invertebrates				
bay scallop	high	Y, J, A	F, R, S	
blue crab	med	Y, J, A	F, R	
lobster	med	Y, J	F, R	
hard clam	low	Y, J, A	F, R, S	no studies conducted in mid-Atlantic Bight.

Conclusions

- Eelgrass meadows are a valuable type of habitat within the LIS ecosystem.
- Eelgrass is an indicator of a healthy estuarine system.
- Eelgrass was once found along the length of Connecticut's coastline. Overall, the current abundance of eelgrass is much reduced relative to historical abundance, even in the eastern areas where eelgrass still exists. It appears that eelgrass continues to decline in some coves and embayments.
- The decline of eelgrass over the last century in LIS reflects a general pattern of seagrass declines elsewhere along the Atlantic coast and the world.
- Eelgrass is now found primarily in depths less than -15 ft MLW in eastern LIS, but may be found in depths slightly greater than -20 ft MLW in areas with very clear water.
- In light of the long-term decline of eelgrass, Connecticut's remaining eelgrass meadows should be conserved to the greatest extent practicable.
- There is a lack of information that specifically describes how eelgrass functions in LIS as fish and shellfish habitat. The following conclusions were based on available information:
  - The value of eelgrass as fish and shellfish habitat is often enhanced, and sometimes determined, by the proximity of other habitat types (e.g. reefs, salt marshes).
  - Species' usage of eelgrass meadows often depends upon the characteristics of the meadows, such as the density of plants, size of the meadow and patchiness of plant colonies. The location and depth of meadows is also important.
  - Fish and shellfish species using eelgrass habitat will also use other habitat types for all or part of their life cycles. It appears that no species in LIS are totally reliant on eelgrass habitat.
  - For most species, eelgrass habitat provides additional feeding and refuge opportunities for certain life-stages.
  - The preponderance of fish using eelgrass habitat are young-of-year and juveniles of a number of species. Adults of some smaller species use eelgrass, and adults of some larger predatory species forage near and around eelgrass.
  - Eelgrass appears to be a preferred habitat of four-spine stickleback, northern pipefish and lined seahorse, which use eelgrass for feeding opportunities, refuge and brooding young.
  - Eelgrass is a preferred habitat of the bay scallop. Larval scallops attach to eelgrass leaves. Juveniles and adults use eelgrass for refuge from predators.
  - Young-of-year and juveniles of two recreationally and commercially valuable finfish – tautog and winter flounder – use eelgrass habitat for feeding opportunities and refuge, but usage appears to depend on the characteristics of the meadows and proximity of other habitats.

    - Atlantic silverside and Atlantic menhaden, two prolific, schooling species that feed on plankton and small crustaceans, are often found near or within eelgrass.
    - Adult striped bass may frequent eelgrass meadows in search of food. Adult summer flounder and winter flounder may forage near the edges of eelgrass meadows.
    - Young-of-year and juvenile American lobster and blue crab use eelgrass habitat for food and refuge. Adults of both species may also use eelgrass habitat.
    - Blue crab, bay scallop and Atlantic menhaden consume eelgrass detritus, but the overall importance of detritus to their diets is unknown.
- Research is needed to better define fish and shellfish use of eelgrass habitat in the Sound, for what purposes, and the overall importance to their population levels.
- An eelgrass monitoring program is needed to track the abundance and distribution of eelgrass over time. The USFWS survey has been funded on a long-term basis and can serve as the core of a monitoring program. Improvements to the survey may be needed and may require additional funding.

Recommendations

- Research is needed to determine more precisely what fish and shellfish species use eelgrass and for what purposes. Additionally, the degree to which eelgrass contributes to the population levels of these species should be investigated.
- Improve the USFWS eelgrass survey by such measures as increasing the number of ground-truthing points and more detailed mapping of certain eelgrass meadows and characteristics.
- Obtain additional funding for the USFWS survey if more resources are needed to implement improvements.

EFFECTS OF RECREATIONAL AND COMMERCIAL FINFISH AND LOBSTER FISHING ON EELGRASS

Since almost all eelgrass is currently found east of the Connecticut River, the Report Workgroup evaluated the potential effects of fisheries operating in eastern LIS. Eastern LIS was defined as Connecticut's waters between the Connecticut River to the Rhode Island border, thereby including Fishers Island Sound.

Data collected by the DEP Marine Fisheries Information System and the DEP Marine Angler Survey were examined for the year 2000 to characterize these eastern LIS fisheries. In addition, the Connecticut General Statutes (CGS Chapter 490 Fisheries and Game) and Regulations of Connecticut State Agencies (RCSA) were reviewed to determine if any statutes or regulations governing the use of fishing gears might protect eelgrass in eastern LIS.

Fisheries in Eastern Long Island Sound

During 2000, a total of 191 commercial fishermen utilized 11 different commercial gear types to take finfish, lobsters and crabs in eastern LIS (Table 2). Some of these fishermen used more than one gear type. The majority (72.3 percent) fished lobster pots, followed by hook & line (22.0 percent), otter trawl (8.9 percent), drift gill net (8.4 percent), fish pot (4.7 percent) and fixed gill net (2.6 percent). Each of the remaining gear types (eel pot, fyke and pound net, and hand harvest) was used by less than 2 percent of the fishermen. As measured by the number of fishing trips, the large majority of fishing effort was made using lobster pots, which accounted for 79.6 percent of the total trips. Three gear types – lobster pot, hook & line and otter trawl – accounted for 96 percent of total fishing trips. Each of the other gear types accounted for less than 1.2 percent of total fishing effort in eastern LIS.

Table 2. Commercial finfish and lobster fishing activity during the year 2000 by gear type between Old Saybrook and Stonington, CT (DEP Commercial Logbook Area 1).

Gear	Number of fishermen*	Percent of fishermen*	Number of trips	Percent of trips
lobster pots	138	72.3	4,205	79.6
hook & line	42	22.0	465	8.8
trawl	17	8.9	402	7.6
gill net, drift	16	8.4	66	1.2
fish pots	9	4.7	62	1.2
gill net, staked or anchored	5	2.6	26	0.5
eel pot	3	1.6	12	0.2
Other (by hand, fyke net, pound net)	4	2.1	35	0.7
Total	*	*	5,273	

*These columns are not additive because some fishermen used more than one gear. The total number of fishermen who reported trips using any of these gears in eastern LIS was 191.

In 2000, the DEP Marine Angler survey estimated that 261,000 recreational anglers made 1.4 million trips on Connecticut's waters (MacLeod 2002). Of the total trips, 59 percent were by boat (personal, rental and party/charter) and 41 percent were from shore. The number of recreational anglers and amount of effort in eastern LIS could not be estimated directly from the DEP Marine Angler survey. Using the number of registered boats by area as an indirect measure, it was estimated that approximately 35 percent to 40 percent of LIS anglers fish in eastern LIS.

State Statutes, Regulations and Policies Relevant to Eelgrass Protection

The DEP, with the Marine Fisheries Division of the Bureau of Natural Resources as the lead office, has regulatory authority over recreational and commercial finfish and crustacean fisheries. These fisheries are conducted according to specific statutes (CGS Chapter 490 Fisheries and Game) and regulations.

There are no CGS or RCSA that explicitly protect eelgrass from fishing activities. However, restrictions on the use of commercial fishing gear in defined areas incidentally provide significant protection for much of the existing eelgrass in eastern LIS. These are discussed below in the relevant sections.

Assessment of Impacts by Gear Type

Otter trawl

An otter trawl is a funnel shaped net that is towed over the sea bottom by a vessel. Vessels outfitted for towing an otter trawl are called trawlers. Towing cables are attached to a pair of rectangular otter boards – more commonly called doors – which are in turn attached by cables to the top (headrope, or float line) and bottom (footrope, or sweep) corners of the net. When pulled by the vessel, the doors ride on edge along the bottom. The water pressure against the doors pushes them outward, which in turn spreads open the mouth of the net. The footrope is generally equipped with a draped chain or rubber discs. The nets and footrope can be configured in a number of ways so that it will catch fish on the bottom, in the water column, or both.

Trawling Activity in Eastern LIS

During 2000, 17 trawl fishermen made 402 trips in eastern LIS (Table 2). The vessels used by these fishermen were relatively small, ranging in length from 15 ft to 36 ft. A total of nine finfish species were reported landed, with three bottom species – winter flounder, little skate (*Raja erinacea*), and summer flounder (*Paralichthys dentatus*) – accounting for 96.4 percent of the total landings by weight (Table 3). Also, three invertebrate species were landed: 2,854 lb of conch (a large marine whelk, *Busycon* sp.), 1,580 lb of squid (*Loligo pealeii*) and 235 lb of lobster (*Homarus americanus*). Trawl fishermen most likely caught these species incidentally when trawling for finfish.

Table 3. Commercial landings in the year 2000 reported by otter trawl fishermen fishing in eastern Long Island Sound.

	Weight (lb)	Percent of total weight
Finfish		
Winter flounder	70,330	47.9
Skates	45,904	31.3
Summer flounder	25,156	17.1
Scup	3,834	2.6
Tautog	1,176	0.8
Butterfish	155	0.1
Weakfish	118	0.1
Black sea bass	57	0.0
Total	**146,730**	
Invertebrates		
Conch	2,854	61.1
Squid	1,580	33.8
Lobster	235	5.0
Total	**4,669**	

Effects of Trawling on Eelgrass

The ASMFC gear impact report did not cite any studies of the effects of otter trawling on eelgrass. However, studies on the effects of trawling on a similar seagrass, *Posidonia oceanica* in the Mediterranean Sea, were discussed. *Posidonia oceanica* has basal meristems and runners near the surface of the seabed that are similar to eelgrass, but a significant difference is that it can grow in much greater depths – down to 130 ft – compared to only about 15 ft for eelgrass in LIS. Researchers found that trawling in and near *Posidonia oceanica* meadows caused significant damage to plants and led to the loss of entire meadows (Ardizzone et al. 2000, Ardizzone and Pelusi 1983).

Trawl net characteristics vary widely in terms of size and how the footrope is configured. Exactly how the trawl nets that damaged the *Posidonia* meadows were configured was not described. Since this was the only study available, the ASMFC concluded that " . . . the impact of trawling on SAV must be evaluated in light of the circumstances under which the fishery is prosecuted." The factors identified included: characteristics of the trawl (e.g. size, weight, otter board weight, presence of tickler chain, presence of rollers on the footrope), gear usage (e.g. ratio of tow cable length to water depth), substrate composition, and SAV species (ASMFC 2000).

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Based on the way trawl nets used in LIS are configured, and the presence of eelgrass in some areas where trawling theoretically could take place, fishing with trawls may damage eelgrass. However, it is likely that negative effects are mitigated by a number of factors.

Trawl nets utilized in LIS generally have a sweep length of 18 ft to 65 ft, but may open only one-half that width while towed. Rubber discs greater than 0.5 ft diameter on the footrope are prohibited. The footrope of trawl nets used in Connecticut is generally rigged to make light contact with the sea bottom (Smith et al. 1985). Uprooting of eelgrass and below seabed damage is unlikely, but leaf shearing, seed or flower shearing and damage to the meristem could occur even with light bottom contact. Of more concern is potential damage from the doors and ground cables that scrape along the sea bottom. Divers observing typical steel V-doors towed by a research vessel in Connecticut recorded scouring ranging from 0 ft to 0.5 ft deep depending upon sediment type (Smith et al.1985). This kind of scouring would likely cause extensive damage to eelgrass by uprooting plants and damaging rhizomes below the seabed. Also, ground cable, which is a length of cable running from the doors to the corners of the net, is sometimes used when fishing for flatfish, which are “herded” by the cable into the path of the net. Since it scrapes along the bottom, it would likely cause leaf shearing, damage meristems, and uproot plants. In addition, frequent trawling near eelgrass meadows could result in sediment disturbance and suspension of bottom sediment (the extent would depend on the sediment type) that could reduce light penetration or bury eelgrass.

A considerable amount of the eelgrass observed in the 2002 eelgrass survey is incidentally protected from bottom trawling by CGS Sec. 26-154 (Maps 3 and 4). Trawling is prohibited shoreward of a series of lines specified in the statute. CGS Sec. 26-185 prohibits trawling in the Poquonock River, or north of a line drawn from the west end of Pine Island to the west side of Avery Point. Collectively, this line is called the *inshore trawl line* (not a true line, but a series of discontinuous lines). Significant eelgrass meadows in Stonington Harbor, Mumford Cove, Bushy Point and vicinity, New London Harbor, Jordan Cove, and most of the eelgrass in Niantic Bay, Niantic River and the mouth of the Pattagansett River are protected from bottom trawling. Of the eelgrass observed in the 2002 survey, 712 acres (58 percent) of the 1,235 acres were in areas where bottom trawling is prohibited.

RCSA Section 26-159a-5 also protects eelgrass, but to a lesser degree and only in Niantic Bay. This regulation prohibits the use of bottom trawl vessels greater than 44 ft in length north of a line (the *large vessel trawl line*) in Niantic Bay (Map 3). This regulation may confer additional protection in the bay because larger vessels can tow larger nets, which would presumably result in greater impact if they were allowed.

Although significant amounts of eelgrass are incidentally protected by the inshore trawl line, eelgrass does occur in some areas where trawling is allowed. Based on the 2002 USFWS survey about 523 acres (42 percent) were in these areas (Table 4). However, not all of these areas can be fished with a bottom trawl. As discussed previously, eelgrass typically grows in depths less than 15 ft. In eastern LIS, many of these shallow areas contain obstructions, such as rocks, reefs, mooring fields and anchorages, which would make trawling impossible. In addition, features such as islands and jetties further complicate towing a trawl net in shallow water. There may be some shallow water areas with enough open, flat bottom to tow a trawl net, but for the most part only small boats towing scaled-down versions of commercial otter trawls could operate there.

Table 4. Amount of eelgrass in 2002 located within areas where bottom trawl fishing is allowed, designated shellfishing areas and designated boat anchorages and mooring areas.

The U.S. Fish and Wildlife Service identified 1,235 acres of seabed containing eelgrass in 2002. This information was used to evaluate how much eelgrass might be encompassed by designated shellfishing areas, boat mooring fields and anchoring areas, and the number of acres in areas that theoretically could be fished with a bottom trawl. Designated shellfishing areas include Approved areas and Conditionally Approved areas, natural beds, leased areas, private beds, and co-managed areas.

Eelgrass within:	Acres of eelgrass[1]	% of total eelgrass
Areas that might be trawled	523	42%
Designated municipal shellfish areas	581	47%
Designated state shellfish areas	100	8%
Designated anchorage areas	44	4%
Designated mooring fields	71	6%
Anchorage and mooring fields combined[2]	82	7%
All areas combined[3]	951	77%

1 The numbers in this column are not additive. For example, some mooring fields overlap with anchorage areas, and so the eelgrass in the overlap areas would be counted twice.

2 Area estimates account for anchorage and mooring field overlap.

3 The values in this row represent the amount of eelgrass that may be encompassed by one or more of the five categories of impacts, accounting for any overlap.

There is an additional reason why trawling is probably is very limited in eelgrass habitat. In 2002 winter flounder, summer flounder, and skate accounted for 96 percent of the total pounds of finfish caught by trawlers in eastern LIS. Juvenile winter flounder and summer flounder may be found in eelgrass, but the adults of these species – which are the ones sought by the commercial fishery – are much more abundant in other habitats. In addition eelgrass presents an obstacle to trawling, especially for small vessels. Loose leaves clog the net and dense meadows cause the net to ride up off the bottom, reducing fishing efficiency substantially for bottom tending fish such as winter flounder, summer flounder, and skate. Therefore, it is unlikely that much trawling takes place in eelgrass meadows.

Although the likelihood of trawlers fishing in eelgrass is low, it is possible that trawlers fish near or through eelgrass meadows in some areas. Trawlers might tow through eelgrass if a pelagic species was being targeted, or tow nets through areas with low-density eelgrass. Trawlers may also fish close to eelgrass meadows, possibly to catch summer flounder or winter flounder. This might prevent the expansion of the meadows due to physical disturbance of the bottom and damage to emerging plants, as well as causing increased sedimentation that can shade or bury nearby plants.

Lobster and Fish Pots

Lobster pots, or traps, are typically rectangular in shape and made of wire mesh. The typical lobster pot is 40 in. long by 24 in. wide by 14 in. high, although some lobstermen fish pots up to 4 ft long (lobster pots in Connecticut's waters are limited by regulation to a maximum volume of 22,950 cu. in). Each pot is baited to attract lobsters. The majority of commercial lobster pots are deployed in pot trawls, or a series of pots strung together. In LIS, lobster pot trawls are typically composed of 2 to 12 pots distributed along a 3/8 in. to ½ in. diameter ground line, with the pots spaced 60 ft to 90 ft apart. In contrast, small-scale commercial fishermen and recreational lobstermen generally deploy their lobster pots individually. The average set time (i.e. the time the pot has been deployed since it was last baited) for a lobster pot in 2000 was 6 days, but during the height of fishing in summer and fall the set time is generally shorter (typically 3 days).

The size of fish pots is limited by regulation to no more than 6 ft in length, width or height. Most fish pots used in LIS are approximately 2 ft by 2 ft, set individually, and baited. Unlike lobster pots that are set and left unattended until they are hauled 3 to 6 days later, fish pots in eastern LIS are personally tended and checked periodically during the trip. Fishermen will generally set about 12 pots, check each one several times during the day, and then return them to shore.

Lobster and Fish Pot Activity in Eastern LIS

In 2000, 138 commercial fishermen reported fishing lobster pots in eastern LIS (Table 2). These fishermen reported making 4,205 trips and hauled 401,425 pots, with an average of 95 pots hauled per trip. In addition, 311 recreational license holders, who are limited to 10 pots each, reported making 63,478 pot hauls. The number of pots fished varies seasonally with the majority of fishing activity during the early summer through late fall.

Nine commercial fishermen using fish traps reported making 62 trips in 2002 (Table 2). They hauled a total of 876 pots, with an average of 14 per trip. These fishermen primarily targeted scup, but also fished for black sea bass.

Effects of Lobster and Fish Pots on Eelgrass

The ASMFC gear impact report did not cite any studies regarding the impact of lobster or fish pots on eelgrass. The report did state, "lobster traps in New England waters have been considered to contribute to eelgrass loss." This statement is based on observations made while conducting surveys of eelgrass meadows in Massachusetts's waters (Phil Colarusso, personal communication). Lobster pots were observed in most meadows surveyed, and damage to plants and denuded areas caused by pots and pot lines were observed[18]. DEP staff also observed that pots hauled off of hard bottom habitat in LIS resulted in scraping of the plants and loss of leaf blades. In soft bottom sediments it appears that hauling traps tended to uproot the plants (Peter Francis, personal communication).

---

[18] The ASMFC gear impact report implied that studies to document these losses were underway, but these studies, which were proposed during the development of the report, have not been initiated (Phil Colarusso, pers comm.).

Based on these observations and the general physical characteristics of lobster pots, it is likely that pots consistently set and hauled in an eelgrass meadow can cause damage by leaf shearing, damaging meristems, uprooting plants and, if left long enough on the bottom, can cause damage by smothering and light attenuation. The extent of damage by pots would depend on the number of pots set, the setover period and hauling frequency.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

It is unknown how many commercial lobster pots are set in eelgrass, but based on a number of factors it is unlikely to be a significant number. It is believed that the majority of commercial lobstermen fish in deeper water where eelgrass does not occur. Also, eelgrass does not appear to be a preferred habitat for legal (3-9/32 in. minimum carapace length) size lobsters (Short et al. 2001). In areas where eelgrass is interspersed among rocks – which is a habitat lobster prefer (ASMFC 2000) – legal size lobster may be present and make feeding forays into the eelgrass. Therefore, fishermen may set pots individually in these areas

Similarly, commercial fish pots are probably not set in eelgrass meadows since the primary species sought – adult scup and black sea bass – are generally not found in eelgrass in large numbers, preferring instead deeper water with structure (e.g. rock reefs). However, as with lobster pots, fishermen might set fish pots in areas where eelgrass is dispersed among rocks.

Recreational lobster fishermen may be more likely to set pots in eelgrass since the majority set pots individually in shallow water where eelgrass is more prevalent. It is difficult to gauge what the effect of the personal use fishery might be, but it is probably not significant. Assuming all 311 personal use license holders each fished the maximum of 10 pots allowed, and each pot was similar to a typical small commercial pot (36 in. by 24 in. by 14 in.), then there would have been 3,110 pots occupying 18,660 sq. ft (0.43 acres) at any time. Only a small fraction of these would be set in eelgrass and damage leading to the death of plants would result in a fraction of those cases. However, another factor would be the number of times these pots were hauled and reset and how long they were deployed (set over days). Accounting for these factors could increase the amount of damage.

Gill net

A gill net is composed of panels of nylon mesh. The net is spread vertically in the water column by the tension created by a float line along the top of the net and a weighted bottom line, or lead line. By varying the weight of the lead line and size of the floats, a gill net can be designed to fish almost any location in the water column. However, they are typically fished either near the surface or near the bottom. Gill nets can be anchored and tended periodically, or can drift with the current while being personally attended. Fish are caught when they attempt to swim through the net mesh. Only a portion of their body will fit through the net, and they become trapped because the mesh gets hooked under their gill covers or entwined in their fins.

Gill net Fishery in Eastern LIS

Commercial fishermen may use gill nets of any length in marine waters. Gill nets generally range from 60 ft to 1,200 ft in length. In 2000, 16 fishermen fished the nets by drifting, whereas 5 fishermen anchored the nets. Of 92 fishing trips, 66 trips were made with drift nets (72 percent of the total) and 26 trips were made with anchored nets (28 percent).

A license is required to fish gill nets recreationally (Personal Use Gill net for Menhaden License). Recreational fishermen are allowed to fish one gill net no longer than 60 ft in length to take menhaden for bait. These nets are typically drifted near the surface and personally attended. In 2000, a total of 194 recreational gill net licenses were issued. Of these, 71 recreational fishermen reported using the nets, making a total of 488 fishing trips.

Effects of Gill nets on Eelgrass

Although no studies were cited, the ASMFC gear impact report concluded: "impacts to SAV are expected to be minimal" from gill nets.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Damage to eelgrass in LIS from gill nets is expected to be minimal or nonexistent. Based simply on the low number of fishermen using gill nets and low number of trips, gill nets would be infrequently fished in eelgrass, if at all. But even if gill nets were frequently fished in eelgrass, the gear itself would not cause significant damage. Gill nets are fished passively (drifted or fixed in place) off the bottom, and with the exception of anchors in the case of fixed gill nets, do not have a "footprint" on the bottom or cause excessive shading.

Pound Net

A pound net is a funnel shaped fixed net with lead nets that guide fish into the "bowl" or "pound." The net is generally set near shore in depths up to 30 ft and held in place by a series of poles driven into the sea bottom. Pound nets can also be floating nets suspended from buoys. Configurations and size vary, but generally a long, straight net called a fence, or leader, extends from shore to the main body of the net, where fish are funneled into the bowl. The entire net, including the leader, can be from 500 ft to over 1,000 ft long. The bowl itself often measures about 30 ft by 40 ft. Pound nets in LIS are generally set in the spring and removed in the fall.

The DEP issues pound net registrations and, by regulation [RCSA 26-142-3a(c)], is required to review the siting of each pound net to ensure that no pound net is set within one mile of another pound net. In addition, a Structures Dredging and Fill Permit from DEP OLISP is required to deploy a pound net, fish weir, or similar structure.

Pound Net Fishing Activity in Eastern LIS

Currently, only one pound net is used in eastern LIS. This net has been set annually in Niantic Bay for the last twenty years. Only one other net has been set in eastern LIS in recent years, just west of the mouth of the Thames River. It was removed after a short time due to public opposition and the difficulty of fishing the net in that location.

Effects of Pound Nets on Eelgrass

The impact of pound nets could be significant if the bowl or pound was set on eelgrass. Since pound nets are set for a long period, they could smother the plants underneath the net. In addition, each time the net was tended, eelgrass plants near sections of the net that are moved could be uprooted or abraded. The net may also cause changes in sedimentation patterns and light attenuation, which could interfere with eelgrass growth.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Despite their potential for damaging eelgrass, the use of pound nets in eastern LIS should have minimal to no effects. The only pound net currently in use is not set in an eelgrass meadow. Siting requirements, both in terms of regulatory requirements and finding a suitable area to set the net, serve to minimize the number of allowable pound nets. Most importantly, a fisherman planning to deploy a new pound net would have to obtain a DEP Structures Dredging and Fill Permit. During the permit review process, the application would be reviewed for effects on eelgrass pursuant to the Coastal Management Act (CGS Chapter 444). Given the potential for damage, if an applicant proposed to set a pound net in an eelgrass meadow, or immediately adjacent to a meadow, it is unlikely a permit would be issued. However, it is less clear if an application would be denied if the proposed location for the net is devoid of eelgrass but supported eelgrass historically, and still had characteristics suitable for eelgrass colonization (i.e. potential eelgrass habitat).

Hook and Line (Commercial and Recreational)

Both recreational and commercial fishermen use hook and line, or “rod & reel.” Anglers fish from shore and boat. There are endless variations of reels, rods and type of fishing line, as well as the types of lures or baits used to catch different species of fish. Similarly, there are numerous techniques, such as trolling lures or baits behind a boat, fishing baits or lures near the bottom while anchored or drifting, and fishing the surface with lures.

Hook & Line Fishing Activity in Eastern LIS

In 2000, 42 commercial hook and line anglers reported 465 trips in eastern LIS. The majority of commercial anglers fish from boats. Commercial fishermen use hook and line techniques similar to the recreational fishery. It is believed that other methods used elsewhere, such as long lining (lines deployed with a series of hooks) or automated reel jigging, are not used in LIS. Commercial fishermen also fish the same areas as recreational fishermen.

It is not known how many recreational anglers fish in eastern LIS. In all of LIS in 2000, an estimated 261,000 recreational anglers made 1.4 million trips (MacLeod 2001). Of the total trips made by anglers, 59 percent were by boat (personal, rental and party/charter) and 41 percent were from shore. Using the number of registered boats by area, it is estimated that approximately 35 percent to 40 percent of these anglers fished in eastern LIS.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Since eelgrass grows in nearshore waters, fishermen may fish in and around eelgrass from either boat or shore. Fishing in eelgrass can be difficult because it can foul baited hooks and lures. However, some fishermen fish along the edges of eelgrass meadows and also fish in open areas dispersed between patches of eelgrass. These areas can be productive for striped bass, bluefish, and summer flounder. But whatever the level of fishing effort, fishing tackle itself has no appreciable effect on eelgrass.

Of greater concern is the potential impact of boats motoring through or anchoring in eelgrass. Due to the large number of recreational fishermen fishing from boats, the cumulative damage to eelgrass from boat propellers, propeller wash and anchors could potentially be significant. Moreover, there are numerous people using boats for other recreational purposes that may cause the same type of impacts. The type and extent of damage caused by these activities in LIS is unknown. This topic is discussed further in the section titled “Other Factors affecting the Abundance and Distribution of eelgrass; Motorized Watercraft.”

