Massachusetts Ocean Management Plan September 2014

DRAFT

Volume 2

Baseline Assessment and Science Framework

Introduction

Volume 2 of the Draft Massachusetts Ocean Management Plan, September 2014 (2014 draft ocean plan) focuses on the data and scientific aspects of the plan and its implementation. It includes these two separate documents:

- **Baseline Assessment Five-Year Update: Report on Changes and Trends since 2009** - The Oceans Act mandated a Baseline Assessment as part of the ocean plan and required a review and update of this Baseline Assessment at least every five years. The 2009 Baseline Assessment constituted an extensive cataloguing of the current state of knowledge regarding human uses, natural resources, and other ecosystem components of Massachusetts ocean waters. The 2014 update to the Baseline Assessment is presented here in Volume 2. It reports on the current condition and status, as well as trends since 2009, in Massachusetts marine waters.

- **Science Framework** - This document provides the updated blueprint for ocean management-related science and data priorities and strategies that will support continued evolution of the ocean plan.

Table of Contents - Volume 2

Baseline Assessment Five-Year Update:

Report on Changes and Trends since 2009

Acknowledgements

This update to the 2009 Baseline Assessment was a major collaborative effort. The following individuals and groups deserve special recognition: Emily Huntley and Dan Sampson from the Office of Coastal Zone Management (CZM) for preparing the Geographic Information System data for the figures of this document; Wendy Leo and Peter Ralston at the Massachusetts Water Resources Authority for their assistance in writing the water quality subchapter; Kevin Brander from the Massachusetts Department of Environmental Protection for updates in the wastewater subchapter; Derek Perry and Tay Evans from the Massachusetts Division of Marine Fisheries for text and data relating to fisheries and eelgrass habitat; the Fisheries Work Group, in particular Kathryn Ford and Brant McAfee, for providing data associated with the fisheries subchapter; and Bob Boeri, Bruce Carlisle, Todd Callaghan, Rebecca Haney, Emily Huntley, Vic Mastone, Adrienne Pappal, Dan Sampson, Prassede Vella, and Brad Washburn from CZM, who wrote or contributed to various sections of this assessment. The members of the Ocean Science Advisory Council also deserve special thanks for their helpful comments on various drafts of this document. Special recognition also goes to CZM's Ann Donovan for her editorial review and sound advice.

Table of Contents

Chapter 1 - Introduction

The Oceans Act of 2008 and section 301 CMR 28.07 of the act's implementing regulations require that the Massachusetts Ocean Management Plan, its Baseline Assessment, and the enforceable provisions of relevant statutes and regulations are reviewed at least once every five years. The scope of the review is determined by the Secretary of Energy and Environmental Affairs (EEA) in consultation with the Ocean Advisory Commission (OAC) and the Ocean Science Advisory Council (SAC).[1] The Massachusetts Ocean Management Plan (ocean plan) was promulgated in December 2009,[2] and the review of the ocean plan was initiated by the Secretary in January 2013.

An important part of the 2009 Massachusetts Ocean Management Plan was its Baseline Assessment, contained in Volume 2 of the ocean plan. Required by the Oceans Act and developed in coordination with the SAC, the Baseline Assessment provided an extensive characterization of the Massachusetts Ocean Management Planning Area (planning area) and surrounding area, cataloging the current state of knowledge regarding human uses, natural and cultural resources, the physical environment, and economic value in Massachusetts and adjacent federal ocean waters.

Using the 2009 Baseline Assessment as the "baseline," this document reports on the current condition, status, and trends in Massachusetts marine waters, with a particular focus on climate change and the special, sensitive, or unique (SSU) estuarine and marine life and habitats and concentrations of water-dependent uses identified in the ocean plan.

For consistency and to aid in cross-referencing, the chapter titles and subchapters in this document mirror those in the 2009 Baseline Assessment. The entire 2009 Baseline Assessment document is available at www.env.state.ma.us/eea/mop/final-v2/v2-complete.pdf. In sections where no noteworthy changes or trends in the last five years were identified, a statement to that effect is reported. In addition to narrative explaining the identified changes since 2009, tables and figures are used to further describe those changes (the figures are all placed at the end of this document).

DATA COLLECTION

Much of the information for this report on the current condition and uses of the Massachusetts coastal zone comes from the reports of the six technical work groups (i.e., the Energy and Infrastructure, Fisheries, Habitat, Recreational and Cultural Services, Regional Sediment Resource Management, and Transportation and Navigation) that were convened in the summer of 2013 to review existing information and to identify important trends in ocean resources and uses. In addition, as in the 2009 Baseline Assessment, the SAC assisted in the development of this document by reviewing the data sources, reviewing the analyses, and providing additional data sources as necessary.

---

1 http://www.mass.gov/eea/docs/czm/fcr-regs/eea-czm-301-cmr-28-ocean-plan-regs-2-7-13.pdf

2 http://www.mass.gov/eea/waste-mgnt-recycling/coasts-and-oceans/mass-ocean-plan/final-massachusetts-ocean-management-plan.html

Members of the SAC:

Priscilla Brooks, Conservation Law Foundation
Todd Callaghan, Massachusetts Office of Coastal Zone Management
John Duff, University of Massachusetts Boston, School of Environment
Kathryn Ford, Massachusetts Division of Marine Fisheries
Carlton Hunt, retired (formerly of Battelle)
Scott Krauss, New England Aquarium
Steve Lohrenz, University of Massachusetts Dartmouth, School of Marine Science and Technology
Bill Schwab, U.S. Geological Survey Woods Hole Coastal and Marine Science Center
David Terkla, Designee of Massachusetts Fishermen's Partnership, University of Massachusetts Boston

GEOGRAPHIC FOCUS

The geographic focus of this document is the same as the 2009 Baseline Assessment. This document serves to present trends and changes in the uses and resources within the Massachusetts Ocean Management Planning Area and the adjacent Massachusetts coastal zone and federal waters.

North of Cape Cod—Gulf of Maine, Acadian Province

There was no significant change or trend identified in the last five years.

South of Cape Cod—Mid-Atlantic Bight, Virginian Province

There was no significant change or trend identified in the last five years.

WEATHER CONDITIONS

See Chapter 8 - Climate Change.

Chapter 2 - Water Column Features

NORTH OF CAPE COD

For temperature trends, see Chapter 8 - Climate Change.

SOUTH OF CAPE COD

For temperature trends, see Chapter 8 - Climate Change.

UPWELLING, FRONTS, AND WAVES

In 2013, the Massachusetts Office of Coastal Zone Management (CZM) received 30 years of hindcast data modeled by Dr. Changsheng Chen at the University of Massachusetts Dartmouth School of Marine Science and Technology. These data were not available in 2009 and are being viewed as a major asset to oceanographic researchers in the region. It is anticipated that these data will eventually be used to identify persistent upwelling regions, temperature and salinity fronts, and areas of relatively high wave energy.

The monthly average wave height at the Massachusetts Bay A buoy between January 2009 and October 2013 ranged from 1.6 to 6.2 feet with an overall average wave height of 3.2 feet. Wave height in Massachusetts Bay, one indicator of storm activity, did not significantly change from the 2001-2009 average (3.3 feet) presented in the 2009 Baseline Assessment (Figure 1).

RIVERINE INPUTS

See Chapter 8 - Climate Change.

SEA TEMPERATURE

Data compiled by the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS) show that the temperature of Massachusetts Bay in 2012 (orange line in Figure 2) was the warmest in the 12-year period of record from 2001-2012. The high sea water temperatures across the region in 2012 resulted in early molting for American lobster (*Homarus americanus*) in the Gulf of Maine and in the temporary shutdown of the Millstone nuclear power station in Connecticut—a plant that receives its cooling water from Long Island Sound. For more on sea temperature, see Chapter 8 - Climate Change.

SEASONAL CHANGES

See Chapter 8 - Climate Change.

WATER QUALITY

Pathogens

There was no significant change or trend identified in the last five years.

Chlorophyll a

There was no significant change or trend identified in the last five years.

Dissolved Oxygen

There was no significant change or trend identified in the last five years.

Harmful Algae Blooms

Alexandrium sp. is a dinoflagellate that produces a toxin that causes paralytic shellfish poisoning (PSP).[3] Although blooms of *Alexandrium* sp. across the Gulf of Maine ranged from significant to low intensity from 2009 to 2013,[4] the Commonwealth has not recently experienced widespread contamination of shellfish beds as was seen in 2005.[5,6] Analysis of PSP toxins in Massachusetts waters in 2013 revealed a limited number of samples with toxicity levels of concern.[7] The samples of concern were not part of a region-wide PSP outbreak, but rather were all identified to be from an area off eastern Cape Cod where an endemic population of *Alexandrium* sp. regularly causes localized shellfish bed closures.

Nutrients

Between 2001 and 2011, the Massachusetts Water Resources Authority (MWRA) Deer Island Treatment Plant discharged 362 million gallons per day of effluent to Massachusetts Bay[8] with an average total nitrogen concentration of 24 milligrams per liter (mg/L). This large loading is the reason why MWRA is required to monitor ambient nutrients in Massachusetts Bay. In 2011, nutrients (nitrate + nitrite) in surface waters ranged from 10 micromolar (μM) in February and March down to 2 μM from April to October. Bottom waters had higher concentrations, ranging from 6-10 μM from February to October, except in the middle of Cape Cod Bay where concentrations were 2-6 μM.[9] This pattern is common for Massachusetts Bay and does not appear to be a change from what was presented in the 2009 Baseline Assessment. A 2009 MWRA report, however, found that ammonia levels in Massachusetts Bay were significantly elevated at nearfield

---

[3] http://www.mass.gov/eea/agencies/dfg/dmf/programs-and-projects/psp-red-tide-monitoring.html
[4] http://www.whoi.edu/page.do?pid=24036
[5] http://seagrant.mit.edu/publications/MITSG_06-7.pdf
[6] http://www.whoi.edu/page.do?pid=23996&tid=441&cid=69337&ct=61&article=13371
[7] http://www.mass.gov/eea/agencies/dfg/dmf/programs-and-projects/psp-toxicity-sampling.html
[8] http://www.mwra.state.ma.us/harbor/enquad/pdf/2012-01.pdf
[9] http://www.mwra.state.ma.us/harbor/enquad/pdf/2012-09.pdf Figures 2-2 and 2-3

versus farfield sampling sites after the ocean outfall started operating in 2001.[10] Marine surveys in Massachusetts and Cape Cod Bays in March and June 2011 clearly show an ammonium plume (concentrations ranging from 2-10 μM). The plume was15 kilometers (km) wide x 12 km long and reached from the surface to 25 meters (m) deep in March and was 15 km wide x 30 km long and was positioned in the 10-40 m depth zone in June.[11]

pH

Increasing atmospheric carbon dioxide (CO_2) increases the amount of CO_2 dissolved in the ocean. Increased ocean CO_2 concentrations in turn lower ocean pH and carbonate ion concentrations, thereby decreasing the saturation state of calcium carbonate in the ocean (Feely et al., 2004).[12] The concentration of calcium carbonate, in particular, aragonite, a form used by a wide variety of marine organisms in their shells, is being monitored by scientists to help better understand the impact of long-term climate change.

Between December 2011 and June 2012, Stellwagen Bank National Marine Sanctuary (SBNMS) staff deployed instruments to measure CO_2, pH, oxygen, temperature, salinity, and beam attenuation on the Traffic Separation Scheme Test Auto Buoy (TSS Test AB) located at 42º 19.946' N, 70º 26.640' W at a depth of 85 m. The purpose of the project was to evaluate the feasibility of incorporating long-term ocean acidification monitoring sensors on existing passive acoustic monitoring moorings. In addition, the University of New Hampshire (UNH) has a surface CO_2 sensor (dissolved CO_2 is related to ocean pH) on its buoy near Appledore Island. The data from UNH are available on the NERACOOS website.[13] A long-term data series has not yet been developed, but may be included in future ocean plan updates.

SBNMS used data from the SBNMS buoy, the UNH buoy, and other buoys in the region to derive omega (Ω), a measure of the saturation state of aragonite. At $\Omega = 1.0$, aragonite is unstable and prone to dissolution. At $\Omega = 1.6$, calcification is compromised in the larvae of commercially important species such as *Mya arenaria* (soft-shelled clam)*, Mercenaria mercenaria* (hard-shelled clam), and *Crassostrea gigas* (Pacific oyster).[14,15] Unpublished data from Pilskaln[16] highlight the effect of low Ω at depth, in that aragonitic plankton remains are not found in the deeper waters of the Gulf of

---

[10] http://www.mwra.state.ma.us/harbor/enquad/pdf/2009-12.pdf Appendix B, Table 2
[11] http://www.mwra.state.ma.us/harbor/enquad/pdf/2012-11.pdf pp. 18, 19
[12] Feely, R.A., et al., 2004: Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. *Science*, 305: 362-366.
[13] http://www.neracoos.org/realtime_map
[14] Salisbury, J., M. Green, C. Hunt, and J. Campbell. 2008. Coastal Acidification by Rivers: A Threat to Shellfish? *Eos,* Vol. 89, No. 50, 9 December 2008.
[15] Barton, A., B. Hales, G.G. Waldbusser, C. Langdon, and R.A. Feely. 2012. The Pacific oyster, *Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects. *Limnology and Oceanography*, 2012; 57 (3): 698.
[16] Pilskaln, C.H. 2009. Seasonal and interannual biogeochemical particle flux dynamics in the Gulf of Maine. *Gulf of Maine Symposium—Advancing Ecosystem Research for the Future of the Gulf, New Brunswick, Canada, Program of Abstracts,* p. 84.

Maine (which have lower pH levels) or in the underlying sediments, despite their high abundance in upper water column sediment trap samples.

The SBNMS results show low Ω (i.e., < 1.6) for most of January-June 2012 with a marked decrease in Ω occurring after mid-March (Figure 3). The near-bottom SBNMS-derived Ω, when viewed with Ω derived from surface measurements at the UNH buoy, describe an apparent decoupling between surface and near-bottom Ω after March (Figure 3), which SBNMS staff suggest implies that dynamics driving acidification near the ocean bottom may be closely coupled to the downward flux of particulate organic matter from phytoplankton blooms at the surface. That is, when a phytoplankton bloom at the sea surface ends and large numbers of plankton cells fall toward the seafloor, this pulse of organic matter can decrease pH and thus decrease the aragonite content in the lower water column, well below that found in the upper water column.

SBNMS is a sentinel site within the National Oceanic and Atmospheric Administration (NOAA) Ocean and Great Lakes Acidification Research Plan. SBNMS staff anticipates developing a more comprehensive monitoring plan for ocean acidification in the Northeast region (Ben Cowie-Haskell, personal communication).

Salinity

There was no significant change or trend identified in the last five years.

Water Clarity

There was no significant change or trend identified in the last five years.

Sound

Since the 2009 ocean plan, several marine acoustic monitoring efforts have been undertaken. First, Cornell University has installed nine buoys in Massachusetts Bay—the Cornell Whale Array—that detect whale calls and alert marine traffic to the presence of whales in the approach to Boston Harbor. NERACOOS provides access to a graphical user interface that highlights which buoys have detected a whale and provides a time-sensitive alert.[17] SBNMS has used the Cornell University acoustic information to develop a smartphone application that augments existing ship navigation tools informing mariners of the safest and most current information to reduce the risk of ship and right whale collisions.[18] Second, the New England Aquarium has developed a Marine Stress Research Program that measures how whales respond to stressors such as underwater noise associated with shipping, seismic exploration, and military sonar.[19] Lastly, NOAA's Northeast Fisheries Science Center conducted a soundscape study in SBNMS in 2013. Given this increase in availability of marine sound data, coupled with increasing industrial use of marine waters, several

---

[17] http://www.neracoos.org/realtime_map
[18] http://stellwagen.noaa.gov/protect/whalealert.html
[19] http://www.neaq.org/conservation_and_research/projects/project_pages/marine_stress_research_program.php

participants in the ocean plan Habitat Work Group voiced an interest in developing a marine sound baseline and soundscape map for Massachusetts and surrounding waters.

Contaminants

There was no significant change or trend identified in the last five years.

BIOLOGICAL FEATURES

Updates to the biological components covered in the planning area are discussed in Chapter 4 - Habitat.

Chapter 3 - Seabed Features

GEOMORPHOLOGY

Since 2009, over 30,000 data points have been added to the CZM/Massachusetts Division of Marine Fisheries (*MarineFisheries*) sediment database, including data from:

- 2010, 2011, and 2012 Ocean Survey Vessel (OSV) *Bold* oceanographic surveys
- U.S. Geological Survey (USGS) sediment lab
- NOAA nautical charts
- Massachusetts Department of Environmental Protection (MassDEP) wetlands sandy beach and rocky shore delineations
- Seafloor photos from the CZM-USGS Seafloor Mapping Cooperative and OSV *Bold* surveys
- CZM Dredged Material Management Plan survey in Buzzards Bay
- *MarineFisheries* 2006 Northeast Consortium study in Massachusetts Bay
- U.S. Army Corps of Engineers grain-size analyses
- MWRA monitoring program

Using this information and additional USGS data, a new surficial sediment map was developed (Figure 4). The new surficial sediment map employs USGS interpretive sediment maps where available, and uses Thiessen polygons, an interpolation method, to map sediment database points where the USGS interpretive maps are not available. Thiessen polygons are an interpolation method that proportionally divides and distributes point data into regions known as Thiessen or Voronoi polygons. Each Thiessen polygon defines an area of influence around its sample point, so that any location inside the polygon is closer to that point than any of the other sample points. The new sediment map also incorporates a data confidence key describing the confidence that the map accurately describes the surficial sediment in a given region of Massachusetts waters.

CZM used the additional data gathered since 2009 to revise the hard/complex seafloor SSU map (Figure 5). The new hard/complex seafloor SSU map incorporates the following new data:

- Updated CZM/*MarineFisheries* sediment database
- USGS interpreted sediment maps (published and unpublished data in review)
- Rocky intertidal shores from MassDEP wetlands data
- Artificial reefs
- Biogenic reefs (specifically *Crepidula* and worm reefs identified in seafloor photos) with 100-m radius buffer around each reef location
- Board of Underwater Archaeological Resources recreational shipwreck sites designated as “exempted sites” (member sites of the NOAA/U.S. Department of the Interior National System of Marine Protected Areas) with 100-m radius buffer around each wreck

- NOAA Automated Wreck and Obstruction Information System (AWOIS) data with 100-m radius buffer around each wreck and obstruction

As with the surficial sediment map, the new hard/complex seafloor map incorporates USGS interpretive sediment maps, where available and interpolated Thiessen polygons derived from the CZM/*MarineFisheries* sediment database where the USGS maps are not available. In addition, the new map eliminates the previous 250 m x 250 m grid cell system of mapping.

