Blue Carbon, Green Eelgrass: Estimating Carbon Storage in Eelgrass in the Gulf of Maine

Funded by U.S. EPA Climate Ready Estuaries Program

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Table of Contents:

Executive Summary

This report describes a study to quantify carbon storage potential in eelgrass (*Zostera marina*) beds in Massachusetts coastal waters. The work was carried out between July and August 2015 by a team of researchers that included: U.S. Environmental Protection Agency (EPA) Region 1, MIT Sea Grant College Program, Massachusetts Bays National Estuary Program (MassBays), Boston University, McGill University and Massachusetts Division of Marine Fisheries *(MarineFisheries)* with funding from the U.S. EPA Climate Ready Estuaries Program. Background and methods are described as well as initial peer review and feedback obtained from the *Blue Carbon, Green Eelgrass Expert Workshop* held in December 2015.

Background

Carbon storage and sequestration by coastal marine ecosystems have been well documented in many areas around the world. Most studies related to carbon sequestration by coastal and marine habitats have focused on mangroves, salt marshes, and seagrasses. Currently, limited data exist on the carbon sequestration potential of seagrass species in temperate areas. This project aims to help fill this geographical data gap by documenting the carbon storage potential of eelgrass (*Zostera marina)* in Massachusetts coastal waters.

Estuarine habitats are among some of the fastest disappearing ecosystems on earth (Mcleod et al., 2011). As a whole, mangrove, salt marsh and seagrass ecosystems are estimated to be disappearing from 2 to 15 times faster than terrestrial forests (Campbell, 2010). Concern for the condition of these habitats is increasing as climate change intensifies. Increased sea surface temperatures and rising sea levels can have negative effects on estuarine ecosystems, and specifically seagrasses. For example, ocean warming has been found to negatively affect *Z. marina* populations by increasing summer die-offs (Carr et al., 2012). This in turn puts coastal urban environments at risk with the loss of these habitats as buffers against storms and sea level rise. Ocean acidification is also anticipated to have impacts on coastal ecosystems. Seagrasses have been identified as a buffer against ocean acidification by Hendriks et al. (2014), but as eelgrass populations decline, any mitigating benefits they may provide to the coastal ecosystem is lost.

Understanding the role that eelgrass ecosystems play in preparing for and mitigating the effects of climate change provides one opportunity to secure protection and restoration resources. In 2014, a pilot study was conducted by EPA, MIT Sea Grant and *MarineFisheries* to estimate blue carbon storage in eelgrass in Massachusetts coastal waters. The team estimated carbon storage in eelgrass beds at two sites: Pirates Cove, Nahant and Niles Beach, Gloucester (Colarusso et al.,

2015) (See Appendix 2, Figure 1). The estimates of carbon storage at the two sites were 0.3 – 0.9 Mg C ha^{-1} in living seagrass biomass and 4 – 25 C_{org} Mg C ha^{-1} in soil (Colarusso et al., 2015).


Eelgrass bed, Sandwich MA 2015 (Photo: P. Colarusso)

Building on the 2014 results, MassBays secured funding from EPA's Climate Ready Estuaries[1] program to coordinate a joint effort with EPA Region 1, MIT Sea Grant, Boston University, and *MarineFisheries* to conduct a study to quantify the carbon storage potential of eelgrass habitats in Massachusetts that will lead to an assessment of carbon sequestration potential of eelgrass and estimation of impacts of sea level rise on eelgrass ecosystem services. This study also seeks to raise awareness among decisionmakers at the federal, state, and local levels about the mitigating role that aquatic habitats, such as eelgrass, play in climate change. This project will continue to build the case for the conservation and restoration of these ecosystems based on services they provide.

Field Survey Methodology

The field survey for this project was conducted between July and September 2015 during which samples of eelgrass and sediment were collected from five eelgrass beds in Massachusetts: Niles Beach, Gloucester; Pirates Cove, Nahant; Cohasset Outer Harbor; Town Neck Beach, Sandwich; and Lagoon Pond, Oak Bluffs (Martha's Vineyard) (See Appendix 2, Map 1). These sites represent a wide range of wave and weather exposure conditions. Sampling methodology for this study follows the Global Seagrass Research Methods (2001, Short and Coles, eds.).