Conclusions

- **Bottom trawls:** Based on a number of factors, it is unlikely that trawlers cause a significant amount of damage to eelgrass. However, it is possible that some localized damage occurs in specific locations, or that in some locations repeated trawling is preventing the expansion of eelgrass meadows. Therefore, further investigation is warranted to determine if this occurs and if the damage is ecologically significant. Additional evaluation of the distribution of eelgrass may show whether significant eelgrass meadows occur in areas where a bottom trawl could be used. If such meadows are identified, a survey could be warranted to document damage. If significant damage were occurring, possible protective measures would be to delineate the meadow and prohibit trawling within it. This would require periodic monitoring of the distribution of eelgrass to update the list of areas to be protected because the distribution of eelgrass changes over time, particularly if restoration efforts succeed in expanding the distribution of eelgrass. Any survey of trawl damage should be conducted as part of a comprehensive survey of the various factors identified in this report that could damage eelgrass.
- **Lobster pots:** Based on the characteristics of the recreational and commercial pot fisheries, they probably have a minor impact on eelgrass in eastern LIS. Therefore regulations to protect eelgrass are not needed at this time. However, further investigation is warranted to determine if significant numbers of pots are set in particular eelgrass meadows, and to quantify the impact. Any survey of pot damage should be conducted as part of a comprehensive survey of the various factors identified in this report that could damage eelgrass.

- **Gill nets:** The effects of gill nets on eelgrass in eastern LIS are minimal or non-existent. Therefore, no action is needed at this time to protect eelgrass from gill nets.
- **Pound nets:** Given the protection afforded eelgrass through the DEP permit review process, additional action is not needed at this time. A new regulation prohibiting the setting of pound nets on eelgrass could strengthen and simplify the permit review process, but this also raises the issue of what action would be needed if eelgrass colonized a permitted site. Such an event must be anticipated by any new regulation.
- **Hook and line:** Recreational and commercial hook and line fishing does not significantly damage eelgrass. However, boats used for this type of fishing, along with other types of boating, have the potential for causing damage. The type and extent of damage has not been documented in LIS. Surveys would be needed to document the extent of such damage resulting from all powerboat operations (i. e. fishing and non-fishing). The results of the surveys would be used to determine if regulations are required, such as closing particularly important and vulnerable eelgrass meadows to motor boating. Such a survey should be conducted as part of a comprehensive survey of the damage caused by the activities identified in this report. In addition, boaters should be informed of the value of eelgrass and encouraged to avoid damaging eelgrass. (This issue is discussed further in the section titled *"*Other Factors affecting the Abundance and Distribution of Eelgrass: Motorized Watercraft*"* in this report.)
- The impacts of commercial and recreational fishing could increase if eelgrass expands into areas that support, or could support, fisheries that have the potential to impact eelgrass (e.g. trawling).

Recommendation

- A field survey should be conducted to assess the impacts of various fishing gears and activities. The survey should be part of a comprehensive survey assessing the impacts of boating, waterfowl and mooring fields to determine if significant impact is occurring in particular eelgrass meadows, and if measures are needed to protect particularly vulnerable meadows

Effects of Recreational and Commercial Shellfishing on Eelgrass

Since almost all eelgrass is currently found east of the Connecticut River, the Workgroup evaluated the potential impacts of shellfisheries operating in eastern LIS. Eastern LIS is defined as Connecticut's waters between the Connecticut River to the Rhode Island border, thereby including Fishers Island Sound.

To establish the level of shellfishing effort, commercial landings data submitted to the DA/BA (both state and municipal waters) were examined for the year 2000 (all commercial fishermen report their landings by county). The number of permits issued by municipalities in 2000 was used to characterize recreational fishing effort. The CGS were reviewed to determine if any statutes or regulations governing the use of fishing gears might protect eelgrass in eastern LIS. In addition, DA/BA leasing and licensing programs and municipal permitting and licensing programs were evaluated to determine how these programs might affect the conservation of eelgrass.

Shellfishing in Eastern Long Island Sound

Commercial shellfish culture and harvesting occurs in waters leased by DA/BA. Both commercial shellfish culture and recreational shellfishing occur in waters under the jurisdiction of municipalities. Oysters (*Crassostrea virginica*) and hard clams (*Mercenaria mercenaria*) were the predominant species harvested (landings reported in New London County). Three companies with a total of five vessels harvested 501 bushels of oysters. Four companies with a total of 8 vessels harvested 11,044 bushels of hard clams using hydraulic dredges. These landings represented less than 3 percent of the reported commercial shellfish harvest in all of Connecticut's waters in LIS. Thirty-four commercial licenses for the taking of conch (*Busycon sp*.) by pots were issued in 2000, but only a small amount of conch was landed. (No significant harvest of soft clams (steamers, *Mya arenaria*), blue mussels (*Mytilus edulis*), razor clams (*Ensis directus*) or scallops (*Argopectin irradians*) was reported.

At present, virtually all oyster culture in eastern LIS is based on some type of aquaculture. The seed oysters are produced in a land-based hatchery and transplanted to seed oyster beds in shallow estuarine areas. The oysters are raised in these beds and then transplanted to cages, which are placed in leased areas for the purposes of depuration[19] or additional growth. The majority of the 501 bushels of oysters landed in the year 2000 were probably raised in this fashion.

---

[19] Depuration refers to the ability of shellfish to rid themselves of contaminants, such as bacteria, when placed in clean water. Shellfish may be cultured and harvested in areas that may contain certain levels of contaminants, but before harvest they must be transferred to approved areas for a defined period of time. For example, oysters must remain in an approved area for 14 days at temperatures above 50 deg F to ensure that contaminants are well below the levels set by the Dept. of Public Health and which meet federal FDA guidelines.

The use of shellfish aquaculture systems has increased significantly in recent years. As of 2001, eight companies were actively using aquaculture structures ranging from individual cages to various longline and floating systems. It is uncertain if the industry will continue to grow, but there has been increasing interest within the industry and some municipal shellfish commissions.

Recreational shellfishing in municipal waters is very popular in eastern LIS. In 2000, municipalities issued 3,468 recreational permits (Groton: 1,800 permits; Stonington Shellfish Commission: 865 permits; Waterford/East Lyme Shellfish Commission: 743 permits issued for the Niantic River; East Lyme: 60 permits). Recreational shellfishing is typically conducted using hand implements in intertidal or subtidal areas.

State and Municipal Statutes, Regulations and Policies Relevant to Eelgrass Conservation

Commercial and recreational shellfishing are regulated and conducted pursuant CGS Chapter 491, State Shellfisheries and CGS Chapter 492, Local Shellfisheries. In 1881, a line was established by statute that placed waters south of the line under the jurisdiction of the state and waters north of the line under the jurisdiction of the municipality in which they are located. Since that time there have been some modifications to the jurisdictions. Currently the State of Connecticut has jurisdiction over shellfishing in areas described in section 3294 of the general statutes, revision of 1918, while the remaining areas are under the jurisdiction of the municipalities in which they are located, with some exceptions defined by Sec. 26-257.

Shellfishing is regulated by DA/BA through leasing and licensing programs. Municipalities typically designate where shellfishing may occur, and regulate activities through permitting and licensing programs. Therefore, in addition to evaluating how specific shellfishing gears could affect eelgrass, it is important to examine how state and local licensing and permitting programs govern how various fishing gears can be used and whether these programs affect the conservation of eelgrass.

The Coastal Zone Management Act

The Connecticut Coastal Management Act (CMA, CGS Chapter 444, Sections 22a-90 to 22a-112) speaks directly to the issue of eelgrass conservation relative to shellfish management. The CMA establishes a single set of policies, standards and criteria to be used at all levels of government for evaluating activities that affect Connecticut's coastal zone. Eelgrass is specifically referenced in CGS 22a-92(c)(2) as a coastal resource to protect, but the statute also allows for agencies to consider its value relative to shellfish management.

> Policies concerning coastal land and other resources within the coastal boundary are: (A) To manage estuarine embayments so as to insure that coastal uses proceed in a manner that assures sustained biological productivity, the maintenance of healthy marine populations and the maintenance of essential patterns of circulation, drainage and basin configurations; *to protect, enhance and allow natural restoration of eelgrass flats except in special limited cases, notably*

> *shellfish management*, where the benefits accrued through alteration of the flat may outweigh the long-term benefits to marine biota, waterfowl, and commercial and recreational finfisheries" (emphasis added).

The CMA further defines unacceptable adverse impacts as "degrading or destroying essential wildlife, finfish or shellfish habitat through significant alteration of the composition, migration patterns, distribution or breeding or other population characteristics of the natural species or significant alteration of the natural components of the habitat" [CGS Sec. 22a-93(15)(G)]. Under this definition, activities damaging or eliminating eelgrass would be considered an adverse impact because of the ecological value of eelgrass. But in the case of shellfish management, the statute authorizes agencies to weigh the value of eelgrass versus using the area to grow and harvest shellfish, even though this might damage or eliminate eelgrass.

As discussed earlier in this report, eelgrass has disappeared from much of its historic distribution in LIS. The amount of eelgrass that currently exists in eastern LIS is probably much less than what existed historically. In addition, there is evidence that eelgrass continues to decline in many of the embayments of eastern LIS. Given the important ecological values of eelgrass, the remaining eelgrass should be protected to the greatest extent practicable. Therefore, at this time it is the opinion of the Report Workgroup that all levels of government should give due consideration to the protection of eelgrass. In particular, DA/BA and municipal shellfish commissions should interpret CGS Sec. 22a-92(c)(2)(A) to favor the protection of eelgrass when considering new leases, permits, and co-management agreements.

Despite the low abundance of eelgrass, the Report Workgroup acknowledges that there may be instances where shellfish management takes priority, such as in the management of naturally occurring shellfish beds and oyster seed beds. There also is the issue of what measures should be taken if eelgrass colonizes leased or permitted areas. This issue is discussed below.

State Shellfisheries Statutes Relevant to Eelgrass Conservation.

There are no statutes that protect eelgrass from shellfishing activities, either specifically or incidentally. However, as authorized by the CMA, the DA/BA could use the existing leasing and licensing program to manage eelgrass in concert with shellfish management.

Section 26-194 authorizes the Commissioner of Agriculture to lease grounds under the jurisdiction of the state to individuals or companies for the purpose of planting and cultivating shellfish. Sec. 26-194 further authorizes the DA/BA to issue leases " . . . under such regulations as he may prescribe . . . " To date, an assessment of how the issuance of leases affects eelgrass has not been part of the leasing process, but Sec. 26-194 provides a mechanism whereby the effects of shellfishing on eelgrass can be managed as appropriate.

Municipal Shellfish Commission Jurisdiction, Policies and Procedures

CGS Chapter 492, Local Shellfisheries, Sec. 26-257a enables municipalities to establish shellfish commissions to administer shellfisheries and shellfish grounds under their jurisdictions. Commissions are authorized to designate shellfishing areas, issue licenses, designate the quantities of harvest, and determine harvesting methods[20]. A municipality can lease shellfish grounds to commercial shellfishermen, or they can enter into a *cooperative management agreement*. The details of these agreements vary, but typically they benefit the municipality's shellfishing program either by stocking public shellfishing areas with some of the shellfish harvested by the commercial fishermen (the amount is usually specified in the agreement), or the municipality receives a portion of the revenue from the sale of shellfish. The towns also sell permits to individuals for harvest from their public shellfish areas.

Since the majority of eelgrass is east of the Connecticut River, shellfish commissions in Old Lyme, East Lyme, Waterford, Waterford-East Lyme, Groton and Stonington were contacted to discuss their overall policy regarding eelgrass conservation (Appendix III). Specific topics included regulations or ordinances relevant to eelgrass conservation, measures taken during the leasing and permitting process to evaluate the effects of shellfishing on eelgrass, and eelgrass monitoring and mapping programs[21].

All commissions expressed concern about eelgrass, but measures to ensure effective conservation varied among commissions. In general the level of protection varied with the level of shellfishing effort. For example the town of Old Lyme has not considered the effects of shellfishing on eelgrass, but the issue is moot because the town does not currently authorize commercial or recreational shellfishing. The Waterford-East Lyme and Stonington shellfish commissions both have well developed eelgrass protection measures. It should be noted, however, that even these commissions do not have formal review procedures defined within their permit review process. The status of eelgrass monitoring and mapping programs also varied, from no program at all to surveys conducted on an occasional basis. More detail of these discussions is provided in Appendix III.

It would be prudent for shellfish commissions to improve and formalize their eelgrass conservation measures. These measures could be included within their shellfish management plans. Sec. 26-257a Subsection (c) states: "The commission shall prepare and periodically update a shellfish management plan. The plan shall be submitted to the Commissioner of Agriculture and any appropriate board of selectmen, mayor or warden for review and comment." This statute sets up a formal process whereby the DA/BA can advise the commissions on various shellfishing issues. Each commission could use their plan, with the assistance of DA/BA and the DEP, to develop eelgrass conservation measures. It is important to note that *periodically* is not defined, and the statute does not specify that the plans must be approved by DA/BA.

Shellfish management plans could incorporate a flexible approach to eelgrass management through their shellfish area designation process and leasing and permitting programs. Essentially, these programs are a form of zoning for the specific purpose of defining where shellfishing may take place and how it will be conducted. Eelgrass can be protected by designating areas where shellfishing will not be allowed, or by only allowing activities that do not significantly damage

---

[20] There is an important jurisdictional distinction between *methods/gears* and *structures*. The commissions have sole jurisdiction over harvesting methods and gears such as hand tools and dredges, whereas aquaculture structures, such as cages and longlines, are under the jurisdiction of several agencies, including DA/BA, DEP and the commissions.

[21] Information was also obtained by CT DEP staff during the course of shellfish aquaculture permit reviews.

eelgrass. A balance should be reached that provides adequate areas for designated types of shellfishing and aquaculture while protecting existing eelgrass, and providing suitable habitat for eelgrass expansion and colonization. This would provide stability for the shellfishing industry, including the possibility of growth, while also ensuring that eelgrass is protected and adequate areas are set aside for expansion and colonization. Plans should include periodic surveys of eelgrass distribution and abundance. This information is necessary to monitor the effects of activities allowed by their leasing and permitting programs, and provide the information necessary to make adjustments to retain an appropriate balance between shellfishing and eelgrass protection.

The town of East Lyme Harbor Management/Shellfish Commission is currently considering the concept of using the Shellfish Management Plan to define eelgrass conservation measures. The Commission has acquired a municipal grant from the state of Connecticut to prepare a comprehensive Shellfish Lease Program. The grant is administered through the DEP OLISP municipal coastal program. The grant will be used, among other things, to revise the Shellfish Management Plan. The grant specifically mentions the need to balance the preservation and restoration of eelgrass with shellfishing activities (For additional information refer to Appendix III).

Municipal shellfisheries are also subject to statutory requirements. However, there are no statutes that specifically protect eelgrass. One statute incidentally confers some protection: section 26-288 only allows the taking of scallops with a scoop net, not more than sixteen inches wide, and operated manually. Since scallops are closely associated with eelgrass, this statute protects eelgrass from potentially more destructive harvesting gears, such as dredges.

Regulation of Shellfish Aquaculture Structures

Although most shellfish are cultivated and harvested directly on the sea bottom using various kinds of gears, the use of cage, bag and rack systems designed to contain the shellfish are gaining in popularity. Collectively, the CGS defines these systems as structures. Structures used for the purposes of aquaculture may be regulated by the DA (CGS Sec 22-11h), DEP OLISP (CGS 22a-359 through 22a-363) and the U.S. Army Corps of Engineers (ACOE) pursuant to Section 10 of the Rivers and Harbors Act of 1899. Municipal shellfish commissions also have a role in determining what structures can be used on municipal shellfishing areas through their permitting and co-management programs. Permitting requirements and jurisdictions depend on a number of factors, including whether the structures are to be placed on state shellfish leases, municipally designated shellfish areas, or on areas not leased by the state or municipalities. The DA and ACOE have implemented a joint permitting program for placement of aquaculture structures on state shellfish leases[22]. Municipal shellfish commission requirements vary, but generally involve issuing a lease, permit, or co-management agreement.

All aquaculture structures, regardless of where placed, might require from OLISP a "concurrence of consistency" with the CT Coastal Management Program pursuant to Section 307 of the Federal Coastal Zone Management Act. Such a review would be required if there were

[22] The permits are actually issued by the ACOE. The DA/BA assists the applicant with the ACOE application process. Proposals to use structures on municipal shellfish areas must also follow this process.

substantial concerns with the project, such as potential adverse environmental impact or conflict with existing water-dependent uses. An ACOE permit cannot be issued if OLISP issues an "objection" (i.e. finds the project is not consistent). In addition, OLISP has regulatory jurisdiction (i.e. a permit would be required from OLISP) in areas outside of municipal and state shellfishing areas, and may have jurisdiction within municipal and state shellfishing areas depending upon such factors as the type and location of the structures and potential impacts to coastal resources or navigation.

The ACOE and DEP OLISP routinely review applications for the use of aquaculture structures for effects on eelgrass. This is discussed in "Assessment of Impacts by Gear Type."

The Distribution of Eelgrass Relative to State and Municipal Shellfish Leases

At a fundamental level, in order for shellfishing to affect eelgrass it must exist in areas where shellfishing could take place. To provide an indication of how much overlap exists, and therefore the potential for shellfishing to occur in eelgrass, the 2002 USFWS eelgrass survey data were mapped with current shellfish leases issued by DA/BA for commercial shellfishing, natural shellfish beds, and municipal public and commercial shellfishing areas. The mapped municipal areas include waters classified as Approved or Conditionally Approved[23], co-management areas, and leased or permitted areas (there may be other areas where shellfishing currently occurs, but the Report Workgroup concluded they are a small fraction of the total area). It should be noted that shellfishing does not actually take place on the entire sea bottom within these areas. Shellfishing is either currently occurring in some portion of the areas or it could be authorized at some time in the future. Furthermore, portions of these areas may be unsuitable for shellfishing due to depth limitations and obstructions such as reefs or other sea bottom features.

As shown in Maps 5 and 6, a significant amount of eelgrass occurs in state shellfish leases and designated municipal shellfishing areas. A total of 55 percent of the eelgrass observed in the USFWS 2002 survey was within these areas, with 581 acres (47 percent) observed in municipal areas and 100 acres (8 percent) observed in state leases. In addition, municipalities have significant jurisdiction over shellfishing activities on much of the sea bottom in depths less than 15 ft. Much of this area is potential eelgrass habitat that could be colonized during periods of favorable environmental conditions, or if eelgrass restoration efforts were to succeed.

The implications of the overlap between existing eelgrass, potential eelgrass habitat and state and municipal designated shellfish areas relative to the types of shellfishing gears used in LIS are discussed below. However, there are two aspects that should be mentioned at this point. First, a considerable amount of the existing eelgrass in LIS and potential eelgrass habitat is within areas where municipalities are responsible for the management of shellfishing gear and practices. Therefore, the municipalities have a very important role to play – as well as a responsibility as set forth in the CMA – in the state's efforts to protect and conserve eelgrass.

[23] Approved and Conditionally Approved areas are two of the seven shellfish classification areas assigned by DA/BA. They are based on National Shellfish Sanitation Program Model Ordinance criteria designed to minimize human health. Contact DA/BA for more information.

Second, it is well known that the distribution and abundance of eelgrass changes from year to year, and even within a year. Shellfishermen and municipal shellfish commission members, who are keenly aware of this aspect of eelgrass ecology, have expressed concern over the adoption of regulations and permit conditions that would prohibit commercial shellfishermen from using aquaculture structures in eelgrass, or prohibit using gears such as dredges either in eelgrass or within a certain distance from eelgrass[24]. Should eelgrass meadows expand into or colonize an actively worked lease, the regulations or permit conditions could prevent them from continuing their shellfishing operations. This issue needs to be taken into account when formulating regulations, designating shellfishing areas, or issuing shellfishing permits and leases.

Assessment of Impacts by Gear Type

Oyster Dredge

Oyster dredges are used for the cultivation and harvest of market oysters on private, state, and municipally designated grounds. The dredge is a rigid, rectangular metal frame that is rigged with a short bag fashioned of chain links and netting. The average size is 50 in. wide at the opening, 24 in. high and 24 in. deep with a capacity of 10 to 12 bushels. The dredge is towed by a cable or chain from a boat in a circular pattern for 1 to 3 minutes, and then hauled to the surface by means of a winch and boom where the contents are emptied on a culling table on the deck. Dredges also have a rectangular shaped baffle or "cutting board" of plywood or sheet metal positioned above the opening of the dredge to exert downward pressure as the dredge is towed. This helps maintain contact with the bottom and steady the dredge, thus increasing its efficiency. The "catching portion" of the dredge is a flat or toothed bar of hardened steel attached along the bottom opening. As the dredge is towed the bar moves under the oysters, lifting them off the bottom and into the chain bag.

Oyster Dredging Activity in Eastern LIS

The extent to which oyster dredges are used in eastern LIS is not known, but it is likely infrequent. In 2000, only 501 bushels of oysters were landed in eastern Connecticut. Furthermore, the majority of these oysters was probably either grown in shellfish cages or was transferred to cages for depuration.

Effects of Oyster Dredges on Eelgrass

The ASMFC gear report did not cite any studies on the impact of oyster dredging on eelgrass. One study was cited that evaluated scallop dredging in eelgrass beds (Fonseca et. al. 1984). It was reported that a greater loss of vegetation occurred in eelgrass beds growing in soft mud

[24] Connecticut Aquaculture Permitting Process Workshop, 11/7/2002 and Eelgrass Survey Workshop June 2, 2003, sponsored by CT Sea Grant. These workshops were attended by DA/BA and DEP staff. The proceedings are not published, but additional information is available from Tessa S. Getchis, Aquaculture Extension Educator, UCONN Avery Point campus.

substrate than hard sand. The study also found that increased dredging (measured by the number of tows) resulted in a significant reduction in vegetation biomass and number of shoots.

More recently the effects of harvesting blue mussels with dredges similar to an oyster dredge were evaluated in Maquoit Bay, Maine (Neckles et al. 2005). Maquoit Bay has an extensive eelgrass meadow of about 1,300 acres, or about half the bottom of the bay. Harvesting occurred throughout the 1990s. The dredge completely removed the plants, including the rhizomes. Aerial photos taken in 2000 showed that about 10 percent of the eelgrass had been disturbed. Scars ranged from 8 to 79 acres in size. Assuming favorable water quality conditions, it was estimated that it would take an average of eleven years for eelgrass to recolonize the scars to a level of 95 percent of the original, undisturbed condition.

Based on the Maquoit Bay study, this type of dredge can cause severe levels of all types of damage reported by the ASFMC gear impact report, i.e. leaf shearing, seed and flower shearing, uprooting, below seabed impacts, burial and cumulative effects.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Although studies of similar types of dredges indicate that oyster dredges could significantly damage eelgrass, there currently appears to be minimal dredging for mature oysters occurring in eastern LIS. At present, virtually all oyster culture in eastern LIS is based on hatchery production. The seed oysters are produced in a hatchery and transplanted to seed oyster beds in shallow estuarine areas. The oysters are raised in these beds and then transplanted to cages for depuration or additional growth in leased areas. If in the future fishermen express an interest to use an oyster dredge, then it would be prudent to evaluate the proposal for potential effects on eelgrass.

Seed Oyster Dredge

The seed oyster dredge is a scaled down version of the larger oyster dredges used for market oysters. The weight and capacity of the seed dredge is limited by state statute (CGS 26-257a(b)) to no more than 30 lb exclusive of the chain bag, or a 1½-bushel capacity. It generally measures 24 in. to 30 in. in width, 8 in. high and 30 in. long.

Seed Oyster Dredging Activity in Eastern LIS

Local shellfish commissions designate seed oyster beds and license seed oyster culture. They also specify the methods used to cultivate and harvest oysters, and the size and quantities of oysters harvested.

The source of oyster seed is primarily from hatchery production. Once they reach a certain size, they are transplanted to the seed beds. The seed beds are continually worked with seed dredges throughout the year, with the exception of the colder months of winter.

Oyster seed beds are located in designated municipal shellfishing areas in the Mystic River, Baker Cove, Poquonock River, Mumford Cove and Little Narragansett Bay. They are typically located on hard bottom in the shallower waters of these embayments and river mouths. In these locations they are sheltered from storms and strong wave action. The water tends to be warmer and has abundant food (e.g. plankton), which produces faster growth. Once the oysters reach a certain size, they are harvested with the seed dredge and transferred either to certified oyster beds or, more typically in eastern LIS, to shellfish cages for additional growth or depuration.

Effects of Oyster Seed Dredges on Eelgrass

In Connecticut, the seed dredge is generally configured and worked to make light contact with the sea bottom in order to skim off the oysters and not dig into the bottom. Given the size and design of the dredge, if towed in eelgrass the dredge would likely cause flower and leaf shearing. The ASMFC gear impact report did not discuss the effects of oyster seed dredges.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

In general, oyster seed beds and eelgrass meadows are mutually exclusive. An eelgrass meadow is not a good habitat for oysters, and it would not be practical to manipulate the oysters with a seed dredge or other methods. However, some seed beds in eastern LIS are located adjacent to eelgrass meadows. While there is no direct impact to the existing meadow, they may be prevented from expanding if shellfishermen work the seed dredges close to the meadows to maintain the area occupied by their seed beds. The extent to which this may occur in eastern LIS is unknown.

As part of the evaluation of oyster seed dredges, the Report Workgroup invited two shellfishermen from the Noank Aquaculture Cooperative (Jim Markow and Steve Plant), and two recreational fishermen (Ed Mitchell, a free lance outdoor writer, and Ron Whitely, President of the CT/RI Coastal Flyfishers) who were concerned that shellfish dredges were being used in eelgrass meadows in the waters of the town of Groton. The shellfishermen described current shellfishing operations in eastern LIS. In particular they explained how seed oysters are grown in a hatchery in Noank and then transplanted to seed beds. It became clear to Mr. Whitely and Mr. Mitchell that these seed beds, which are the only areas worked with a dredge, are not located in eelgrass meadows.

Hydraulic Clam Dredge

The typical hydraulic clam dredge is a sled-like rectangular steel cage measuring 4 ft to 5 ft long and 2.5 ft wide. It is fitted with an adjustable flat or toothed catching bar about 2 ft wide at the opening, with a water jet manifold mounted ahead of the bar. As the dredge is towed across the bottom, the water jets hydrate, or fluidize, the bottom sediments, loosening the bottom and the clams that live in the sediment. As the dredge is towed, clams pass over the cutting blade and are deposited in the basket portion. The catching bar can be adjusted from 1 in. to 6 in. below the dredge that slides or rides smoothly across the bottom. The duration of the tow is usually very short (3 to 6 minutes), and will vary from area to area depending on the density of clams. The dredge is hoisted aboard the vessel by winch and boom where the catch is deposited on a culling table. The capacity of the clam dredge ranges from 5 to 10 bushels of clams.

Hydraulic Clam Dredge Activity in Eastern LIS

In 2000, a total of 4 companies with eight vessels harvested 11,044 bushels of hard clams and landed them in New London County. More recently, eastern LIS shellfishermen have indicated that only one company has been actively engaged in hydraulic dredging for clams, but several others have the gear and could become active in the future.

Hydraulic clam dredging can occur year round. A clam bed is generally worked until the effort expended becomes uneconomical, or when additional harvest would not leave enough clams to repopulate the shellfish bed. Generally a clam bed is worked for one year and left fallow for a year or two before being brought back into production.