The hard/complex seafloor SSU area map presented in the 2009 ocean plan covered a total of 904 km^2, or 16% of the planning area. The updated map for the 2014 ocean plan, including artificial and biogenic reefs, wrecks, and obstructions, covers a total area of 756 km^2, or 14% of the planning area. This 16% reduction in the mapped hard/complex seafloor SSU area is the result of additional data points and increased accuracy.

SEDIMENT TRANSPORT

In the last five years, USGS Woods Hole has used models of surficial sediment, wave height, currents, and bathymetry to generate predictions of seafloor stress along the continental shelf (Figure 6). These predictions in turn can be used to generate maps of how frequently seafloor sediments are mobilized (Figure 7). Knowing how frequently sediments are mobilized helps researchers understand rates of particle resuspension and settlement, the distribution of surficial sediments, the formation and sustainability of biogenic and geologic habitats, and rates of scour around underwater objects (e.g., cables, pipelines, and wind turbines).

SEDIMENT QUALITY

There was no significant change or trend identified in the last five years.

BIOLOGICAL FEATURES

From 2012 to 2013, CZM analyzed 8,911 seafloor photographs from within the planning area taken between 1999 and 2012 by several organizations.[20] CZM used the Coastal and Marine Ecological Classification Standard (CMECS)[21] to classify and create a searchable database of the biological groups observed in each photo. By overlapping the distributions of select taxonomic groups of interest with the original (2009) and revised (2014) hard/complex seafloor SSU maps, CZM determined the percent of known taxonomic group locations that are within the hard/complex seafloor SSU area. Percentages were calculated by dividing the number of photos with a group/taxon identified within the hard/complex seafloor area by the total number of photos where the group/taxon had been observed (Table 1).

[20] USGS, CZM, and *MarineFisheries*
[21] http://www.csc.noaa.gov/digitalcoast/publications/cmecs

Table 1. The percent occurrence of select taxa in photographs occurring within the 2009 hard/complex seafloor SSU area and the revised 2014 hard/complex seafloor SSU area.

Taxa/Group	Number of Photos in Planning Area	Hard/ Complex Seafloor SSU Area (2009)	Hard Seafloor Only (2014)	Hard/ Complex Seafloor SSU Area (2014)
Alcyoniina (Soft Coral)	63	78%	62%	78%
Astrangia sp. (Stony Coral)	85	36%	38%	41%
Attached Fauna	680	58%	51%	61%
Attached Hydroids and Bryozoans	423	59%	47%	57%
Attached Mussels and Mussel Reefs	315	87%	86%	92%
Benthic Macroalgae	1,230	62%	66%	71%
Bivalvia (Clam Bed)	907	22%	6%	12%
Bivalvia and Soft Sediment Mussels	1,115	31%	14%	22%
Brachiopoda	371	77%	53%	76%
Canopy-Forming Algal Bed (Kelps)	96	79%	86%	90%
Diverse Colonizers	29	93%	100%	100%
Porifera (Sponge, Sponge Bed)	1,030	67%	53%	68%
Tube-Building Fauna	735	27%	7%	13%

The data in Table 1 suggest that the 2014 hard/complex seafloor SSU area includes the majority of seafloor where attached fauna and flora have been found via photographs, including important habitat formers such as kelps (90%) and mussels (92%). As expected, the hard/complex seafloor SSU area does not capture areas where clams and tube-dwelling fauna are found, because in general, these areas are dominated by soft sediments. The analysis also demonstrates that the "complex" component of hard/complex seafloor is important because when it is combined with hard seafloor locations, more habitats of sessile, easily disturbed species (e.g., soft corals, sponges) are captured than by hard seafloor alone. The photographic analysis conducted since the 2009 ocean plan has been important in providing physical evidence of the habitat of various species/taxa that are included within the mapped hard/complex seafloor SSU area.

Chapter 4 - Habitat

PRIMARY AND SECONDARY PRODUCERS

As an important primary producer and biogenic habitat in Massachusetts, eelgrass (*Zostera marina*) was one of the 12 SSU areas identified and mapped in the 2009 ocean plan. The eelgrass SSU map in the 2009 ocean plan was derived from MassDEP aerial photography from 1995 and 2001. The revised eelgrass SSU map in the 2014 ocean plan now also includes analysis of eelgrass beds derived from 2006/2007, 2010, 2012, and 2013 imagery. The new eelgrass map also includes several diver-surveyed eelgrass beds as well as *MarineFisheries* eelgrass restoration sites in Boston Harbor (Figure 8) and Salem Sound (Figure 9).

In 2012, superstorm Sandy had a substantial effect on eelgrass beds on the North Shore of Massachusetts. Normally extensive beds off of Beverly and Lynn/Nahant (Figure 10) were replaced with sand (Tay Evans, personal communication).

The long-term trend in eelgrass coverage in Massachusetts and throughout North America and Europe is one of decline.[22] Despite this, approximately one third of the beds monitored by MassDEP have shown increases in acreage in recent years.[23] To document these changes, MassDEP used aerial photographs taken between the months of May and August (the eelgrass growing season) to identify 33 eelgrass regions that were mapped over three time periods (t_1 = 1994-1996, t_2 = 2000-2002, and t_3 = 2006-2007). These data were not available at the time of the 2009 Baseline Assessment.

Across all regions of the state, the average annual loss of eelgrass beds was 2% per year from t_2-t_3, which is an improvement over the t_1-t_2 rate of 5% per year. Of the 33 beds, only 11 increased in size from t_2-t_3 (Table 2). The greatest aerial increases were on Martha's Vineyard and in Boston Harbor; however, Westport and Lynn also had substantial aerial increases over this time period. In terms of percent increase in a given bed (which may be a better measure of change because larger beds will tend to have larger aerial changes), Boston Harbor had the largest percent change per year from t_2-t_3, while Salem Harbor and Gloucester Harbor also had notable percent increases in bed size (Table 2). The increases in bed sizes of this water quality-sensitive plant in urbanized harbors is testament to the substantial public investment in treating wastewater, stormwater, and combined sewer overflows in these population centers.

---

[22] http://www.iucnredlist.org/details/153538/0

[23] Costello, C.T. and W.J. Kenworthy. 2010. Twelve-Year Mapping and Change Analysis of Eelgrass (*Zostera marina*) Areal Abundance in Massachusetts (USA) Identifies Statewide Declines. Estuaries and Coasts 34:232-242. http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/egtrends.pdf

Table 2. The five-year increase in eelgrass bed size in Massachusetts as mapped by MassDEP (2002-2007); 11 of 33 beds increased in size. Data from Costello and Kenworthy 2010.[23]

Eelgrass Bed Location	Five Year Bed Increase (hectares)	Five Year Bed Increase (% per year)
Cape Poge, Pocha and Caleb Ponds	34.77	2.96
Boston Harbor	20.07	29.22
East/West Branches of Westport River	19.23	1.94
Lynn Harbor	12.81	0.97
New Bedford Outer Harbor	8.52	3.79
Gloucester Harbor	6.09	9.46
Morris Island	5.37	1.78
Salem Harbor	4.84	9.73
Ryders Cove/Crow Pond/Bassing Harbor	2.01	0.82
West Falmouth	0.21	0.20
Madaket Harbor	0.16	0.01
Mean	**10.37**	**5.53**

Another important primary producer in Massachusetts is kelp (*Laminaria* spp., *Agarum cribrosum*, and *Alaria* spp.). Kelp beds are important because they support higher species diversity than neighboring unvegetated areas and provide shelter to the various life stages of many fish and invertebrates.[24] CZM's analysis of seafloor photos (as described in Chapter 3) has identified several locations in Massachusetts waters that contain kelp (Figure 11). These locations provide a necessary first step in identifying the full extent of these beds so that they can be mapped and considered for inclusion in future versions of the ocean plan.

Phytoplankton is the major contributor to primary production in Massachusetts waters. As in the 2009 Baseline Assessment, monitoring of phytoplankton in Massachusetts Bay by MWRA demonstrated distinct peaks (blooms) in abundance in early spring (usually April), summer (June), and fall (October). However, in 2012 the bloom of one common species, *Phaeocystis pouchetii*, peaked in March instead of April.[25] Total microflagellate algae abundance also peaked earlier than usual in 2012. MWRA suggests that this may have been due to the unusually warm winter sea temperatures in 2012 (e.g., see Figure 2). Phytoplankton blooms will be monitored to determine if a trend develops.

For the most part, zooplankton abundances in Massachusetts waters have been following trends seen in previous years.[25] However, one zooplankton species of interest, *Calanus finmarchicus,* a copepod that is an important food source for the North Atlantic right whale, peaked in abundance earlier than usual in 2011, and in 2012 was found at historically low levels (Figure 12). Because North Atlantic right whale aggregations near Massachusetts tend to respond to *C. finmarchicus* blooms, the presence of a large number of North Atlantic right whales on the western side of Cape

[24] http://www.gulfofmaine.org/habitatprimer/biogenichabitats.pdf
[25] http://www.mwra.state.ma.us/harbor/enquad/pdf/2013-14.pdf

Cod Bay in 2013, when they usually concentrate on the eastern side of Cape Cod Bay, has led some to speculate that *C. finmarchicus* may have been more prevalent on the western side of Cape Cod Bay in 2013. Others have demonstrated with models that *C. finmarchicus* in Cape Cod Bay and Massachusetts Bay may be influenced by prevailing winds and the North Atlantic Oscillation.[26]

BENTHIC COMMUNITIES

CZM's identification and mapping of benthic communities has increased since the 2009 ocean plan. As stated above in Chapter 3, since the 2009 ocean plan, CZM has analyzed 8,911 seafloor photographs, which has allowed CZM to map observations of several taxa. CZM now has maps and coordinates of important biogenic habitat such as mussel beds and reefs (Figure 13), as well as rare and sensitive invertebrates such as soft corals (Figure 14). Combining the hard/complex seafloor map with invertebrate and algae maps demonstrates that there is overlap at > 75% of the known locations of brachiopods (76%), soft corals (78%), kelps (90%), mussels (92%), and small, encrusting invertebrates collectively known as "diverse colonizers" (100%) (see Table 1 on page 10). This overlap indicates that by prohibiting construction activities within the hard/complex seafloor SSU area, these species are also protected. Maps of these resources can help CZM and permitting agencies avoid or minimize impacts during marine construction planning, permitting, and implementation.

Another significant change from 2009 is that CZM and *MarineFisheries* undertook three research surveys (in the summers of 2010, 2011, and 2012) aboard the U.S. Environmental Protection Agency's (EPA) OSV *Bold* to collect seafloor imagery and grab samples as part of its seafloor mapping program and to help inform ocean plan mapping (Table 3). Benthic infauna analysis identified several interesting pieces of information that might be useful in future seafloor mapping efforts. In northern Cape Cod Bay, the abiotic variables that best described differences in infauna communities were depth and percent sand. Median phi (sediment grain size) was also important. In southern Cape Cod Bay, the abiotic variables that best described differences in infauna communities were mean phi, the standard deviation of phi (a measure of sediment heterogeneity), and the percent silt in surrounding sediments. South of Martha's Vineyard and Nantucket, there was no single abiotic parameter or combination of parameters that CZM investigated that best described differences in infaunal communities, leading to speculation that some measure of disturbance was more important (disturbance or seafloor stress were not part of the analysis) or perhaps some form of biotic interaction, such as predation or competition was structuring infaunal communities in that area. In Buzzards Bay, the abiotic parameters that best explained differences among infauna communities were percent sand, median phi, and standard deviation of phi. Further analysis demonstrated that a major separation in infaunal groups in Buzzards Bay was determined by whether a site's surficial sediment composition (as sampled by a Van Veen grab) was > 91% sand.

[26] http://www.int-res.com/abstracts/meps/v349/p183-197/

Table 3. Summary of CZM and *MarineFisheries* efforts to gather seafloor mapping information during the three research surveys on the U.S. EPA OSV *Bold*.

	2010	2011	2012	Total
# Research Stations Occupied	200	319	350	869
# Seafloor Photos Taken	194	1,114	2,081	3,389
# Sediment Samples Taken	130	270	219	619
# Infauna Samples Taken	100	214	207	521

FISHERIES RESOURCES, SHELLFISH, AND HABITAT

In the 2009 ocean plan, the important fish resources SSU area was derived from the mean biomass or abundance of 22 selected species found in *MarineFisheries* spring and fall resource assessment trawl surveys, from 1978-2007. In 2013, the Fisheries Work Group revised the important fish resources SSU area by using the same methods and extending the trawl survey data series to 2012. The inclusion of an additional five years of data did not change the distribution of important fish resources (Figure 15). *MarineFisheries* also updated the commercial fishing by effort and value map (Figure 16). The largest changes since 2009 were seen on the eastern sides of Cape Cod and Nantucket and within Nantucket Sound.

In direct response to the 2009 ocean plan recommendations, in 2010 *MarineFisheries* implemented trip-level reporting for commercial fishermen with state permits. Before 2010, a permit holder could potentially have to fill out 18 species-specific annual catch reports. Now, under the new system, catch reporting is streamlined and *MarineFisheries* can more easily generate the data to update the concentrations of water-dependent use area (i.e., the high commercial fishing effort and value map in the ocean plan).

As recommended in the 2009 Science Framework,[27] the Fisheries Work Group developed a map that includes existing aquaculture facilities and an aquaculture development area that overlap with the planning area (Figure 17). The aquaculture facilities that overlap the planning area are in the towns of Westport, Fairhaven, Mattapoisett, Chilmark, West Tisbury, Orleans, Eastham, and Wellfleet. The aquaculture development area is in the waters of Provincetown and Truro.

Fisheries in the Northeast saw a huge change in management between 2009 and 2013 as the region's multispecies fishery moved to sector-based management instead of "days-at-sea." The New England Fishery Management Council defines a sector as "a group of persons holding limited access vessel permits…who have voluntarily entered into a contract and agree to certain fishing restrictions for a specified period of time, and which has been granted a total allowable catch in order to achieve objectives consistent with the applicable [Fisheries Management Plan] goals and objectives."[28]

[27] http://www.env.state.ma.us/eea/mop/final-v2/v2-sf.pdf, Action 2.3, p. SF-53
[28] http://www.nero.noaa.gov/sfd/sfdmultisector.html

CZM used data from NOAA's Status of Stocks Reports for 2009[28] and 2013[29] to summarize trends in New England fish stocks (Table 4). There was no change in the overfishing status of Gulf of Maine and Georges Bank Atlantic cod stocks or in the Georges Bank and Cape Cod/Gulf of Maine yellowtail stocks from 2009 to 2013. The southern New England/Mid-Atlantic yellowtail, white hake, and winter flounder stocks are no longer on the overfishing list. However, five stocks (Gulf of Maine haddock, windowpane flounder, witch flounder, thorny skate, and winter skate) were added to the overfishing list. There was a net gain of one additional fish stock added to the overfishing list so that the number of stocks on the overfishing list is nine, up from eight in 2009.

Nine of 16 overfished stocks in 2009 remained overfished in 2013 (Table 4). Three new species (Atlantic wolffish, Gulf of Maine/Georges Bank windowpane flounder, and witch flounder) were added to the overfished lists since 2009, and seven stocks were removed from the overfished list. Seven stocks (goosefish, Gulf of Maine haddock, Georges Bank haddock, pollock, redfish, windowpane flounder, and southern New England/Mid-Atlantic yellowtail) were listed as fully rebuilt since 2009 (Table 4).

Table 4. Trend in commercially harvested groundfisheries from NOAA Status of Fisheries Reports 2009[29] and 2013[30]. GOM = Gulf of Maine, GB = Georges Bank, SNE/MA = Southern New England/Mid-Atlantic, CC = Cape Cod.

Stock Status	2009	2013 (as of 9/30/13)	Stocks Rebuilt Since 2009
Stocks on the overfishing list	Atlantic Cod - GOM Atlantic Cod - GB Yellowtail - GB Yellowtail - CC/GOM Yellowtail - SNE/MA White Hake - GB/GOM Winter Flounder - SNE/MA Winter Flounder - GB	Atlantic Cod - GOM Atlantic Cod - GB Yellowtail - GB Yellowtail - CC/GOM Haddock - GOM Windowpane - GOM/GB Witch Flounder Thorny Skate - GOM Winter Skate - GB/SNE	
Stocks on the overfished list	Atlantic Salmon Atlantic Cod - GOM Atlantic Cod - GB Haddock - GOM Haddock - GB American Plaice Yellowtail - GB Yellowtail - SNE/MA Yellowtail - CC/GOM White Hake - GB/GOM Windowpane - SNE/MA Winter Flounder - SNE/MA Ocean Pout Atlantic Halibut Thorny Skate - GOM Smooth Skate - GOM	Atlantic Salmon Atlantic Cod - GOM Atlantic Cod - GB Atlantic Wolffish Yellowtail - GB Yellowtail - CC/GOM Windowpane - GOM/GB Winter Flounder - SNE/MA Ocean Pout Atlantic Halibut Thorny Skate - GOM Witch Flounder	Goosefish - GOM/GB Haddock - GOM Haddock - GB Pollock - GOM/GB Acadian Redfish - GOM/GB Windowpane - SNE/MA Yellowtail - SNE/MA

SEAFOOD QUALITY/CHEMICAL CONTAMINANTS

There was no significant change or trend identified in the last five years.

AVIFAUNA

Several surveys of bird abundances and habitat use in and around Massachusetts have become available since the 2009 ocean plan. In 2010, a joint USGS and Bureau of Ocean Energy Management (BOEM) Outer Continental Shelf (OCS) report, referred to as the "Compendium,"

[29] http://www.nmfs.noaa.gov/sfa/statusoffisheries/2009/StatusFisheries_2009.pdf
[30] http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/

compiled 65 datasets and over 400,000 seabird occurrences from studies between Florida and Canada in the time period 1978-2009.[31] The data in the USGS/BOEM Compendium report are effort-corrected sightings for each species and are mapped in a grid of 15 minute x 15 minute cells (approximately 21 km x 28 km). The Compendium data demonstrated that Nantucket Sound and the waters around Nantucket and Martha's Vineyard Islands were of regional importance to sea ducks in winter (Figure 18).