Eelgrass extent at each location was determined by driving parallel transect lines around each sampling site and then processing these data to create a mosaic of each meadow. At Pirates Cove, and Niles Beach, previous dual-beam (Biosonics) acoustic measurements with *in situ* confirmation by divers were used to delineate the areal extent of the meadows. At Cohasset and Sandwich, sidescan acoustic imagery with photo groundtruthing was used to map the beds during sampling conducted by divers. Previous aerial imagery was used to help define meadow boundaries as well. In Lagoon Pond, the meadow was delineated by direct observation by divers recording the location of the perimeter with differential GPS. The acoustic surveys to develop maps of eelgrass beds in the study locations were conducted by *MarineFisheries* (Sandwich and Cohasset) and by MIT Sea Grant (Gloucester and Nahant).

Collecting sediment cores 2015 (Photo: P. Colarusso)

In Nahant and Gloucester, eelgrass beds spanned large depth ranges. Ten eelgrass samples and three sediment cores were randomly collected from each depth zone: shallow water (0 – 2m MLW), mid-water (2 – 4m MLW), and deep water (4 – 6m MLW). In Cohasset, Sandwich and Martha's Vineyard, meadows occupied a narrower depth range, and therefore ten eelgrass samples and three sediment cores were taken from one depth zone only at each site. Eelgrass shoots were collected from 10 randomly placed quadrats at each depth zone. Three sediment cores from a reference site (no eelgrass) at each location were also collected. At each location, each sediment core was processed into 10-cm subsamples and 20-ml samples collected from each subsample for further analyses in the laboratory. Each eelgrass shoot collected was measured from the meristem to the tip to provide data for shoot length. Ten shoots were randomly selected from each location and wrapped in aluminum foil for further analyses in the laboratory. Eelgrass shoots collected in Nahant, Cohasset and Gloucester were examined for invasive species, in particular tunicates, and data on the species observed were recorded.

Eelgrass and sediment sample analyses

Shoot density and length were measured in the field. Eelgrass biomass and sediment bulk density were measured at MIT. Percent carbon (C), nitrogen (N), stable isotopes and organic matter in shoots and sediments were measured at Boston University. Conversion factors were then developed to estimate the absolute carbon from percent organic matter.

Wave exposure and fetch

Wave exposure values (Thomas, 1986) were estimated for each site in order to examine possible correlations with above-ground organic carbon as well as eelgrass meadow density. The wave exposure index was calculated for each site.

Table 1: Exposure Index values at the survey stations.

Eelgrass location	Exposure Index
Niles Beach, Gloucester	4.478
Pirates Cove, Nahant	5.782
Cohasset Harbor	9.570
Town Beach, Sandwich	8.632
Lagoon Pond, Oak Bluffs (Martha's Vineyard)	2.991

Results

In both 2014 and 2015, sediments within eelgrass meadows were found to store more carbon than sediments in adjacent, unvegetated reference sites. The amount of carbon in the sediments was also more variable within eelgrass beds than in reference sites. There was no correlation between carbon storage and wave exposure indices (Figure 1).

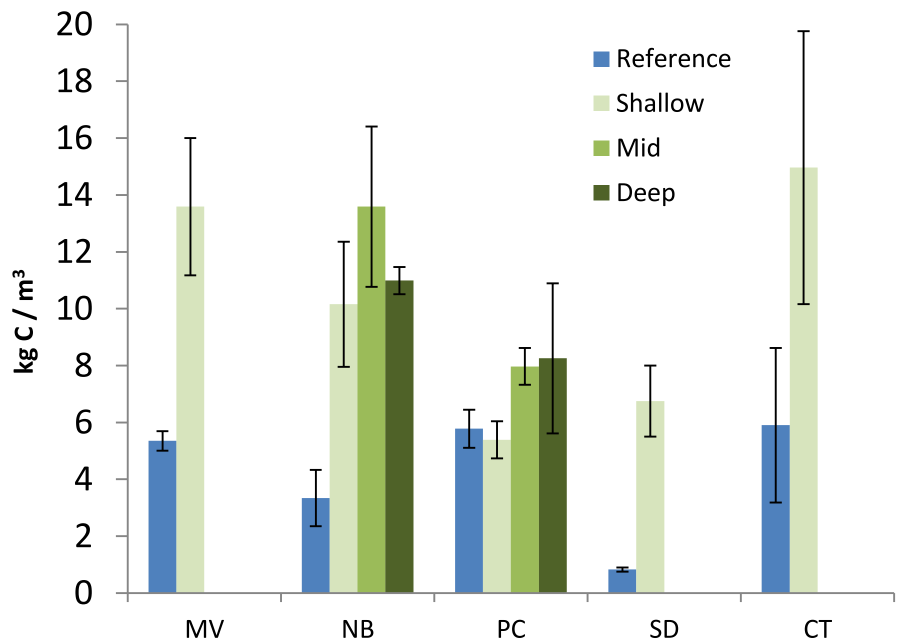

Figure 1. Carbon standing stock in the top 30 cm of sediment, measured in 2015. Sites are arranged on x axis along a wave exposure gradient (MV = lowest, CT = highest). Error bars are +/- s.e. [Lagoon Pond = MV; Gloucester = NB; Nahant = PC; Sandwich = SD; Cohasset = CT].