Effects of Hydraulic Clam Dredges on Eelgrass

The ASMFC gear impact report cited a number of studies documenting the destructive effects of hydraulic dredges on SAV. Stevenson and Confer (1978) reported that when hydraulic clam dredging occurs in SAV meadows it digs up all vegetation in a swath the width of the dredge. Clam dredging can also significantly increase local turbidity (Ruffen 1995), which may affect the growth and survival of plants near the areas dredged. The ASMFC gear impact report made several references to eelgrass damage in the coastal bays of Delmarva Peninsula in Maryland and Virginia, where commercially valuable densities of clams may be found in eelgrass (Moore and Orth 1997; Orth 1999). Both hydraulic dredges and modified oyster dredges were used to harvest hard clams (*Mercenaria mercenaria*). Intensive harvesting evidently started in 1995, and severe damage was first reported in 1997.

A more recent study was conducted in Maryland and Virginia to assess the damage caused by clam dredging (Orth et al. 2002). In Maryland's coastal bays, the cumulative damage up to the year 1999 was estimated. A total of 1,217 ha, or 31 percent of Maryland's eelgrass, were scarred by dredging (a scar was defined as an area within an eelgrass meadow that was either completely denuded by dredging or sparsely vegetated). In Virginia's coastal bays, where the modified oyster dredge was used, cumulative damage was estimated up to the year 1997: a total of 123 ha were scarred, or 6.3 percent of eelgrass in the bays.

The rate of revegetation was also investigated for the scars created by the modified oyster dredge. The authors estimated that they take at least three years to recover, and possibly much longer for the large scars.

Based on these reports, hydraulic clam dredges can cause severe levels of all types of damage reported by the ASFMC gear impact report, i.e. leaf shearing, seed and flower shearing, uprooting, below seabed impacts, burial and cumulative effects.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Although hydraulic clam dredges have been shown to cause significant damage in the coastal bays of Virginia and Maryland, damage at such levels in eastern LIS appears unlikely. Most commercial clam operations on state leases apparently occur in depths greater than 15 ft, which is deeper than where eelgrass typically grows. In municipal shellfishing areas, shellfish commissions are unlikely to knowingly permit dredging in eelgrass, but it should be noted that not all commissions review leases for the presence of eelgrass.

While damage is probably not extensive, some level of damage is possible. Existing state and municipal areas should be more closely evaluated for overlap between eelgrass habitat and shellfishing. Other potential impacts are: continually working areas adjacent to eelgrass meadows can prevent the natural expansion of meadows by destroying expanding rhizomes and emergent plants; sedimentation from clam dredging could negatively affect eelgrass by reducing light penetration and by smothering nearby plants; and an expansion of the clam fishery could occupy potential eelgrass habitat that is valuable for restoration efforts.

Hand Harvest Implements

A variety of hand-held implements – rakes, forks, hoes and shovels – are used to harvest shellfish commercially and recreationally. They are used in the intertidal zone and shallow areas along the coast.

Hand harvest implements may vary in design according to preference, but in general they are short-handled, fork-like implements with four to six flat or round tines. Shovels are generally of the garden spade variety. Scratch rakes (basket rakes) are used in relatively shallow water where the bottom can be worked by wading or from a small boat. These rakes are similar in design to a garden rake with a basket attached behind the head. The teeth are worked through the bottom toward the digger and the dislodged clams or oysters are collected in the basket portion of the rake. The rake is then retrieved in a vertical fashion.

Tongs are another method of harvest. They are operated by hand from a boat and consist of two wooden handles joined together in a scissors-like fashion, with opposing heads consisting of a wire frame and teeth that form a basket.

The bull rake is another type of gear primarily used for harvesting clams. It is similar in design to the scratch rake; however, the bull rake is larger and heavier. The rake basket may be up to 3 ft or 4 ft wide and is primarily used in soft mud or sand bottom. It is fitted with a detachable handle that may consist of several sections depending on the water depth. The maximum working depth – generally 20 ft or less – is determined by the abundance of shellfish, bottom type, tidal velocity, and the strength and skill of the harvester.

Hand Harvest in Eastern LIS

Recreational shellfishers most commonly use hand implements. The most commonly used implements are rakes, forks, hoes and shovels. Most of the recreational shellfishing activity occurs during the summer, but some shellfishing continues throughout the year. Virtually all hand harvest activity occurs in municipal leased and public shellfish beds. There are numerous public recreational shellfish areas in the Niantic River, Poquonock River, Mumford Cove to West Cove, Groton Long Point, near Masons Island and Andrews Island, and various areas in

Stonington. Compared to recreational shellfishing, commercial shellfishing using hand implements is a minor activity at this time. One or two part-time commercial shellfishermen harvest clams for sale by hand harvest.

Effects of Hand Harvest on Eelgrass

The ASMFC gear impact report cited only one study that was limited to the impact of bull rakes and pea diggers (a four-tined hand rake). The configuration of these gears was not provided (the report notes that some bull rakes may be pulled by a vessel, and therefore would not be considered a hand implement in that case). The bull rake removed 80 percent of shoots and rhizomes in a completely raked area, and the pea digger removed 55 percent of shoots and 37 percent of rhizomes. The impacts of other hand implements were not discussed.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Hoes, forks and shovels are generally used in the intertidal zone where eelgrass does not occur. Small hand rakes, scratch rakes, bullrakes and tongs are utilized in shallow, subtidal water where eelgrass can occur. The extent to which these implements are used in eelgrass is unknown. Given the number of individuals involved, some damage to eelgrass is possible. The locations of recreational fishing relative to eelgrass meadows should be more closely examined.

Conch Pots

Conch pots used specifically for taking conch (a large marine snail, *Busycon sp.*) resemble lobster traps, except that the top of the pot is open. The pots vary in size and shape, but they are generally square and constructed of wood, without entry portals in the sides. Pots are fished as single units with a separate buoy line, or several pots can be attached to one long line. The pots are usually set on sand or mud bottom.

Conch Fishing Activity in LIS

Conch is harvested both recreationally and commercially. Any person who takes more than one-half bushel of conch per day is required to obtain a license. Thirty-four commercial licenses for the taking of conch were issued by DA/BA in 2000. It is unknown how many people fish for conch recreationally.

Conch fishing can occur in river mouths, harbors, coves, and in the open waters of LIS. Most conch fishing activity appears to occur in the spring when the conch move inshore, with the remainder of fishing occurring primarily in fall. Pots are generally set for three days to one week.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

The ASMFC gear impact report did not cite any studies regarding the impact of lobster or fish pots on eelgrass. It is possible that setting conch pots on eelgrass and the process of retrieval would cause leaf shearing, uprooting, damage to meristems, smothering and light attenuation.

However, due to the small number of conch fishers and their practice of setting pots individually (as opposed to setting them in strings), damage to eelgrass should be minimal.

Scallop Scoop Net

Bay scallops are typically harvested recreationally by utilizing a scoop net and "looking box." Scoop nets are constructed of a wire hoop or ring with a nylon net that is secured to the end of a long handle. Municipal Shellfish Commissions generally restrict the diameter of the scoop net, with a maximum of 8 in. a common restriction. Also, some commissions prohibit dragging the net across the bottom; the scallops must be spotted and then dipped or scooped. Municipalities establish an open season for scoop netting bay scallops, generally opening in October and extend for two to three months.

Scallop Scoop Net Fishing Activity in Eastern LIS

Scoop netting for bay scallops is conducted in areas under the jurisdiction of municipalities. Since eelgrass is a preferred bay scallop habitat, scallop scoop netting certainly occurs in eelgrass meadows.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Scoop netting for bay scallops has been carried out for many decades without apparent harm to eelgrass. The restrictions imposed by the municipal shellfish commissions (e.g. prohibition on dragging a scoop net and limiting the size of the net) serve to minimize damage to eelgrass. Limiting the number of permits also serves to minimize damage.

Shellfish Aquaculture Structures

Aquaculture structures provide an alternative to the traditional practice of planting, cultivating and harvesting shellfish directly on the sea floor. Structures vary considerably in design. They are usually composed of containers that hold shellfish during culture, growth, depuration or conditioning. The containers can be placed on the bottom, float on the surface, or can be suspended in the water column at various depths. On-bottom rearing devices include mesh bags, cages and trays. Off-bottom floating structures may consist of rafts, barrels, tanks, silos, cages, nets, bags or trays suspended by buoys or other flotation devices.

Shellfish Aquaculture Activity in Eastern LIS

In eastern LIS, 8 companies submitted aquaculture applications in 2001 and 2002 and received permits to deploy aquaculture structures. The applications ranged in size from 30 containers (shellfish grow-out cages) to 56,580 containers of various types, including cages, bags, and lantern nets. Current permits allow for the deployment of 6,913 cages and bags on the sea bottom, 440 floating culture structures, 165 longlines with suspended lantern nets, and five upwellers (two motorized, three attached to docks)[25]. The structures could be deployed in water

[25] Source: CT PGP No. 41 permits issued by the ACOE, New England District, Concord, MA. The information in these permits was summarized by DEP Inland Fisheries Division HCE staff.

depths ranging from -1 ft to -30 ft MLW. If all of the permitted structures were deployed (cages, bags and floating arrays, but not including longlines and upwellers), it would occupy or shade approximately fifteen acres of sea bottom.

Impact of Shellfish Aquaculture Structures

The ASMFC gear impact report (2000) identified a number of potential impacts that aquaculture structures can have on eelgrass. These include: shading, direct displacement, current changes, increased nutrients in the vicinity of the structures, and exclusion of fish from eelgrass within enclosures.

The types of structures used in eastern LIS could damage eelgrass in any of the six ways identified in the ASMFC gear impact report. Shellfish cages placed on eelgrass and the process of retrieval could cause leaf shearing, uprooting, damage to meristems, smothering and light attenuation. The amount of damage would depend on the purpose of the cages (e.g. for depuration or growing), method of deployment, structure density, and how frequently they are hauled and re-deployed. Floating grow-out structures and upwellers, if placed over eelgrass meadows, could reduce the amount of light reaching the eelgrass, causing poor growth and even killing the plants. The deposition of pseudofeces from shellfish could increase nutrient availability under and near the structures. This could render the habitat unsuitable for eelgrass growth, or cause an increase of algae that could out-compete eelgrass for light and growing space.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

To date, the amount of aquaculture structures deployed in eastern LIS is small, but this will increase as newly permitted structures are deployed and additional permits are issued. Given that the gear has the potential to have significant adverse impact, it is important that the appropriate precautions be taken.

As discussed previously, the DA/BA, DEP, ACOE and municipal shellfish commissions have various roles in the regulation of aquaculture structures. During the review of permits, the DEP, DA and the ACOE recognized the potential impact that aquaculture structures may have on eelgrass, particularly if the amount of structures continues to increase. The agencies have been developing common guidelines for protecting eelgrass, and as of this writing they have agreed that no type of shellfish aquaculture structure should be placed in or above existing eelgrass. If an applicant proposes to deploy structures in potential eelgrass habitat, an eelgrass survey has been required. The siting of aquaculture structures has been denied in cases where a survey documented the presence of significant amounts of eelgrass in a proposed deployment location. At this time, however, the guidelines that define what constitutes a *significant* amount of eelgrass relative to the type and amount of structures being deployed are not well defined.

The permitting guidelines for eelgrass protection continue to evolve. Permitting agencies recognize that the impact of aquaculture structures varies depending upon a number of factors, not least of which is the size of an operation – the use of ten shellfish cages used for depuration would have negligible impact whereas hundreds of structures used for growing shellfish could have significant impact. Over the last few years a complete prohibition on the placement of shellfish aquaculture structures in eelgrass has been appropriate due to the uncertainty of cumulative effects, particularly if individual companies and the industry as a whole continue to grow. In the future it may be possible to allow the placement of certain types of structures in eelgrass if it can be shown that they will not have significant impact[26]. A well-developed Shellfish Management Plan that balanced shellfishing with eelgrass conservation would help address these issues.

Conclusions

- A significant portion of the eelgrass observed in 2002 was within waters under the jurisdiction of municipalities. In addition, a significant portion of potential eelgrass habitat is within their jurisdictions.
- Municipalities regulate the methods used to harvest shellfish in the waters under their jurisdiction.
- A small percentage of existing eelgrass is within existing shellfish leases issued by the state of Connecticut.
- At this time recreational and commercial shellfishing has minimal effect on existing eelgrass in eastern LIS.
- Damage to eelgrass caused by recreational and commercial shellfishing could increase in the future because the distribution and abundance of eelgrass varies annually. In addition, future restoration efforts may restore eelgrass to areas where eelgrass occurred historically.
- Although shellfishing activities currently do not cause significant damage to eelgrass, it would be useful to characterize and quantify impact as part of a comprehensive field survey designed to quantify the impact caused by the various factors identified in this report.
- The current state shellfish leasing process can be improved by incorporating eelgrass conservation and protection measures.
- Municipalities, which have a very important role in protecting eelgrass, can improve their permitting and leasing programs by adopting measures to conserve eelgrass.
- The aquaculture permitting process has been adequate to protect eelgrass. However, permitting agencies have not yet developed guidelines that address how eelgrass meadow characteristics (e.g. plant density, patchiness) should be used to determine whether a specific aquaculture proposal should be approved, denied, or modified.
- Permit requirements that prohibit deploying aquaculture structures in eelgrass or prohibit using gear such as dredges within a certain distance from eelgrass may create a dilemma for commercial shellfishermen and regulators. Should eelgrass meadows expand into or colonize

[26] As of this writing, the CT Sea Grant Extension Program at the University of CT, Avery Point, has initiated a study that will assess the effects of shellfish cages on eelgrass. The direct affects of shellfish cages on eelgrass will be assessed during the 2006 growing season. It is hoped this study will provide information that regulatory agencies and shellfish commissions can use to assess whether the placement of cages in eelgrass should be restricted. Contact Tessa S. Getchis, Aquaculture Extension Specialist, for further information.

an actively worked lease, the regulations would prevent them from continuing their shellfishing operations. This issue needs to be addressed.

Recommendations

- Although the amount of activity within eelgrass located in state shellfish leases appears to minimal at this time, the following should be determined: the actual extent to which shellfishing occurs within eelgrass, the types of gear and aquaculture structures used, potential damage, and measures required to protect eelgrass within the leases.
- Although the amount of shellfishing activity within eelgrass located in municipal shellfish areas appears to be minimal at this time, the following should be determined: the extent to which shellfishing occurs within eelgrass, the types of aquaculture structures used, potential damage, and measures required to protect eelgrass within the leases.
- Due to the disappearance of eelgrass from much of its historical distribution, the DA/BA should interpret CGS Sec. 22a-92(c)(2)(A) to favor protection of existing eelgrass meadows when reviewing new shellfish lease applications.
- Due to the disappearance of eelgrass from much of its historical distribution, municipalities should interpret CGS Sec. 22a-92(c)(2)(A) to favor the protection of eelgrass when considering new leases, permits, and co-management agreements.
- Permitting agencies should evaluate how the density, or quantity, of aquaculture structures affects eelgrass meadows exhibiting a range of characteristics. This information can then be used in the permitting process to determine how best to regulate the types and density of structures relative to the characteristics of an eelgrass meadow.
- The DA/BA should develop procedures, and regulations as needed, for evaluating new lease applications and lease renewals for effects on eelgrass.
- The DA/BA should evaluate the current shellfish leasing and permitting programs as a basis for providing long-term protection of eelgrass. A balance should be reached that provides adequate areas for designated types of shellfishing and aquaculture while protecting existing eelgrass and providing suitable habitat for eelgrass expansion and colonization. A useful tool for assessment would be to determine the area currently used by each type of shellfishing activity relative to the amount of eelgrass. Such an approach would provide stability for the shellfishing industry, including the possibility of growth, while also ensuring that eelgrass is protected and suitable area is set aside for expansion and colonization.
- The DA/BA should work with shellfish commissions to incorporate an eelgrass conservation plan into the shellfish management plans that are required to be submitted periodically to the DA/BA for review and comment [CGS Sec. 26-257a(c)]. The DEP should assist with plan development. Plans could incorporate the following features:
  - Plans could incorporate a flexible approach to eelgrass protection through their shellfish area designation process and leasing and permitting programs. Essentially, these programs are a form of zoning for the specific purpose of defining where shellfishing may take place and how it will be conducted. Eelgrass can be protected

by designating areas where shellfishing will not be allowed, or by only allowing activities that do not significantly damage eelgrass.

- A balance should be reached that provides adequate areas for designated types of shellfishing and aquaculture while protecting existing eelgrass and providing suitable habitat for eelgrass expansion and colonization. This would provide stability for the shellfishing industry, including the possibility of growth, while also ensuring that eelgrass is protected and suitable area is set aside for expansion and colonization.
- Plans could include periodic assessments of eelgrass in order to monitor the effects of activities allowed by their leasing and permitting programs and make appropriate adjustments.

Other Factors affecting the Abundance and Distribution of Eelgrass

Reasons for Inclusion in this Report

Public Act 01-115 directed the DA and DEP to evaluate the impact of commercial and recreational finfishing and shellfishing on eelgrass in LIS. However, a review of the literature and personal observations of DEP and DA staff indicated that there are other factors that can have significant impacts on the occurrence and abundance of eelgrass, including climate, water quality (primarily nitrogen enrichment), disease, recreational boating, anchoring, mooring of boats, docks and the feeding behavior of waterfowl. These factors could have far greater impacts to eelgrass in Connecticut's waters than recreational and commercial fishing. In particular, of the human related factors, nitrogen loading to coastal waters has been identified as a major reason for worldwide losses of seagrasses (e.g. Short and Wyllie-Echeverria 1996). Other U.S. coastal states have come to a similar conclusion. For example, the state of Florida, after a comprehensive evaluation the effects of fishing gear and boating on seagrasses in their coastal waters, concluded: "It should be noted, that in Florida, the threats to SAV habitats from fishing gear (and even prop scarring by vessels) is minor compared to the widespread threats associated with degrading water quality. Nutrient enrichment, development and associated water quality and clarity degradation are by far the largest threats to SAV habitat in Florida*"* (ASMFC 2002).

For these reasons, the Report Workgroup decided that other factors that can affect eelgrass should be evaluated. With this information, the various factors that have affected eelgrass in LIS over the last century, and the degree to which these factors threaten the remaining eelgrass in eastern LIS, can be placed in perspective.

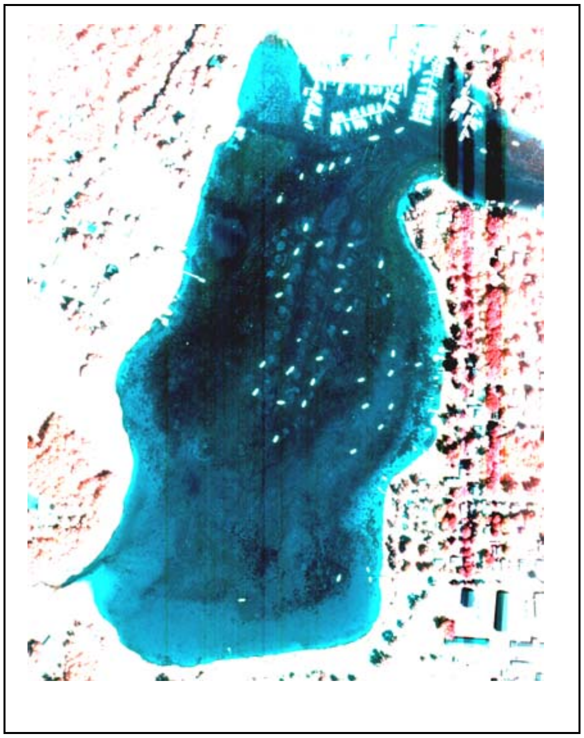
Factors That Have Localized Effects on Eelgrass

Recreational boating, mooring fields, anchorage fields, dredging and waterfowl feeding may have impacts similar to the potential impacts of fishing gear in that they may damage or deplete eelgrass in localized areas by mostly mechanical means. Each of these is discussed in the following sections.

Boat Moorings and Anchorages

Effects on Eelgrass

Boats are moored in municipally designated mooring fields, private mooring fields (e.g. marinas), and on private moorings deployed by individuals. Municipalities and private marinas also designate anchorage areas for use by transient recreational and commercial boaters.



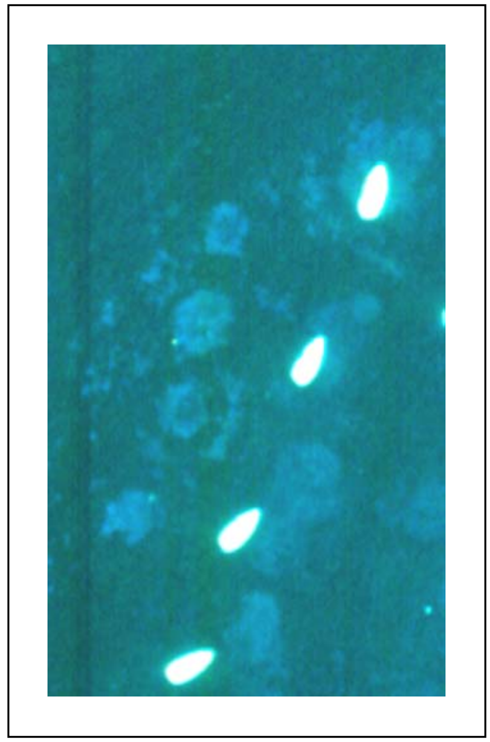


Figure 4. Mooring field in Smith Cove, Niantic River (left), and a closer view showing mooring ring scars (right).
DEP file photos, 1974.

A typical mooring is composed of a metal mushroom anchor, a mooring buoy and a length of chain attached to the anchor and mooring buoy. The length and weight of the chain must accommodate changes in water levels due to tides or river flow, which often means that some part of the chain is lying on the sea bottom. One or two moorings are used to moor a vessel. In cases where only one mooring is used, the bow of the boat is secured to the chain by a rope line. With this arrangement, the boat can rise and fall with the tide and swing with the current around the mooring. In some cases, such as in constrained areas, the stern of the vessel is secured to a second mooring to prevent the boat from swinging with the current.

If a mooring is located within an eelgrass meadow, the chain can damage plants in numerous ways, ranging from leaf shearing to below ground impacts. In cases where a single mooring is used, the mooring chain is dragged across the bottom repeatedly with each tidal cycle and changes in wind direction. With repeated scouring the chain completely denudes a circular area defined by the length of the chain and angle of sweep. A boat that swings 360 degrees around the mooring will form a circular "mooring ring scar" in the eelgrass meadow (see Figure 4). Damage to eelgrass may also occur in anchorages. Setting and retrieving anchors in eelgrass meadows can dislodge and damage eelgrass leaves and rhizomes.

The type and extent of damage that moorings can cause has been extensively studied in Australia, which has a number of seagrass species (see Hastings et al. 1995). A regional study in the Perth metropolitan area found that boat moorings were responsible for the loss of less than 2 percent of the total seagrass in the region. Since it was noted that effects vary at the local level, a study was conducted of two areas in the region where more extensive damage had been reported: Rocky Bay and Thompson Bay (Hastings et al. 1995).

In Thompson Bay, the estimated loss of seagrass from 1941 to 1992 was less than 5 percent as a direct result of the moorings, although fragmentation of the seagrass meadow was pronounced near heavily used areas, and it was uncertain if these scars were continuing to expand. In Rocky Bay it was estimated that 18 percent of the seagrass meadow was eliminated during the same period. Most of the loss (13 percent) occurred after 1981, coinciding with a doubling in the number of moorings and increased boat traffic and size. Some scars expanded and coalesced with other scars to form larger bare patches, increasing the damage beyond just the immediate damage caused by the mooring chain. As a result, areas of the seagrass meadow became fragmented. The authors identified a number of factors that affect the extent of damage, including the position of the mooring field relative to the prevailing swell, whether sediment deposition or erosion takes place (a function of local currents and sediment grain sizes), and the growth rates of the affected species of seagrass. It was suggested that the loss of seagrass in Rocky Bay was due to swell and current conditions that favored expansion of the mooring scars.

Given the ecological values of seagrasses in Australian waters, the authors concluded that in both of these local cases the loss of seagrasses represented a significant reduction of habitat. In Rocky Bay in particular the authors found the increasing trend of seagrass loss to be "alarming." Management approaches were suggested, such as reducing the number of moorings in Rocky Bay and using an "environmentally friendly" mooring design. However, at the regional level, the authors noted that moorings represented a minor problem relative to eutrophication[27]. For example, in the Cockburn Sound region of the Perth metropolitan area, eutrophication was associated with the loss of 78 percent of the seagrasses from 1954 to 1978.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

In eastern LIS, mooring fields and anchorages are typically located in areas where eelgrass can grow. In addition, most boating takes place during the summer and fall, the primary growing season for eelgrass. While the current extent of damage to eelgrass is unknown, photographs taken in 1974 of a mooring field in Smith Cove, Niantic River show that some level of damage is possible (Figure 4). However, the studies conducted in Australia demonstrate that the extent and significance of damage is contingent upon a number of factors and needs to be assessed on a case-by-case basis.

---

[27] *Eutrophication* is an increase in the rate of organic matter supplied to a system. The organic matter could be coming from production within the system, such as from the growth of algae, or from land sources. Eutrophication may be caused by a variety of factors, but most often by an increase in the nutrient supply. The authors did not mention if nitrogen enrichment was the underlying reason for the eutrophication of Cockburn Sound.

Potential impact of new moorings, mooring fields and anchorages

New private moorings, mooring fields and anchorages require a Structures, Dredging and Fill Permit from DEP OLISP pursuant to CGS Sec. 22a-361. This provides a mechanism by which DEP can assess and minimize the impacts of such designations on eelgrass. Applicants are required to conduct surveys of the sea bottom in the proposed location, which would include the presence or absence of eelgrass, as well as other species of SAV. During the permit review process, environmental impacts would be assessed and minimized to the greatest extent possible. Various options would be explored, such as alternative locations and alternative boating access options.

One option that should be explored to minimize impacts is mooring systems that have a smaller footprint and keep the tackle off the bottom. In place of a mushroom anchor, a helical anchor can be used. A helical anchor is a shaft that is screwed into the sea bottom and, unlike mushroom anchors that are often removed after each season for inspection, remains in place year-round. Instead of a length of chain, which causes the most damage, an elastic rode that stretches like a bungee cord can be attached to the anchor. The length of the rode is short enough to stay off-bottom during low water conditions but can stretch to accommodate an increase in water level. These types of mooring systems have not been commonly used in LIS, but due to its minimal environmental impact its use should be encouraged.

Another means by which DEP can implement measures to protect eelgrass is through the review and approval of harbor management plans. CGS Chapter 444a enables municipalities to establish a harbor management commission (Sec. 22a-113k). In consultation with DEP and the Dept. of Transportation, the commission can develop a harbor management plan (HMP), with the final plan submitted for DEP and DOT approval (Sec. 22a-113m). Modifications of the plan must be approved by DEP and DOT, and plans must be submitted annually for DEP and DOT review (Sec. 22a-113m). One factor that must be considered in the HMP is the "conservation of natural resources" (Sec. 22a-113o).

Using HMPs, DEP and the municipalities can minimize the effects of mooring and anchorages in a variety of ways. For example, as illustrated in the DEP's model harbor management plan, mooring specifications may be specified in HMPs (CT DEP 1985). Using such a model, the HMP could specify less damaging, off-bottom mooring tackle under defined circumstances.