Because the Compendium data were only available on a relatively coarse scale, CZM obtained effort-corrected bird densities gathered via winter aerial surveys ranging from Florida to Maine between 2008 and 2012 from the U.S. Fish and Wildlife Service (USFWS).[32] The scale for the USFWS study was 5 minute x 5 minute, a resolution that is useful for Massachusetts ocean planning efforts (see more on this in the Waterfowl section below).

Another source of bird observations since 2009 comes from researchers from the College of Staten Island, City University of New York (CUNY), who have been conducting surveys of seabirds by airplane in an area that includes the waters between and south of Martha's Vineyard and Nantucket. That work is being funded by the Massachusetts Clean Energy Center (MassCEC) and is focused on improving the characterization of the Massachusetts Wind Energy Area (WEA) south of Martha's Vineyard and Nantucket Islands. Those data were not available for analysis by the Habitat Work Group.

Since 2009, there have also been various Mass Audubon reports, a synthesis report produced by Applied Science Associates (ASA) for MassCEC, and an upcoming USFWS Monitoring Avian Productivity and Survivorship (MAPS) survey funded by BOEM that will be documenting seabirds along the same transect lines used in the 2008-2012 work.

Shorebirds

There was no significant change or trend identified in the last five years.

Colonial Waterbirds

In 2013, the Massachusetts Natural Heritage and Endangered Species Program (NHESP) conducted a survey of nesting sites along the coast of Massachusetts. The information from a similar survey was the basis of the 2009 SSU maps for Roseate Tern core habitat, special concern tern core habitat, Leach's Storm-Petrel important nesting habitat, and colonial waterbirds important nesting habitat. Since 2009, there have been no significant changes in the number of nesting birds at these sites and

---

[31] O'Connell, A.F., B. Gardner, A.T. Gilbert, and K. Laurent, 2009, Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the United States, Final Report (Database Section - Seabirds). Prepared by the USGS Patuxent Wildlife Research Center, Beltsville, MD. U.S. Department of the Interior, Geological Survey, and Bureau of Ocean Energy Management Headquarters, OCS Study BOEM 2012-076.
[32] Silverman E.D., D.T. Saalfeld, J.B. Leirness, and M.D. Koneff. 2013. Wintering sea duck distribution along the Atlantic coast of the United States. Journal of Fish and Wildlife Management 4(1):178-198; e1944-687X. doi: 10.3996/122012-JFWM-107.

no additional sites of >100 nesting pairs of birds, the threshold for determining an important nesting site (Tom French, personal communication).

Waterfowl

In 2009, the distribution of Long-tailed Ducks around Nantucket Island was mapped as an SSU area. The only information available in 2009 was a one-year Mass Audubon satellite telemetry study documenting the movements of several Long-tailed Ducks around Nantucket. Since that time, CZM has obtained additional information on Long-tailed Ducks and other sea ducks (Figure 19), as described above, that has lead to the expansion of the SSU area to include core winter habitat for five sea duck species (Figure 20).

Songbirds

There was no significant change or trend identified in the last five years.

Pelagic Seabirds

There was no significant change or trend identified in the last five years.

Raptors and Other Predatory Birds

There was no significant change or trend identified in the last five years.

Species with Special Protection

There was no significant change or trend identified in the last five years.

MARINE MAMMALS AND REPTILES

There were three marine mammal habitat maps in the 2009 ocean plan: North Atlantic right whale core habitat, humpback whale core habitat, and fin whale core habitat. These maps were derived from whale observations from several databases spanning 1970-2005. Since 2002, there has been a shift in the use of Cape Cod Bay by North Atlantic right whales (Stormy Mayo, personal communication).

Two recommendations of the Habitat Work Group assigned with the revision of the marine mammal habitat maps in 2013 were: 1) conduct an investigation of the unusual distribution of North Atlantic right whales on the western side of Cape Cod Bay in 2013, and 2) update the North Atlantic right whale core habitat map for the 2014 ocean plan. The Habitat Work Group advised a re-analysis and re-mapping of the North Atlantic right whale core habitat using the most recent observational data (1998-2014) for the 2014 ocean plan. This more recent time period (1998-2014) also coincides with regular, directed aerial surveys of Cape Cod Bay by the Provincetown Center for Coastal Studies. In an effort to remain consistent, humpback and fin whale observations were also re-analyzed from 1998-2014.

CZM worked with Bob Kenney from the University of Rhode Island (URI) and manager of the North Atlantic Right Whale Consortium (NARWC) database to synthesize effort-corrected (sightings per unit effort [SPUE]) data for North Atlantic right whales from the NARWC database. The North Atlantic right whale SPUE data for each year from 1998-2014 and for all years combined were provided.

The new North Atlantic right whale SPUE data cover an area roughly the same as the North Atlantic right whale SSU area for the 2009 ocean plan, with the exception of some additional area to the west of the planning area to capture all of Massachusetts state waters and additional area to the south to capture the recent MassCEC survey work (Figure 21). As in the 2009 ocean plan, the SPUE data were binned into 5 minute x 5 minute grid cells (approximately 7 km x 9 km) with the sightings data assigned to the centroid of each cell. The gridded SPUE data were then interpolated using the Natural Neighbors tool in ArcGIS 10.2. CZM investigated other methods of interpolation (Kriging, Inverse Distance Weighting) and determined that Natural Neighbors had the best fidelity to the original data and required the least amount of subjective decision-making associated with applying the interpolation algorithm. The interpolated North Atlantic right whale SPUE data were then classified into quantiles (Figure 22).

CZM also performed the same data analysis on the 2013 North Atlantic right whale data (Figure 23). It is clear that more whales were using the western side of Cape Cod Bay in 2013. The 2013 data were included in the overall analysis, with the result that the North Atlantic right whale SSU area (the top two quantiles in the North Atlantic right whale density map) now includes more area in western Cape Cod Bay (Figure 24).

The Habitat Work Group investigated three potential sources of endangered sea turtle data for mapping; however, none of the sources at this time are effort-corrected, and they are therefore not suited to the unbiased identification of important habitat. The three data sources were:

- The Mass Audubon database of opportunistic sea turtle sightings. These data are not currently digitized and were not available for mapping.
- Surveys conducted by the New England Aquarium for the MassCEC in support of the offshore Massachusetts WEA. While the WEA is outside of state waters, observations are recorded while the aircraft is transiting state waters (e.g., Buzzards Bay, Vineyard Sound, Muskeget Channel). CZM is working with MassCEC to obtain and map these data.
- Aerial survey data gathered by Mass Audubon as part of the Cape Wind project. CZM acquired the Mass Audubon data from the Cape Wind project and mapped the locations of observed sea turtles (Figure 25).

INVASIVES

Most of the information known about invasive species presence in Massachusetts is reported through monitoring surveys of the low intertidal to shallow subtidal zone, such as the regularly occurring Rapid Assessment Survey (RAS).[33,34,35]

Invasive species composition within the planning area is not well known, but given the life history characteristics of marine invasives, it is reasonable to assume that the majority of these species could inhabit or impact the planning area.

The number of marine invasive species has steadily been increasing within New England waters. During the 2010 RAS, 29 species were found while 36 species were found in 2013. Since the completion of the 2009 Baseline Assessment, 11 new species have been documented in Massachusetts coastal waters (Table 5). Invasion histories and descriptions of a subset of species are detailed below.

Table 5. New invasive species discovered since 2009.

Species	Taxonomic group
Tricellaria inopinata	Bryozoa
Palaemon elegans	Crustacea (Shrimp)
Palaemon macrodactylus	Crustacea (Shrimp)
*Ianiropsis serricaudis**	Crustacea (Isopod)
Stenothoe marina	Crustacea (Amphipod)
Melita palmata	Crustacea (Amphipod)
Colpomenia peregrina	Phaeophyceae (Brown alga)
Heterosiphonia japonica	Rhodophyta (Red Alga)
Gracilaria vermiculophylla	Rhodophyta (Red Alga)
Pyropia yezoensis	Rhodophyta (Red Alga)
Antithamnion hubbsii	Rhodophyta (Red Alga)

*previously described to genus only

Heterosiphonia japonica is a red filamentous alga. Native to Asia, this species was first recorded in France in 1984, and has now spread across Europe, likely introduced there from the western Pacific as a hitchhiker on oysters for aquaculture.[36] *Heterosiphonia japonica* was first found on the outer coast of Rhode Island in 2009 and then discovered in Massachusetts in 2010.[37] In the spring and summer of 2012, this species in particular received much attention and press reports of masses washing up on beaches. As *H. japonica* (like many of the red filamentous algae) is difficult to identify (requires

---

33 http://www.mass.gov/eea/docs/czm/invasives/ras-2010-final.pdf
34 http://seagrant.mit.edu/publications/MITSG_05-3.pdf
35 http://www.mass.gov/eea/docs/czm/invasives/ras-2013-final.pdf
36 http://www.aquaticinvasions.net/2008/AI_2008_3_4_Sjotun_etal.pdf
37 Schneider, C.W. 2010. Report of a new invasive alga in the Atlantic United States "Heterosiphonia" japonica in Rhode Island. Journal of Phycology 46: 653-657.

magnification), all of these reports have not been substantiated. However, recent collections indicate this species is expanding its distribution along the coast of Massachusetts and elsewhere.[38]

Colpomenia peregrina is a relatively new invader species in Massachusetts waters, first reported in 2011.[38] It forms a hollow mass or bubble as it grows and is visually similar to the native species *Leathesia marina*. First recorded in the Northwest Atlantic in Nova Scotia in 1960, it has made its way south with populations recently recorded in Maine, New Hampshire, and Massachusetts.[39] It is unclear at this time what impact this species will have in Massachusetts waters, but its tendency to grow on native seaweeds, shellfish, and other species could lead to shading and other competitive impacts.[35]

The European rock pool shrimp *Palaemon elegans* was first documented in New England during the 2010 RAS at a single site in Salem.[32] *P. elegans* can grow to over two inches in length and is able to consume a number of smaller marine organisms. It has since rapidly spread as far north as southern Maine and as far south as Provincetown. The range of *P. elegans* and other Massachusetts invasives can be viewed on the Massachusetts Ocean Resource Information System (MORIS).[40]

Tricellaria inopinata, a bryozoan native to the western Pacific, was found at a single site in Woods Hole (Eel Pond) in 2010.[41] Since that time it has quickly spread as far north as Gloucester (Wells and Pappal, personal observation) and south to Rhode Island. During the 2013 RAS, this bryozoan was found at nine of the 18 sites from Salem, MA, to Newport, RI.[34]

MAN-MADE HABITAT, MITIGATION, RESTORATION

Shellfish

There have been no changes since 2009 to the shellfish restoration areas that were developed with mitigation funds from the Hubline project between 2006 and 2008.[42]

Artificial Reefs

In 2009, there were three artificial reefs in Massachusetts, one in Boston Harbor, one in Dartmouth, and one in Yarmouth. In 2013, *MarineFisheries* completed the permitting for two additional reefs, a 10-acre site in Harwich and a 120-acre site in Yarmouth. As of August 2014, structures have not yet been put in place.

---

[38] Savoie, A.M. and G.W. Saunders. 2013. First record of the invasive red alga *Heterosiphonia japonica* (Ceramiales, Rhodophyta) in Canada. BioInvasions Records 2(1): 27-32.

[39] Green, L.A., A.C. Mathieson, C.D. Neefus, H.M. Traggis, and C.J. Dawes. 2012. Southern expansion of the brown alga *Colpomenia peregrina* Sauvageau (Scytosiphonales) in the Northwest Atlantic Ocean. Botanica Marina 55(6): 643-647.

[40] http://www.mass.gov/czm/mapping/index.htm

[41] Johnson, C.H., J.E. Winston, and R.M. Woollacott. 2012. Western Atlantic introduction and persistence of the marine bryozoan *Tricellaria inopinata*. Aquatic Invasions 7: 295-303.

[42] http://www.mass.gov/eea/docs/dfg/*MarineFisheries*/programsandprojects/hubline/hubline-5yr-shellfish-stock-enhancement.pdf

Eelgrass

Since 2004, there have been several eelgrass restoration projects in Massachusetts. From 2004 to 2007, *MarineFisheries* restored five acres of eelgrass to Boston Harbor at Long Island and Peddocks Island. Monitoring in 2013 showed that the sites have more than doubled in area as they grow and expand into adjacent suitable habitat. *MarineFisheries* continues to work in Boston Harbor and has recently planted eelgrass at Governors Island Flats, Great Brewster Island, and Green Island (Figure 8). Beginning in 2010, *MarineFisheries* also restored three sites in Salem Sound: Woodbury Point in Beverly, and Fort Pickering and Middle Ground in Salem (Figure 9). In addition, the Massachusetts Bays National Estuary Program funded a restoration project in Plum Island Sound. Four sites were selected in 2012 for test plot planting and subsequent full-scale planting in 2013. The results of the test-transplanting indicate that conditions in the southern region of Plum Island Sound are favorable for eelgrass growth. Additionally, in 2013 a new eelgrass bed was identified in an area that has not had eelgrass for 75 years in Essex Bay. Although only a quarter of an acre in size, this bed instigated further research for transplanting in southern Plum Island Sound and Essex Bay in 2014.

Chapter 5 - Archaeological Landscape and Cultural Heritage

In order to inform ongoing ocean planning and management, studies and new and updated data over the past five years were examined. Management of cultural resources has evolved to emphasize the adoption of the cultural landscape approach as an analytical framework to understand places and their associated resources.[43] Analogous and complementary to ecosystem-based management, this approach examines the relationships among living and non-living resources and their environment, which spans the land-sea boundary.

NATIVE AMERICAN SITES AND CULTURE

Recent work in Buzzards Bay and Vineyard Sound by USGS indicates that it is possible to detect and re-create now submerged and buried ancient post-glacial landscapes. Between 2009 and 2011, using sub-bottom profiling, images of sediment layers and rocks/bedrock beneath the sea bottom were obtained. From these geophysical data, USGS identified river and stream channels, lakes, shorelines, and other geomorphological features. The data support research on the Quaternary evolution of Buzzards Bay and Vineyard Sound, the influence of sea-level change and sediment volume on coastal evolution, and efforts to understand the type, distribution, and quality of subtidal marine habitats in the coastal ocean of Massachusetts.[44]

A paleolandscape is not intended to replace site-specific studies to be undertaken by potential project proponents, but to provide information in data gathering efforts. In order to create an accurate paleolandscape, geophysical interpretation and oral tradition of native peoples must be incorporated. The oral traditions of the indigenous peoples provide information on subsistence lifestyle and settlement patterns. This in turn indicates the location and identification of submerged ancient Native American material culture. Heritage sites and areas designated and valued by native peoples are vital components of the rich maritime heritage of the United States.

SHIPWRECKS AND OTHER HISTORIC RESOURCES

The uncertainty of locations of most documented maritime disasters generally precludes the accurate assessment of impacts to specific resources. Information on the location of a shipwreck, particularly at sea, and the types of vessel losses reported is often ambiguous and incomplete. Over the last several months, over 3,600 records in the Board of Underwater Archaeological Resources (BUAR)

---

[43] Mather, I. Roderick. and John O. Jensen. 2010 *Investigations into Block Island's Submerged Cultural Sites and Landscape for the Rhode Island Ocean Special Area Management Plan 2010*. Technical Report #5 in *Rhode Island Ocean SAMP Volume 2*. Adopted by the Rhode Island Coastal Resources Council October 19, 2010.

[44] Ackerman, S.D., Andrews, B.D., Foster, D.S., Baldwin, W.E., and Schwab W.C. 2012, High-resolution geophysical data from the inner continental shelf—Buzzards Bay, Massachusetts: U.S. Geological Survey Open-File Report 2012-1002, http://pubs.usgs.gov/of/2012/1002/.

database were used to assign the reported locale of vessel loss to proximate municipal location. In turn, the municipal boundary was projected seaward to the edge of the territorial sea. Locale was the most common and reliable available spatial component at this time; precise geographical coordinates are either not available or need to be ground-truthed. In some instances, areas outside but adjacent to the planning area are depicted to present a more holistic view of wreck site distribution. The results of this work by URI and CZM were used to develop a sensitivity map (Figure 26).

The 2009 Baseline Assessment depicts only shipwrecks listed in the NOAA AWOIS database. This database is not a comprehensive listing of shipwrecks but rather includes shipwrecks considered hazards to navigation. The data are often imprecise and composed mainly of steel vessels lost after 1900, making the data biased temporally to the modern period and spatially to major travel routes. Unlike the geo-referenced precision of terrestrial archaeological sites, nearly all published shipwreck inventories suffer from an imprecision and/or lack of validation in location and resource description and therefore cannot replace investigatory surveys at this time.

The Commonwealth maintains a list of 40 shipwreck sites that since designation in 1985 have been specifically preserved for recreational activities, mainly diving (Figure 27). These "exempted sites" refer to underwater archaeological resource sites that because of their location, condition, history, or resource value are best left in the public domain and recreational diving activities on these sites do not require a permit (MGL c.6.s.180 and c.91.s.63) but any major disruption of the site is prohibited.

Although the AWOIS database is not considered a historically reliable depiction of the location of historical shipwrecks and/or artifacts, it is a valuable piece of information for development and management proposes. The AWOIS and Exempted Sites databases have been added as additional layers to the hard/complex seafloor SSU area (Figure 5) in the 2014 ocean plan, thereby including them in site-specific assessments that may need to be conducted for development and management purposes.

Chapter 6 - Human Uses

COMMERCIAL FISHING

The New England Fishery Management Council made significant reductions in allowable groundfish catch amounts in 2013. This restriction will affect the fishing industry and commercial vessel traffic, and may have a long-term effect on shore-side facilities in local ports. For more information, refer to subchapter "Fisheries Resources, Shellfish, and Habitat" in Chapter 4 above.

AQUACULTURE

Since the 2009 ocean plan was promulgated, one offshore mussel culture farm was established, and is still operating northeast of Cape Higgon, within Chilmark coastal waters in Vineyard Sound (Tom Shields, personal communication).

RECREATIONAL USES

Recreational Fishing

In order to improve estimates of saltwater fisheries data, a federal mandate required the establishment of a recreational saltwater fishing permit program in coastal states. In response to this mandate, in 2011 the Commonwealth of Massachusetts established the Recreational Saltwater Fishing Permit, administered by *MarineFisheries*. In conjunction with the permit, the Marine Recreational Fisheries Development Fund was established as a dedicated fund to ensure a "user-pay/user-benefits" program.