There was no clear trend of decrease in carbon content with depth of core, with consistent sediment carbon content throughout the 30 cm of the cores, with the exception of the Cohasset site where carbon content actually increased with sediment depth (Figure 2).

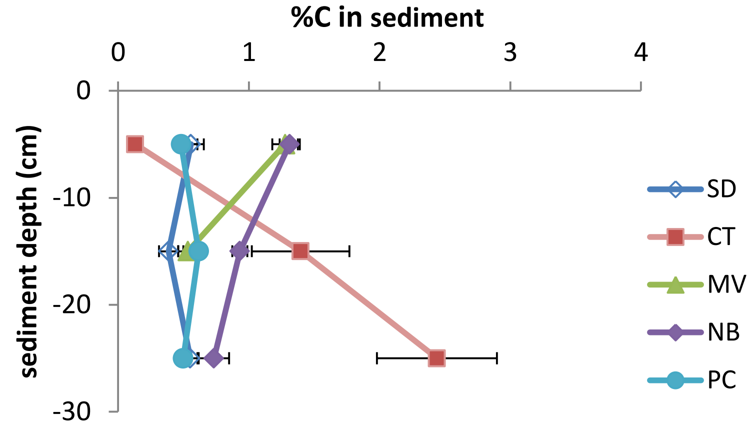

Figure 2. Percent carbon in sediments with depth of core. Error bars are +/- s.e. [Lagoon Pond = MV; Gloucester = NB; Nahant = PC; Sandwich = SD; Cohasset = CT].

Stable isotopes of carbon and nitrogen in sediments did not match values for either eelgrass tissue (measured in this study) or for phytoplankton and particulate organic matter (values from studies conducted in Massachusetts Bay, Woods Hole, and Narragansett Bay; Oczkowski et al. 2014, Fry and Wainright 1991), but fell in between those two ranges. This suggests that the carbon in the meadow sediments represents a combination of these two likely sources, and that the stored carbon is sequestered both through fixation (photosynthesis performed by the eelgrass) and collection of organic matter from the water column (Figure 3).

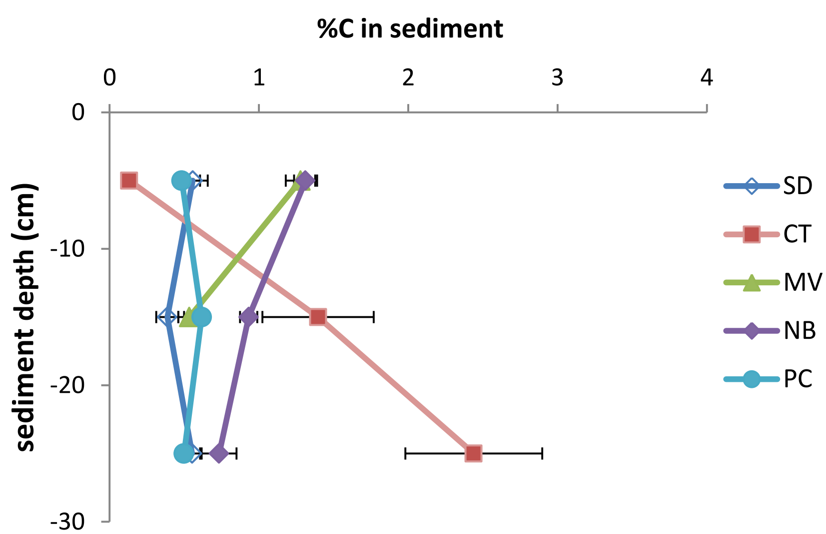

Figure 3. Stable isotope values measured in above ground plant tissues and sediments. The green shaded box represents the range of isotope values of phytoplankton (PP) and particulate organic matter (POM) published in studies from Massachusetts Bay and off the south coast of Cape Cod.