Potential impact of existing mooring fields and anchorage areas

There are a considerable number of existing private moorings and mooring fields in eastern LIS. In addition, many of the municipalities have an approved Harbor Management Plan, which defines the locations of mooring fields and anchorages in waters under their jurisdictions. As of this writing, Old Lyme, East Lyme, Waterford, Noank in the Town of Groton, and the Mystic River in the town of Stonington have state and municipally approved HMPs. Groton City, the Pawcatuck River in Stonington and the Town of Groton have HMPs in the planning stages (as of this writing the Pawcatuck River HMP has state approval and municipal approval is pending).

The distribution of eelgrass determined by the 2002 USFWS survey overlaps to some extent with existing mooring fields and anchorage areas (Maps 7 and 8). A total of 82 acres (7 percent) of the 1,235 acres observed in 2002 overlap with the current mooring and anchoring areas (Table 4).

Obviously, all eelgrass in mooring areas is not vulnerable to anchor chain scouring since moorings are spaced to avoid collision of moored vessels and to allow vessels to navigate the mooring field. A typical mooring field and the extent of damage to eelgrass is shown in Figure 4. The total area impacted by moorings would be a function of the area scoured by each mooring chain and the number of moorings. The damage caused by anchoring would depend on the size of the anchor and frequency with which boats are anchored. However, as demonstrated by the Australian studies, damage can extend beyond the moorings themselves.

Given the amount of eelgrass within existing, approved mooring and anchorage areas, the amount of damage should be evaluated and its significance assessed. If the damage is ecologically significant, then measures should be explored to minimize damage. It should be noted that permits for moorings are granted in perpetuity. Regulatory procedures do exist to address significant problems that might arise with approved structures, but the significance of the problem would have to be well documented to initiate a review.

Similarly, mooring fields and anchorage areas specified in approved HMPs are permanently designated unless a harbor management commission chooses to modify the plan. In such a case, the modification must be submitted to OLISP for review and approval. In addition, applications for moorings placed in these designated areas are covered under a state Harbor Mooring General Permit. Effectively, a permit from OLISP is not required for each new mooring, but a permit must be obtained from the harbormaster and it must be consistent with the HMP (Sec. 22a-113r). Therefore, any measures to protect eelgrass, such as mooring standards, must be specified within the HMP.

If a field survey demonstrated significant ecological impact to eelgrass, there are a number of options for minimizing impact. During the HMP annual review, the DEP can work with the municipalities to modify the HMP to incorporate measures to protect eelgrass, such as the use of off-bottom mooring tackle[28]. Also, as with private moorings, a permit (in this case, the Harbor Mooring General Permit) can be subject to review if a significant impact were identified.

Mooring fields and anchorages and the changing distribution of eelgrass

Current permitting procedures and harbor management reviews do not take into account the fact that the distribution of eelgrass can be dynamic as a result of natural processes, or that restoration efforts may result in the re-establishment of eelgrass in areas that were colonized in the past. For example, in Smith Cove, Niantic, eelgrass was not detected by the USFWS 2002 survey, and the Millstone Environmental Laboratory surveys have not observed eelgrass since 1989. If an application for a mooring were to be reviewed today, a field survey would determine that eelgrass is not present and a typical mooring probably would be permitted. However, the pictures

[28] The annual review is required by CGS Sec. 22a-113m. It is important to note that the review is not conducted for the purpose of approving the HMP on an annual basis.

in Figure 4 show that eelgrass was present in Smith Cove in 1974 and moorings were causing damage. If as a result of natural conditions or human intervention eelgrass recolonizes Smith Cove, there is no effective mechanism to detect a potential problem and take measures as needed.

To address this issue, a field study and impact analysis on the effects of moorings and anchorages should take into account potential eelgrass habitat, or perhaps project to “restored” conditions. Such an analysis would be useful to determine if permitting procedures should take into account the likelihood of eelgrass colonizing an otherwise barren area. In addition, periodic surveys of eelgrass should be conducted to determine if changes should be made to moorings and anchorages to better protect eelgrass.

Motorized Watercraft

Effects on Eelgrass

Eelgrass can be damaged when motorized watercraft are piloted across meadows during low water conditions or by accidental groundings. Turbulence from propeller wash and boat wakes can break off leaves, dislodge sediments and uproot plants. Repeated shearing of leaves may reduce the productivity of meadows. The engine’s propellers can shear leaves or cut into the bottom, damaging or destroying rhizomes. In severe cases, propellers cutting into the bottom may completely denude an area (e.g. see Figure 5). It has also been hypothesized that repeated boating through eelgrass meadows suspends enough sediment to significantly inhibit photosynthesis, or perhaps even bury the plants.

Some Atlantic coast states have characterized and quantified the damage caused by motor boats. The most comprehensive studies have been conducted in Florida’s waters. The first study, conducted in the early 1990s, estimated that 173,000 acres of Florida’s 2,7000,000 acres of SAV were scarred (Sargent et al. 1995). Scarring was often concentrated in particular areas. Although this is only 6.4 percent of the area occupied by seagrasses, it is still a substantial amount attributed to only one cause of many that could be affecting Florida’s seagrasses.

The effects of boating have also been conducted in the Isle of Wight Bay, Maryland, and the Chesapeake Bay, Virginia. In the Isle of Wight Bay from 1998 through 2000, scarring was estimated to be as high as 8 percent of individual SAV meadows, and was attributed primarily to recreational boating activities (Rutgers University 2000). In the Chesapeake Bay, scarring was evident on aerial photographs taken from 1987 to 2000 (Orth et al. 2001). Based on the available evidence, the authors attributed most of the scarring to commercial fishing vessels using crab scrapes and haul seines, and were caused by the vessels (probably the propellers) rather than the fishing gears (Figure 5). Very little of the scarring was attributed to recreational boats. The amount of damage was not assessed relative to the total SAV present in Chesapeake Bay. However, the authors concluded: “Although the actual amount of grass removed during the formation of these scars is small relative to the total amount of grass in the meadow, protection of even small amounts of grass is becoming more important, particularly given the recent interest in restoration projects and in avoiding net losses of SAV from nonwater [sic] quality impacts.”

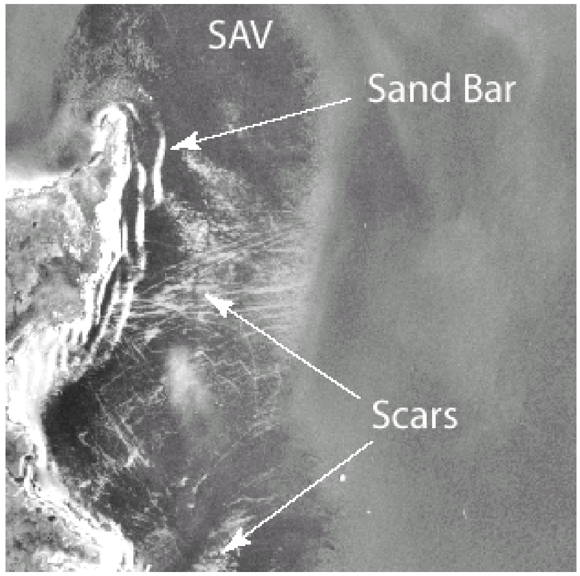


Figure 5. Propeller scars in submerged aquatic vegetation in Browns Bay, Virginia.

The scars, visible as white lines, were likely caused by commercial haul seine vessels. (From Orth et al. 2001; photo courtesy of Virginia Institute of Marine Sciences)

In 2000, the New Jersey Department of Environmental Protection's Coastal Management Program, the Institute of Marine and Coastal Sciences at Rutgers University and the Jacques Cousteau National Estuarine Research Reserve held two workshops titled Small *Motorized Watercraft Workshops* (Rutgers University 2000). The workshops were organized in response to the concern that the increasing use of small motorized boats and personal watercraft (a.k.a. jet skis) in shallow water was having a negative effect on the plants, animals and habitats of the nearshore zone. Small motorized watercraft were defined as jet-driven or propeller-driven boats less than approximately 6 m in length, and personal watercraft (PWC) were defined as vessels less than approximately 5 m long and propelled by water-jets. The goals of the workshops were to evaluate the current state of the science describing impacts to shallow water environments, generate information for use in managing impacts, and identify data gaps.

In addition to the Florida and Maryland studies discussed above, several presenters discussed long-term effects of scarring. Scars may remain unvegetated for a number of years. Studies done in Florida have estimated that scars typically require from three to seven years to revegetate, and possibly longer in severe cases involving very deep propeller scars and vessel groundings. In some cases scars expand and coalesce to form larger denuded areas. Revegetation rates, as well as the potential for scar expansion, depend upon a number of factors, including the species of seagrass, sediment characteristics, bathymetry and the prevailing wind and current patterns.

One researcher at the workshops with considerable expertise in this area (Joseph Zieman, Dept. of Environmental Sciences, University of Virginia) noted that while much effort has been directed toward quantifying damage, little research has been done to determine the significance of the damage. For example, little has been done to determine which scars are prone to erosion and which ones will stabilize and recolonize. Furthermore, he noted that: "Much work remains to sort out the relative effects of natural vs. anthropogenically driven changes in seagrass meadows, and to what extent scars cause detectable ecological degradation [vs.] just being aesthetically unpleasing." Regardless, Florida, having documented the extent of damage, has instituted aggressive measures to reduce and minimize impacts. The overall strategy is broad in scope, including education programs, delineating closed and restricted use areas, and adopting penalties for damaging seagrasses.

While there has been concern that small boats and personal watercraft might negatively impact SAV by suspending sediments, one conclusion of the workshops was that relationship between small motorized watercraft and scarring impacts has not been "unequivocally established in New Jersey waters or elsewhere." An exception could be aggressive operation of personal watercraft in depths less than 1.5 ft. The workshop participants concluded that more research was necessary.

The organizers of the Small Motorized Watercraft Workshops concluded that additional research and baseline data was necessary to formulate effective environmental management strategies in New Jersey's waters. They noted that, while studies are being conducted elsewhere in the United States, there was not a strong body of knowledge specific to New Jersey's waters, both in terms of the identification of critical environmental habitats susceptible to damage and the extent and significance of damage actually occurring.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Similar to the situation in New Jersey, there is limited information available to assess the level of damage to eelgrass caused by motorized watercraft in eastern LIS. Damage caused by boats in eastern LIS has never been documented, but there have been anecdotal reports of damage in the Niantic River (Rick Kantor personal communication). It is possible that some damage occurs elsewhere since there is a considerable amount of boating activity in eastern LIS. Of the approximately 112,000 boats registered in Connecticut, an estimated 25,000 to 30,000 boats operate in eastern LIS (Westerson personal communication). The majority of these boats are used for recreational purposes, with 50 percent to 60 percent used for sport fishing. Some recreational motor boats undoubtedly pass through areas containing eelgrass and it is possible that some commercial vessels may pass over eelgrass, particularly commercial fishing vessels. But given the low abundance of eelgrass and lack of reports of damage, it is unlikely that damage is widespread. Nonetheless, it would be prudent to document the extent of damage and determine if management measures are needed in particular places.

Despite the lack of definitive data describing boating impacts, at least two municipalities – East Lyme and Waterford – have taken steps to minimize damage to eelgrass. It was noticed that motor boats traveling across shallow water flats in the Niantic River were shearing leaves and uprooting plants. The joint Waterford-East Lyme Shellfish Commission instituted a program to inform boaters of the value of eelgrass and steps that they can be taken to minimize damage caused by boating activities. In addition, the commission marks the current locations of eelgrass meadows within the river so that boaters can avoid motoring through the meadows.

During the preparation of this report, the DEP began to educate boaters about various environmental issues related to boating, including the value of eelgrass meadows and how to avoid damaging them. The Marine Fisheries Division included information on eelgrass in the widely distributed Anglers Guide. The Boater's Guide now has a section titled Boating and Environmental Awareness, which includes a discussion about submerged aquatic vegetation. The Boating Division developed an Action Guide for Boaters dedicated to environmental issues, with one chapter devoted to sensitive habitats such as eelgrass. Finally, the Boating Division includes a discussion about eelgrass conservation in the boating education class that is required for obtaining a Boating Certificate.

Piers, Docks and Other Structures

Effects on Eelgrass

There are a number of different types of structures constructed in the marine environment that can affect eelgrass, including docks, piers, bulkheads, seawalls, groins and jetties. Docks and piers are usually pile-supported structures that can impact eelgrass in two ways: (1) pile driving causes direct loss and (2) the shadow cast by the structure can prevent eelgrass growth. Shading decreases photosynthesis, flowering and the density of eelgrass plants (Dennison 1987; Short and Burdick 1995). One study in Waquoit Bay, Massachusetts in 1987 estimated that docks covered approximately 0.06 percent of the total sea bottom containing eelgrass (Short and Burdick 1995). Although a small percentage of the total, damage extended out beyond the dock due to shading as the sun's angle changed, and most docks showed large scars caused by boats approaching and leaving the docks. The authors concluded that although docks were clearly not responsible for the decline of eelgrass observed in Waquoit Bay, the effects of docks and associated boat activities might cause fragmentation and disruption of eelgrass meadows, thereby contributing to their loss.

Structures that alter wave energy or currents can degrade or destroy eelgrass plants. Bulkheads, seawalls and riprap "harden" the shoreline and deflect wave energy rather than absorb it as an undisturbed shoreline would. The deflected wave can combine with the incoming wave and create additional scour of sediment waterward of the structure. This scenario is exemplified when sandy beaches disappear in front of seawalls following their construction. The long-term negative impacts of hardened shorelines are changes in localized wave attenuation, longshore currents, and sedimentation patterns. Secondary impacts to eelgrass occur during the construction of these structures when temporary sediment plumes are created, reducing light penetration.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Similar to dredging and filling, some loss of eelgrass due to the construction of structures probably occurred prior to the passage of the CMA in 1980. Since then, DEP developed a permitting process pursuant to the CMA that applies additional permit criteria designed to minimize the effects of structures and in-water work on eelgrass. A resource survey is required as part of the application process, and alternatives must be explored to minimize impacts to resources identified in the project area, such as eelgrass. For example, if eelgrass exists in the vicinity of the proposed dock, the permit can require that the dock be designed in a manner that allows sufficient light to reach eelgrass plants (e.g., proper elevation and a north to south orientation to minimize shading. See Burdick and Short 1995 for an example of guidelines).

Dredging and Filling

Effects on Eelgrass

Marine sediments are generally dredged with a barge-mounted crane and a bucket, although other methods are employed, such as suction dredging and land-based excavators (e.g. backhoe). Dredging is done for a variety of reasons, including the construction or maintenance of marinas, docks, pipeline crossings, and navigation channels. Dredging completely removes eelgrass plants, may render the habitat unsuitable for recolonization, and may smother adjacent plants. Filling the marine environment with materials such as soils of terrestrial origin and marine sediments is equally as catastrophic, as the eelgrass plants are buried and the habitat is usually rendered unsuitable for eelgrass recolonization.

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Prior to the passage of the CMA in 1980, dredging for the purpose of increasing boating access (e.g. marinas, boat basins and navigation channels) and filling activities (e.g. disposal of dredged sediment, extending upland facilities) likely resulted in a significant loss of eelgrass meadows. This practice was common when waterborne commerce was the main mode of transportation and upland area was needed for uses such as boat yards or cargo ports. Dredged sediments from navigation channels were often disposed of in shallow waters or cast alongside the channel.

Since the passage of the CMA the loss of eelgrass to dredging and filling has been largely eliminated through the DEP OLISP Structures, Dredging and Fill permitting process. New dredging, or dredging in an area that does not meet certain criteria that demonstrates a history of dredging, undergoes a rigorous review to establish that resources such as eelgrass will not be significantly damaged. Proposals to fill the marine environment (e.g. to extend upland facilities) receive similar scrutiny.

The majority of eelgrass habitat that was lost prior to 1980 in all likelihood cannot be restored. In most of these places, if an applicant can demonstrate historical dredging that meets certain criteria, they are eligible for a Certificate of Permission (COP) that allows maintenance (i.e. dredging) of the area. In most of these cases the maintenance dredging is allowed in the original dredged footprint subject to conditions and approved procedures. Resource surveys must still be conducted, but if the survey showed that eelgrass colonized, for example, a navigation channel, it is likely that the value of maintaining the channel would outweigh the value of conserving the eelgrass. It should be noted, however, that COP eligible projects are examined on a case-by-case basis. A permit can be issued with conditions that further minimize effects on eelgrass or require compensation for the loss of eelgrass.

Waterfowl

Effects on Eelgrass

Eelgrass is an important food source for native waterfowl such as Atlantic brant (*Branta bernicla hrota*), black ducks (*Anas rubripes*), and canvasback ducks (*Aythya valisineria*). Waterfowl consume the nutritious seeds and tubers and root stalks. Wintering Atlantic brant and many species of ducks rely upon eelgrass leaves and seeds as a principal food source in the winter and spring migratory period. The non-migratory Canada goose (*Branta canadensis*), and the introduced mute swan (*Cygnus olor*) also consume eelgrass. Studies done in Maryland and Rhode Island indicate that mute swans feed heavily upon eelgrass (Willey and Halla 1972, Perry et al. 2001).

Swans and Canada geese are known to negatively impact SAV, including eelgrass, to a greater degree than other waterfowl due to their numbers, size, high consumption rates, feeding behavior and year-round presence along the coast. Both swans and geese are able to forage on SAV to a greater depth than other waterfowl species such as black duck or Atlantic brant. Adult swans can typically feed in water as deep as three feet, so eelgrass plants shallower than the 3-foot contour at low tide are completely vulnerable (including the rhizomes). Plants deeper than the 3-foot low tide contour may be susceptible to grazing depending upon the height of the leaves.

Repeated grazing by swans and geese can negatively affect the ecological value of the plants as well as their survival. Mute swans tend to uproot much more vegetation than they consume, leading to greater degradation of SAV than indicated by their rate of consumption. Their feeding behavior suspends sediment, which may cover remaining leaves or reduce light penetration. The aquatic vegetation of tidal estuarine areas may be especially vulnerable to waterfowl damage because plants become more accessible to such foragers at low tide. As an example of what this feeding behavior can do, mute swans in Chesapeake Bay have negatively impacted eelgrass restoration efforts and destroyed existing eelgrass meadows to such an extent that the overall health of the bay was brought into question (Maryland Legislature 2002, House Joint Resolution 12; USFWS 2003).

Assessment of Potential Impacts to Eelgrass in Eastern LIS

Mute swan numbers along the Connecticut coast have remained relatively stable for the past ten years. In 2002, the DEP Wildlife Division estimated there were 1,091 swans along the coast, with the majority distributed east of the Connecticut River. Mute swans are commonly present in shallow coves in very large numbers, from fifty to several hundred birds. The resident Canada goose population in Connecticut is approximately 42,000 birds. This is a statewide estimate; the number inhabiting coastal areas has not been quantified. The number of resident geese has increased significantly in the last decade to the point that they have become a nuisance problem in many areas.

Research studies undertaken in other states have determined that mute swans can significantly impact eelgrass, especially eelgrass in depths less than 3-foot contour measured at the maximum low tide. Funded by a LIS License Plate Fund grant, the CT DEP Wildlife Division and University of Connecticut are evaluating the effects of mute swan and Canada goose on eelgrass in CT waters. Because eelgrass is currently at low abundance, it would be prudent to implement population control measures to protect vulnerable eelgrass meadows if the research in CT waters documents adverse impacts.

In 2005, the USFWS clarified the legal status of mute swans (Federal Register V70 No 49). Mute swans are considered a nonnative bird species and therefore unprotected under the Migratory Bird Treaty Act of 1918. This means that the management of mute swans is the sole responsibility of the states. In 2003, the USFWS completed a report titled *Environmental Assessment of mute swan management in the Atlantic Flyway* (USFWS 2003). That document advocated the reduction of the mute swan population in the Atlantic Flyway by 67 percent, and in CT by 85 percent. The *Atlantic Flyway Mute Swan Management Plan 2003-2013*, adopted by the Atlantic Flyway Council in 2004, advocated similar reductions (AFC 2003).

Conclusions

- The DEP has permitting programs that are adequate to minimize the effects of various structures and activities such as dredging on eelgrass.
- Motorboats, boat moorings and anchorages are not responsible for widespread damage to eelgrass, but could cause significant damage in localized areas. The extent and ecological significance of damage must be determined on a case-by-case basis.
- Research in other states has documented that mute swans adversely impact submerged aquatic vegetation, including eelgrass, due to their feeding behavior, large body size, fecundity and longevity. Shallow water eelgrass meadows in Connecticut's waters may be particularly vulnerable. To prevent the continued loss of important habitats such as eelgrass, and to prevent the impacts to the native species associated with the loss of habitat, a control plan for mute swans should be developed and implemented based on the results of ongoing research in Connecticut.
- The effects of resident Canada geese on eelgrass should be evaluated.

Recommendations

- The DEP should survey existing mooring fields and anchorages to characterize damage to existing eelgrass meadows. With this information, the ecological significance of damage within each mooring field or anchorage could then be evaluated. If such damage is significant, the DEP should work with towns and private mooring owners to minimize damage. Any survey of damage should be conducted as part of a comprehensive survey of the various factors identified in this report that could damage eelgrass.

- The DEP should work with municipalities to develop and include provisions in HMPs that call for periodic eelgrass surveys, assessments of impact, and implementation of measures to minimize impact as appropriate.
- The DEP and municipalities should evaluate the benefits of using moorings with off-bottom mooring tackle in areas that contain eelgrass, are near eelgrass meadows, or are located in potential eelgrass habitat.
- Because motorized watercraft have the potential to damage eelgrass, the DEP, with appropriate funding, should initiate a field study to determine if boating impacts are occurring. If certain eelgrass meadows are found to be sustaining damage, then means to minimize damage, ranging from posting informational signs to designating areas closed to boating, should be considered. Any survey of damage caused by boating activities should be conducted as part of a comprehensive survey of the various factors identified in this report that could damage eelgrass.
- The DEP and DA should continue to develop and implement measures to educate boaters and fishermen (recreational and commercial) as to the value of eelgrass and value of operating their boats in such a way as to minimize damage to eelgrass. Measures in addition to those already being taken could include: providing information to organizations and individuals teaching boating courses such as the Coast Guard Auxiliary; providing an eelgrass informational brochure with all DEP commercial fishing licenses, personal use lobster licenses and DA/BA shellfish licenses and leases; and working with the municipal shellfish commissions to develop an informational program, such as developing a brochure that could be provided with shellfish permits and leases.
- If research and data evaluation determines that mute swan foraging adversely impacts eelgrass in Connecticut, then the DEP Wildlife Division should prepare and implement a program to control the mute swan population.
- Complete the resident Canada geese impact evaluation and prepare measures to minimize impacts to eelgrass as appropriate.

Factors That Have Long-term and Large-scale Effects on Eelgrass

Climate and disease have been associated with periods of low eelgrass abundance on both local and regional scales during the last century. There is considerable evidence that a decline in the water quality of coastal waters – primarily due to nutrient enrichment – may be responsible for the long-term disappearance of eelgrass from much of its historic distribution along the Atlantic Coast. In the past, when eelgrass has declined due to climate or disease, periods of recovery would often follow. Nitrogen enrichment appears to have created conditions that hinder recovery. In the following discussion, these factors are related to the historical abundance and distribution of eelgrass described earlier in this report (see "The Distribution Of Eelgrass In Long Island Sound and Trends in Abundance"*)*.

Disease

Although there may be a number of eelgrass diseases, most research has focused on a disease referred to as "wasting disease." The disease is caused by a marine slime mold, *Labyrinthula zosterae*[29] (Muehlstein et al. 1991, referenced in Ralph and Short 2002). The disease was first observed and described during the widespread decline of eelgrass in North America and Europe in the 1930s. Many researchers believed that the disease caused the die-off, but the reasons for the die-off were never definitively determined. According to one report (Thayer et al. 1984): "Bacteria, fungi, commercial harvesting of fishery organisms, pollution, and competing species have been implicated as possible causative agents in the decline, but they have never been conclusively shown to have contributed to the 'wasting disease' event." However, it is very likely that *Labyrinthula zosterae* played an important role in the die-off of the 1930s. It has been demonstrated that the slime mold is a primary pathogen of healthy eelgrass plants (Ralph and Short 2002). In addition, the organism has been associated with localized die-offs in recent times, such as in the Great Bay Estuary on the New Hampshire-Maine border from 1981 to 1984 (Short et al. 1986), and in the Niantic River, Connecticut, where eelgrass declined during the mid 1980s (Short 1988).

Labyrinthula zosterae is probably present in healthy eelgrass meadows that show little signs of the disease. It is thought that severe outbreaks might occur when plants are physiologically stressed. Possible stressors are elevated temperatures and nitrogen enrichment (see discussions below). Some outbreaks may result when several stressors co-occur. At this time, however, it is not definitively understood what conditions cause outbreaks (Ralph and Short 2002). Interestingly, it appears that plants living in a low salinity environment can survive infection (Burdick et al. 1993 referenced in Ralph and Short 2002). Apparently eelgrass populations that survived the 1930s epidemic were located primarily in low salinity waters. Similarly, eelgrass in the low salinity areas of Great Bay Estuary survived the die-off observed there in the 1980s (Short et al. 1986).

---

[29] This organism belongs to a group whose taxonomic position has been the subject of much research and revision. It is typically referred to as a marine slime mold, or slime-mold like protist. Although single-celled, it forms colonies of cells that are amoeboid in appearance and behavior.

Climate

As is the case with all plants, large-scale climatic cycles, short-term variations in weather and specific weather events play a role in determining the abundance and distribution of eelgrass. Climate directly affects eelgrass growth and reproductive success by controlling factors such as water temperature, salinity and the amount of light reaching the water's surface. These factors may also indirectly affect eelgrass growth and survival by affecting interactions between eelgrass and other organisms such as the slime mold *Labyrinthula zosterae.* Weather events such as storms can destroy large areas of eelgrass, and cold winters produce substantial ice cover in embayments, which can scour eelgrass meadows (see Thayer 1984 for a more complete discussion).

Definitive information linking the effects of variations in climate on periods of eelgrass decline or resurgence is generally lacking. Researchers have had to rely principally upon associating past climate events with the abundance of eelgrass. For example, periods of low eelgrass abundance in New England in 1894, 1908, 1915 and 1930 lined up with periods of lower than normal precipitation (Martin 1954). In the Niantic River, where eelgrass meadows have been transient over the last two decades, there was an increase in abundance in 1997 and 2003 that occurred coincident with periods of high rainfall. These are interesting observations, but how would drought cause low survival and high rainfall cause high survival? One mechanism could involve the slime mold. As noted above, it is believed that the slime mold is present in eelgrass in the Niantic River. Less rainfall could result in higher nearshore salinities, which in turn is more favorable to the growth of slime mold. However, there is simply not enough information to be sure that this is the explanation.