The 2009 ocean plan identifies and maps areas of concentrations of water-dependent use for recreational fishing. These maps were based on data collected in 2009 by a rapid assessment of recreational fishermen selected by *MarineFisheries* for their knowledge of the fishery. This survey was repeated in the fall 2013 with a larger number of participants. A total of 26 respondents identified areas of importance for recreational fishing. Additionally, in 2012 SeaPlan (formerly the Massachusetts Ocean Partnership) conducted a survey on recreational boating in the Northeast. This survey collected data on activities conducted by recreational boaters and over 330 recreational fishing point locations in the planning area were identified by boaters. Over 90% of the data points coincided with the areas identified through the 2013 *MarineFisheries* expert survey.

The Fisheries Work Group analyzed the results of the 2013 expert survey and recommended that the data be used to update the map depicting concentrated recreational fishing areas for the 2014 ocean plan. CZM used an overlap assessment to classify the areas identified as important for recreational fishing and to determine recreational fishing hotspots (Figure 28). Recognizing the shortcomings of the datasets in providing better identification and mapping of spatial patterns of recreational fishing in Massachusetts, CZM and *MarineFisheries* identified information needs and resources available to gather demographic and economic data as well as spatial data that can be used to update the map in the ocean plan.

Recreational Boating

Recreational boating was recognized in the 2009 ocean plan as an important and popular activity in Massachusetts coastal waters. The 2009 ocean plan identified areas of concentrated recreational boating activity based on the results of a rapid assessment survey of expert recreational boaters conducted in summer 2009 by the Massachusetts Marine Trades Association (MMTA). The 2009 ocean plan prioritized the need for more statistically robust recreational boating data for comprehensive ocean planning.

In 2010, a comprehensive survey of recreational boaters was conducted by a team of partners led by SeaPlan.[45] The survey gathered information on boating activity in Massachusetts waters, and about 850 recreational boaters provided data on boating use, boating traffic patterns, and economic implications. The 2010 survey confirmed that the highest intensity of boating activity occurs close to shore with the most popular boating areas being Boston Harbor, Cape Ann, and Buzzards Bay (Figure 29). Additionally, popular boating routes were identified, such as from Boston to Provincetown and from Cape Cod to Buzzards Bay via the Cape Cod Canal. The 2010 survey revealed that the most popular activities included cruising, fishing, and sightseeing, with July and August being the busiest months for this activity.

Building on this effort, in 2012, SeaPlan, the Northeast Regional Ocean Council (NROC), and partners conducted a recreational boater survey for the entire Northeast region (Maine to New York) as part of regional ocean planning efforts. The survey of randomly sampled boaters acquired data on recreational boating patterns, activities, demographics, and economic impacts for each state, including Massachusetts. Responses from recreational boaters in Massachusetts confirmed that most boaters stay close to shore and along the major transit routes (Figure 29).

Using the information from the 2010 and 2012 surveys, CZM applied a methodology to analyze the data and categorize recreational boating density patterns in the planning area. Working with CZM, the MMTA conducted a rapid assessment survey of recreational boaters in the summer of 2013. Importantly, this information augmented the 2010 and 2012 datasets and affirmed many of the density patterns indentified in those surveys. The data from the 2010 and 2012 boating surveys together with the data from the 2013 rapid assessment work provide a significantly more robust and accurate representation of recreational boating activity in Massachusetts and provide spatial, temporal, and socioeconomic information to inform ocean planning. The data have been used to

---

[45] Hellin, D., Starbuck, K., Terkla, D. Roman, A. and Watson, C. (2011). 2010 Massachusetts Recreational Boater Survey (03.uhi.11). Boston: Massachusetts Ocean Partnership. http://massoceanpartnership.org/wp-content/uploads/2011/06/2010_massachusetts_recreational-tr-uhi-11.pdf

update the concentrations of water-dependent use area for recreational boating for the 2014 ocean plan (Figure 30).

In addition, in June 2014, all of state marine waters in the Commonwealth were designated as a No Discharge Zone (NDZ). NDZs are designated bodies of water where the discharge of all boat sewage, whether treated or not, is prohibited. CZM and *MarineFisheries* have programs and support local efforts to increase boat pumpout facilities to make proper sewage disposal more convenient for boaters.

Public Access

Access to coastal waters is an important component of recreational boating. Although marinas, moorings, and public boat ramps are mostly found outside of the planning area, the location of this infrastructure influences the patterns of boating within the planning area. The Recreational and Cultural Services Work Group recommended including information on access infrastructure in the 2014 ocean plan. Data were provided by CZM and the Massachusetts Department of Fish and Game (Figure 31).

The Massachusetts coastline has widespread public beaches. These beaches offer important access to the public for recreational purposes and provide other important services such as habitat and storm surge protection. The locations of public and semi-public beaches were provided by the Massachusetts Department of Public Health (DPH) (Figure 32). Although outside the planning area, the location of beaches is important for management purposes and has currently become a priority in discussions on beach erosion and nourishment—including the evaluation of potential sand sources from within the planning area.

In both 2009 and 2013, 60 communities provided beach testing data to DPH.[46] In each year, roughly 600 beaches were tested and more than 8,100 individual water quality samples were taken over the bathing season. There were 569 exceedances and 597 total beach postings (closures) in 2009, and these numbers decreased in 2013 to 475 and 424 respectively. There appeared to be a decrease in the number of exceedances and postings since 2009. However, 2009 had the greatest percent of exceedances (7%) in the time period from 2001-2013, while the four-year period from 2010-2013 varied within the range of 4-6% exceedances. It therefore appears that 2009 is an outlier and the number of beach closures over the last five years has been relatively stable at a low level.

Wildlife Viewing

Whale watching is a popular activity in Massachusetts. The number of rare and endangered species of whales that visit Cape Cod Bay, and the proximity to SBNMS, make this one of the top-ten whale

[46] http://www.mass.gov/eohhs/docs/dph/environmental/exposure/beach-reports/beach-annual-report13.pdf

watching locations in the world, attracting over a million people annually.[47] In 2002-2003 and again from 2008 to present, SBNMS has been working with volunteers to track whale watching vessels: where they leave from, where they go, and how long they stay. The data show routes from the main harbors (Newburyport, Gloucester, Boston, Plymouth, Hyannis, Provincetown, and others) and provide an indication of destination (mainly SBNMS). However the data were collected from specific boats and lack the randomness necessary to obtain statistically robust data. This precluded the use of these data for the 2014 ocean plan at this time.

The 2012 Northeast Recreational Boater Survey led by SeaPlan identified the activities conducted by recreational boaters. Wildlife viewing was one of the selected categories and some data on popular locations for this activity were gathered (Figure 33). While this information does not represent a comprehensive inventory of this marine activity, it is more information than was available for the 2009 ocean plan

Scenic

The 2009 ocean plan examined the visual aspect of the planning area as it related to the siting of commercial wind energy development. Although no such development has taken place in the last five years within the planning area, the Recreational and Cultural Services Work Group recommended updating the maps and incorporating data from the Massachusetts Department of Conservation and Recreation's (DCR) scenic landscape inventory in the 2014 ocean plan (Figure 34). This map identifies "Distinctive" and "Noteworthy" landscapes along the Massachusetts coast. Distinctive locations refer to areas of the highest visual quality and typically consist of openness, low population density, high relative relief, historical structures and land uses, agriculture, surface water, significant vegetation, important geological features, and lack of contemporary development. Noteworthy locations are areas of lesser, but nevertheless important, visual quality and typically contain the same factors as the Distinctive landscapes but in lesser amounts or of lower quality. There were no changes in the National Register of Historic Places data, which were last updated in 2007, but a map of locations is included (Figure 35).

Diving

The 2009 ocean plan includes a map of popular diving sites based on data compiled by the BUAR and web searches of popular diving locations listed by recreational and commercial groups. However, this is not a comprehensive list and compiling a comprehensive database of recreational diving hotspots and associated information such as economic contribution is one of the tasks that will be undertaken in the short-term.

---

[47] U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Office of National Marine Sanctuaries. 2010. Stellwagen Bank National Marine Sanctuary Final Management Plan and Environmental Assessment. Silver Spring, MD. http://stellwagen.noaa.gov/management/fmp/pdfs/sbnms_fmp_5_human.pdf

For the 2014 ocean plan, the BUAR has compiled a list of sites linked to underwater archaeological resources that because of their location, condition, history, or resource value are best left in the public domain. These underwater archaeological sites are designated as "exempted sites" and there are 40 of them in Massachusetts (Figure 27). Exempted shipwreck sites are intended for the continued enjoyment of recreational diving as a water-dependent human use. Recreational diving activities on these sites do not require a permit but any major disruption of the site is prohibited.

Hunting

Hunting for sea ducks (Long-tailed Duck, Scoter, and Eider), other ducks, Canada goose, and Brant takes place in the planning area from both land and boat, between September 3 and February 15.[48] Data on hunting as a recreational activity are reported in the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation conducted by the USFWS every five years.[49] The survey provides information on the intensity of the recreational activity in Massachusetts as well as economic valuation and impacts but does not distinguish between hunting inland, coastal, or at sea. There has been no change in migratory bird hunting since 2009.

Gambling Boats

There are currently two gambling boats in Massachusetts. Atlantic Casino Cruises operates out of Gloucester and runs daily from Rowe Square in Gloucester's Inner Harbor and the S.S. Horizon's Edge Casino Cruises operates out of Lynn. This is a change since 2009 when only the Atlantic Casino Cruises was in operation. A third gambling boat called the Aquasino operated out of Lynn in 2013 but was not operating in 2014.

TRANSPORTATION

Shipping - Containers, Bulk Products, and Fish

Following the global trend for the past several years, local maritime commerce has been negatively impacted by the economic recession, and overall cargo volumes for a variety of commodities (e.g., petroleum, chemicals, manufactured goods, and food products) are down in most ports in Massachusetts. With the economy improving, it is expected that cargo volumes will increase[50] In addition, several major transportation infrastructure projects are underway, both locally (e.g., Boston Harbor Deep Draft Navigational Improvement Project) and globally (e.g., Expansion of the Panama Canal) that will enhance trade routes and facilitate maritime trade.

The Massachusetts Department of Transportation (MassDOT) established the Massachusetts Port Compact in 2012. The purpose of the Compact is to improve coordination between its members (Boston, Fall River, Gloucester, New Bedford, and Salem) and adopt a collaborative approach to the

[48] http://www.mass.gov/eea/docs/dfg/dfw/regulations/2013-14-waterfowl-abs-final.pdf
[49] http://www.census.gov/prod/2012pubs/fhw11-nat.pdf
[50] https://www.massport.com/media/261138/massport_final_report_17july2014_updated.pdf

planning, design, funding, construction, operation, and maintenance of the Commonwealth's water-based transportation and waterfront port facilities. The Ports of Massachusetts Strategic Plan, to be prepared by the Compact, will provide recommendations and guide future investments, policy, initiatives, and planning around these five major Massachusetts ports.

Boston (Including Everett, Chelsea, Revere, Quincy, and Weymouth)

The Boston Harbor Deep Draft Navigational Improvement Project will deepen Boston Harbor to accommodate deeper draft vessels. This project will not enable the port to accommodate the new post-Panamax vessels, which will be limited to a number of deep draft ports (e.g., Los Angles and New York), but it is anticipated to draw more Panamax class vessels that could be diverted from larger ports.

Fall River

There was no significant change or trend identified in the last five years.

Gloucester

There was no significant change or trend identified in the last five years.

New Bedford

The City of New Bedford, in collaboration with the Commonwealth, is making significant improvements to its South Terminal facility to enable it to serve as a hub for offshore wind energy construction and operations support and other marine commerce uses.

Salem

There was no significant change or trend identified in the last five years.

Cruise Ships and Coastal Lines

Boston

Despite the recent economic downturn, the local cruise industry activity has increased in Massachusetts in recent years. For example, the Port of Boston has seen a significant increase in total number of passengers each year. The Massachusetts Port Authority (Massport) is considering an expansion of its passenger cruise terminal at Black Falcon Terminal to address this growth.

Fall River

There was no significant change or trend identified in the last five years.

Gloucester

There was no significant change or trend identified in the last five years.

New Bedford

There was no significant change or trend identified in the last five years.

Ferries and Commuter Boats

MassDOT established the Ferry Compact in 2012. The principal mission of the Compact is to identify an overall vision for the ferry system in Massachusetts that improves the transportation of people, goods, and vehicles by water. The Compact's membership includes a mix of state agencies, state and local elected officials, and other organizations who are dedicated to improving ferry transportation in the Commonwealth.

Boston

There was no significant change or trend identified in the last five years.

Cape Cod

In 2012, the Commonwealth designated the state waters within Nantucket and Vineyard Sounds as a boat sewage No Discharge Zone. At that time, two small corridors were not designated in order to allow the Steamship Authority to continue to treat and discharge sanitary waste to marine waters until it had enough time to retrofit its fleet with holding tanks as well as build the necessary landside infrastructure for pumping out. At that time, the Hy-Line ferries were discharging wastewater in federal waters in the middle of Nantucket Sound. In 2014, the Steamship Authority completed retrofitting all of its fleet and building the necessary landside infrastructure to accept its sanitary waste and the Commonwealth designated all state waters, including the previously undesignated corridors, as no discharge for vessel sewage. By the end of 2014, the Hy-Line will have retrofitted all of its vessels with holding tanks and completed a system to pump its sanitary waste into the Barnstable sewer system.

Fall River

There was no significant change or trend identified in the last five years.

Gloucester

There was no significant change or trend identified in the last five years.

New Bedford

There was no significant change or trend identified in the last five years.

Navigational Aids and Lanes

Boston

There was no significant change or trend identified in the last five years.

Cape Cod Canal

There was no significant change or trend identified in the last five years.

New Bedford

There was no significant change or trend identified in the last five years.

ENERGY GENERATION

Since the release of the 2009 ocean plan, energy generation patterns in Massachusetts have shifted, while generation capacity has remained steady. The energy generation fuel mix has changed, with a notable increase in the amount of natural gas utilized for energy generation from 38% in 2010 to 48% in 2012. While the total capacity of generating plants in Massachusetts has remained steady (~13,300 megawatts [MW] in 2010 and 13,100 MW in 2012), peak demand has increased slightly from 11,890 MW in 2009 to 12,429 MW in 2012.[51]

Since the release of the 2009 ocean plan, there have been several important changes in coastal energy generating facilities, including the following:

- In January 2010, NRG Energy ceased operations of the Somerset Station.
- In May 2011, Dominion announced that the coal-fired Salem Harbor Station power plant would shut down by June 2014. In 2012, Footprint Power acquired Salem Harbor Station and proposed a quick-start, natural gas-fired power plant at the site. In September 2013, Salem Station received what is expected to be its final shipment of coal. The proposed Footprint plant is a natural gas facility and is being designed with closed-cycle cooling, so there will no longer be an intake or discharge flow. In October 2013, the Energy Facilities Siting Board approved the petition of Footprint Power to construct the 692 MW power plant.
- In 2012, Brayton Point Power Station completed retrofits of its once-through cooling to utilize closed-cycle cooling, so its permitted intake/discharge flow is now only 70 million gallons per day (mgd). In October 2013, Dominion Energy—owner of the coal-fired Brayton Point Power Station—filed papers with Independent System Operator New England (ISO-NE) indicating that the plant would cease energy generation in May 2017.
- According to ISO-NE, as of July 2013, New Boston Station, Canal Electric, and Somerset Station no longer operate and are classified as "retired."
- Kendall Station will be reducing its intake and discharge by 95% to 3 mgd and will be selling its heat as steam.

[51] http://www.mass.gov/eea/docs/czm/oceans/ocean-plan-updates/energy-infrastructure.pdf

Renewable Energy

Significant changes since the 2009 ocean plan have occurred in Massachusetts renewable energy generation. Major increases in the amount of installed solar- and wind-generated energy have been realized (though all installations have occurred outside of the planning area):

- In 2009, the total installed solar capacity was 18.5 MW, and as of June 2014, the total capacity was 518 MW. In May 2013, the Patrick Administration met its 2017 goal to have 250 MW of solar power installed in Massachusetts and announced a new goal of 1,600 MW of solar energy by 2020.
- In 2009, the total installed wind capacity was 14 MW, and as of June 2014, the total capacity was 103 MW. The Patrick Administration has set a goal of 2000 MW of wind energy by 2020.
- The Department of Public Utilities approved two 15-year contracts (one for 234 MW and the other for 127.5 MW) between Cape Wind and two Massachusetts electric distribution companies.

Energy Production, Consumption, and Needs in Massachusetts

Since 2009, Massachusetts has continued implementation of its nation-leading energy efficiency measures. Patterns to note include:

- Per capita energy consumption in Massachusetts continued to be very low, making Massachusetts one of the least energy-intensive states in the United States. Between 2008 and 2011, while the national rank for Massachusetts held steady at 48^{th} (out of 51, including District of Columbia), the per capita demand decreased from 243 million British thermal units (Btu) to 211 million Btu.
- As reflected by the nationwide analysis ranking by the American Council for an Energy-Efficient Economy, Massachusetts rose from second place in 2009 to first place in energy efficiency in both 2011 and 2012.
- Peak demand in Massachusetts, as reported by ISO-NE, went from 11,890 MW in 2009 to 12,429 MW in 2012, consistent with the forecasted annual increase.

Offshore Wind Development

Significant progress has been made in the planning, analysis, and leasing stages of offshore wind development in federal waters adjacent to Massachusetts. This work is led by BOEM in close coordination and consultation with EEA, CZM, and other agencies through two Offshore Wind Intergovernmental Task Forces and state-led working groups on both fisheries and habitat. Major milestones and outcomes since 2009, include:

- December 2010 - BOEM issued a Request for Interest (RFI) for an offshore wind lease area off of Massachusetts, seeking developer interest and input as to resources and concerns.