The results of the 2014 study, the current study (2015), and a comparison to global values are presented in Table 2 below.

Table 2: Living seagrass biomass and soil C_{org} global values and Gulf of Maine values.

	Living Seagrass Biomass MgC ha^{1} (mean +/- 95%Cl)	**Soil C_{org} MgC ha^{-1} (mean +/- 95%Cl)**
*North Atlantic	0.85 ± 0.19	48.7 ±14.5
*Global Average	2.51 ± 0.49	194.2 ± 20.2
2014 Study (Colarusso et al. 2015)	0.3 – 0.9	4.0 – 25.0
2015 Study (unpublished)	0.25 – 3.0	12.0 – 50.0
**Data from Fourqurean et al. 2012 (1 MgC ha^{-1} = 100 gC m^{-2})*		

Other findings from the 2015 Blue Carbon study include:

- Eelgrass beds in Massachusetts hold more carbon compared to unvegetated habitats, in amounts comparable to or exceeding values reported from the North Atlantic.
- The growth of eelgrass may be carbon-limited at some sites. Higher wave exposure was correlated with higher amounts of above-ground organic carbon and with lighter ^{13}C values in plant tissues.
- Carbon is likely sequestered through both fixation and collection. Stable isotope values suggest carbon stored in sediments does not originate solely from eelgrass, but likely also originates from phytoplankton and other particulate organic matter. A substantial amount of carbon is fixed annually in above-ground plant tissues, and its fate and longevity are largely unknown.
- Opportunities for inland migration of coastal communities are limited. Sea level rise may thus reduce eelgrass' valuable carbon storage capacity in the future, both through lack of space for migration as well as increase in water depth.

Blue Carbon, Green Eelgrass Workshop

The preliminary results of the 2015 Blue Carbon study were presented to a group of experts at the *Blue Carbon, Green Eelgrass Workshop* in Saugus, MA on December 9, 2015. The goal of the workshop was to examine the methodology and preliminary results of this field study, suggest future analyses, highlight public outreach opportunities, and identify possible policy recommendations and directions to inform decision making. The project team presented: 1) a comprehensive review of historical literature on eelgrass in Massachusetts and review of current literature on blue carbon in eelgrass and other seagrass species, 2) project background, 3) field sampling and laboratory work, and 4) mapping of eelgrass beds and comparison with historical aerial photography. Attendees included researchers and managers from fields related to eelgrass work. A complete list of participants is provided in Appendix 1. Discussion among attendees addressed the following questions intended to further the project team's understanding of the carbon storage value of eelgrass in Massachusetts.

1. Based on the preliminary results of the study, can we estimate the carbon storage in existing eelgrass beds in Massachusetts and make conclusions about its value as an ecosystem service?
2. Based on anticipated sea level rise, do we know how carbon storage by eelgrass in Massachusetts may change?
3. Can we estimate the amount of eelgrass loss that could result from sea level rise? Will shoreward migration occur that will mitigate the loss of deep edges?
4. How important is mapping in this project and how accurate does it need to be? How sensitive are the carbon estimates to the area of eelgrass?

Recommendations:

- Core samples to determine sequestration rate should be taken using a graduated sampling method using 1-cm samples from the top of each subsample. It is also important to determine what information the core samples are providing to the study. If the last 50 years of carbon sequestration is only accounted for in the upper 4 cm of the sample, then only that section should be subsampled, as the deeper sections of the core will only indicate what conditions were like in sandy areas when eelgrass was not present.
- Core samples should be divided, harvesting the top layer to be dried and measured for bulk density, then the entire core homogenized before subsampling. It may also be beneficial to obtain a short-term snapshot image of the sediment deposition rate at various sites. This could be done by deploying sediment traps in the areas of interest.
- The laboratory protocol called for rocks and shells to be ignored for bulk density determinations. However it is recommended that bulk density be determined for the entire integral sample, regardless of sediment size and composition. The sample should be homogenized prior to subsampling. The purpose of bulk density is to determine the water content of the sample. When the sample is extruded from the corer most of the water content is lost. Installing ports in the side of the core sampler would allow samples to be acquired without losing any interstitial water. Carbon concentration in sediment may also be influenced by bulk density. It is recommended that these calculations be incorporated rather than strictly using results of mass spectrometry.
- Grain size analysis should be incorporated into the methodology as there is a strong correlation between grain size and loss of ignition.
- The study analyzed eelgrass shoot density versus exposure, however in the future it may be better to examine the relationship between biomass and exposure.