Temperature may also play a role in determining periods of high and low eelgrass abundance. As with salinity, researchers have observed that periods of high temperatures often coincide with periods of low eelgrass abundance. Periods of seagrass decline in Denmark were associated with exceptionally mild winters followed by warm summers (Rasmussen 1973). Similar climate conditions prevailed in Connecticut in the late 1990s due to a prolonged period of El Niño and La Niña[30] (Ron Rozsa personal communications). Starting in 1995 water temperatures gradually increased, peaking in 1999 (DNC 2005). In August, temperatures in the Niantic River ranged from 77.0 deg to 80.5 deg F. That year, the Millstone Environmental Laboratory reported that the last eelgrass meadow had completely disappeared by August (NUSCO 2000; Keser et al. 2003). However, laboratory staff also reported a shift to finer grained sediment at this location, and thick mats of a red macroalga covering the sediment surface and lower portions of the eelgrass blades before the die-off.

Temperature, influenced by changes in climatic conditions, was associated with annual differences in a study of eelgrass abundance in Coos Bay and Willapa Bay, Oregon, from 1998 to 2001 (Thom et al. 2003). Annual abundance in Willapa Bay varied as much as 700 percent, and was attributed primarily to large-scale changes in climate that influenced water temperatures. From 1997 to 1998 the climate changed from an El Niño event to a La Niña condition, which

[30] El Niño and La Niña are two large-scale climate events taking place in the Pacific Ocean that can alter global atmospheric circulation, forcing changes in climate far from the Pacific, including North America.

was characterized by warmer winters and cooler summers. After the shift, temperatures were cooler during the eelgrass growing season and the researchers observed a pronounced increase in eelgrass density, biomass and flowering from 1998 through 2000 in Willapa Bay. However, annual variations in Coos Bay were less dramatic. According to the authors, this may have been due to a stronger oceanic influence on water in the bay, which would moderate changes in water temperature.

While it is obvious that factors influenced by climate such as temperature, salinity and light availability can affect eelgrass growth and survival, the questions germane to this report are: has climate played a role in the long-term decline of eelgrass in LIS, and will future climatic conditions help or hinder restoration efforts? The question of whether climate has played a role in long-term trends in eelgrass abundance and distribution has not been answered. Most researchers now agree that a long-term global warming trend is occurring. However, there is no indication that the changes that have occurred thus far have played a role in the long-term decline of eelgrass observed during the last century (see Short and Neckles 1999 for a summary of potential changes due to climate change).

It is also unclear what the implications of global climate change would be for future eelgrass restoration efforts. The long-term warming trend will certainly affect the distribution of SAV in the future, most obviously as a result of sea level rise (eelgrass is depth limited, so eelgrass will adapt accordingly). At this point it is uncertain if increasing water temperatures are influencing eelgrass survival. Elevated temperatures have been shown to affect eelgrass growth and health (e.g. Touchette et al. 2003 and Bintz et al. 2003). There is some indication that elevated temperatures could exacerbate the effects of other factors, such as nutrient enrichment. Indeed, the authors of one study opined that the combined effects of increasing nutrient concentrations and increasing summer water temperatures is likely responsible for declines of eelgrass observed over the last few decades (Bintz et al. 2003).

In LIS it is difficult to conclude at this time that temperature has been, or will be in the foreseeable future, a major determinant of eelgrass survival. Eelgrass occurs over a wide temperature range from North Carolina to Nova Scotia, and LIS is well within that temperature range. Eelgrass occurs in a wide variety of habitats in LIS, from shallow embayments to the open waters of LIS. It may be that eelgrass in shallow, nearshore areas such as the Niantic River will be more susceptible to temperature changes than meadows located in areas more open to LIS, particularly if nitrogen loading has increased to levels detrimental to eelgrass.

Water Quality

The Role of Nitrogen

As discussed earlier in this report, eelgrass thrives in a low nutrient environment with good water clarity conditions. In such an environment, if nutrient loading is increased either through natural processes or human activity, algae will eventually out-compete and replace eelgrass. It is widely believed that nitrogen enrichment is the primary cause for much of the loss of eelgrass and other seagrasses in the coastal waters of the United States and the world (e.g. Short and Wyllie-Echeverria 1996; Hauxwell et al. 2003).

High nitrogen levels promote the growth of short-lived, fast-growing species of phytoplankton (microscopic algae), epiphytic algae (algae growing on the eelgrass leaves) and macroalgae. As these plants proliferate they reduce water clarity, which increasingly favors plants with low light requirements. These types of algae only require 2 percent to 3 percent of the light falling at the water's surface compared to the 20 percent needed by eelgrass (see Dennison et al. 1993 for a summary of light requirements). Eventually, the algae out-compete eelgrass for light and growing space. For example, sea lettuce (*Ulva lactuca*), a macroalga that can grow into large sheets that drift with the tides and currents, can become so abundant that it covers eelgrass plants over a broad area, preventing light from reaching the plants and eventually eliminating them.

As phytoplankton grow and cause a decrease in water clarity the combination of high nutrients and low light requirements favors those species of algae that can live higher in the water column. In extreme cases a succession of algal species takes place, with each species occupying a higher place in the water column as water clarity decreases and light becomes less available. Eelgrass is usually eliminated very early in this process (for a thorough discussion see Duarte 1995).

Excessive nitrogen can come from a number of sources, such as sewage treatment plants, septic systems, atmospheric deposition, lawn fertilizers, and agricultural practices. A sewage treatment plant is considered a point source because the effluent is discharged to a waterbody from an outfall pipe. Sources such as lawn and agricultural fertilizers are classified as a nonpoint source because nitrogen is dissolved in surface runoff or enters groundwater and is "discharged" over a broad area.

The possibility that nonpoint sources of nitrogen can affect eelgrass is often hard to conceptualize since the "discharge" into the waterbody is often not visible or easily quantified. However, non-point sources of nitrogen have been extensively investigated in other coastal states and have been linked to the loss of eelgrass. For example, on Cape Cod, Massachusetts, extensive research on the effects of residential development (a source of nonpoint nitrogen) on eelgrass distributions has been conducted in Waquoit Bay as part of the Waquoit Bay Land Margin Ecosystems Research project. Waquoit Bay, which is a designated National Estuarine Research Reserve, is well suited to study this relationship, as it has a number of watersheds emptying into the bay with varying levels of development. Eelgrass has been steadily declining in Waquoit Bay (Figure 6), and the location and extent of decline correlates strongly with the extent of residential development and estimated nitrogen loads (e.g. Valiela et al. 1992; Short and Burdick 1996; Hauxwell et al. 2003). Although this type of analysis does not definitively establish that increased nitrogen is the root cause of the decline of eelgrass, this explanation is further supported by the results of controlled mesocosm studies, which have demonstrated how added nitrogen can negatively affect plant growth through the stimulation of algal production (e.g. Short et al. 1995).

Nitrogen Enrichment and the Distribution of Eelgrass in LIS

As previously discussed, eelgrass populations in LIS largely died in the 1930s. Re-colonization of the central and western areas of LIS was minimal and eventually failed. DEP staff and the scientific community believe that the most likely explanation for the present day absence of

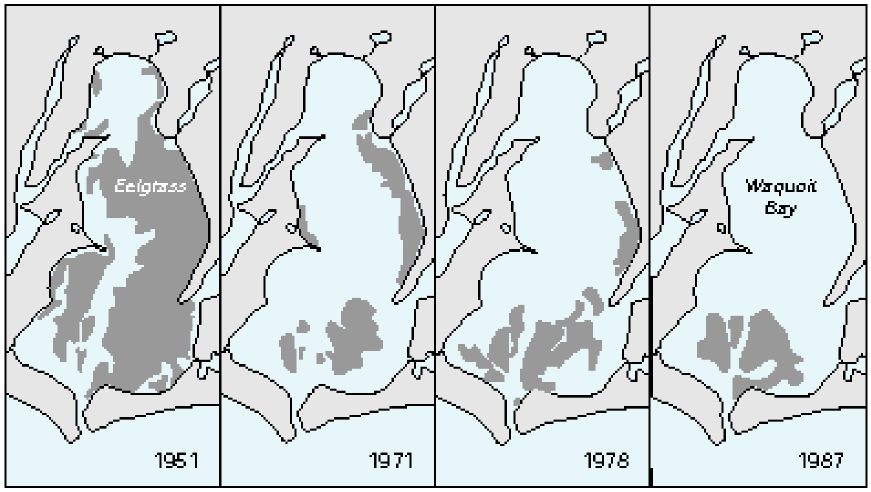


Figure 6. The distribution of eelgrass in Waquoit Bay, Cape Cod, Massachusetts, 1951 to 1987.
(From Valiela et al. 1992)

eelgrass in these areas is nitrogen enrichment by human activities, which has created an unfavorable environment for eelgrass growth and survival. The increase in nitrogen concentrations since pre-colonial times and subsequent ecological consequences (e.g. increased production of phytoplankton, and hypoxia, or low dissolved oxygen) has been well documented (e.g. US EPA 1994). Although not as acute, nitrogen enrichment also affects the central portion of LIS. Compounding the problem for eelgrass in these areas is the wide tidal range and high background turbidity which historically restricted eelgrass to shallower depths compared to eastern LIS (Koch and Beer 1996), as well as the other stressors identified above.

In contrast to the western and central portions of LIS, eelgrass recovered in portions of eastern LIS after the 1930s die-off. Recovery may have been possible because of better water quality conditions. However, beginning sometime in the 1980s eelgrass once again declined in some areas, including the Niantic River, Poquonock River, Clinton Harbor, Little Narragansett Bay, Mystic Harbor and Stonington Harbor.

In the Niantic River there are no point sources of nutrients, and so current research (discussed below) is focusing on whether nonpoint sources of nitrogen could be playing a role along with various environmental parameters such as temperature and salinity. Similar research is being conducted in Clinton Harbor, which receives a number of different types of nonpoint sources as well as a small sewage treatment discharge. In addition to nonpoint sources, Little Narragansett Bay, Mystic Harbor and Stonington Harbor also receive discharges from one or more sewage treatment plants, which may figure prominently in the demise of eelgrass in these areas.

In Little Narragansett Bay, a significant ecological shift appears to have occurred that strongly suggests significant nitrogen loading to the system. As discussed previously, Connecticut College professor Scott Warren observed a significant change in the wrack line at Barn Island, which changed from predominantly eelgrass to the macroalga Cladophora. Stonington Shellfish

Commission member Alan Banister also believes there has been an increase in macroalgae. In his 1998 survey, Cladophora was the dominant macroalga (Alan Banister personal communication). And Lance Stewart (Marine Biologist, UCONN Extension Service) has observed a shift in the benthic fouling community of the lower Pawcatuck River from a typical eastern LIS fouling community to one dominated by macroalgae, particularly Cladophora (Lance Stewart, personal communication). These observations suggest a classic shift from a low nutrient system with eelgrass to a high nutrient system dominated by annual species of macroalgae.

The dramatic exception to the paucity of eelgrass observed in embayments in recent years is Mumford Cove. The likely reason for the resurgence of eelgrass in the cove was the removal of the Groton sewage treatment discharge 1987. Researchers at the University of Connecticut summarized the available information on ecological changes in the cove between 1988 and 1992, and conducted additional investigations in 1999 and 2002 (James Kremer, personal communication). Prior to removal, eutrophic conditions existed in the cove and the dominant macrophyte was the alga *Ulva lactuca*, or sea lettuce. Apparently this alga thrived on the high nutrient load from the sewage treatment plant, but began to decline after the outfall was removed. Some eelgrass seedlings, as well as widgeon grass (*Ruppia maritima*), were observed in the cove in 1988 and 1989, but these did not appear to develop into meadows. Limited eelgrass and widgeon grass were again observed in 1992, as well as by Yarish in 1993. A modest expansion of eelgrass and widgeon grass was observed in 1999. Then, in 2002, a dramatic expansion of eelgrass occurred, with approximately 48 acres observed by the USFWS.

If high nutrient levels were the cause for the absence of eelgrass in Mumford Cove, why did it take so long to come back? One possible explanation is that nutrients accumulated in the sediments during the lifetime of the sewage outfall. In the absence of eelgrass, which stabilizes sediments, the sediments would be continually re-suspended and the nutrients would be made available to algae. Both suspended sediment and algal growth would inhibit eelgrass colonization. Over time, this condition may have abated, creating favorable conditions for eelgrass growth that led to the proliferation of eelgrass in the cove. While this explanation is plausible, there are no data to support it and so the reason for the delay in recovery remains unknown[31]. Whatever the reasons, the recovery of eelgrass in Mumford Cove does provide strong evidence that improving water quality can create favorable conditions for eelgrass colonization and growth.

These observations coupled with the strong empirical relationship between nitrogen loading and eelgrass health suggest nitrogen loading is a major factor affecting the distribution and health of eelgrass in LIS. However, without additional research it would be an oversimplification to conclude at this time that nitrogen loading is the main determinant, especially when attempting to explain eelgrass distribution and trends in particular locations. The effects of nitrogen are likely to be either compounded or mitigated by prevailing physical, chemical and biological conditions. Weather, climate, disease, habitat disturbance, physical insult, and grazing may all

[31] There appears to be few reports in the literature of monitoring the response of SAV to the removal of large sources of nitrogen. One well-documented cases is Tampa Bay, Florida, where advanced nutrient removal systems were installed beginning in 1979 with the goal of reversing eutrophication (Lewis et al. 1999). It took about five years to detect a decrease in macroalgae and microalgae blooms and an increase in water transparency. The long-term decline of seagrasses in the bay was not reversed until about 1982, 12 years after the first major reduction in nutrients.

take their toll and certain combinations may be especially harmful (e.g. nitrogen enriched waters subjected to unusually warm weather). Some combinations of effects have rarely or never been considered, such as how waterfowl grazing on the upper portion of eelgrass blades near the water's surface might affect the plant's ability to capture enough sunlight for growth and survival. All possibilities warrant additional study.

The Role of Nitrogen: Status of Research and Management in Connecticut

Using the statutory authority specified in the CMA and the Connecticut Water Pollution Control Act (CGS Chapter 446k), the DEP has established a number of programs designed to improve and maintain appropriate water quality conditions for Connecticut's waterways. These programs involve a number of offices within DEP and extensive partnerships outside of DEP. While beyond the scope of this document to detail how these programs are being used to protect and restore eelgrass, a few of the major programs deserve mention.

The Bureau of Water Protection and Land Reuse (BWP) has two programs that are key to the management of nitrogen loading: the Long Island Sound Program and Nonpoint Source Management Program (NPSMP). The NPSMP is composed of a number of program elements, including the Coastal Nonpoint Pollution Control Program, which was recently approved by the federal government. Using these programs, the BWP is working to enhance management of all point sources of nitrogen (e.g. sewage treatment plants) and nonpoint sources (e.g. farms, residential communities and vessels) that contribute to the load of nitrogen entering LIS.

The Long Island Sound Program is the principal means through which Connecticut participates – along with New York – in the EPA administered Long Island Sound Study (LISS). The LISS determined that nitrogen enrichment is the primary reason why the bottom waters in the western end of LIS, and to some extent bottom waters in the central area of LIS, experience hypoxia (low dissolved oxygen concentrations) during the summer months (EPA 1994). To address this problem, as well as low oxygen levels in general, the BWP has established Water Quality Standards and Criteria[32] for coastal waters based on oxygen levels. In order to achieve the WQS, the DEP conducted a total maximum daily load (TMDL) analysis for nitrogen (DEP 2000). The analysis has led to the development of a TMDL that specifies target reductions in nitrogen and measures to achieve the targets. With regard to eelgrass, it is possible that the nitrogen reduction targets may not be stringent enough to foster eelgrass growth in the shallow water areas of western LIS and portions of central LIS.

In general, the water quality conditions in the open waters of eastern LIS are good, but DEP staff and the scientific community believe that nitrogen loading from nonpoint and point sources may create unfavorable conditions for eelgrass in embayments. If true, then eelgrass could flourish if these sources are controlled. Therefore, current research has focused on the role of nitrogen enrichment on eelgrass in the embayments in eastern LIS.

[32] The WQS are an important element in Connecticut's clean water program (CGS Chapter 446k, Water Pollution Control). In accordance with CGS Section 22a-426, they set an overall policy for management of water quality as required by Section 303 of the Federal Clean Water Act. Revisions to the WQS require a public participation process.

Determining how nitrogen, in combination with other conditions and impacts, affects eelgrass growth and survival is a key piece of a comprehensive eelgrass restoration program. Researchers at the University of Connecticut – using funding from, among other sources, CT Sea Grant and the U.S. Environmental Protection Agency's Non-Point Source grant program (Clean Water Act, Section 319, Non Point Source Management Program) administered in partnership with the CT DEP – are currently investigating the role of nitrogen in Clinton Harbor, Mumford Cove, the Niantic River and the Pawcatuck River. It is hoped these studies will provide the data that is needed to determine if nonpoint nitrogen is the reason for the decline and absence of eelgrass in many of Connecticut's embayments. As of this writing DEP is applying for funding from the EPA Long Island Sound Study to further this research. The DEP BWP, in partnership with the U.S. Geological Survey (USGS) and through a grant with the University of Connecticut, proposes to use the data to determine if nitrogen control is the key to eelgrass vitality and, if so, what levels of nitrogen loading are acceptable.

Should a relationship between excessive nitrogen loading and eelgrass demise in Connecticut's waters be conclusively demonstrated, the next step would be to determine how to reduce nitrogen loading to appropriate levels. To accomplish this task, the DEP BWP and the USGS propose to use the data from the various studies to develop watershed nitrogen management plans that will help DEP and local government agencies determine how best to reduce and control sources of nitrogen.

The DEP BWP may also develop WQS that are based on the levels of nitrogen loading that impairs eelgrass survival. Waterbodies that did not meet the WQS would be listed as impaired relative to the conditions needed for eelgrass survival. The DEP BWP would then prepare a management plan for each impaired waterbody - either a total maximum daily load analysis or similar approach – that outlines measures needed to reduce nitrogen to levels suitable for eelgrass growth and health. Such plans would be an important component of a comprehensive eelgrass restoration strategy.

Conclusions

- Although the exact reasons for the decline of eelgrass in LIS remain unknown, the available evidence indicates that nitrogen enrichment from human sources played an important role. While perhaps not causing the catastrophic 1930s decline, nitrogen enrichment may have created unfavorable conditions for recovery. The inability of eelgrass to recolonize the western coastline suggests that nitrogen enrichment may be an important factor in the more recent declines observed in areas of the eastern Sound.
- The available evidence indicates that excessive nitrogen loading to LIS and its nearshore waters contributes to eelgrass decline in eastern LIS and threatens recovery to historical distributions.
- While nitrogen is likely to be a primary stressor for eelgrass, consideration must be given to the roles of additional stressors identified in this report such as weather, climate, physical disturbance, disease, and grazing. Interrelationships may be complex and require additional research or monitoring.

- Variation in regional and local climate, which can affect temperature, salinity and light availability, is also an important factor affecting eelgrass growth and reproductive success.
- Disease is an important factor affecting eelgrass survival, but the reasons why disease outbreaks occur is unknown. Outbreaks may be related to other factors that stress eelgrass plants, such as nitrogen enrichment and above average temperatures.
- It is likely that the effects of excessive nitrogen and variations in climate, considered either individually or together, have had a much larger effect on the abundance and distribution of eelgrass than all of the factors that cause mechanical damage.
- The considerable abundance of eelgrass observed in Mumford Cove in 2002 is probably the result of removing a sewage outfall in 1987, which improved water quality conditions (i.e. reduced nitrogen loading). The paucity or absence of eelgrass in other embayments in 2002 probably indicates that water quality conditions in these embayments are unfavorable for eelgrass growth and survival, or that the combined effect of other stressors affected eelgrass in areas of marginal water quality.
- Additional research addressing the effects of nitrogen on eelgrass in Connecticut's waters is needed, including the development of watershed models that characterize nitrogen loading to embayments.
- The DEP has strong programs in place that can facilitate research on the effects of nitrogen loading on eelgrass, and manage nitrogen loading as needed. However, additional funding is needed to conduct research and management.

Recommendations

- In accordance with Public Act No. 02-50, which calls for DEP to develop an eelgrass restoration plan and periodically monitor the effectiveness of measures to protect and restore eelgrass, the DEP should do the following:
    - Conduct periodic monitoring of eelgrass abundance and distribution.
    - Identify and map habitat that historically supported eelgrass and could be suitable for restoration of eelgrass.
    - Continue DEP involvement in efforts to verify and quantify the effects of nitrogen and other pollutants from sewage treatment plants and upland nonpoint sources in concert with other likely stressors on eelgrass in localized areas such as embayments and harbors, and, if warranted, develop watershed water quality models to aid in the management of nitrogen loading.
    - Incorporate the following program additions into existing DEP water management programs: establish nitrogen loading or concentration thresholds necessary for eelgrass restoration and maintenance in LIS and its embayments; identify impaired waterbodies (i.e. LIS and individual embayments) based on nitrogen thresholds; and develop watershed management plans as needed to establish favorable conditions for eelgrass growth.

- Continue Connecticut's nitrogen reduction programs, in cooperation with New York, so as to reduce nitrogen loading to LIS.
- Continue to investigate how climate, grazing, disease and nitrogen collectively affect eelgrass growth and survival.

SUMMARY

As required by PA 01-115, DEP and DA/BA evaluated the effects of commercial and recreational fishing on eelgrass. At this time, there is little reason to believe that recreational and commercial fishing are having, or have had in the past, an ecologically significant impact on the abundance and distribution of eelgrass in eastern LIS, or that they were responsible for the long-term decline and disappearance of eelgrass in the western and central portions of LIS.

The possibility remains that some fishing activities or other factors evaluated in this report such as moorings and recreational boating activities may cause localized scarring or reduced growth in some eelgrass meadows. If such an area is identified, the issue can be addressed through existing DEP, DA/BA and municipal permitting, leasing and educational programs, and through the suggested improvements to these programs identified in this report.

Periodic investigations of damage to eelgrass should be conducted because the distribution of eelgrass changes. In particular, future restoration efforts could succeed in expanding eelgrass to historic distributions, some of which may overlap with areas used for fishing or other activities.

There is a considerable amount of information that indicates nutrient enrichment of coastal waters by human activities may be the primary reason for the decline in abundance and distribution of eelgrass, and may be a major threat to eelgrass restoration. In particular, evidence suggests that nitrogen is the nutrient responsible for triggering ecological changes that have created unfavorable conditions for eelgrass growth in a number of estuaries. However, there are likely to be complicated interactions with other identified stressors such as weather, climate, physical disturbance, disease, and grazing that should be evaluated and quantified. Restoration efforts, such as planting eelgrass, may fail if nitrogen loading and other contributing stressors are not identified and addressed first. Research has been initiated that will examine whether nitrogen enrichment is responsible for the declines observed in Connecticut's embayments and, if so, what the appropriate loading level of nitrogen is that would be protective of eelgrass meadows. This research should receive additional support.

LIST OF REFERENCES

Able, K. W. and M. P. Fahay. 1998. The first year in the life of estuarine fishes in the Middle Atlantic Bight. Rutgers Univ. Press, New Brunswick, N.J. 342 pp.

Able, K.W., M.P. Fahay, K.L. Heck, Jr., C.T. Roman, M.A. Lazzari and S.C. Kaiser. 2002. Seasonal distribution and abundance of fishes and decapod crustaceans in a Cape Cod estuary. Northeastern naturalist. 9: 285-302.

Able, K. W. and S. C. Kaiser. 1991. Species composition and abundance of fishes and selected decapod crustaceans in southern New Jersey eelgrass habitat: a comparison with sea lettuce and unvegetated substrate. SNJ DEP habitat quality of estuarine seagrass (Able) IMCS Pub. No. 9124. *In:* Perf. Rpt. To NJ DEP, Proj. No. F-15-R-32; Job 2: the functional ecology of seagrass habitats in New Jersey, June 1 1990 to May 31, 1991. 27 pp.

Addy, C. E. and R. Johnson. 1947. Status of eelgrass along the Atlantic coast during 1947. In Proceedings, Northeastern Game Conference, p. 73-78.

AFC 2003. Atlantic Flyway Mute Swan management plan 2003-2013. Snow Goose, Brant, and Swan Committee, Atlantic Flyway Council. U.S. Fish and Wildlife Serv. 39 pp.

Ardizzone, G.D. and P. Pelusi. 1983. Fish populations exposed to coastal bottom trawling along the Middle Tyrrhenian Sea. Rapp. Roc. Verb. Reun. CIESM. Vol. 28(5): 107-110.

Ardizzone, G.D., P. Tucci, A Somaschini, and A. Belluscio. 2000. Is bottom trawling partly responsible for the regression of *Posidonia oceanica* meadows in the Mediterranean Sea? pp. 37-46 in M.J. Kaiser and S.J. de Groots, eds. The effects of fishing on non-target species and habitats: Biological, Conservation and Socio-economic issues. Blackwell Science.

ASMFC 2000. Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies. ASMFC habitat management series No. 5. Washington, D.C. 38 p.

ASMFC 1997a. Atlantic coastal submerged aquatic vegetation: A review of it ecological role, anthropogenic impacts, state regulation and value to Atlantic coastal fisheries. ASMFC habitat management series No. 1. Washington, D.C. 78 p.

ASMFC 1997b. Submerged aquatic vegetation policy. Atlantic States Marine Fisheries Commission habitat management series No. 3. Washington, D.C. 9 p.

ASMFC 2002. State Submerged Aquatic Vegetation Conservation Plans. Atlantic States Marine Fisheries Commission, Washington, D.C. November 2002.

Baille, P.W. 1987. Comparative study of benthic microalgae biomass on the Clinton Harbor tidal flats and in the Cedar Island Marina, Clinton, CT. Prepared by Priscilla W. Baille, Ph.D. for Cedar Island Marina, Inc. 26pp.

Berzelius Society. 1878. A catalogue of the flowering plants and higher cryptogams growing within 30 miles of Yale College. Sheffield Sci., New Haven.

Bintz, J.C., Nixon, S.W., Buckley, B.A., Granger, S.L. 2003. Impacts of temperature and nutrients on coastal lagoon plant communities. Estuaries 26(3): 765-776.

Brant, W., Touchette, Joann M. Burkholder, and Howard B. Glasgow, Jr. 2003. Variations in Eelgrass (*Zostera marina* L.) Morphology and Internal Nutrient Composition as Influenced by Increased Temperature and Water Column Nitrate. Estuaries 26(1):142-155.

Briggs, P. T. 1971. Comparison of shore-zone fishes over naturally vegetated and sand-filled bottoms in Great South Bay. NY Fish and Game J. Vol. 18, No. 1: 15-41.

Buchsbaum, R.N., Short, F.T., & Cheney, D.P., 1990. Phenolic-nitrogen interactions in eelgrass Zostera marina: possible implications for disease resistance. Aquat. Bot., 37: 291-297.

Burdick, D.M. and F.T. Short. 1995. The effects of boat docks on eelgrass beds in Massachusetts coastal waters. Final Report, Massachusetts Coastal Zone Management, Boston, Massachusetts. 32 pp.

Cloern, J.E. 2001. Our evolving conceptual model of the coastal eutrophication problem. Mar. Ecol. Progr. Ser., 210: 223-253.

Collette, B. B. and G. Klein-MacPhee, eds. Bigelow and Schroeder's fishes of the gulf of Maine. 3rd ed. Smithsonian Institution. 748 pp.

Costa, J. 1988. Eelgrass in Buzzards Bay: distribution, production, and historical changes in abundance. EPA 503/4-88-002.

Cottam, C. 1935. The eelgrass situation in 1934. Proceedings from Twenty-First Game Conference. p. 295-301.