- May 2011 - At the request of the Patrick Administration, the RFI area was reduced to protect areas critical to commercial fisheries, marine fauna, and navigation.
- February 2012 - BOEM identified a Wind Energy Area adjacent to Rhode Island and Massachusetts (RI-MA).
- May 2012 - BOEM identified a second Wind Energy Area adjacent to Massachusetts.
- May 2013 - A ground-breaking event marked the launch of construction on the state's New Bedford Marine Commerce Terminal. Once constructed, the terminal will be the first facility in the nation designed to support the construction, assembly, and deployment of offshore wind projects. The terminal will also be able to handle high-volume bulk and container shipping, as well as large specialty marine cargo.
- June 2013 - BOEM issued a Finding of No Significant Impact for the Environmental Assessment and Final Sale Notice for the RI-MA Wind Energy Area.
- July 2013 - BOEM held the first-ever competitive lease sale for offshore wind renewable energy in federal waters for two lease areas in the RI-MA Wind Energy Area. Deepwater Wind New England LLC was awarded both areas.
- June 2014 - BOEM released the Proposed Sale Notice for the Massachusetts Wind Energy Area.

Hydrokinetic Energy Development

The 2009 ocean plan identified four tidal projects in Massachusetts state waters that had applied for preliminary permits under the Federal Energy Regulatory Commission's (FERC) hydrokinetic licensing process. As of September 2013, only one project—the Muskeget Channel Tidal Energy Project—has met the FERC-specified schedule of activities, target dates, and reporting on the status of studies and is in pre-licensing. The Muskeget Project is a partnership of the Town of Edgartown on Martha's Vineyard, the Marine Renewable Energy Collaborative, and the University of Massachusetts School for Marine Science and Technology. The proposed project includes the installation of 14 tidal energy units with a nameplate capacity of 5 MW, suspended approximately 25 feet below the sea surface and anchored to the seabed in areas of the channel at least 100 feet deep. A total of approximately 206 acres of channel area is required for all 14 units, including the anchoring system and space between units. A submarine cable would connect the tidal energy units to an on-shore site at either Chappaquiddick or Katama. The Secretary's Massachusetts Environmental Policy Act (MEPA) certificate on the Environmental Notification Form (ENF) required the preparation of a Draft Environmental Impact Report (DEIR) and provided a scope for the DEIR that included pre- and post-deployment monitoring of potential impacts to fisheries, marine mammals, large pelagic species, sea turtles, and avian species. Since the issuance of the Secretary's Certificate, the proponent has been conducting pre-deployment monitoring and preparing the DEIR.

TELECOMMUNICATION AND POWER CABLES

Since 2009, energy transmission changes in Massachusetts have included new electric grid system upgrades, regional planning to address known deficiencies for the ISO-NE area, the suspension of a deepwater Liquified Natural Gas (LNG) port and its delivery of natural gas through marine pipelines, and the first approval under the ocean plan for a shared electric and telecommunications cable across Vineyard Sound.

Telecommunication Cables

Following thorough pre-application consultation and comprehensive marine surveys and characterization, the Comcast/NStar bundled submarine fiber optic communications/electric cable completed its final MEPA review. The Secretary's Certificate in September 2012 confirmed that the proponent had satisfactorily demonstrated that the project would not significantly alter SSU resources or concentrations of water-dependent uses defined in the ocean plan. MassDEP issued a Chapter 91 license and 401 Water Quality Certification in October 2013. Installation of the bundled cables took place in May 2014.

Power Cables

In addition to the Comcast/NStar bundled communications/electric cable, since 2009 there was also a major transmission upgrade project to address system reliability concerns in the lower southeastern Massachusetts area. The project included adding a new 345 kilovolt (kV) transmission line from a substation in Carver to a new 345/115 kV substation west of Barnstable on Cape Cod.

PIPELINES

Since 2009, there were no new pipelines constructed in the planning area; however, there were some changes to existing pipelines.

Natural Gas Pipelines

The Neptune and Northeast Gateway LNG pipelines were used minimally since 2009 as ship-delivered natural gas markets were more lucrative outside of the United States. On July 24, 2012, the U.S. Department of Transportation's Maritime Administration approved a request from Neptune LNG LLC to amend its federal Deepwater Port License to include a five-year temporary suspension of port operations. Neptune's request indicated that recent conditions within the Northeast region's natural gas market had significantly impacted the Neptune Port's operational status and its ability to receive a consistent supply of natural gas imports. As a result, the Neptune Port has remained inactive over the past several years and will likely remain inactive for the foreseeable future. The suspension period became effective on June 26, 2013, and will extend for a period of five years.

The Northeast Gateway Deepwater Port opened in 2009 and remains open. There were six visits to the port by specialized Energy Bridge Regasification Vessels (EBRV) between February 2008 and

December 2009. There was no natural gas delivery on the first visit in February 2008 (it was strictly a commissioning event), there was a 33% cargo delivery in May 2008, a full cargo delivery that began in January 2009 and was not completed until May 2009 due to a methane hydrate blockage, a < 5% cargo delivery in November 2009, a full cargo delivery in December 2009, and a second delivery in December 2009 that was not successful because of an equipment malfunction.

Sewer Lines

In 2014, the Town of Marblehead proposed replacement of its sewage conduit across Salem Harbor to the South Essex Sewer District's treatment plant.

WASTEWATER, STORMWATER, AND INDUSTRIAL DISCHARGES

There have been notable changes to combined sewer overflow controls and few changes to the status of other wastewater, stormwater, and industrial discharges to the planning area. However, one interesting development is that the MWRA is exploring the benefits and costs of "co-digestion," that is, the introduction of non-wastewater derived organic waste material into the wastewater anaerobic digestion process. Digester gas is already used as a high-value green energy source at the Deer Island Treatment Plant. Recent state regulatory changes encourage the diversion of organic wastes from landfills and incinerators to energy production. Co-digestion could potentially substantially increase digester gas production and electricity generation at Deer Island.

Combined Sewer Overflows

MWRA made significant progress on its Combined Sewer Overflow (CSO) abatement plan, closing 37 outfalls by 2011. Of the 35 projects in the plan, 31 were complete and operational by 2013; three projects benefitting the Reserved Channel and the Alewife Brook were in construction; and the final project, also benefitting the Alewife Brook, will move into construction in 2014. Eleven of the 46 outfalls proposed to remain are predicted not to activate during the typical rainfall year. This leaves 35 outfalls that are predicted to discharge, cumulatively, up to 170 times in the typical rainfall year for a total average annual volume of up to 410 million gallons, of which 381 million gallons (93%) will be treated. CSO discharges have been eliminated or effectively eliminated (i.e., eliminated up to and including the 25-year storm) at 12 outfalls (BOS 081-BOS 090, BOS093, and BOS095) adjacent to or upstream of the beaches of Dorchester Bay (including South Boston beaches).

The Lynn Water and Sewer Commission (LWSC) operates four CSOs, one to the Saugus River, two to Lynn Harbor, and one to Nahant Bay (King's Beach). LWSC remains under the terms and conditions of a 2001 Consent Decree with MassDEP and EPA, which requires LWSC to proceed with projects to eliminate CSO discharges to King's Beach and Lynn Harbor. Lynn completed a Supplemental CSO Facilities Plan in October 2004 after LWSC determined that elimination of CSO discharges may not be feasible. Since the 2004 plan was completed, LWSC has focused all the construction work on mitigating CSO discharges to King's Beach. CSO discharges for the last three years, based on CSO metering, went from 360 million gallons/year in 2010 to 46 million gallons/year in 2012. As a result of the considerable sewer separation work done in Lynn, especially in the East Lynn area tributary to King's Beach, the annual activations have dropped dramatically, from a baseline range of 38-43 events a year at all outfalls prior to implementing CSO controls.

The City of Gloucester has been under a Consent Decree with MassDEP and EPA since September 2, 2005. The City completed a Long-Term CSO Control Plan (LTCP) in June 2005, which recommended targeted sewer separation projects intended to minimize discharges at all the City's CSOs. The focus was largely on the area tributary to CSO 002 to minimize discharges to the beach area. During design for a portion of the sewer separation work, the City and their engineers determined that another outfall, identified as 009, discharges to the Inner Harbor. The City also determined that an alternative combination of sewer separation projects would be a more cost-effective approach to achieve the same high level of CSO control. The updated recommended plan includes $7.4 million in sewer separation work, which is projected to close three CSO regulator structures and limit CSOs to 1-2 per year at all of the CSO locations (excluding outfall 009). The Consent Decree was modified in 2012 to incorporate the updated plan to require work to address overflows at outfall 009. Based on a combination of CSO metering/modeling, CSO activations/volumes went from 6.6 million gallons/year in 2010 to 1.3 million gallons/year in 2012. The status of outfall 009 as a CSO or Sanitary Sewer Overflow (SSO) location has not been fully clarified. In accordance with the modified Consent Decree, the City has completed an evaluation report for outfall 009, which is under review by the regulatory agencies.

Desalination Plants

The Swansea Water District has had a National Pollutant Discharge Elimination System (NPDES) permit since 2008 but did not begin withdrawing water until 2013. The NPDES permit allows the District to withdraw 3.89 mgd of brackish water from the Palmer River for desalination and to discharge 2.71 mgd of brine back to the river. The salinity of the discharge must be less than 32 parts per thousand and the dissolved oxygen concentration must be greater than or equal to 6 mg/L. The District plant uses a cylindrical wedge-wire screen constructed of 0.25-inch mesh buried under five feet of stone and crushed stone to keep organisms out of the intake. The District has an ambient monitoring program to verify the dilution provided by the diffuser, to confirm the size of the mixing zone (about 32 feet from the diffuser ports), and to confirm that water quality standards are met at the edge of the mixing zone. The first environmental monitoring report was received by state agencies in 2013 and contained information on water quality, ichthyoplankton, fish and crabs, infaunal and benthic invertebrates, and sediment type in the vicinity of the intake and discharge.

The Taunton River Desalination Plant has a NPDES permit to withdraw up to 10 mgd and discharge up to 5.4 mgd of brackish water from the Taunton River. The salinity of the discharge must be within two parts per thousand of the ambient salinity of the river during the discharge cycle. Because the Taunton River is one of the state's most important anadromous fish habitats, the Taunton River Desalination Plant uses multiple redundant fish exclusion devices including a flat wedge-wire screen with two cylindrical wedge-wire screens, and between March 1 and November 15, a filter fabric curtain called a Gunderboom. Monitoring in the vicinity of the plant has been ongoing since 2007. The data show that very few larvae make it through the exclusion devices to the raw water pump station. However, in each year several hundred river herring and other species have been found trapped between the Gunderboom system and the shore. Taunton River Desalination Plant staff is required to seine and return these trapped fish to the Taunton River. Despite the low numbers of ichthyoplankton entering the plant's raw water system, agencies still require annual monitoring because the plant has only been withdrawing enough water to keep its pumps and reverse osmosis system operable. The City of Brockton, the Taunton River Desalination Plant's only client, has not requested water from the plant in large quantities, with monthly totals for March/April, May, and June 2013 being only 6.8, 15.4, and 7.2 million gallons respectively, well below the potential monthly withdrawal of 300 million gallons.

MILITARY TRAINING, DEFENSE, AND LAW ENFORCEMENT

U.S. Air National Guard

There was no significant change or trend identified in the last five years.

U.S. Army Corps of Engineers

There was no significant change or trend identified in the last five years.

U.S. Coast Guard

There was no significant change or trend identified in the last five years.

U.S. Navy

There was no significant change or trend identified in the last five years.

OCEAN DISPOSAL

There was no significant change or trend identified in the last five years.

PROTECTED AREAS

Areas of Critical Environmental Concern

There was no significant change or trend identified in the last five years.

Cape Cod National Seashore

There was no significant change or trend identified in the last five years.

National Estuarine Resource Reserve

There was no significant change or trend identified in the last five years.

National Wildlife Refuges and National Wildlife Areas

There was no significant change or trend identified in the last five years.

No Discharge Zones

In June 2014, all of state marine waters in the Commonwealth were designated as a No Discharge Zone (NDZ). NDZs are designated bodies of water where the discharge of all boat sewage, whether treated or not, is prohibited. CZM and *MarineFisheries* have programs and support local efforts to increase boat pumpout facilities to make proper sewage disposal more convenient for boaters. The statewide NDZ will help reduce the risk of pathogens that can close beaches and shellfish beds.

Ocean Sanctuaries

There was no significant change or trend identified in the last five years.

Outstanding Resource Waters

There was no significant change or trend identified in the last five years.

EDUCATION AND RESEARCH

There was no significant change or trend identified in the last five years.

AESTHETICS

There was no significant change or trend identified in the last five years.

SHORELINE PROTECTION AND FLOODPLAIN MANAGEMENT

Dynamic coastal environments shift and change in response to increases in energy (wind and waves), alterations to regional sediment resources (sand, gravel, and cobble), and increasing sea levels. Although the Massachusetts shoreline is outside the planning area, activities within the planning area can directly and indirectly impact processes and activities on the shoreline. Coastal land loss and erosion, flooding associated with storms, and tidal inundation are already major challenges that coastal communities face. Erosion and flooding are the primary coastal hazards that lead to the loss of lives and damage to property and infrastructure in developed coastal areas. Therefore, proposed activities in the planning area should consider potential impacts on coastal areas as a result of changes in ocean circulation, marine sediment transport, and water levels. To address these concerns, the Commonwealth, through CZM's StormSmart Coasts program, other agency efforts, and high-level committees such as the 2006-2007 Coastal Hazards Commission (CHC), the Climate Change Adaptation Advisory Committee (2009-2011) and Coastal Erosion Commission (2014), continues to work to address coastal floodplain, shoreline management, and climate adaptation issues. Primary components of this work includes: (1) developing and synthesizing technical information, maps, and decision support tools and making this information accessible and actionable; and (2) providing direct hands-on technical and financial assistance to communities to improve local and public understanding of hazards and risk and promote sound planning, strategies and practices to reduce vulnerability and increase resilience along the coast.

SAND EXTRACTION FOR BEACH NOURISHMENT

While many projects in Massachusetts have used either upland sources of material or sand dredged from navigation channels, offshore sediment sources may be needed to make projects requiring larger volumes practicable. Two larger beach fill projects using offshore sources of sediment were proposed for Winthrop Beach and Siasconset Beach on Nantucket. In 2008, the U.S. Army Corps of Engineers denied the permit application to extract approximately 500,000 cubic yards of sediment from an offshore source to nourish the beach along Winthrop Beach. The primary reason for denial was concern regarding impacts to fisheries resources at the proposed borrow site. The project was subsequently redesigned, and half of the nourishment project was completed in 2013 using sand excavated from a tombolo adjacent to the nourishment site. The second half is being constructed in 2014 and 2015 using fill trucked to the beach from the I-95 highway embankment in Saugus and Revere. In 2008, the proponents withdrew the permit applications for the Siasconset nourishment project on Nantucket due to concerns regarding nearshore cobble habitat that would have been filled by the proposed nourishment and fisheries concerns with the proposed offshore borrow site. As options for climate change adaptation are considered and strategies are developed, interest in offshore sediment sources from the planning area will likely increase. The CHC recommended the identification of upland and offshore sources of sand as well as an assessment of the environmental impacts of mining activities.[52] This analysis is essential to allow beach nourishment proponents to make informed decisions when evaluating potential sediment sources that minimize environmental impacts.

The 2009 ocean plan called for further work to advance the identification of potential areas with suitable sand resources for beach nourishment, and the scope for the 2014 draft ocean plan called for work to advance the planning for and identification of appropriate potential locations for offshore sand areas, taking into account important criteria including compatible sand resources, potential environmental impacts, interactions with existing water-dependent uses, and consideration of other key factors.

Since 2009, CZM has continued its long-term partnership with the U.S. Geological Survey (USGS) and other partners on a cooperative seafloor mapping program. As of 2014, the cooperative has mapped 1,393 square miles of state marine waters and has published or is preparing to release these data as USGS Open-File Reports. Geophysical data, including bathymetry, acoustic backscatter (a measure of seafloor hardness and roughness), and seismic-reflection profiles (pictures of sub-surface sediment layers), have been collected in these areas. In addition, seafloor sediment samples and photographs/videos of the seafloor were gathered to validate the geophysical data. CZM and the state Division of Marine Fisheries (MarineFisheries) undertook three research surveys in 2010, 2011, and 2012 aboard the U.S. Environmental Protection Agency's OSV Bold, visiting 870 stations to collect seafloor imagery and grab samples and conduct sediment and benthic infaunal analysis as part of its seafloor mapping program to inform ocean planning and management. These data have been used to create interpretive data products such as maps of surficial seafloor sediments, seafloor sediment depth to bedrock, and physiographic zones (a term used by geologists to define regions of the seafloor based on morphology and sediment types). CZM, with guidance from and in close consultation with the USGS Woods Hole Science Center, has also worked to identify areas of sand deposits based on geologic mapping by USGS, other published geologic maps, and available information from seismic data and sediment cores.

Through an optimization and screening analysis, detailed in Chapter 2 of Volume 1, that identified exclusionary areas and areas of particular concern based on SSU areas, seafloor geology, navigational and other areas of significant impact or incompatibility, the 2014 ocean plan identifies several preliminary sand resource areas for further investigation. Further characterization of the preliminary sand resource areas as well as the development of regional sediment budgets are priorities in the 2014 draft ocean plan Science Framework.

Chapter 7 - Economic Impact of the Marine Sector

The ocean economic sector in Massachusetts includes Tourism and Recreation, Maritime Transportation, Ship and Boat Building, Maritime Construction, Living Resources, and Offshore Mineral Extraction. The linkages among the various economic sectors affect the amount of revenue generated within the local economy. This chapter briefly describes the impacts of marine sectors in coastal Massachusetts including the following counties: Essex, Middlesex, Suffolk, Norfolk, Plymouth, Barnstable, Dukes, and Nantucket (unless otherwise stated). Since 2009, the Tourism and Recreation industry remained the largest contributor of the maritime economy to the overall Commonwealth's Gross Domestic product (GDP), followed by Maritime Transportation and Living Resources (which includes commercial and recreational fishing).