- The living seagrass biomass and soil C_{org} results for this study are presented across a range of conditions. It may be more useful to calculate a mean to facilitate comparison with similar studies.
- The information collected from this study is representative of the processes that are occurring in these beds at one point in time. Additional factors such as grain size, fetch, plant cover, and water depth should also be considered to determine which of these factors is most important.
- Standard measures of percentage cover are needed to connect carbon storage estimates with eelgrass beds of varying density.
- Clammers, Conservation Commission, shellfish wardens, harbormasters, and coastal planners should be engaged to increase seagrass protection.
- The same sites should be studied in future investigations. It would be best to use improved sampling methods (as described above) in at least some of the same sites used in this study.
- The goals of this project seem too broad. It is important going forward that the study is looked at with a more focused research question in mind.

Conclusions

1) Based on the preliminary results of the study, can we estimate the carbon storage in existing eelgrass beds in MA and make conclusions about its value as an ecosystem service?

    The preliminary results of this study could be used to estimate carbon storage in existing eelgrass beds in Massachusetts with a few caveats. In order for estimates to be reliable, mapping of eelgrass beds would have to be done with a relatively high level of confidence. With accurate mapping, extrapolations from beds with calculated carbon storage values could be completed with increased confidence. Accurate estimates of sediment type and eelgrass cover density are also important if existing maps are to be used to forecast carbon storage. It would also be important to consider that the calculated carbon storage quantities from this study were taken from high density beds. Current mapping shows that some beds in Massachusetts are patchy while some are continuous. Applying the carbon storage number from a high density bed to the entire Massachusetts coast may result in a potentially inflated value.

2) Based on anticipated sea level rise, do we know how carbon storage by eelgrass in Massachusetts may change?

Blue carbon is likely going to decrease with increasing sea level rise. Even if seagrass beds are able to migrate upshore, the initial beds developed will be sparse. It will take many years for carbon to accumulate in the sediment.

3) Can we estimate the amount of eelgrass loss there could be from sea level rise? Will shoreward movement occur that will mitigate the loss of deep edges?

   This study provides good shoreline information from a geological perspective and detailed bathymetry information for a few sites in Massachusetts. This information highlights the fact that sea level rise and its corresponding effect on carbon storage in eelgrass is something that needs more research and attention. Using coastal LiDAR data may be helpful. Any shoreward movement that occurs as a result of sea level rise will not immediately mitigate the loss of deep edges, as it will take many years for carbon to accumulate in new beds.

4) How important is mapping in this project and how accurate does it need to be? How sensitive are the carbon estimates to the area of eelgrass?

   The mapping component of this project is very important in order to determine the potential for carbon storage. Where mapping needs to occur can be more accurately assessed once more detailed research questions and goals are identified. If the objective is to gain a comprehensive understanding of the carbon storage in eelgrass beds for the entire Massachusetts coast, then accurate mapping is a very important component. As only high density beds were surveyed in this study, it is essential that a standard measure of cover is established. This will enable estimates of carbon storage for varying densities of eelgrass meadows. As a substantial amount of carbon is fixed in above ground biomass, patchy beds may have very different carbon storage values than dense beds.

Next Steps

Funding has been secured from EPA Office of Research and Development to continue research on carbon storage in eelgrass for the 2016 and 2017 field seasons. More focused research questions will be developed and methodologies improved based on the input provided at the Blue Carbon Expert Workshop will be employed where possible.

Outreach is the next step in this study under the Climate Ready Estuaries grant. Drawing on conclusions from the expert workshop, clammers, conservation commissioners, shellfish wardens, harbormasters, and coastal planners will be the target audience. MassBays and MIT Sea Grant will be leading the outreach phase of this project.