Cottam, C. and D. A. Munroe. 1954. Eelgrass status and environmental relations. J. Wildl. Mgmt. 18(4):449-460.

Crawford, H.M. 1989. A scientific literature review and investigation of the sediment conditions of Quiambog and Wilcox Coves in Stonington, CT. *In*: Crawford, H.M. and K.M. Aftab, historical and environmental survey of Quiambog and Wilcox Coves in Stonington, CT; a report submitted in two parts. Submitted to the Board of Selectmen, Town of Stonington Shellfish Commission.

CT DEP 1985. Model Municipal Harbor Management Plan. State of Connecticut, Dept. of Environmental Protection, Coastal Management Program. 64 p.

CT DEP and NY DEC 2000. A total maximum daily load analysis to achieve water quality standards for dissolved oxygen in Long Island Sound. NY DEC, Albany, NY; CT DEP, Hartford, CT. 73 p.

Deegan, L.A, J. T. Finn and J. Buonaccorsi. 1997. Development and Validation of an Estuarine Biotic Integrity Index. Estuaries. 20(3). 17pp.

Dennison, W.C. 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquat. Bot. 27:15-26.

Dennison, W. C., R. J. Orth, K.A. Moore, J. C. Stevenson, V. Carter, S. Kollar, P. W. Bergstrom and R. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation. *Bioscience.* 43:86-94.

DNC (Dominion Nuclear Connecticut Inc.). 2005. Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station, Waterford, CT. Annual rpt 2004. 284 pp.

Duarte, C.M. 1995. Submerged aquatic vegetation in relation to different nutrient regimes. Ophelia 41:87-112.

Fonseca, M.S., G.W. Thayer, A.J. Chester, and C. Foltz. 1984. Impact of scallop harvesting on eelgrass (Zostera marina) meadows: implications for management. North American Journal of Fisheries Management. 4:286-293.

Frederick T.S. and H. A. Neckles. 1999. The effects of global climate change on seagrasses. Aquatic Botany, Vol. 63: 3-4. 27 p.

Goldberg, R., B. Phelan, J. Pereira, S. Hagan, P. Clark, A. Bejda, A. Calabrese, A. Studholme and K. W. Able. 2002. Variability in habitat use by young-of-the-year winter flounder, *Pseudopleuronectes americanus*, in three northeastern U.S. estuaries. Estuaries Vol. 25. No. 2, p. 215-226.

Gottschall, F. G., M. W. Johnson and D. G. Simpson. 2000. The distribution and size composition of finfish, lobster and long-finned squid in Long Island Sound based on the Connecticut Fisheries Division bottom trawl survey, 1984-1994. NOAA Technical Rpt NMFS 148. 195p.

Graves, C.B., E. H. Eames, C.H. Bissel, L. Andrews, E.B. Harger, and C.A. Weatherby. 1910. Catalogue of the flowering plants and ferns of Connecticut. Conn. Geol. Nat. Hist. Surv. Bull. 14, 569 p.

Hastings, K., H. Patrick and G. A. Kendrick. 1995. Seagrass loss associated with boat moorings at Rottnest Island, Western Australia. Ocean and Coastal Management, Vol. 26 No. 3 225-246.

Hauxwell, J., J. Cebrian, and I. Valiela. 2003. Eelgrass *Zostera marina* in temperate estuaries: relationship to land-derived nitrogen loads and effect on light limitation imposed by algae. Mar. Ecol. Prog. Ser. Vol. 247: 59-73, 2003.

Heck, K. L., K. W. Able, M. P. Fahay, and C. T. Roman. 1989. Fishes and decapods of Cape Cod eelgrass meadows: species composition, seasonal abundance patterns and comparison with unvegetated substrates. Estuaries, 12: 59–65.

Hughs, J. E., L. A. Deegan, J. C. Wyda, M. J. Weaver, and A. Wright. 2002. The effects of eelgrass habitat loss on estuarine fish communities of southern New England. Estuaries Vol. 25, No. 2. p. 235-249.

Hughes, J. E., L. A. Deegan, J. C. Wyda, and A. Wright. 2000. An Index of Biotic Integrity Based on Fish Community Structure Applied to Rhode Island and Connecticut Estuaries. Proceedings of the Long Island Sound Research Conference, November 17-18, 2000 at UCONN Stamford. CT Sea Grant publication CTSG-01-02.

Kemp, M., W. R. Boynton, R. Twiley, J. Stevenson, and J. Means. 1983. The decline of submerged vascular plants in upper Chesapeake Bay: Summary of results concerning possible causes. Mar. Tech. Soc. J. 17:78-89.

Keser, M., J.T. Swenarton, J.M. Vozarik, J.F. Foertch. 2003. Decline in eelgrass (Zostera marina L.) in Long Island Sound near Millstone Point, Connecticut (USA) unrelated to thermal input. J. Sea Res. 49: 11-26.

Knight, R.L. and R.B. Lawton. 1974. Report on the possible influences of thermal addition on the growth of eelgrass (Zostera marina) in Jordon Cove, Waterford, CT. Report to NUSCO. Waterford, CT. 12 pp.

Koch, E. W. and S. Beer. 1996. Tides, light and the distribution of *Zostera marina* in Long Island Sound. Aquatic Botany 53:97-107.

Lazzari, M. A. 2002. Epibenthic fishes and decapod crustaceans in northern estuaries: a comparison of vegetated and unvegetated habitats in Maine. Estuaries: Vol. 25, 6A, p. 1210-1218.

Lewis III R.R., P.A. Clark, W.K. Fehring, H.S. Greening, R.O. Johansson, R.T.Paul. 1999. The Rehabilitation of the Tampa Bay Estuary, Florida, USA, as an Example of Successful Integrated Coastal Management. Marine Pollution Bulletin, Vol 37, No 8. 6 pp.

Lipson, A. J. and R. L. Lipson. 1984. Life in the Chesapeake Bay. John Hopkins University Press. 229 pp.

Lockwood, J. C. 1990. Seagrass as a consideration in the site selection and construction of marinas. Environmental Management of Marina Conference. Sept. 5-7, Washington D.C. Technical Reprint Series, International Marina Institute, Wickford, Rhode Island.

Ludwig, M. 1977. Environmental assessment of the use of explosives for selective removal of eelgrass (Zostera marina). In: Proceedings of the second conference on the environmental effects of explosives and explosions (13-14 October 1976). Naval Surface Weapons Center, Silver Spring, MD. 6 pp.

MacKenzie, C.L., A. Morrison, D.L. Taylor, V.G. Burrell, Jr., W.S. Arnold and A. T. Wakida-Kusunoki. 2002. Quahogs in Eastern North America: Part I, Biology, Ecology, and Historical Uses. Marine Fisheries Review. 64(2) 2002. 55p.

MacLeod et al. 2002. Job 1: Marine Angler Survey. *In* A study of marine recreational fisheries in Connecticut. Annual performance report. CT DEP Fisheries Division, Old Lyme, CT. 166 pp.

Manderson, J. P., B. A. Phelan, A. W. Stoner and J. Hilbert. 2002. Predator-prey relations between age-1+ summer flounder (*Paralichthys dentatus*) and age-0 winter flounder (*Pseudopleuronectes americanus)*: predator diets, prey selection, and effects of sediments and macrophytes. J. Exp. Mar. Bio. And Eco. 25-: 17-39.

Matson, E.A. 1982. The use of tetrazolium salts in studies of carbon and energy dynamics in anoxic sediments. PhD dissertation. University of Connecticut.

Mattila, J., G. Chaplin, M.R. Eilers, K.L. Heck, Jr., J.P. O'Neal and J.F. Valentine. 1999. Spatial and diurnal distribution of invertebrate and fish fauna of a *Zostera marina* bed and nearby unvegetated sediment in Damariscotta River, Maine (USA). Journal of Sea Research 41:321-332.

Marshall, N. 1960. Studies of the Niantic River, Connecticut, with special reference to the bay scallop, *Aeguipecten irradians*: Limnology and Oceanography, v. 5, p. 86-105.

Marshall, N. 1994. The scallop estuary, the natural features of the Niantic River. Th' Anchorage Publisher, Maryland. 152 pp.

Martin, A.C. 1954. A clue to the eelgrass mystery. In Trans. of Nineteenth North American Wildlife Conference, p. 441-449.

McGill, D.A. 1974. A study of the Niantic River estuary. Part III. Further studies of the estuarine ecosystem. Section B. Chemical and biological relationships in the Niantic River estuary. Rpt No. RDCGA 29. U.S. Coast Guard Academy, New London, CT. 128 pp.

Muehlstein, L.K., D. Porter and F.T. Short. 1991. Observations of Labyrinthula zosterae sp. nov., the causative agent of wasting disease of eelgrass, Zostera marina. Mycologia 83:180-191.

Neckles, H.A., F.T. Short, S. Barker, and B.S. Knopp. 2005. Disturbance of eelgrass *Zostera marina* by commercial mussel *Mytilus edulis* harvesting in Maine: dragging impacts and habitat recovery. Marine Ecology Progress Series 285:57-73.

Nichols, G.E. 1920. The vegetation of Connecticut (VII). The plant associations of depositing areas along the seacoast. Bull. Tor. Bot. Club 47:511-548.

NUSCO (Northeast Utilities Service Company). 2000. Eelgrass. Pages 219-233. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station, Waterford, CT. Annual Rpt 1999. 252 pp.

NYSDS and USFWS 1999. Molluscan shellfish, South Shore Estuary Reserve Technical Report Series. Prepared for the South Shore Estuary Reserve Council by the NY State Dept. of State and USFWS Southern New England - NY Bight Coastal Ecosystems Program, Charlestown, RI. May 1999.

Orth, R. J. and K. A. Moore. 1983. Chesapeake Bay: An unprecedented decline in submerged aquatic vegetation. *Science* 222:51-52.

Orth, R J., J. R. Fishman, A. T. Tillman, S. E. Everett, K. A. Moore. 2001. Final report to the Virginia Saltwater Recreational Fishing Development Fund, Virginia Marine Resources Commission, Newport News, Virginia. 54 p.

Orth, R. J., J. R. Fishman, D. J. Wilcox, and K. A. Moore. 2002. Identification and management of fishing gear impacts in a recovering seagrass system in the coastal bays of the Delmarva Peninsula, USA. J. Coastal Research Spec. Iss. No. 37:111-129.

Perry, M. C., P. C. Osenton, and E. J. R. Lohnes. 2001. Food habits of mute swans in the Chesapeake Bay. Proceedings of the 2001 Wildfowl Trust Symposium: Mute swans and their Chesapeake Bay habitats.

Peterson, C.H., Summerson, H.C., and Duncan, P. B. 1984. The influence of seagrass cover on population structure and individual growth rate of a suspension-feeding bivalve, *Mercenaria mercenaria*. J. Mar. Res. 42: 123–138.

Ralph, J.P. and F. T. Short. 2002. Impact of the wasting disease pathogen, *Labyrinthula zosterae*, on the photobiology of eelgrass *Zostera marina*. Mar. Ecol. Prog. Ser. Vol. 226: 265-271.

Randall, T. A., J. K. Carlson, M. E. Mroczka. 1999. Distribution and density of submerged aquatic vegetation beds in a Connecticut Harbor. Rhodora Vol. 101, No. 905, 6 pp.

Raposa, K. B. and C. A. Oviatt. The influence of contiguous shoreline type, distance from shore and vegetation biomass on nekton community structure in eelgrass beds. Estuaries, Vol. 23, No. 1. p. 46-56.

Rasmussen, E. 1973. Systematics and ecology of the Isef Fjord marine fauna (Denmark) with a survey of eelgrass (Zostera) vegetation and its communities. Ophelia 11(2-3):1-507.

Rasmussen, E. 1977. The wasting disease of eelgrass (*Zostera marina*) and its effects on environmental factors and fauna. In C.P. McRoy and C. Helfferich, Eds. Seagrass ecosystems, a scientific perspective. Marcel Deker, New York.

Ruffen, K. 1995. Effects of hydraulic clam dredging on nearshore turbidity and light attenuation in Chesapeake Bay, Maryland. MS Thesis, University of Maryland. 97 pp.

Rutgers University. 2000. Small Motorized Watercraft Workshops 2000, Linking Science to Management. Institute of Marine and Coastal Sciences, New Brunswick, NJ. 53 pp.

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kruer. 1995. Scarring of Florida's seagrasses: assessment and management options. FMRI Tech. Rep. TR-1. Florida Marine Research Institute, St. Petersburg, Florida. 37 p. plus appendices.

Short, F.T., A.C. Mathieson and J.I. Nelson. 1986. Recurrence of the eelgrass wasting disease at the border of New Hampshire and Maine, USA. Marine Ecology Progress Series 29:89-92.

Short, F.T. 1988. Eelgrass-scallop research in the Niantic River: Final report to the Waterford-East Lyme Shellfish Commission. Nov 15, 1988. Unpublished report. Waterford, CT 22 pp.

Short, F.T., D.M. Burdick, and J.E. Kaldy III. 1995. Mesocosm experiments quantify the effects of eutrophication on eelgrass, *Zostera marina*. Limnol. Oceanogr. 40:740–749.

Short, F. T. and D. M. Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries. 19: 730-739.

Short, F. T. and S. Wyllie-Echeverria. 1996. Natural and human-induced disturbances of seagrasses. Environ. Cons. 23(1): 17-27.

Short, F. T., K. Matso, H. M. Hoven, J. Whitten, D. M. Burdick, and C. A. Short. 2001. Lobster use of eelgrass habitat in the Piscataqua River on the New Hampshire/Maine border, USA. Estuaries Vol. 24, No., 2, p. 249-256.

Smith, E., M.A. Alexander, M.M. Blake, L. Gunn, P.T. Howell, M.W. Johnson, R.E. MacLeod, R.F. Sampson, D.G. Simpson, W.H. Webb, L.L. Stewart, P.J. Auster, N.K. Bender, K. Buchholz, J. Crawford, and T.J. Visel. 1985. A study of lobster fisheries in the Connecticut waters of Long Island Sound with special reference to the effects of trawling on lobsters. Unpublished report. CT DEP, Marine Fisheries Program.

Sogard, S. M. and K. W. Able. 1991. A comparison of eelgrass, sea lettuce macroalgae, and marsh creeks as habitats for epibenthic fishes and decapods. Estuarine, Coastal and Shelf Science 33, 501-519.

Sogard, S. M. 1992. Variability in growth rates of juvenile fishes in different estuarine habitats. Mar. Ecol. Prog. Ser. 85: 35-53.

Stanley, J., R. DeWitt. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) – hard clam. U.S. Fish and Wildlife Service Biol. Rep. 82(11.18) pp 19.

Stevenson, J.C. and N.M. Confer. 1978. Summary of available information on Chesapeake Bay submerged vegetation. U.S. Fish and Wildlife Service Office of Biological Services. FWS/OBS-78/66. 335 pp.

Teixeira, R. L. and Musick, J. A. 2001. Reproduction and food habits of the lined seahorse, Hippocampus erectus (Teleostei: Syngnathidae) of Chesapeake Bay, Virginia. *Rev. Bras. Biol.*, vol.61, no.1, p.79-90.

Thayer, G.W., W.J. Kenworthy, and M.S. Fonseca. 1984. The ecology of eelgrass meadows of the Atlantic coast: A community Profile. U.S. Fish and Wildlife Service Office of Biological Services. FWS/OBS-78/66. 335 p.

Thom, R.M., Borde, A.B., Rumrill, S., Woodruff, D.L., Williams, G.D., Southard, J.A., Sargeant. S.L. 2003. Factors influencing spatial and annual variability in eelgrass (Zostera marina L.) meadows in Willapa Bay, Washington, and Coos Bay, Oregon, estuaries. Estuaries 26(4B): 1117-1129.

Tiner, R., H. Bergquist, T. Halavik, and A. MacLachlan. 2003. Eelgrass survey for eastern Long Island Sound, Connecticut and New York. U.S. Fish and Wildlife Service National Wetlands Inventory Program, Northeast Region, Hadley, MA. National Wetlands Inventory Report. 14 pp plus Appendices.

United States Fish and Wildlife Service. 2003. Environmental Assessment for the Management of Mute Swans in the Atlantic Flyway. Dept. of Interior, Arlington VA. 81pp.

US EPA. 1994. The Long Island Sound study, the comprehensive conservation and management plan. March 1994.U.S. EPA Long Island Sound Office, Stamford, CT. 184 pp.

Valiela, I., K. Foreman, MG. LaMontagne, D. Hersh, J. Costa, P. Peckol, B. DeMeo-Anderson, C. D'Avanzo, M. Babione, C.H. Sham, J. Brawley and K. Lajtha. 1992. Couplings of watersheds and coastal waters: sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts. Estuaries 15:443-457.

Vozarik, J.M., M. Keser and J.T. Swenarton. 2000. Distributional surveys of eelgrass (*Zostera marina* L.) at two locations in eastern Long Island Sound from 1974 to 1997. In: Proceedings of the 4rth Biennial Long Island Sound Research Conference. Nov 13-14, 1998.

Welsh, B.L., W.F. Bohlen and J.D. Buck. 1985. An investigation of impacts produced by settling basin discharges on the Copps Brook/Quiambog Cove system. Preliminary Rpt. Submitted to: The Connecticut-American Water Company, Greenwich, CT.

Wilkins, E. W. 1982. Waterfowl utilization of a submerged vegetation (Zostera marina and Ruppia maritima) bed in lower Chesapeake Bay. M.A. Thesis, College of William and Mary, Williamsburg, VA. 83 pp.

Willey, C. H. and B. F. Halla. 1972. Mute swans of Rhode Island. R.I. Dept. of Natural Resources. 47 pp.

Wyda, J. C., L. A. Deegan, J. E. Hughes and M. J. Weaver. The response of fishes to submerged aquatic vegetation complexity in two ecoregions of the mid-Atlantic bight: Buzzards Bay and Chesapeake Bay. Estuaries Vol. 25, No. 1, p. 86-100.

Yarish, C. In preparation. Environmental monitoring, seagrass mapping and biotechnology as a means of fisheries habitat enhancement along the Connecticut coast. Report #CWF 314-R to the CT DEP.

Zieman, J.C. 1976. The ecological effects of physical damage from motorboats on turtlegrass beds in southern Florida. Aquat. Bot. 2:127-139.

List of Personal Communications

Colarusso, Phil. Environmental Protection Agency, Boston, MA, Communication cited in ASMFC 2000.

Colarusso, Phil. Environmental Protection Agency, Boston, MA, 2002. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Francis, Peter F. 2002. Supervising Analyst, DEP OLISP. Communication with Ron Rozsa, Supervising Analyst, DEP OLISP.

Francis, Peter F. 2004. Supervising Analyst, DEP OLISP. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Groton Shellfish Commission. Communications conducted by Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program, with Ron Chappell, Chairman, 2002 and 2003; Ed Martin, Commissioner, 2002, 2003, 2005 and 2006 (currently Chairman); and Roger Sherman, 2006;

Howell, Penny and David Molnar. 2006. CT DEP Marine Fisheries Division. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Kremer, James. 2003. Professor of Marine Sciences, UCONN. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Landers, Don. 2002, 2004 and 2005. Chairman, East Lyme Harbor Management/Shellfish Commission. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Lazzari, M.A., K.W. Able, and M.P. Fahay. 1989. Life history and food habits of the grubby, *Myoxocephalus aeneus* (Cottidae), in a Cape Cod estuary. Copeia 1989(1): 7-12.

Ludwig, Mike. 1994. Fishery Biologist, National Marine Fisheries Service. Communication with Ron Rozsa, Supervising Analyst, DEP OLISP.

Old Lyme Shellfish Commission. Communication conducted by Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program, with Merv Roberts, Chairman, 2004.

Phil Colarusso, U.S. EPA Region I, Boston, MA. 2002. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Powell, Christopher. 2003. Marine Fisheries Biologist, RI Div. Of Fish and Wildlife. Communication with Mark Johnson Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Stewart, Lance, Marine Biologist, UCONN Cooperative Extension System, 2002. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

Stonington Shellfish Commission. Communications conducted by Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE, with Donald Murphy, Chairman, 2002, 2003 and 2005; and Alan Banister, 2002-2006.

Swenarton, John. 1991. Environmental Biologist, Millstone Environmental Laboratory. Communication with Juliana Barrett, Ecologist, with The Nature Conservancy, 1991, summarized in a letter from Juliana Barrett to Linda Gunn, Marine Fisheries Biologist, CT DEP, 9/24/1991, with enclosed maps.

Swenarton, John. 2006. Environmental Biologist, Millstone Environmental Laboratory. Communication with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program.

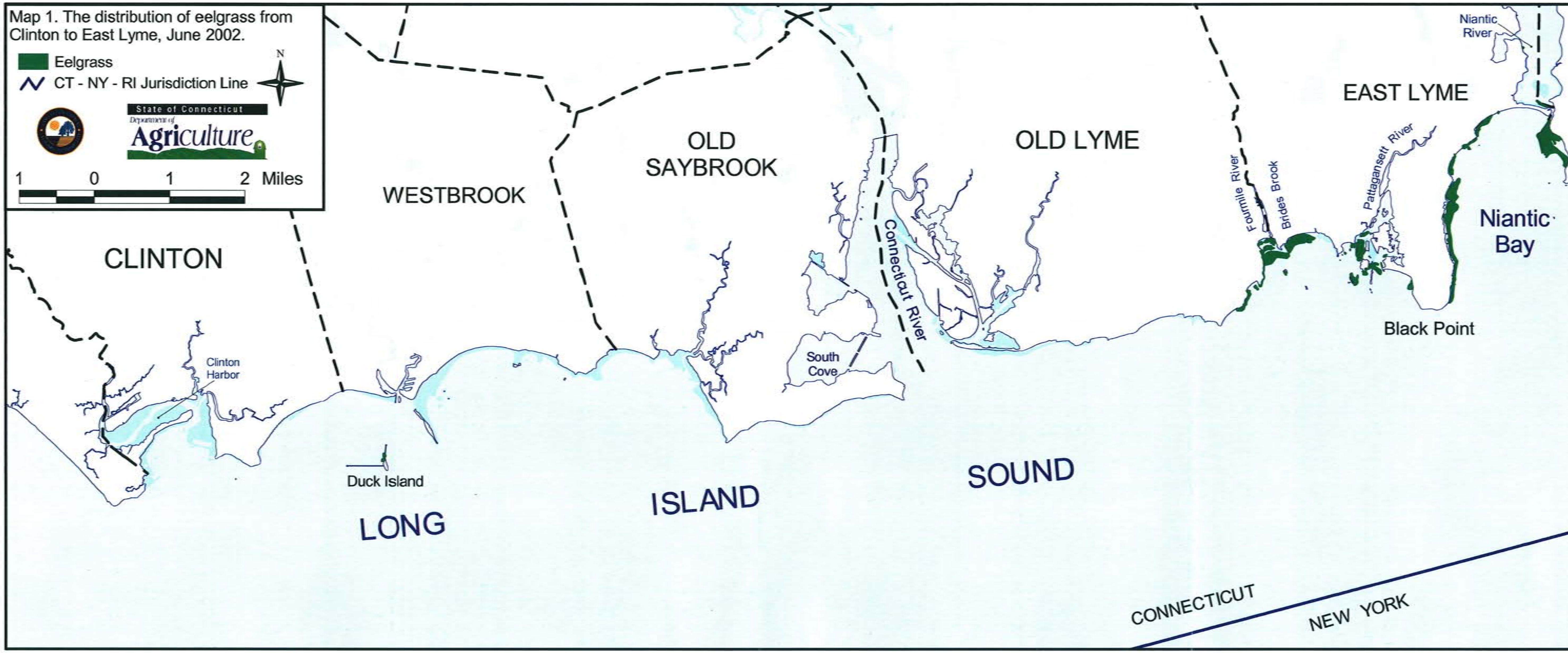
Warren, Scott. 2006. Professor of Botany, Connecticut College. Communication conducted by Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE,

Waterford Shellfish Commission. Communication conducted by Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE, with William Steinmiller, Chairman, 2002 and 2005.

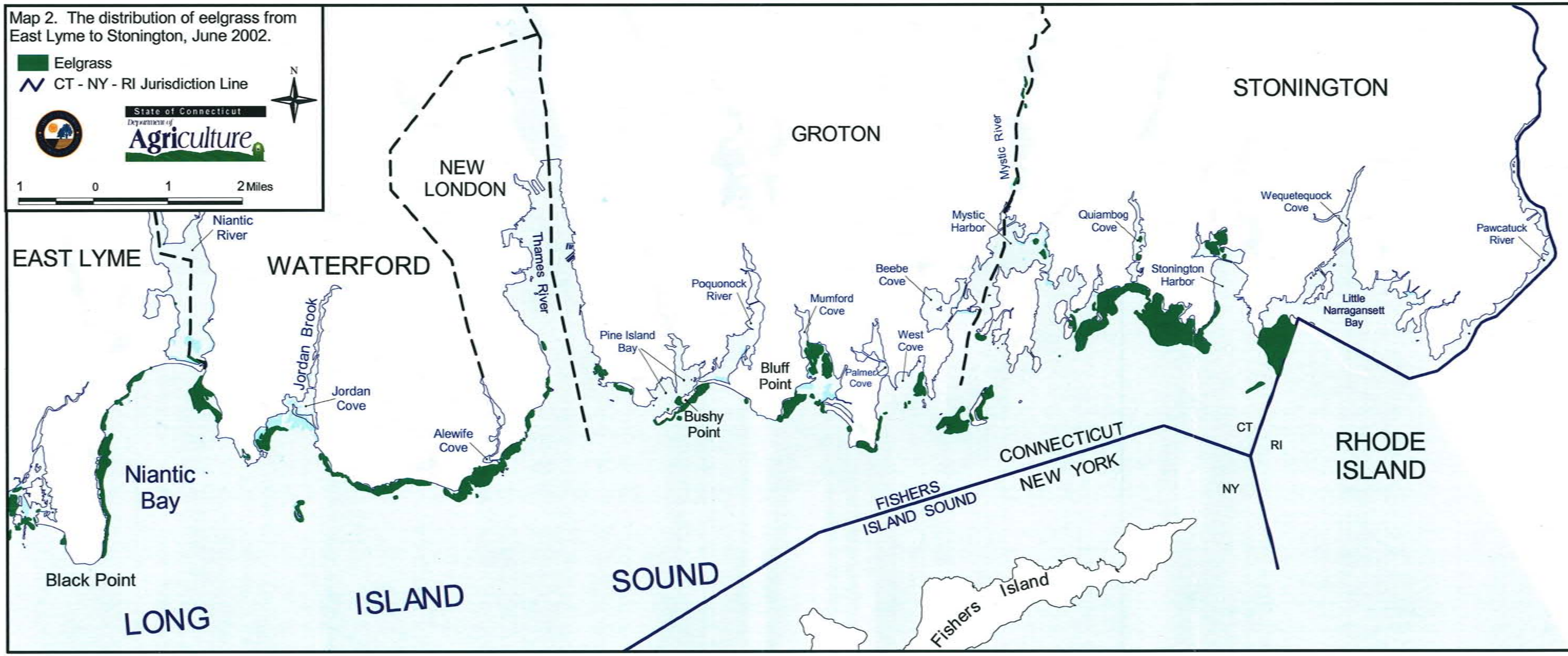
Waterford/East Lyme Shellfish Commission. Communications conducted with Mark Johnson, Senior Fisheries Biologist (Coastal), DEP/IFD/HCE program, with: Lorenz, Rinek, Chairman, 2002; Rick Kanter, Vice-Chairman, 2002, 2003, 2004 (currently Chairman), and Patrick Kelly, 2004.