Since 2006, maritime-related establishments in Massachusetts coastal counties increased from 4,867 to 5,234 in 2011. During this time, employment increased from 74,470 in 2006 to 81,610 in 2011 respectively. This generated a concomitant increase to the Commonwealth's GDP from $3.5 billion in 2006 to $4.9 billion in 2011.[52]

MARITIME TRANSPORTATION

The maritime transportation industry in Massachusetts is the second highest contributor to the ocean economic sector and includes transportation of foreign and domestic freight, passengers, towing and tugboat services, as well as marine pipeline and gas transmission. In 2006, this sector employed 15,343 individuals but the economic downturn resulted in a decrease to 15,000 in 2009 and again to 14,715 in 2011. Despite this declining employment, the industry generated $1.1 billion and $1.2 billion of economic activity in 2009 and 2011 respectively.[53]

There are seven major ports in Massachusetts: Boston, Gloucester, Salem, New Bedford, Fall River, Plymouth, and Provincetown. These ports currently serve and/or aim to expand their capabilities to serve various markets (cargo, passenger transportation, fishing and fish processing, and new technology sectors). For example, Boston's container terminal (Conley) is New England's only dedicated container facility and handles approximately 30% of all waterborne cargo arriving in Boston, resulting in a $2.4 billion economic impact and sustaining 34,000 jobs. Conley's location and

[52] Digital Coast (NOAA Coastal Services Center): ENOW Explorer http://www.csc.noaa.gov/enow/explorer/ (accessed May 2014). Data courtesy of Bureau of Labor Statistics, Bureau of Economic Analysis and NOAA Coastal Services Center

infrastructure resources create the potential for diverting at least 30% of cargo from New York directly to Boston.[53]

Massport's cruise business at Cruiseport Boston/Black Falcon has grown in the last 30 years from 13 vessels and 11,723 passengers in 1986 to 117 vessels and 380,000 passengers in 2012, a 23% increase over 2011. The recent spurt of growth was supported by rising gas prices and high airfares to Florida, and timely $11 million renovation and expansion of Black Falcon in 2010.

The Massachusetts Bay Transport Authority (MBTA) runs the commuter ferry system in Boston Harbor, which transported 1.3 million passengers in 2011. This and the scheduled ferry service to the Boston Harbor Islands are part of the "excursion" business as defined by MassDOT, which includes whale watches, sightseeing, dinner cruises, charter fishing, etc. MassDOT estimated the excursion business generates over 600 direct jobs and $200-300 million in annual spending by residents and visitors engaged in these activities.[53]

Massport owns and operates the Boston Fish Pier, home to the Boston fishing fleet and the oldest continuously operating seafood processing facility in the United States. While Boston's frozen fish processors obtain very little, if any, of their product from Boston's fishing fleet, the nexus between fresh fish processing and local landings is potentially important. Although not at the level of Gloucester or New Bedford, Boston's seafood processing industry employs 270 people.[53]

COASTAL TOURISM AND RECREATION

The tourism and recreation industry is consistently the largest among marine-related businesses in coastal counties in Massachusetts, comprising 77.3% of marine businesses and employing over 74% of people in the industry in 2011.[54] The sector comprises three subsectors: food, entertainment and recreation, and lodging. Tourism includes both domestic and international travelers visiting coastal counties in Massachusetts in a particular year. In 2012, total domestic and international output in Massachusetts amounted to $28.2 billion, up 4.7% from 2011, and 20.7 million domestic and 2.1 million international visitors in Massachusetts spent $17.7 billion on transportation, lodging, food, entertainment and recreation, and retail shopping, up by 4.9% from 2011. This supported a total of 204,500 jobs, a 1.2% increase from 2011. Analyses revealed that coastal counties generated 90, 670 jobs. This trend continues shifting upward following its downturn in 2008/2009.

Activities associated with the tourism and recreation sector include recreational boating, saltwater fishing, wildlife viewing, and beach going. According to the Massachusetts Office of Travel and Tourism's (MOTT) 2012 economic impact analysis of the travel industry in the Commonwealth's

---

[53] The Ports of Massachusetts Strategic Plan – Technical Memorandum 4: Analysis of the Massachusetts Ports System (MassDOT, 2012. In prep.) http://www.massdot.state.ma.us/Portals/17/docs/ports/TechMemo4Nov142013access.pdf

[54] Digital Coast (NOAA Coastal Services Center): ENOW Explorer http://www.csc.noaa.gov/enow/explorer/ (accessed May 2014).

economy, out of approximately 22.8 million visitors, 16.1% reported beach going as their top activity during their stay.[55]

In 2010 and 2012, SeaPlan (formerly the Massachusetts Ocean Partnership) conducted two recreational boating surveys (a detailed description is provided in Chapter 6). During the surveys, recreational boaters in coastal counties in Massachusetts provided data on their boating patterns in marine waters as well as their primary activities and direct spending during these activities. In 2010, there were approximately 145,000 motorboats (including boats in which the motor is not the primary means of propulsion) registered with the Massachusetts Boat, Recreation Vehicle, and Snowmobile Registration Bureau (boat registry) and 12,000 documented vessels (large boats that are issued a marine document and registration through the U.S. Coast Guard). The survey revealed that recreational boaters spent about $529 million in 2010, primarily on fuel, dockage, mooring and storage, maintenance, and servicing, generating 4,730 jobs in the process. A conservative total economic contribution of $806 million to the 2010 economy was estimated.[56]

In 2012, SeaPlan (working with NROC, state agencies, and other partners) conducted a region-wide survey (Maine to New York). In 2012, the boat registry listed 139,645 vessels in Massachusetts. Marine boaters from Massachusetts spent an estimated $515 million on recreational boating in 2012, of which $470.1 million were spent in-state. Spending on recreational boating has a ripple effect throughout the Massachusetts economy. Economic modeling indicates an overall contribution of $839.5 million to the state's GDP. Spending by boaters from Massachusetts accounts for 96% of this impact, the rest contributed by transient boaters, adding nearly $33 million in output per year to the Commonwealth's economy. Similar to 2010, the top spending on goods and services included docking, mooring, and storage; routine maintenance; boat loans; and repairs. In 2012 recreational boating in saltwater in Massachusetts supported 6,498 year-round jobs in leisure and hospitality, trade and transportation, and boat maintenance and repair.[57]

COMMERCIAL AND RECREATIONAL FISHERIES

The commercial fishing industry in Massachusetts is one of the most valuable in the United States. The highest revenue is made from the harvest and landing of scallops, lobsters, and groundfish. The four main ports in Massachusetts where most seafood products are landed include: New Bedford, Gloucester, Provincetown-Chatham, and Boston. Landings and revenues change through the years depending on the economic conditions and changes in regulations and quotas for a particular fishery. In 2004, a total of 312.1 million pounds of seafood product where landed at these four ports

---

[55] MOTT, 2012. The Economic Impact of Travel in Massachusetts Counties. http://www.massvacation.com/wp-content/uploads/2013/09/econ-impact-12.pdf (accessed May 2014)

[56] Hellin, D., Starbuck, K., Terkla, D., Roman, A., and Watson, C. (2011, June) 2010 Massachusetts Recreational Boater Survey (03.uhi.11). Boston: Massachusetts Ocean Partnership. http://www.seaplan.org/wp-content/uploads/2010_massachusetts_recreational-tr-uhi-11.pdf

[57] Starbuck K, Lipsky A. SeaPlan. 2012 Northeast Recreational Boater Survey. Technical Report Dec 2013. Boston (MA): Doc #121.13.10,p.105. http://www.seaplan.org/wp-content/uploads/2012-NE-Survey-tech-report121.13.101.pdf

in Massachusetts, for a value of $273.5 million. In 2012, 297 million pounds (up from 255 million pounds valued at $565 million in 2011) yielded a value of $618 million. In 2012, Massachusetts ranked second in U.S. landings by value.[58]

For the last 12 years, New Bedford has been ranked by NOAA as the nation's top fishing port in landed dollar value, landing 117 million pounds in 2011 (value $369 million) and 143 million pounds in 2012 (values $411 million). Together with Fair Haven, New Bedford has over 1,100 jobs in fishing and over 700 in the fish processing industry. Gloucester had landings of 77 million pounds valued at $61 million in 2011 and 83 million pounds valued at $57 million in 2012. In 2012, Massachusetts had the highest catch of mackerel (4.1 million pounds) in the United States.[58]

New Bedford and Gloucester serve as fishing ports of national importance where the fishing fleet and seafood processing industry are the main employers. However, management and regulation of commercial fisheries requires a complex balancing of sustainable fish stocks for the future and economic viability for the present. Before 2008, the Gloucester fleet consistently landed over 100 million pounds of direct catch; however, according to NOAA's latest U.S. port statistics released in September 2012, from 2009 to 2011, Gloucester landings declined by 63%, from 122 million pounds to 77 million pounds. This resulted in loss of jobs and decreased income, and in 2012, the Department of Commerce declared the New England groundfishery an economic disaster. As groundfish landings have diminished, the number of fresh fish processors and commercial fishing-related services has declined.

Recreational fish catch rose from 5.98 million fish in 2004 to 6.22 million in 2008. A substantial decrease in 2009 to 3.32 million could have been a result of the economic downturn, reflecting reduced fishing effort as recreational fishermen cut back on their spending. The number of fish caught is showing some recovery to 4.45 million fish (11.9 million pounds harvested) and 4.65 million (13.1 million pounds harvested) in 2011 and 2012) respectively.[54] The number of recreational fishermen in 2011 and 2012 did not change substantially, going from 898,000 in 2011 (32.6% out-of-state) to 941,000 (32.8% out-of-state). Some of the most commonly caught fish by recreational saltwater anglers include scup, mackerel, striped bass, bluefish, black sea bass, tautog, and cod.[58]

In 2011, a recreational saltwater fishing permit was established in Massachusetts in response to Section 17C of Chapter 130 of Massachusetts General Laws, and prompted by a federal mandate enacted to improve estimates of saltwater fishing effort and catch data. A fee for the permit was set at $10 for both residents and non-residents alike, and is free for recreational anglers who are 60 years and older. In conjunction with the permit, the Marine Recreational Fisheries Development Fund was established as a dedicated fund to ensure a 'user-pay/user-benefits' program.

[58] Fisheries of the United States. Current Fishery Statistics No. 2012. Alan Lowther, Ed. NOAA National Marine Fisheries Services, Office of Science and Technology. Silver Spring, MD. September 2013.

AQUACULTURE

Production of farmed shellfish in Massachusetts has been expanding by 10% annually since 2000 with increasing number of towns, shellfish farmers, and areas licensed for culture. The Fisheries Work Group reported that since 1996, the number of private aquaculture permits for shellfish culture went up from about 250 to over 300, while the areas privately licensed for culture have increased from 600 acres to over 1,000 acres. Over 95 percent of this culture area is located on intertidal and subtidal flats within Cape Cod and Martha's Vineyard.

MARINE SCIENCE AND TECHNOLOGY

There was no significant change or trend identified in the last five years.

MARINE-RELATED CONSTRUCTION AND INFRASTRUCTURE

There was no significant change or trend identified in the last five years.

Chapter 8 - Climate Change

TEMPERATURE CHANGE

Data collected since 1883 in Woods Hole, Massachusetts[59], indicate that sea temperature has been increasing in Massachusetts for some time, at least south of Cape Cod (Figure 36). Average sea surface temperature at Woods Hole has considerable variation, year to year and decade to decade; however, there is a clear increasing temperature trend of 0.02° Fahrenheit (F) per year. The Woods Hole data also show that winter (December-February) sea surface temperature is increasing more rapidly than summer (June-August) temperature (0.027 vs. 0.016° F per year; Figures 37 and 38).

The most readily available continuous sea temperature data set for Massachusetts waters north of Cape Cod is from the Massachusetts A buoy.[60] With the data that are available, the increasing sea temperature trend does not appear to be as pronounced north of Cape Cod as it is to the south. Sea surface and bottom temperature in Massachusetts Bay as measured at the Massachusetts A buoy has not appeared to increase significantly from 2002-2012, either at the sea surface or bottom (Figures 39 and 40). However, a trend may be detected if a longer continuous time series becomes available.

CHANGES IN PRECIPITATION

Annual rainfall data compiled by DCR since 1852[61] show that the amount of rain in coastal watersheds has been increasing in recent decades. Since the 1990s, rainfall has been above the long-term average of 45 inches per year. The average decadal rainfall in the 2000s and early years of the 2010s (49 and 54 inches per year, respectively) is greater than any other decade in coastal Massachusetts since the 1860s (Figure 41).

The precipitation is not falling equally across all coastal watersheds. Since 1986, the North Coastal (50.0 inches/year), South Coastal (51.0 inches/year), and Taunton River (58.9 inches/year) watersheds have experienced rainfall that is more than one standard deviation greater than the overall coastal watershed average (47.4 inches/year). The Boston Harbor and the Islands watersheds were both more than one standard deviation below the overall coastal watershed average (T. Callaghan, unpublished data).

The pattern of increasing rainfall is also evident in river discharge data. As reported in the 2009 Baseline Assessment, the Merrimack River and the Charles River are the two largest rivers discharging into the planning area. A long-term plot of Merrimack River flow collected at the USGS river gauge[62] describes a considerable amount of interannual variation in mean river flow (Figure 42). However, when observing the decadal average discharge data, it is clear that there has been an

---

[59] http://www.mblwhoilibrary.org/collections/rare-books-and-mbl-archives
[60] http://www.neracoos.org/realtime_map
[61] http://www.mass.gov/dcr/watersupply/rainfall/precipdb.htm and http://www.mass.gov/dcr/watersupply/rainfall/drought.htm
[62] http://waterdata.usgs.gov/nwis/rt

increasing trend since the 1960s when all decadal averages are above the 88-year average of 7,959 cubic feet per second (cfs) (Figure 43). A similar pattern is seen for the Charles River discharge data (data not shown).

SEA LEVEL RISE

Data from the NOAA tide gauge in Boston Harbor describe an increase in sea level of about 0.11 inches/year (in/yr) since 1921, which translates to a 0.92 foot increases over a 100-year period (Figure 44). Similar increases have been measured at long-term tide stations in Woods Hole and Nantucket.[63] The mean sea level trends from these long-term stations are listed in Table 6. Analysis by NOAA indicates that the recent trend in mean sea level is increasing, with the rate from 1921-2006 at 2.63mm/yr (0.10 in/yr) and the rate from 1921-2013 at 2.80 mm/yr (0.11 in/yr) (Figure 45).

Table 6: Mean sea level trends for NOAA's Massachusetts tide gauge stations.[64]

Station	Mean sea level trend and 95% confidence interval		Period
	(millimeter/year)	(inch/year)	
Boston, MA	2.63 ± 0.18	0.104 ± 0.007	1921-2006
Woods Hole, MA	2.61 ± 0.20	0.103 ± 0.008	1932-2006
Nantucket, MA	2.95 ± 0.46	0.116 ± 0.018	1965-2006

CHANGES IN WIND PATTERNS

There was no significant change or trend identified in the last five years.

INCREASING FREQUENCY AND INTENSITY OF STORMS

In June 2012, the Intergovernmental Panel on Climate Change (IPCC) released the document: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*,[65] which reports an increasing trend in high precipitation events since 1950 in North America. The recent National Climate Assessment (NCA) released in May 2014 finds that the intensity, frequency, and duration of North Atlantic hurricanes have increased since the early 1980s, but the contributions of human and natural causes to these increases are still uncertain. The NCA projects hurricane-associated storm intensity and rainfall rates to increase as the climate continues to warm.[66]

OCEAN ACIDIFICATION

See pH subchapter in Chapter 2.

[63] http://tidesandcurrents.noaa.gov/inventory.html?id=8443970
[64] http://tidesandcurrents.noaa.gov/sltrends/msltrendstable.htm
[65] http://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf
[66] http://nca2014.globalchange.gov/report/our-changing-climate/changes-hurricanes

Figures

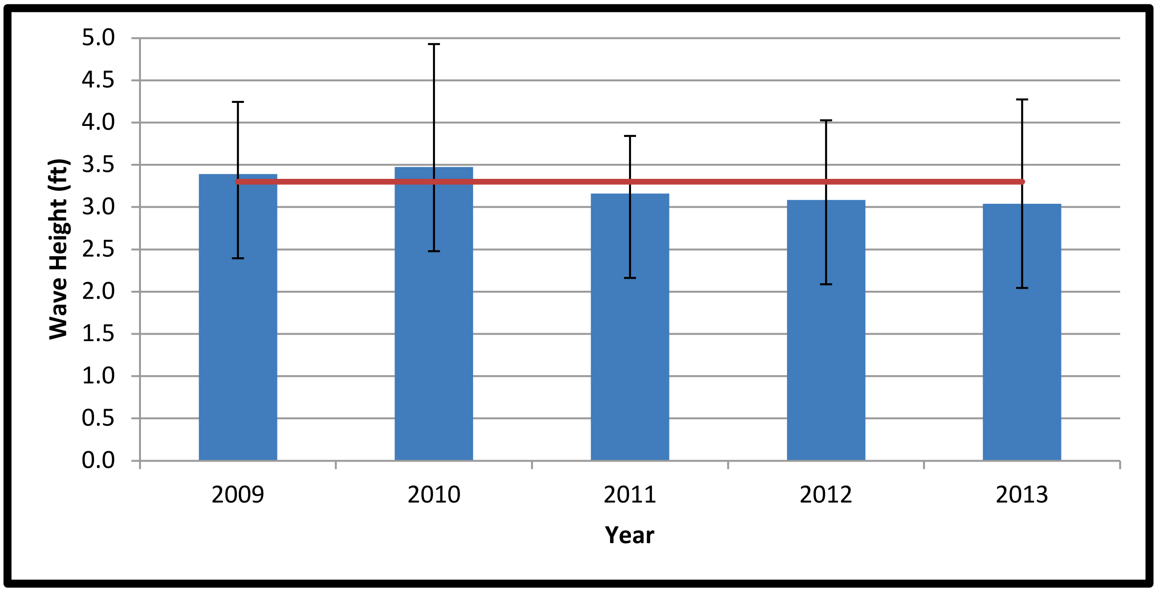


Figure 1. Annual mean wave height (feet) at the Massachusetts Bay A buoy. The red line is the 2001-2009 mean of 3.3 feet. Error bars are +/- 1 standard deviation.