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Appendix 1

2015 Blue Carbon, Green Eelgrass Project Team (alphabetical):

Phil Colarusso, U.S. Environmental Protection Agency Region 1

John Deane, McGill University

Pamela DiBona, Massachusetts Bays National Estuary Program

Kathryn Ford, Division of Marine Fisheries

Regina Lyons, U.S. Environmental Protection Agency Region 1

Alyssa Novak, Boston University

Mark Rousseau, Division of Marine Fisheries

Julie Simpson, MIT Sea Grant College Program

Sarah Stanley, Massachusetts Bays National Estuary Program

Prassede Vella, Massachusetts Bays National Estuary Program

2015 Blue Carbon, Green Eelgrass Workshop Attendees (alphabetical):

Kathryn Baltes, MIT Sea Grant College Program

Tay Evans, Division of Marine Fisheries

Melanie Hayne, Marine Biological Laboratory

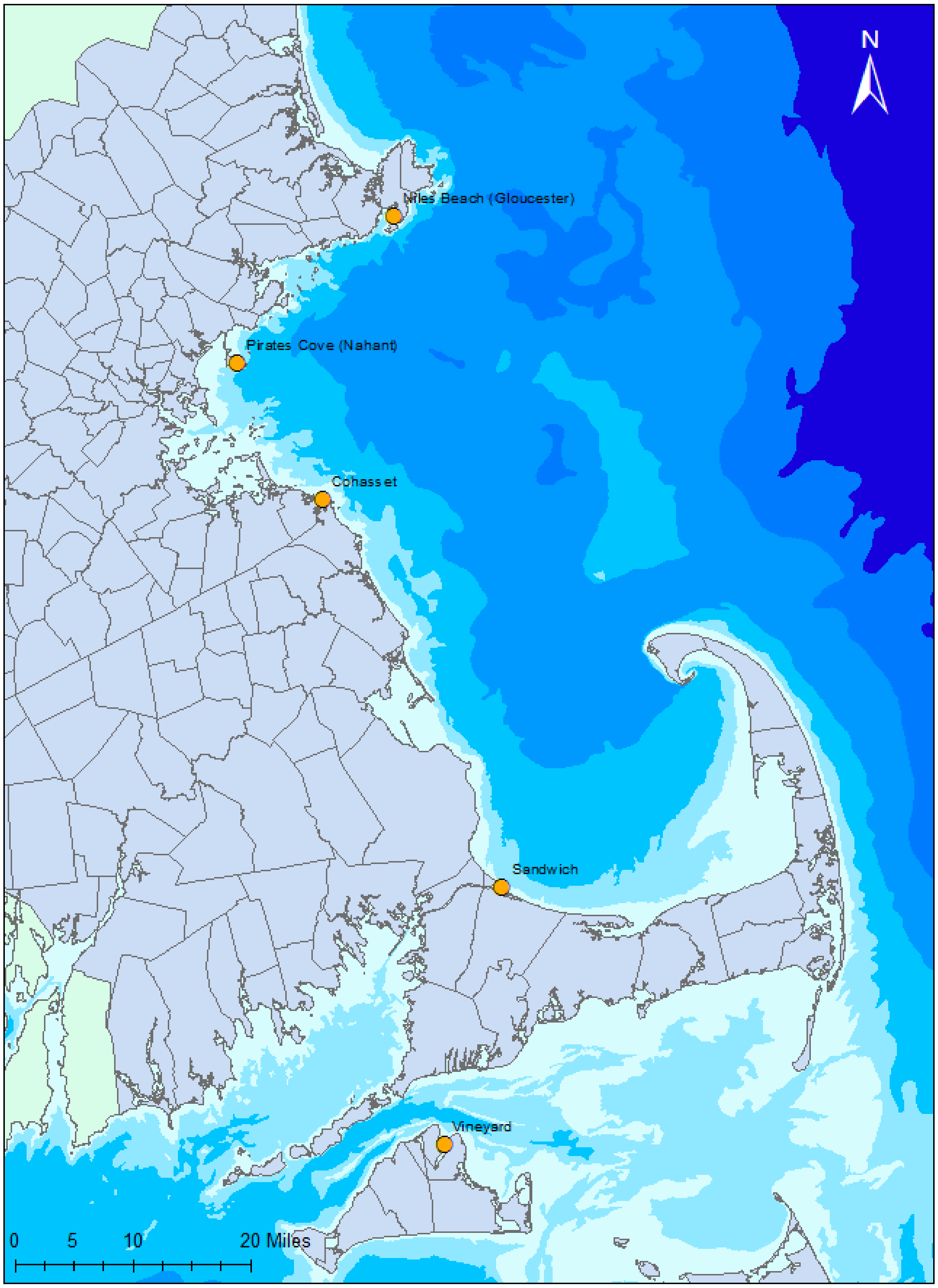
Mike McHugh, Department of Environmental Protection

Hilary Neckles, United States Geological Survey

Peg Pelletier, U.S. Environmental Protection Agency (Narragansett)

Fred Short, University of New Hampshire

Appendix 2



Map 1:: Eelgrass sampling stations 2015