Westerson, G. 2002. Connecticut Marine Trades Association. Communication with Ernest Beckwith, Director (former), DEP/MFD.

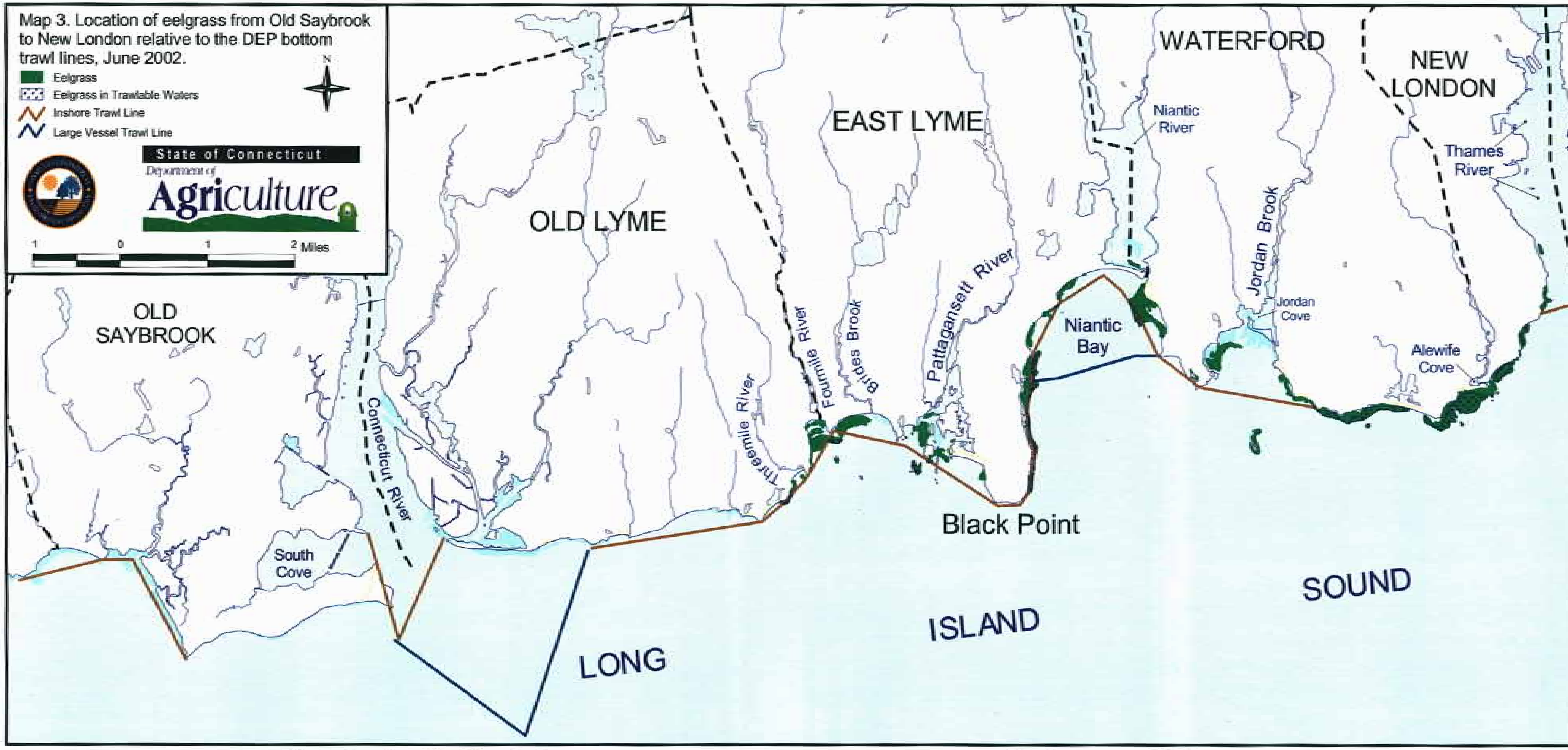
Maps Showing the distribution of eelgrass in eastern Long Island Sound in 2002 and Locations of Eelgrass relative to various regulatory designations.



This map depicts the locations of eelgrass as estimated by an eelgrass survey conducted by the U.S. Fish and Wildlife Service (Tiner et al. 2003). The locations of eelgrass were determined by evaluating a set of aerial photographs taken at low tide on June 18, 2002. The western most extent of eelgrass was near Duck Island, Westbrook.

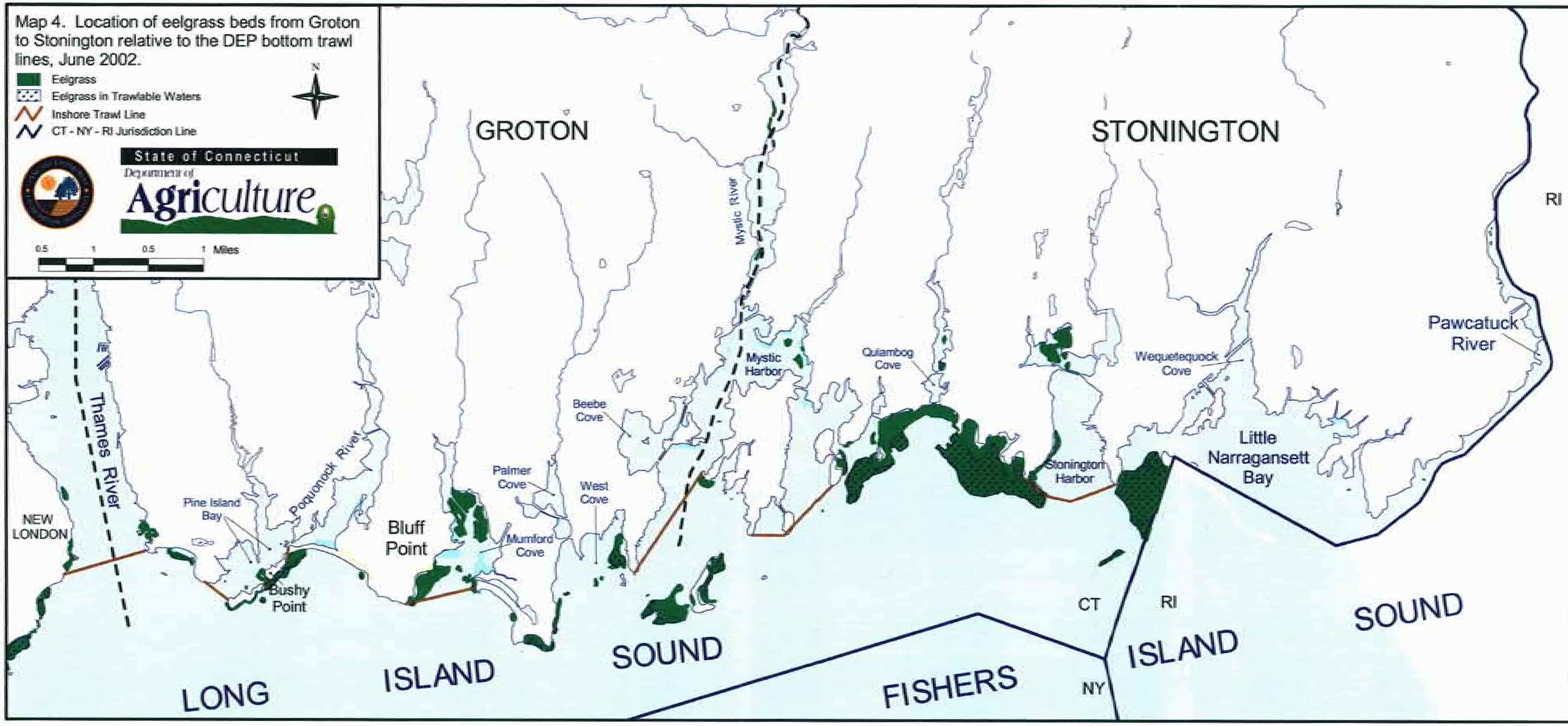


This map depicts the locations of eelgrass as estimated by an eelgrass survey conducted by the U.S. Fish and Wildlife Service (Tiner et al. 2003). The locations of eelgrass were determined by evaluating a set of aerial photographs taken at low tide on June 18, 2002.



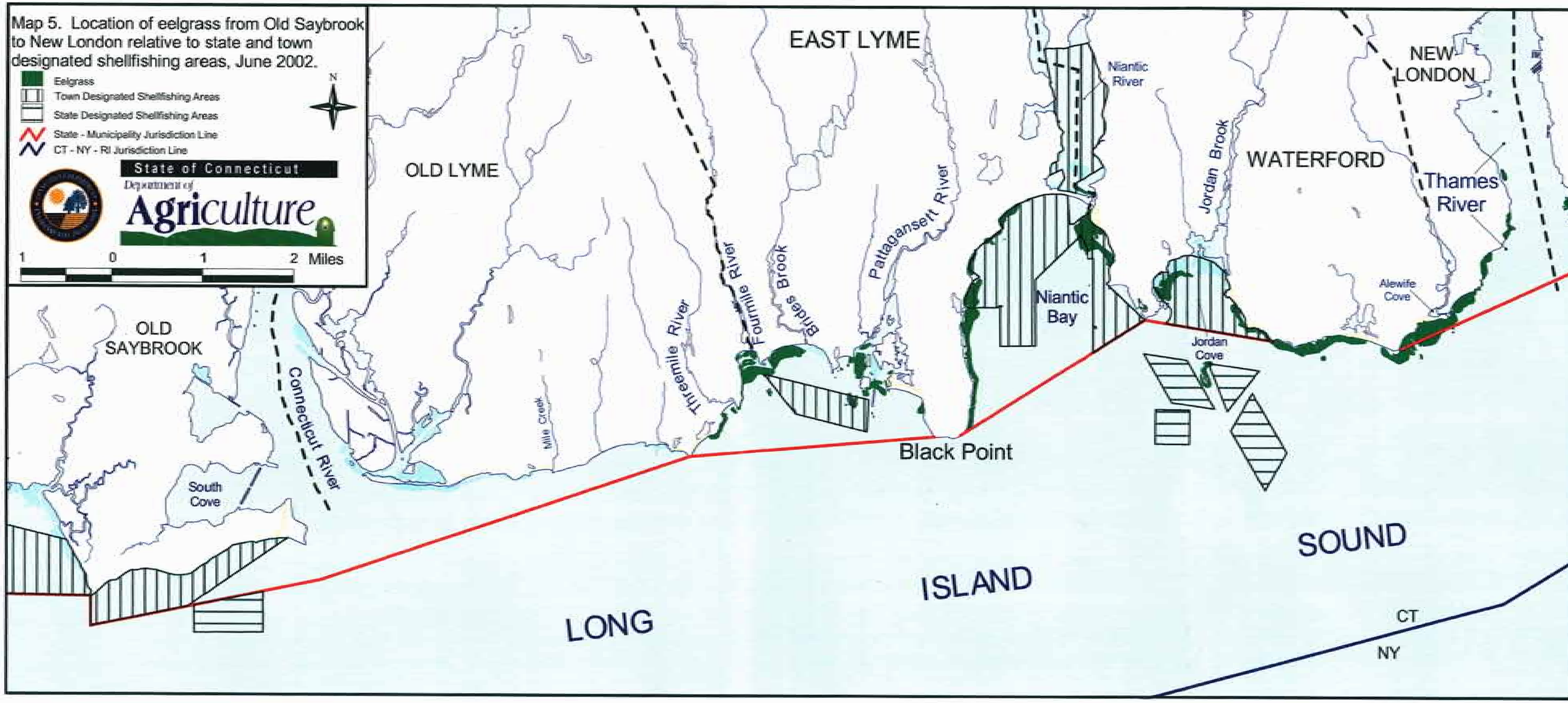
Map 3. Location of eelgrass from Old Saybrook to New London relative to the DEP bottom trawl lines, June 2002.

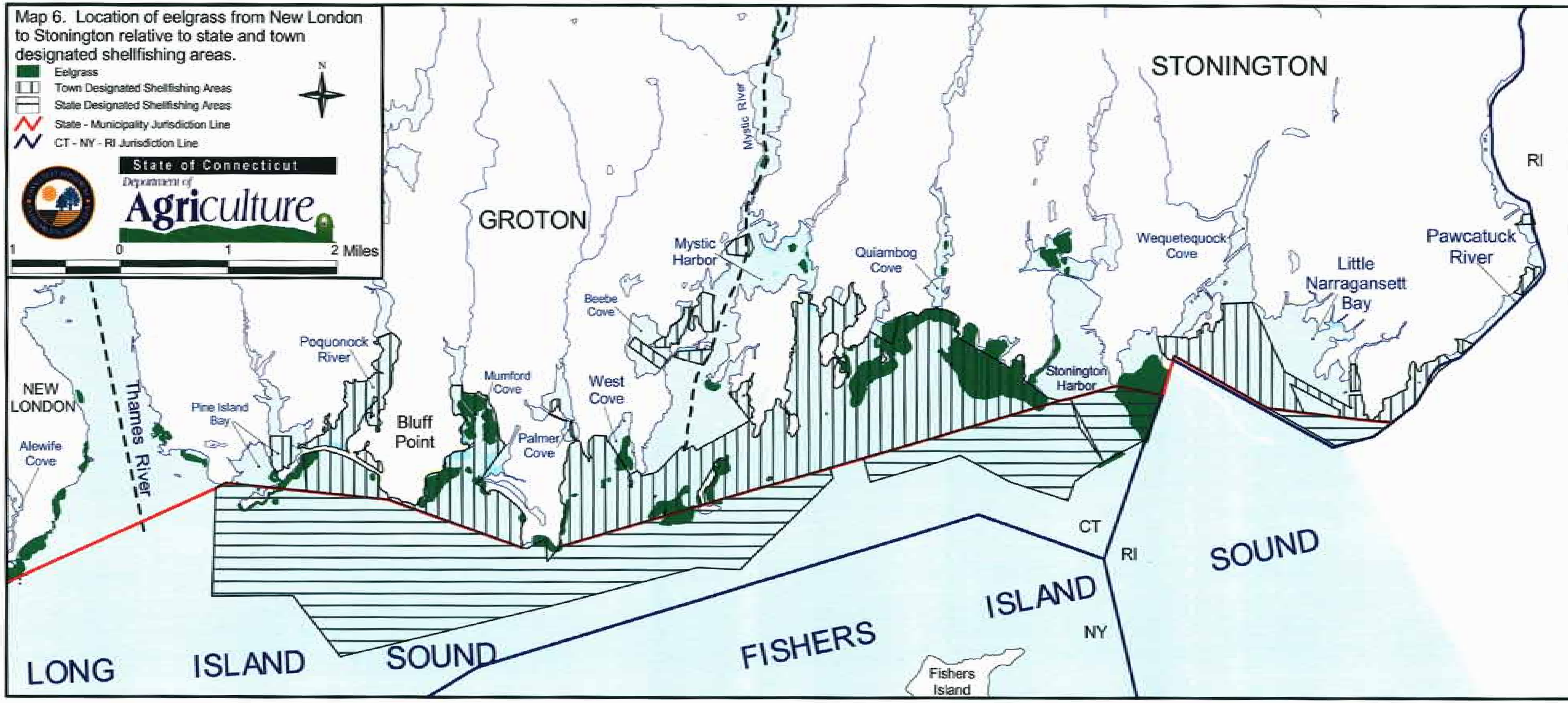
Trawling is prohibited shoreward of the inshore trawl line. Vessels larger than 26' are prohibited from towing a trawl net on weekends shoreward of the large vessel trawl line at the mouth of the Connecticut River, and vessels larger than 44' are prohibited from towing trawl net shoreward of the large vessel trawl line in Niantic Bay. Note that although some eelgrass was observed within areas that theoretically could be trawled, many of these areas cannot be trawled due to inadequate depth, obstructions and other factors. The distribution of eelgrass was based on the U.S. Fish and Wildlife 2002 eelgrass survey (Tiner et al. 2003).

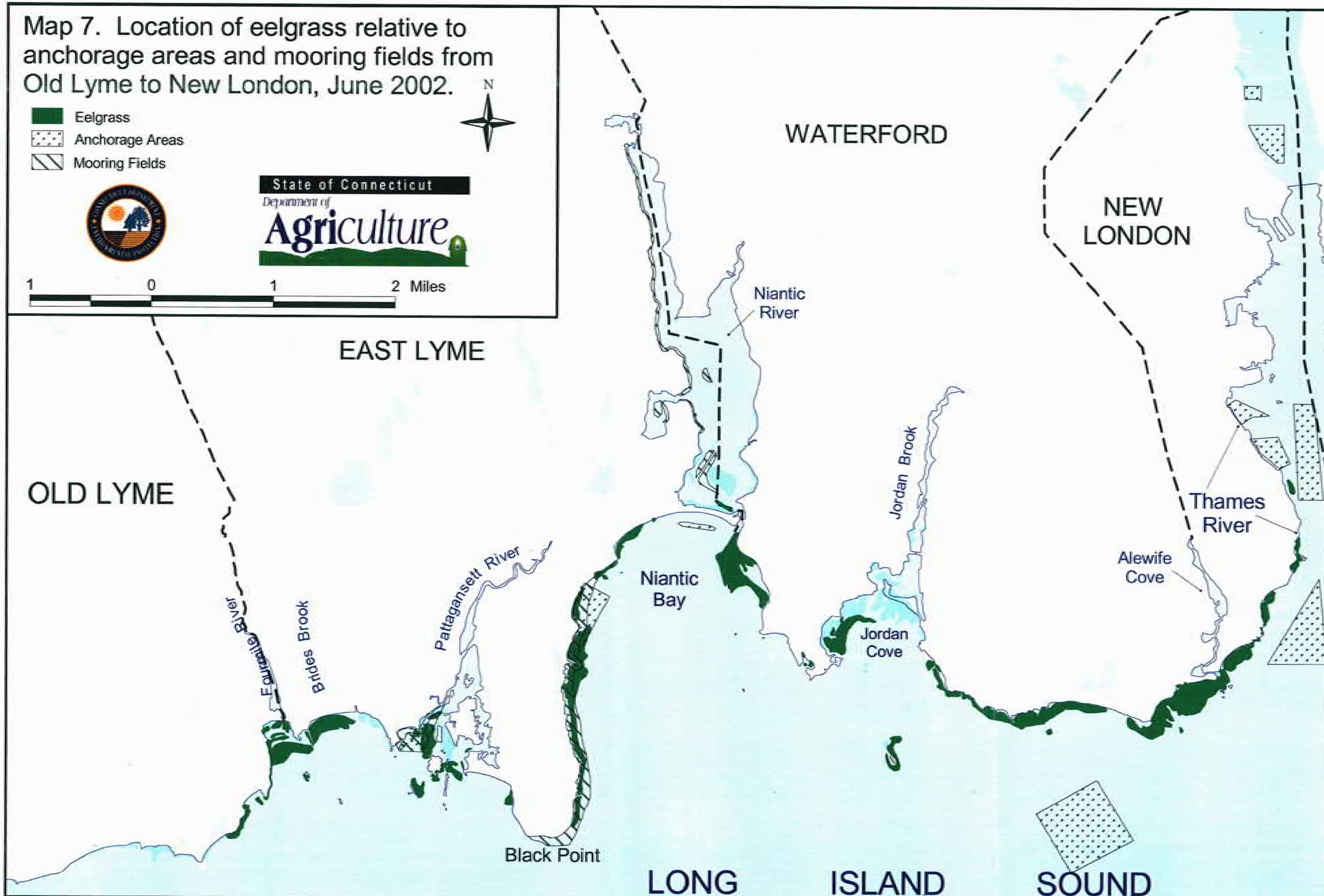


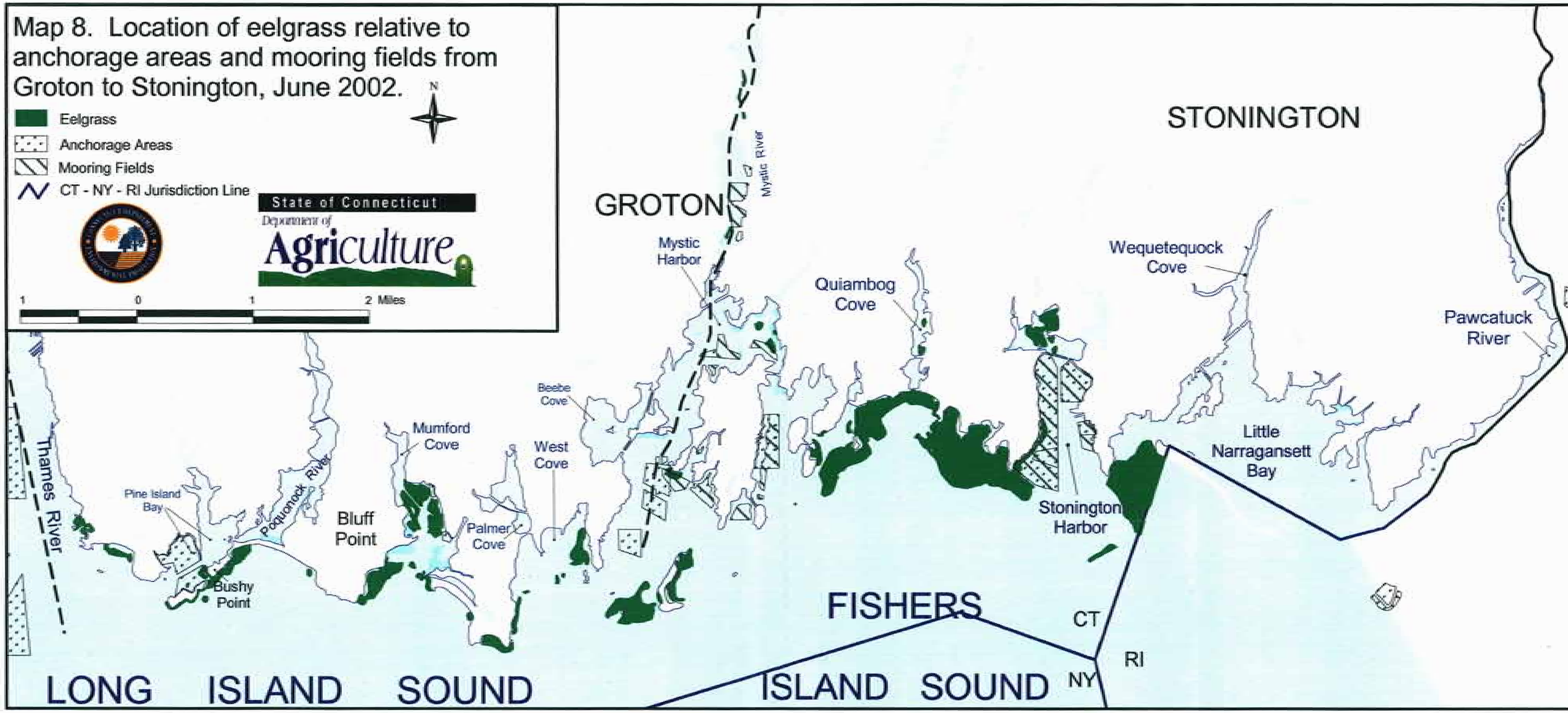
Map 4. Location of eelgrass beds from Groton to Stonington relative to the DEP bottom trawl lines, June 2002.

Trawling is prohibited shoreward of the inshore trawl line. Vessels larger than 26' are prohibited from towing a trawl net on weekends shoreward of the large vessel trawl line at the mouth of the Connecticut River, and vessels larger than 44' are prohibited from towing trawl net shoreward of the large vessel trawl line in Niantic Bay. Note that although some eelgrass was observed within areas that theoretically could be trawled, many of these areas cannot be trawled due to inadequate depth, obstructions and other factors.The distribution of eelgrass was based on the U.S. Fish and Wildlife 2002 eelgrass survey (Tiner et al. 2003).


Map 5. Location of eelgrass from Old Saybrook to New London relative to state and town designated shellfishing areas, June 2002.
Eelgrass
Town Designated Shellfishing Areas
State Designated Shellfishing Areas
State - Municipality Jurisdiction Line
CT - NY - RI Jurisdiction Line
N
State of Connecticut
Department of
Agriculture
1 0 1 2 Miles
OLD LYME
EAST LYME
WATERFORD
NEW LONDON
OLD SAYBROOK
Niantic River
Jordan Brook
Thames River
Pattagansett River
Bridges Brook
Fourmile River
Threemile River
Mile Creek
Connecticut River
South Cove
Niantic Bay
Jordan Cove
Alewife Cove
Black Point
LONG ISLAND SOUND
CT
NY


Map 6. Location of eelgrass from New London to Stonington relative to state and town designated shellfishing areas.
Eelgrass
Town Designated Shellfishing Areas
State Designated Shellfishing Areas
State - Municipality Jurisdiction Line
CT - NY - RI Jurisdiction Line
N
State of Connecticut
Department of
Agriculture
1 0 1 2 Miles
STONINGTON
GROTON
Mystic River
RI
Mystic Harbor
Quiambog Cove
Wequetequock Cove
Little Narragansett Bay
Pawcatuck River
Beebe Cove
Poquonock River
Mumford Cove
West Cove
Stonington Harbor
NEW LONDON
Thames River
Pine Island Bay
Bluff Point
Palmer Cove
Alewife Cove
CT
RI
SOUND
ISLAND
NY
LONG ISLAND SOUND
FISHERS
Fishers Island


Map 7. Location of eelgrass relative to anchorage areas and mooring fields from Old Lyme to New London, June 2002.
N
Eelgrass
Anchorage Areas
Mooring Fields
State of Connecticut
Department of
Agriculture
1 0 1 2 Miles
EAST LYME
WATERFORD
NEW LONDON
OLD LYME
Niantic River
Jordan Brook
Thames River
Alewife Cove
Niantic Bay
Jordan Cove
Pattagansett River
Brides Brook
Fourmile River
Black Point
LONG ISLAND SOUND


Map 8. Location of eelgrass relative to anchorage areas and mooring fields from Groton to Stonington, June 2002.
N
Eelgrass
Anchorage Areas
Mooring Fields
CT - NY - RI Jurisdiction Line
State of Connecticut
Department of
Agriculture
1 0 1 2 Miles
GROTON
STONINGTON
Mystic River
Mystic Harbor
Quiambog Cove
Wequetequock Cove
Pawcatuck River
Little Narragansett Bay
Stonington Harbor
Beebe Cove
West Cove
Mumford Cove
Palmer Cove
Bluff Point
Poquonock River
Pine Island Bay
Bushy Point
Thames River
FISHERS
ISLAND SOUND
CT
RI
NY
LONG ISLAND SOUND

APPENDICES

Appendix I. Public Acts 01-115 and 02-50.