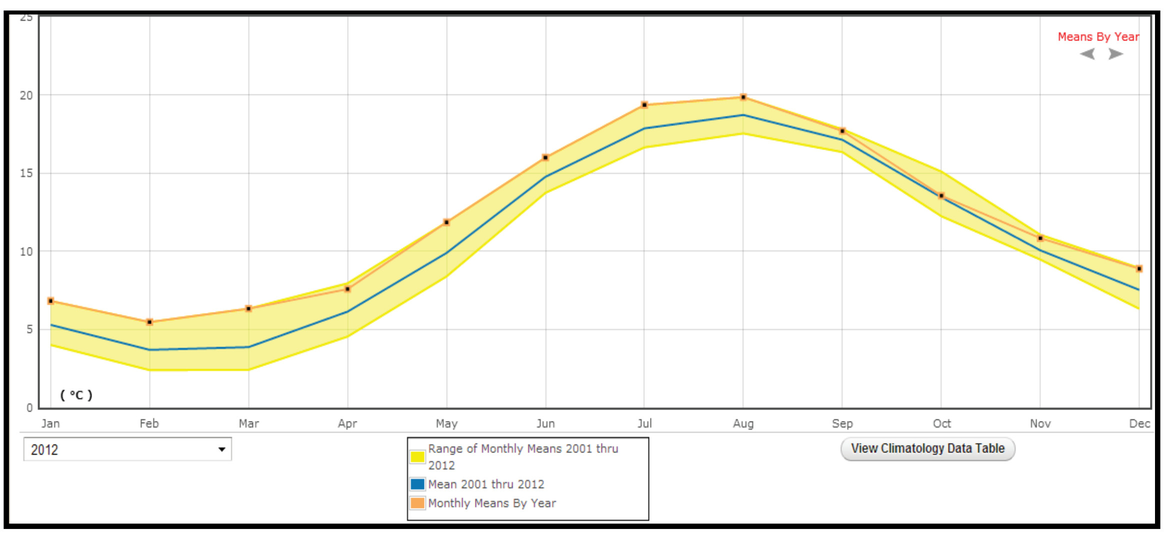


Figure 2. The monthly sea surface temperature (˚C) in Massachusetts Bay 2001-2012. Yellow shading represents the range of monthly mean temperatures over the 12-year time series while the blue line is the mean. The orange dots are the monthly means for 2012. Note that all monthly averages in 2012 except that of October were the times series' maxima.

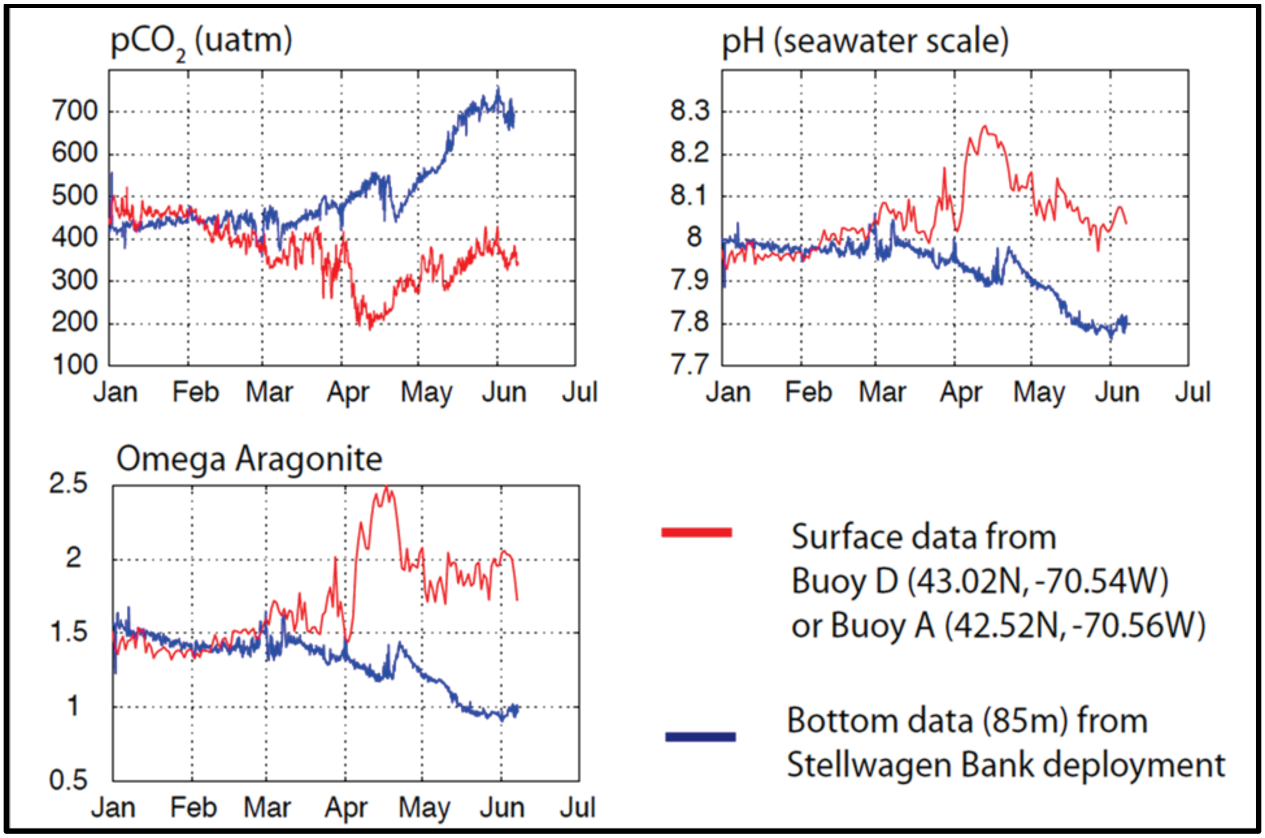


Figure 3. The partial pressure of CO_2 (microatmospheres), pH, and derived aragonite saturation (omega) at the surface (-2 m, red) and bottom (-85 m, blue) of the western Atlantic ocean. The surface measurements were recorded at the University of New Hampshire (UNH) buoy near Appledore Island.[67] The bottom measurements were recorded by Stellwagen Bank National Marine Sanctuary on a buoy in Massachusetts Bay. Figure courtesy of Joe Salisbury, University of New Hampshire.

[67] http://www.neracoos.org/realtime_map

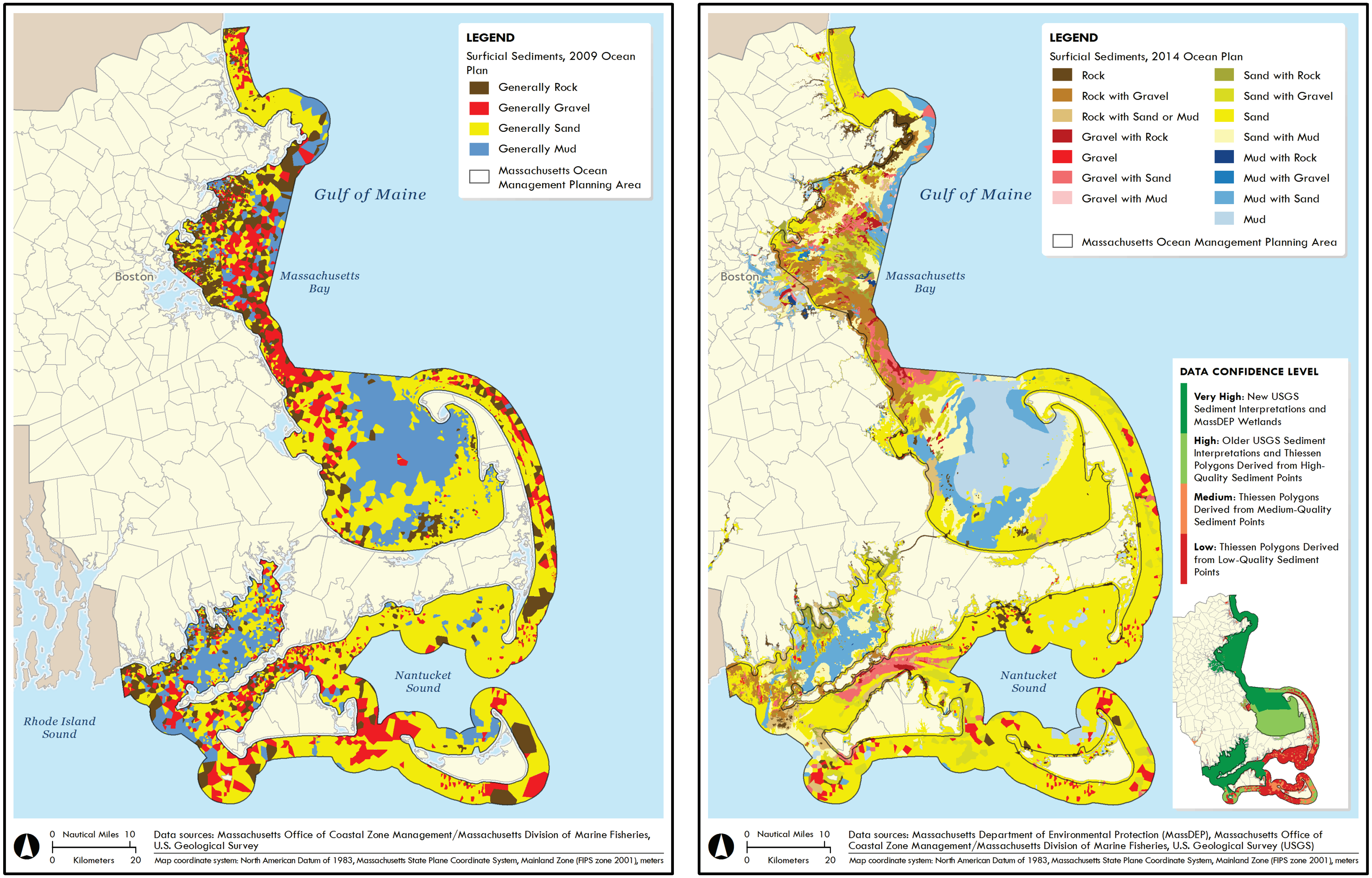


Figure 4. A comparison of the 2009 ocean plan surficial sediment map (left) to the 2014 ocean plan surficial sediment map (right). In both maps, blue represents mud, yellow represents sand, red represents gravel, and brown depicts rock. The map on the right is substantially more accurate, containing new USGS sediment interpretations and 30,000 more data points than the 2009 map.

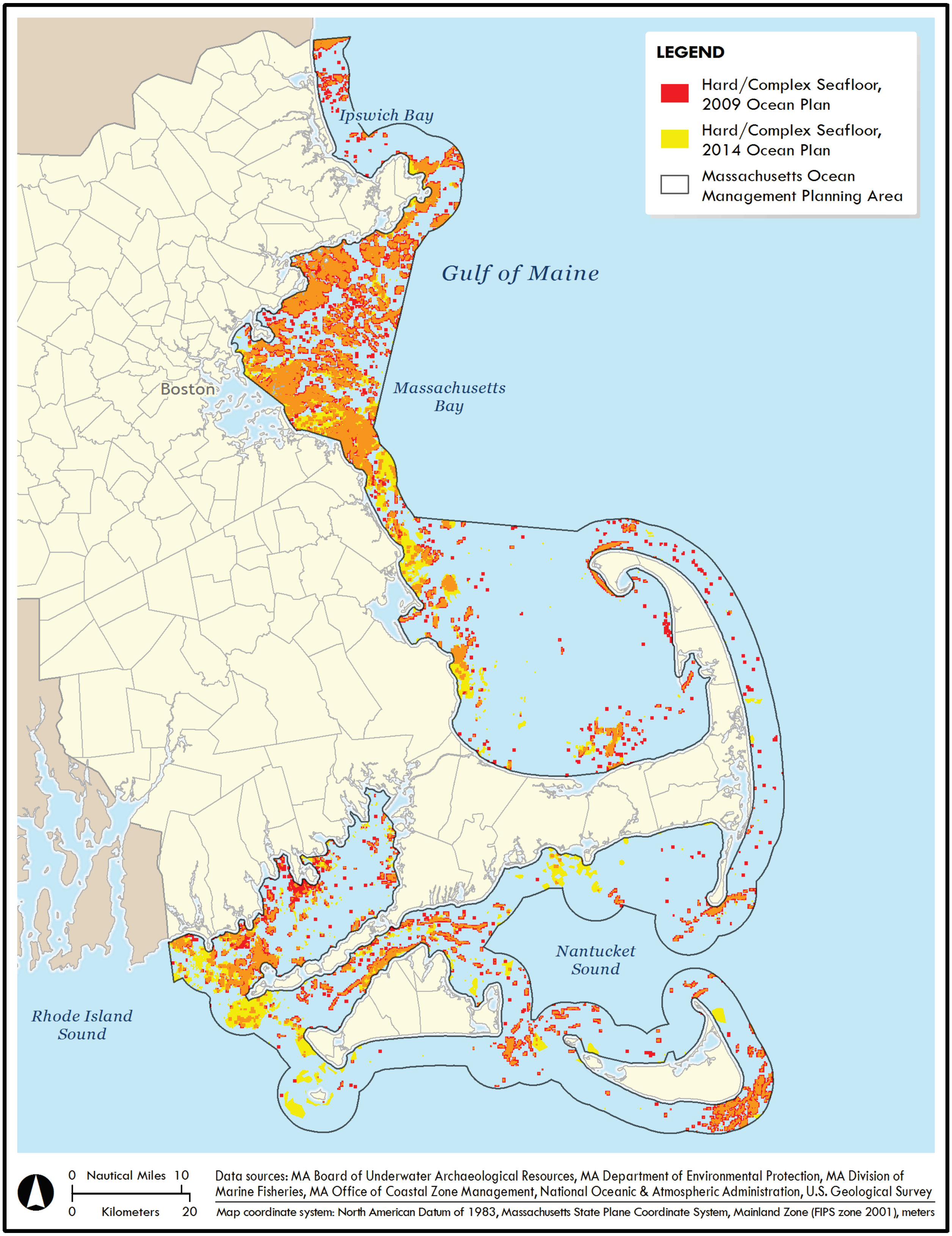


Figure 5. The 2009 ocean plan hard/complex seafloor SSU area (red) and the revised 2014 hard/complex seafloor SSU area (yellow); areas common to both years in orange.

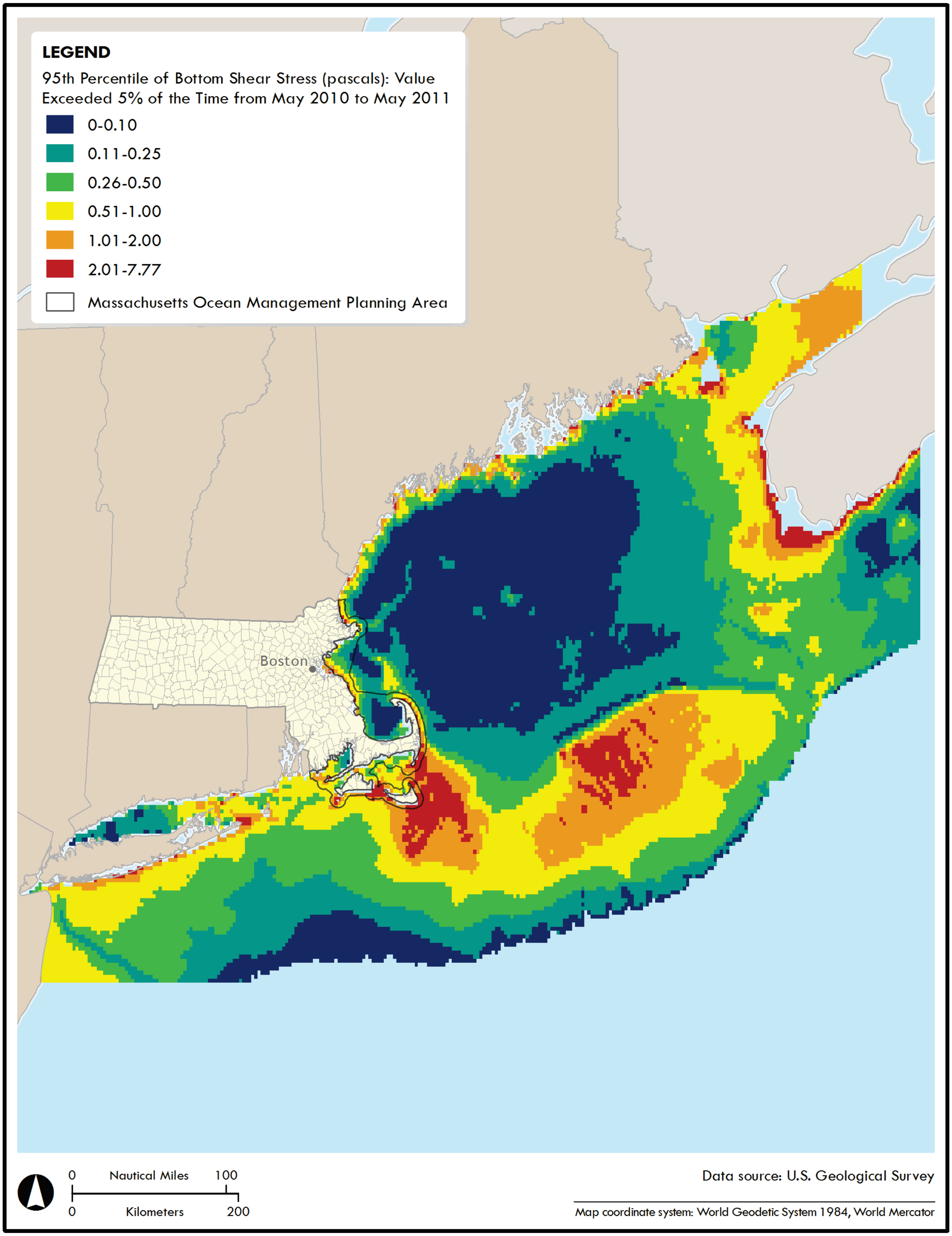


Figure 6. Annual 95th percentile (values exceeded only 5% of the time) seafloor shear stress (measured in pascals) from May 2010-May 2011.