Public Act No. 01-115

AN ACT CONCERNING RECREATIONAL FISHING IN CONNECTICUT.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

Sec. 4. Not later than January 1, 2002, the Department of Environmental Protection, in consultation with the Department of Agriculture, shall submit a report on its findings and recommendations concerning the effect of commercial and recreational fishing activities on glass eel beds in the state to the joint standing committee of the General Assembly having cognizance of matters relating to the environment, in accordance with the provisions of section 11-4a of the general statutes.
Sec. 5. This act shall take effect July 1, 2001.
Approved June 20, 2001

Public Act No. 02-50

AN ACT CONCERNING THE PROTECTION OF CONNECTICUT FISHERIES.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

Sec. 4. (NEW) (Effective from passage) The Commissioner of Environmental Protection shall adopt regulations, in accordance with chapter 54 of the general statutes, to protect and restore eelgrass, including the protection of existing eelgrass beds from degradation, the development of a restoration plan to restore eelgrass and the periodic monitoring of the effectiveness of such measures to protect and restore eelgrass.
Approved May 9, 2002

Note: Sections 1-3 of PA 01-115 and sections 1-3 of PA 02-50 are not relevant to this report and so were not included.

Appendix II. The Value of Eelgrass as Fish and Shellfish Habitat in Long Island Sound

Very little information is available that describes how eelgrass functions as fish and shellfish habitat in LIS, and the importance of eelgrass habitat to Connecticut's fisheries have not been documented. Therefore studies conducted in other states were also used to infer what species use eelgrass in LIS and for what purposes.

Fish and Crustaceans

Only one study of fish utilization of eelgrass habitat has been conducted in Connecticut's waters. This study sampled eelgrass habitat in Mumford Cove and the Niantic River (Hughes et al. 2000). However, the study was limited in scope, with sampling only conducted in July 1999. Sampling was conducted with a 4.8 m semi-balloon otter trawl during the day. The abundance of eelgrass in these areas was much reduced from historical levels, and one objective of the study was to determine if the remaining eelgrass was still functioning as fish habitat. The two most abundant fishes captured were Atlantic silversides (*Menidia menidia*) and four-spined stickleback (*Apeltes quadracus*). Other species that were captured in low numbers were: three-spined stickleback (*Gasterosteus aculeatus*), nine-spine stickleback (*Pungitius pungitius*), winter flounder (*Pseudopleuronectes americanus*), northern pipefish (*Syngnathus fuscus*), Atlantic tomcod (*Microgadus tomcod*), tautog (*Tautoga onitis*), cunner (*Tautogolabrus adspersus*), scup (*Stenotomus chrysops*), grubby (*Myoxocephalus aeneus*), and mummichog *(Fundulus heteroclitus)*. Although eelgrass was very limited in Mumford Cove and Niantic River, the authors concluded that it was still functioning as fish habitat.

A number of studies assessing the value of eelgrass as fish habitat have been conducted along the Atlantic Coast. Studies from New Jersey to Maine were selected since it is likely that a significant portion of the fish communities using eelgrass in these areas would be similar to that of LIS. Studies have been conducted in coastal embayments in New Jersey (Able and Kaiser 1991, Great Bay/Little Egg Harbor complex), New York (Briggs and O'Connor 1971; Great South Bay, L.I.), Rhode Island (Hughes et al. 2000, various coastal ponds), Massachusetts (Heck et al. 1989, Able et al. 2002, Nauset Marsh complex, Cape Cod; Wyda et al. 2002, Buttermilk Bay and Waquoit Bay, Cape Cod) and Maine (Mattila et al. 1999, Damariscotta River; Lazzari 2002, Casco Bay and Weskeag River).

Similar to Hughes et al. (2000), these studies typically used sampling methodology – small otter trawls, throw nets and beach seines – that are suitable for capturing juveniles and adults of small species. The same species were observed in these studies, with Atlantic silverside, sticklebacks and pipefish typically the numerically dominant species. A number of other species were observed, although they were either in low numbers or rare. Of these, the species that might be found in Connecticut's eelgrass meadows are: rainbow smelt (*Osmerus mordax*), black sea bass (*Centropristis striata*), lined seahorse (*Hippocampus erectus*), American eel (*Anguilla rostrata*), oyster toadfish (*Opsanus tau*) northern puffer (*Sphoeroides maculatus*), bay anchovy (*Anchoa mitchilli*), sheepshead minnow (*Cyprinodon variegatus*), bluefish (*Pomatomus saltatrix*), Atlantic menhaden (*Brevoortia tyrannus*), and Atlantic herring (*Clupea harengus*) (Table 1). A number of other species were observed inconsistently across studies and in very low numbers, indicating that eelgrass is probably not an important habitat for those species.

For most of these species, little is known about the relative importance of eelgrass habitat to their populations. The value of eelgrass habitat depends on a number of factors, such as which life-stages use the habitat (e.g. larvae, juvenile, adult), for what purpose they use it (e.g. spawning, refuge, feeding), and to what extent and purpose other habitats are used. The characteristics of the meadows can be important factors, such as the density and height of eelgrass plants, size of meadows and depth of water. The types of adjacent or integrated habitats (e.g. rocks, rocky reefs, macroalgae, open sea bottom) and location (e.g. within an embayment, open LIS) also play an important role, as most species utilize more than one habitat.

Following is an evaluation of the relative importance of eelgrass habitat in LIS for a selected list of species. The usage and value of eelgrass as fish habitat was inferred from the fish habitat utilization studies listed above, an ASMFC report that evaluated the reliance of recreationally and commercially important fish species on SAV habitat that are under ASMFC management (ASMFC 1997), and the considerable body of knowledge of fish ecology in LIS and along the Atlantic coast. Eelgrass habitat usage for each species, as well as a qualitative ranking of importance, is summarized in Table 1.

Sticklebacks, pipefish and seahorse. Of the species observed in studies conducted in southern New England, eelgrass is probably most important for sticklebacks (primarily four-spined stickleback) and northern pipefish. Four-spined stickleback and northern pipefish were observed in high numbers in all of the studies. These species are habitat specialists that are well adapted for life in eelgrass habitat, although they can be found in other habitats such as macroalgae and salt marshes. Eelgrass habitat is used for protection from predators, feeding and brooding young. Sticklebacks build nests, either on eelgrass leaves or on the bottom among the plants, in which eggs are laid. The long, slender body of the pipefish can mimic eelgrass leaves, which can be an aid to hunting prey and avoiding being the prey of larger fishes. When water temperatures decrease in late fall these species leave eelgrass habitat to overwinter in deeper water (Able and Fahay 1998).

As with pipefish and sticklebacks, lined seahorse is a habitat specialist well adapted to eelgrass habitat (see Lipson and Lipson 1984 for a good discussion of lined seahorse in Chesapeake Bay). Lined seahorse occurs from Uruguay to Nova Scotia bay (Teixeira and Musick 2001), but are rare in the northern part of the range. They occur in shallow water habitats, including eelgrass, in warmer months and appear to overwinter in deeper water (Able and Fahay 1998).

Of the eelgrass studies listed above, only one study in New Jersey (Able and Kaiser 1991) and one study in Rhode Island (Hughs et al. 2000) observed lined seahorse. In LIS, the Millstone Environmental Laboratory observed 253 lined seahorses in trawl samples from 1976 to 2004 (DNC 2005). The bottom type at the trawl sites is hard sand and depths ranged from 8 ft to 25 ft. Trawling was not conducted in eelgrass, but eelgrass was adjacent to the sites where the majority of the seahorses were observed. Most were observed in September, and none were observed in winter (John Swenarton, personal communication). DEP Marine Fisheries Division staff has observed eight seahorses in seine samples conducted since 1988. Of the total, six were observed in eelgrass in Clinton Harbor, one was observed at in Milford sample site attached to the alga *Codium* (*Codium fragile*), and one was observed at a Greenwich site, also attached to *Codium* (David Molnar, personal communication).

Although lined seahorse prefer eelgrass habitat, it should be noted that they are relatively rare in LIS, and it is questionable as to whether self-sustaining populations exist in LIS. Two researchers who studied the lined seahorse in Chesapeake Bay, where the species is also relatively uncommon, opined that mating within the bay was unlikely due to low numbers and sedentary habits (Teixeira and Musick 2001). They further speculated that egg-carrying males probably came into the bay attached to drifting vegetation that originated from areas south of the bay. If true, then it is likely this mechanism is responsible for the occurrence of lined seahorse in LIS.

Grubby. This species is a relatively small (typically less than six inches) member of the sculpin family. They range from shallow nearshore waters to deeper waters on the continental shelf and are found on a variety of habitats (Collette and Klein-MacPhee 2002). Spawning occurs in winter and the eggs are deposited on a variety of substrates. In nearshore waters they appear to prefer eelgrass habitat when available (Lazzari et al. 1989; Collette and Klein-MacPhee 2002). They were observed in eelgrass in most of the eelgrass habitat studies conducted in the mid-Atlantic Bight and Gulf of Maine. One study investigating the life history of grubby in the Nauset Marsh system on Cape Cod found most grubby were in eelgrass habitat compared to other habitats during December, suggesting that eelgrass was also a preferred spawning habitat (Lazzari et al. 1989).

Winter flounder – young-of-year and juveniles. Young-of-the-year and juvenile winter flounder likely use eelgrass habitat for feeding and protection from predators. It does not appear that eelgrass is a preferred habitat for winter flounder since most studies observed higher densities on open bottom. These studies should be viewed with caution, however, since it is unclear how efficiently a seine or trawl samples young-of-year flounder in eelgrass compared to open bottom. Young-of-year flounder can be abundant in low-density eelgrass (Goldberg et al. 2002), and some studies have indicated that they may prefer the open bottom adjacent to eelgrass meadows (Sogard and Able 1991; Saucerman 1990). Also, predator-prey experiments have shown that winter flounder are more likely to survive predation by summer flounder in eelgrass habitat compared to other habitats (Manderson et al. 2000). This study suggests that nearby, higher density eelgrass can serve as a refuge from predation. One study conducted in Maine found more winter flounder in medium density eelgrass compared to mudflat, but this study had very low sample size and the mudflat was not in the vicinity of the eelgrass meadow, making comparisons questionable (Mattila et al. 1998).

Tautog and black sea bass – young-of-year and juveniles. The young-of-year of these species were observed in most studies examining fish usage of eelgrass habitat, although the abundance of black sea bass was always low. Both species are very dependent upon structured habitat. Of the two, eelgrass is likely more important to tautog young-of-year and older juveniles. They probably use eelgrass for protection from predators and feeding on invertebrates during summer and fall. The relative importance of eelgrass habitat to their populations is unknown (ASMFC 1997). Both of these species use other habitats, such as macroalgae and rocky areas, where they are generally more abundant. Tautog young-of-year are often found nearshore in aggregations of sea lettuce (*Ulva lactuca*), whereas black sea bass are found from the nearshore out onto the continental shelf among various types of structured habitats, ranging from shell hash to rocky/macroalgae habitat (Able and Fahay 1998).

Atlantic tomcod and rainbow smelt. The juveniles and adults of these two species may use eelgrass habitat for feeding and refuge. Tomcod were frequently observed in most of the studies conducted in other coastal states (they were often seen in samples, but the number of individuals was low), and rainbow smelt were also observed. Both of these species have declined in LIS for unknown reasons. The relative importance of eelgrass habitat to their life history and survival is unknown, but the frequency with which they were observed in eelgrass habitat is intriguing.

Atlantic silverside. This small, but prolific, schooling species was commonly observed in most fisheries surveys of eelgrass habitat. In LIS, it is probably common in eelgrass, using the habitat for feeding and refuge from predators. However, schools of Atlantic silverside move among a variety of habitats. For example, densities of Atlantic silverside can be very high in marsh creeks (Sogard and Able 1991) and over open bottom (Briggs and O'Connor 1971).

Mummichog and sheepshead minnow. The occurrence of mummichog (another small, prolific schooling species that has been observed in some studies) in eelgrass habitat is probably dependent upon the proximity of eelgrass habitat to salt marshes and creeks (Raposa and Oviatt 2000), which is their primary habitat. They may make feeding forays into eelgrass or use it to hide from predators. Only one study reported sheepshead minnow (Briggs and O'Connor 1971), which is another small species common to salt marshes. This species may also make feeding forays into eelgrass, although its strong dependence upon salt marshes probably limits its occurrence in eelgrass (Able and Fahay 1998).

Scup – young-of-year and juveniles. Scup feed on a broad range of species, including many of the invertebrate animals prevalent in eelgrass. However, in all of the studies their absence or low numbers observed in studies indicates that eelgrass is probably not an important habitat for juvenile scup, particularly when their extensive use of other habitats is considered (e.g. see Gottschall et al. 2000 for a description of the distribution and occurrence of scup in depths greater than 25 ft in LIS).

American eel. This species was observed in most studies, although in low numbers. The type of sampling gear and methods probably under-sampled them (e.g. trawls, small throw nets, daytime sampling), so they may be more abundant than was indicated. American eel probably uses LIS eelgrass habitat for feeding on invertebrates and small fish and protection from predators. However, they use a wide variety of habitats for these purposes (Collette and Kein-MacPhee 2002), and can be particularly abundant in marsh habitat (ASMFC 1997).

Atlantic herring (young-of-year) and bay anchovy. Bay anchovy (all ages) and young-of-year Atlantic herring often occur in large numbers in New England estuaries, including LIS. In the studies cited above, only a few observed them in eelgrass habitat, and the numbers observed were low. Therefore, direct usage of LIS eelgrass habitat is probably minimal. But since these species can be found in the same depths as eelgrass, it would seem likely that in some locations schools of Atlantic herring young-of-year and bay anchovy may pass over and around eelgrass as they move among habitats, feeding on zooplankton in the water column. Conceivably, they may also use eelgrass as a refuge from predators.

Atlantic menhaden. Although few Atlantic menhaden were taken in surveys of eelgrass habitat, schools of this prolific fish are constantly moving among habitats as they filter food from the water. They can be found swimming above eelgrass, and will take advantage of the cover if attacked by predators. Eelgrass could also contribute to the diet of juvenile menhaden in two ways: (1) juveniles can digest cellulose and plant matter, and there is evidence accruing that detritus of vascular plant origin (salt marsh plants, possibly eelgrass) may be an important component in their diet; and (2) juveniles feed on small crustaceans (e.g. copepods), which feed on plant detritus and other material (see ASMFC 1997).

Adults of larger species: winter flounder, summer flounder, bluefish, striped bass and tautog. None of the studies mentioned above attempted to determine how larger sized individuals of these species use eelgrass (the sampling gears and methods were generally not suitable for catching them). They are all mobile predators that use a variety of habitats, and in LIS eelgrass meadows probably provide additional feeding opportunities. Adult winter flounder and summer flounder (*Paralichthys dentatus*) prefer open bottom, but probably hunt invertebrates and fish more along the edges of meadows and within less dense eelgrass, perhaps even using the meadows to escape from predators. If rocky habitat is nearby in suitable depths, adult tautog, which depends on that habitat, may make feeding forays into eelgrass, seeking invertebrates such as mussels and crabs. Bluefish (*Pomatomus saltatrix*) and striped bass (*Morone saxatilis*) are likely found around eelgrass. Bluefish, however, are probably not seeking out eelgrass habitat in particular since they are highly mobile predators, moving quickly in schools, chasing baitfish such as menhaden, bay anchovy and Atlantic silversides. In contrast, striped bass might hunt more deliberately around the edges and above eelgrass, looking for species such as Atlantic silversides, as well as various crustaceans (e.g. crabs, shrimp, amphipods, lobster).

American lobster and blue crab. Numerous crustaceans utilize eelgrass habitat, most notably American lobster (*Homarus americanus*) and blue crab (*Callinectes sapidus*). Studies of blue crabs in more southerly estuaries of the mid-Atlantic Bight (e.g. Chesapeake Bay) have found higher abundances in eelgrass compared to unvegetated areas. The meadows are settling areas for post-larval blue crabs and are used by juveniles for protection from predation and feeding. Adults also use the meadows for feeding and protection, and may use eelgrass as overwintering habitat. In addition, eelgrass detritus may be a part of the blue crab diet (see ASMFC 1997). It should be noted, however, that blue crabs use a variety of habitats, and they are not reliant on seagrasses. During a major seagrass decline in Chesapeake Bay from 1965 to 1980, commercial blue crab landings did not correspondingly decline, and some estuaries in South Carolina, Delaware and New Jersey that do not have seagrasses have substantial blue crab populations (ASMFC 1997). Similar studies have not been conducted in New England estuaries, and the usage and importance of eelgrass habitat is unknown. However, given the high usage in southern estuaries, it is likely blue crabs use eelgrass habitat in LIS for some of the same purposes.

Lobsters occupy a variety of structured habitats (ASMFC 1997). In LIS they are also very abundant on mud bottoms (see Gottschall et al. 2000 for a description of lobster distribution on sedimentary bottom types in LIS). The use of eelgrass as a structured habitat is not well documented. Lobster use of eelgrass habitat was studied in an estuary on the New Hampshire and Maine border (Short et al. 2000). Juvenile lobsters were more abundant in eelgrass compared to bare mud, burrowed among eelgrass plants, and overwintered in eelgrass. In mesocosm studies[33], juvenile lobster preferred eelgrass to bare mud. Other researchers have stated that lobster has a "strong reliance" on eelgrass habitat, but supporting documentation was not available (see ASMFC 1997). Lobster was only observed in one other study (Heck et al. 1989), but in low numbers, and the authors concluded that eelgrass was not an important habitat in that area (Nauset Marsh, Cape Cod). Based on this information, juvenile lobsters may use eelgrass habitat in LIS for burrowing, refuge and feeding. Furthermore, if rocky habitat were nearby, the adults and juveniles occupying that habitat probably would make feeding forays into eelgrass meadows. But, given the significant usage of other types of habitats, the relative importance of eelgrass habitat to lobster populations is unknown.

Shellfish

Similar to fish usage of eelgrass habitat, little has been done to document the extent to which shellfish use eelgrass habitat in LIS. One exception is the bay scallop (*Argopectin irradians*), one of the more notable species of shellfish found in eelgrass. Of all the finfish, crustacean and shellfish species considered in this report, it is probably the closest to being totally dependent upon eelgrass habitat (Thayer et al. 1984; ASMFC 1997). Young scallops settle out of the water column and attach to eelgrass leaves. Throughout their brief life (about two years) juveniles and adults use the meadows as a refuge from predators. Eelgrass detritus can be an important component of the bay scallop diet (Thayer et al. 1984).

Declines in eelgrass have often been associated with the disappearance of bay scallop. However, as with other species such as blue crab, populations of bay scallop can exist without eelgrass. For example, it appears that some of the largest harvests of bay scallops from the Niantic River occurred after eelgrass disappeared in the 1930s (Marshall 1960, Marshall 1994). Eelgrass is clearly an important habitat for bay scallop, but the Niantic River case demonstrates that the factors affecting population levels can be varied and complex.

Hard clams (*Mercenaria mercenaria*) inhabit a variety of substrates ranging from sand and gravel to mud, with preferences varying by region (Stanley and DeWitt 1983). Eelgrass meadows are not listed as a preferred habitat (e.g. see Stanley and DeWitt 1983; NYSDS and USFWS 1999; McKenzie et al. 2002).

Hard clams can be found in eelgrass meadows, but the extent to which they populate meadows is not well documented. A study of hard clams in eelgrass meadows of North Carolina found that densities of clams ranging in age from newly recruited to two years old was more than five times the average density of clams in nearby sand flats (Peterson et al. 1984). In addition, hard clams from eelgrass meadows appeared to be larger on average than those from sand flats. It was hypothesized that baffling of currents by the eelgrass might play a role: the reduction in currents enhances the deposition of fine sediments and suspended materials, providing a rich food source

[33] A mesocosm is a large tanks set up to mimic a natural ecosystem. Nutrients, animals or plants can be introduced in controlled quantities and resulting effects observed and measured.

for juvenile clams. On the other hand, adult hard clam abundance and growth rates were reported to be low in eelgrass meadows in the south shore embayments of Long Island (NYSDS and USFWS 1999).

In the shallow waters of the coastal bays of the Delmarva Peninsula (Virginia and Maryland), densities of hard clams in eelgrass meadows was sufficient to attract considerable commercial fishing effort (Orth et al. 2002). In Rhode Island, commercial and recreational harvest is not extensive in eelgrass, but does occur (Christopher Powell, personal communication).

Appendix III. Overview of Municipal Shellfish Commission Policies and Procedures Relevant to Eelgrass Conservation.

From 2001 through December 2005, municipal shellfish commissions in eastern LIS were contacted to discuss regulations or ordinances relevant to the conservation of eelgrass, measures taken during the leasing and permitting process to conserve eelgrass, and eelgrass monitoring and mapping programs (all personal communications conducted by Mark Johnson, Coastal Fisheries Biologist with the DEP Inland Fisheries Division, Habitat Conservation and Enhancement program). Phone conversations were conducted with one or more commissioners of each commission, including the Chairman of each commission if available. These discussions were conducted either for the direct purposes of this report or as part of shellfish aquaculture permit reviews. The summary of these discussions is not meant to be a complete description of each commission's permitting and leasing programs; rather, it is meant to highlight aspects of these programs that are most relevant to eelgrass conservation.

Old Lyme Shellfish Commission

The commission has responsibility for the authorization of commercial shellfishing and the regulation of recreational fishing through a permitting program. There are no regulations for either fishery. At this time, there is no commercial fishing activity. The last agreement the town had with a commercial fishermen was approximately ten years ago, which involved oyster harvest and relay in the vicinity of Griswold Point. Also at this time the town has suspended recreational harvest of shellfish because town waters are not classified as Approved (Merv Roberts, Chairman, personal communication). The town currently does not have sufficient funds to administer and enforce a recreational shellfishing program in waters otherwise classified (e.g. Conditionally Approved).

In the past the commission has not considered the effects of shellfishing on eelgrass. Since the commission associates eelgrass with scallops, and the town has not had a scallop fishery, little attention has been devoted to the distribution and status of eelgrass in town waters (Merv Roberts, Chairman, personal communication).

East Lyme Harbor Management/Shellfish Commission

The commission issues leases for commercial activities for a period of five years. Leases would not be granted in areas known to contain eelgrass; however, the presence of eelgrass is not assessed during the leasing review process. Recreational gear is limited to clam rakes and tongs. Commercial shellfishing is allowed in depths greater than 6 ft. While a hydraulic dredge is allowed to harvest clams commercially, this gear has been used in depths greater than 15 ft. There are currently no programs for mapping, monitoring, or restoring eelgrass. (Don Landers, Chairman, personal communication).

The commission will soon be making comprehensive revisions to the Shellfish Management Plan and Harbor Management Plan. A comprehensive overhaul is needed because the plans are outdated and unable to address the dramatic increased use of the town's waters in Niantic Bay by a variety of users, including shellfishermen (Don Landers, Chairman, personal communication).

The DEP OLISP municipal coastal program will be assisting the commission with this project. The CMA provides DEP OLISP with a variety of ways to assist towns with the requirements of the CMA, primarily through their municipal coastal programs and municipal plans of development (CGS Chapter 444, Sec. 22a-102 through Sec. 22a-112). To assist the town of East Lyme, a municipal grant was awarded in accordance with Sections 22a-112(a) for the purposes of funding a comprehensive assessment of the competing uses in the Easy Lyme coastal zone and updates of the Shellfish Management Plan and Harbor Management Plan as needed. The grant will also be used to develop a GIS application for data storage and analysis (for additional information about this grant, contact Marcia Balint, DEP OLISP).

The project will provide the town of East Lyme with the means to incorporate eelgrass protection and conservation measures in the plans. One key issue identified in the grant is to "Develop a clear policy for shellfish leases, including the clarification of the selection procedure, with the goal of promoting a viable shellfish industry in Niantic Bay while minimizing conflicts with boating and other public uses. Such policy shall be consistent with coastal resource protection and use policies of the Connecticut Coastal Management Act, *including those related to the preservation and restoration of eelgrass"* (emphasis added). The results of this project could serve as a model for other shellfish commissions looking to update their shellfish management plans with eelgrass management measures (Note: the plan was completed and submitted for adoption in 2005. Contact the East Lyme Shellfish Commission for additional information).

Waterford Shellfish Commission

Recreational shellfishing requires a permit from the Commission. Permits for recreational shellfishing stipulate that hoes or dredges cannot be used. Commercial shellfishing in Waterford town waters also requires a permit; however, the permit program is not well developed since there has been very little commercial shellfishing activity.

The Waterford Shellfish Commission currently does not have a policy concerning the protection of eelgrass. There are currently no programs for mapping, monitoring or restoring eelgrass (William Steinmiller, Chairman, personal communication). However, the commission is in the process of updating the Shellfish Management Plan, which will update the commercial permitting program and may include provisions for taking into consideration the effects of shellfishing on eelgrass.

Waterford/East Lyme Shellfish Commission

This Commission has joint jurisdiction over the Niantic River. The Commission has a recreational permit program and an experimental shellfish aquaculture program. There are no environmental regulations or ordinances that specifically protect eelgrass; however, Commission policy is to restrict activities that would negatively affect eelgrass. Scallops may be taken with ring and scoop nets of specified size, and clams may be taken with hand implements. Dredges are not allowed (Lorenz Rinek, former Chairman, Eric Kanter, Vice-Chairman, personal communication).

The Commission has a long history of promoting research and eelgrass conservation in the Niantic River. The Commission has been involved in eelgrass and bay scallop research and restoration, and has sought to protect eelgrass by enacting such measures as posting the location of eelgrass meadows in order to warn boaters not to motor through them, and by publishing and distributing informational pamphlets aimed at raising the boating community's awareness of eelgrass conservation issues. Although the Commission does not conduct regular eelgrass surveys, the Millstone Nuclear Power Station Environmental Laboratory has been conducting studies since 1985.

Groton Shellfish Commission

Applicants wishing to conduct shellfishing operations can apply for a co-management agreement that is valid for two years. The project is screened for negative impacts and conflicts with existing uses. After two years a report is submitted, and the shellfisherman can apply for a second 5-year agreement if no significant adverse impacts are identified. A shellfishing site would not be approved if eelgrass were present. However, since sites are not surveyed as part of the permit process, it is unknown if the policy protects eelgrass. The Commission currently does not have an eelgrass mapping, monitoring or restoration program. In 2003, commissioners attempted to conduct a visual survey by boat, and were able to determine the distribution of eelgrass in depths less than -4 ft MLW. The commission hopes to improve on eelgrass survey methods and conduct periodic surveys. (Ron Chappell, Chairman [former], and Ed Martin, Chairman [current], personal communications).

Stonington Shellfish Commission

The Commission has several shellfishing programs. A licensing program promotes small shellfishing businesses. Yearly, written reports are required, but no environmental assessment is included. There are no prohibited gears, but the type of gear must be specified during in the application. A Commercial Harvest Shellfish Permit allows individuals to harvest shellfish with bullrakes, tongs and a 14 in. hydraulic dredge. Another permit category allows the harvest of wild clams using the same types of gears.

The Commission has actively promoted eelgrass protection and restoration. Although there are no specific environmental regulations or written permitting guidelines for the protection of eelgrass, the Commission does consider the impacts on eelgrass when issuing permits. Hydraulic gear is not allowed in eelgrass. The Commission does not have a policy governing the use of aquaculture gear such as cages, but the need for a policy is currently being evaluated.

The Commission does not conduct formal, periodic, eelgrass surveys, but individual Commission members are familiar with the locations of eelgrass from year to year. The commission conducted a comprehensive survey in Little Narragansett Bay in 1998. One Commission member tested a method of transplanting eelgrass plants as a restoration method. (Donald Murphy, Chairman, Alan Banister, Commissioner, personal communication).