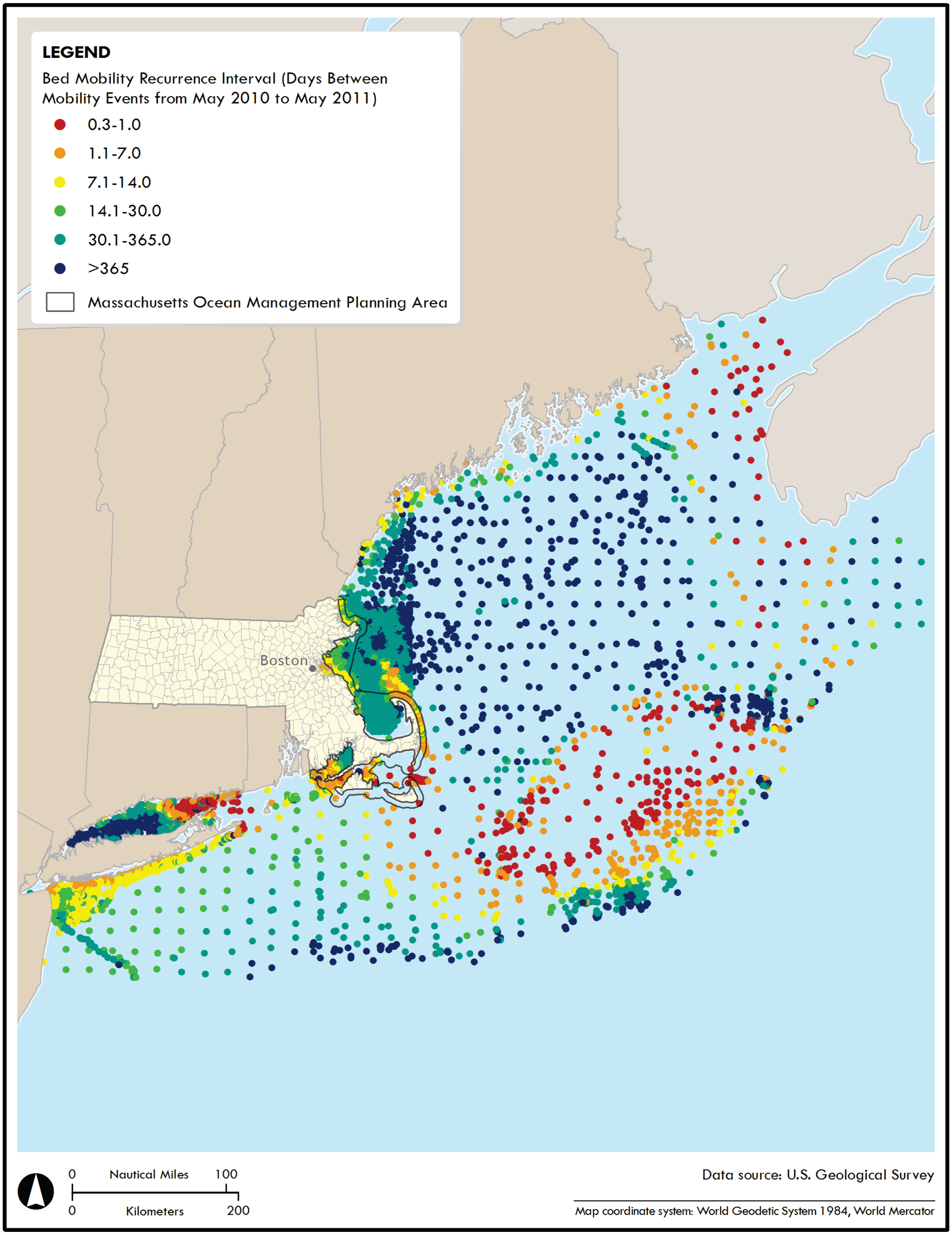


Figure 7. Days between seabed mobility events from May 2010 to May 2011. Areas represented by warmer colors (red, orange, and yellow) are less stable than areas represented by cooler colors (green, turquoise, and blue).

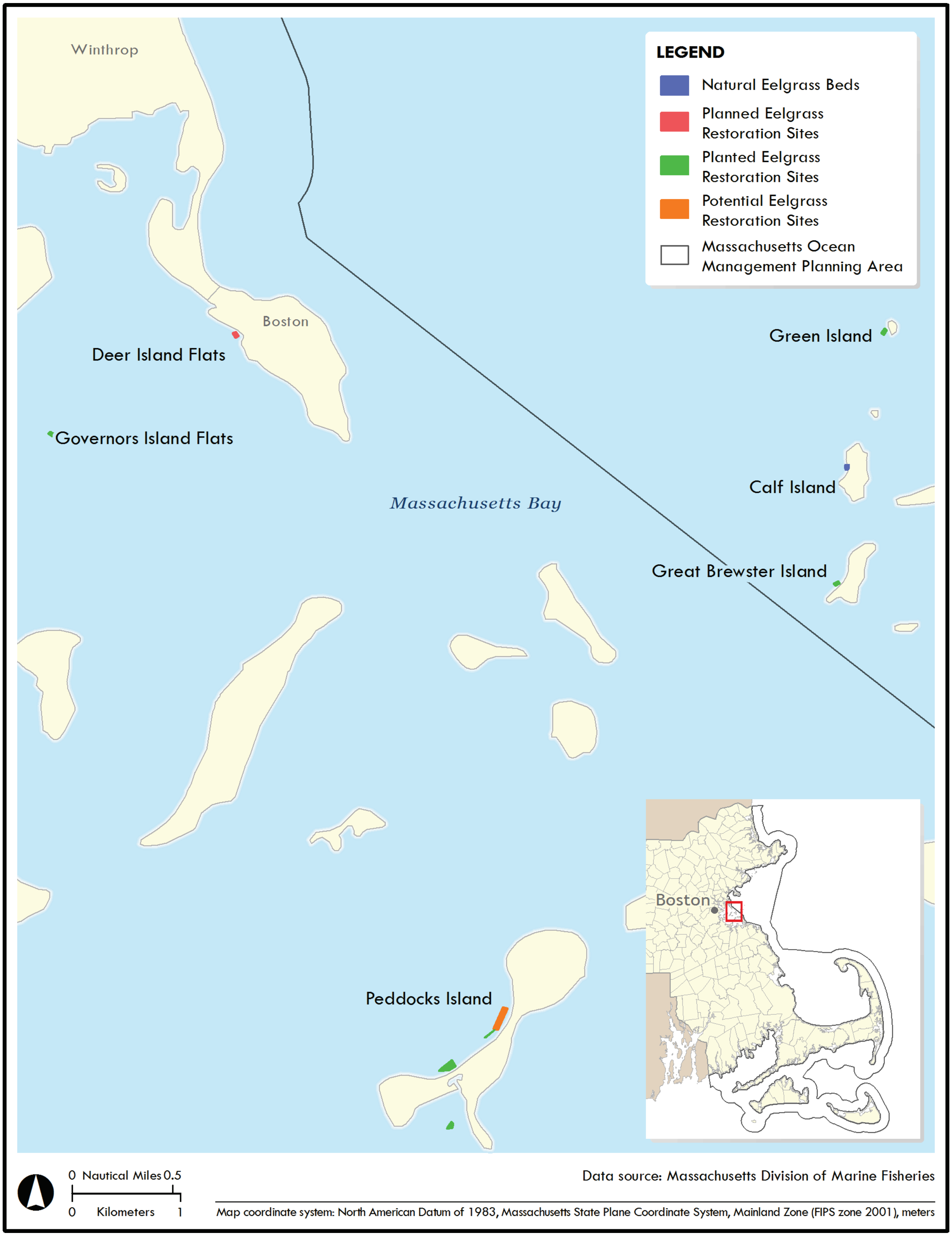


Figure 8. The location of *MarineFisheries* eelgrass restoration sites and one recently discovered (2011) natural bed (adjacent to Calf Island) in Boston Harbor.

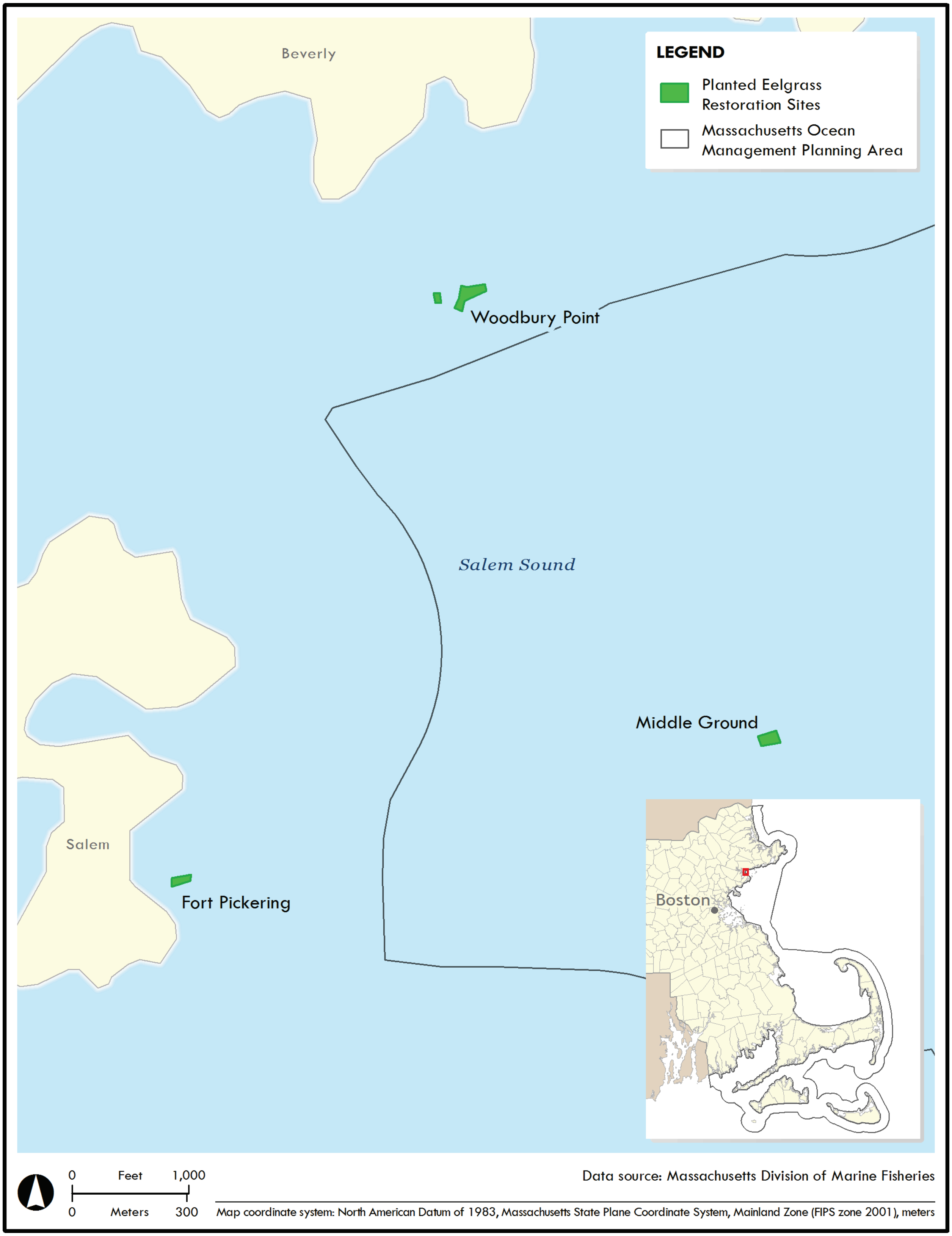


Figure 9. *MarineFisheries* eelgrass restoration sites in Salem Sound: Woodbury Point (to the north), Middle Ground (to the southeast), and Fort Pickering (to the southwest).

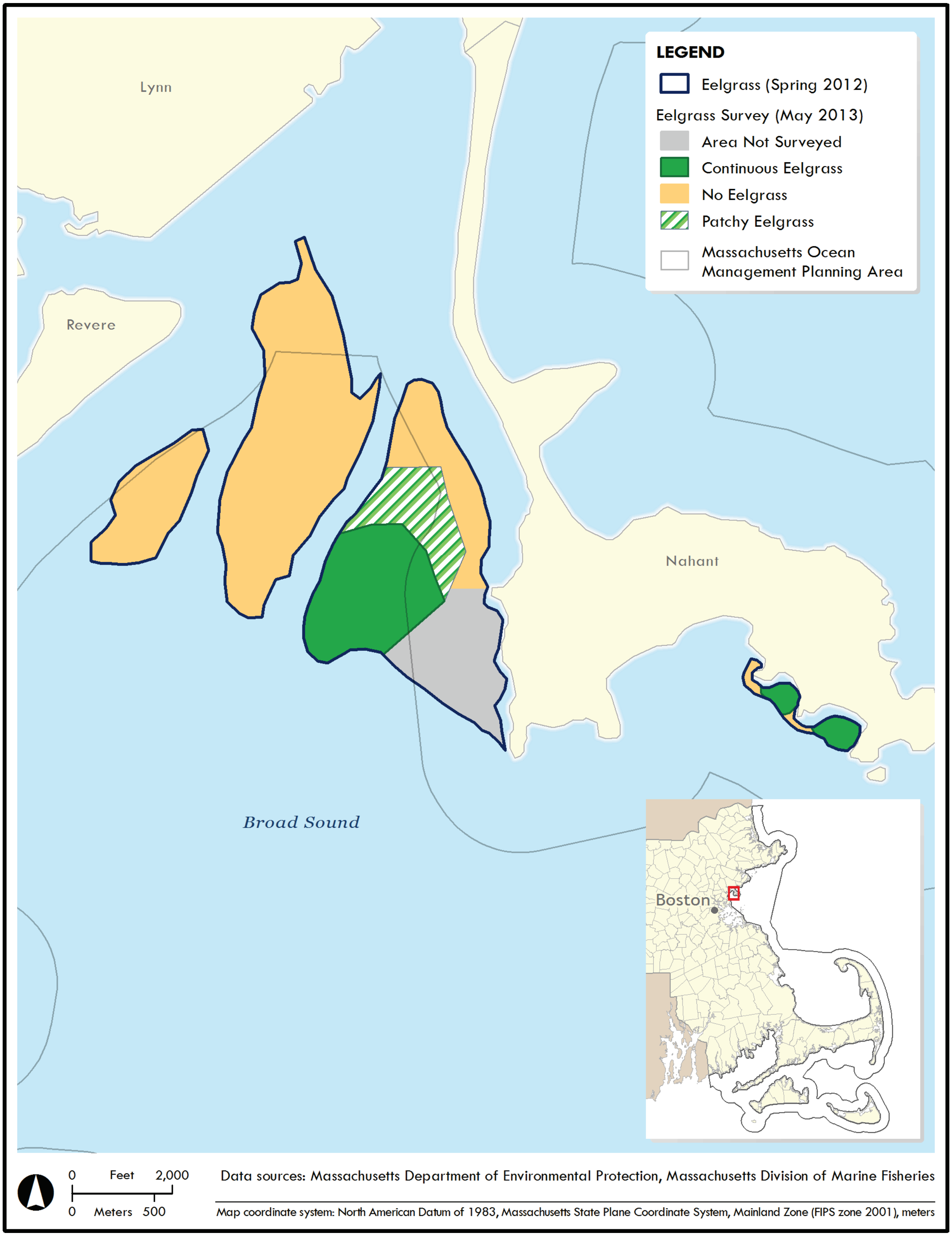


Figure 10. Change in eelgrass bed extent off of Nahant, before and after Hurricane Sandy (October 2012).

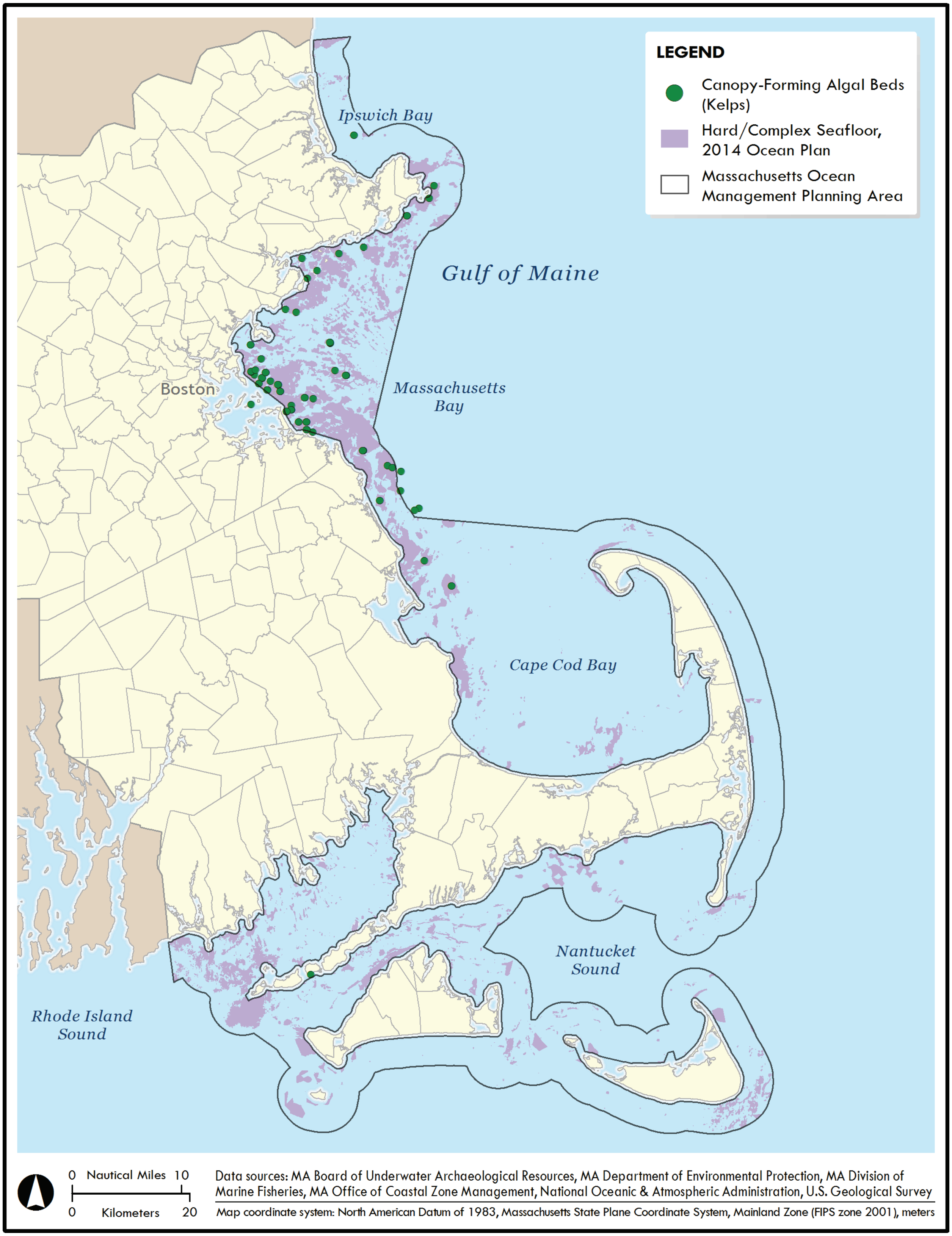


Figure 11. The location of canopy-forming algae (kelp) in Massachusetts waters as determined from opportunistic seafloor photos.

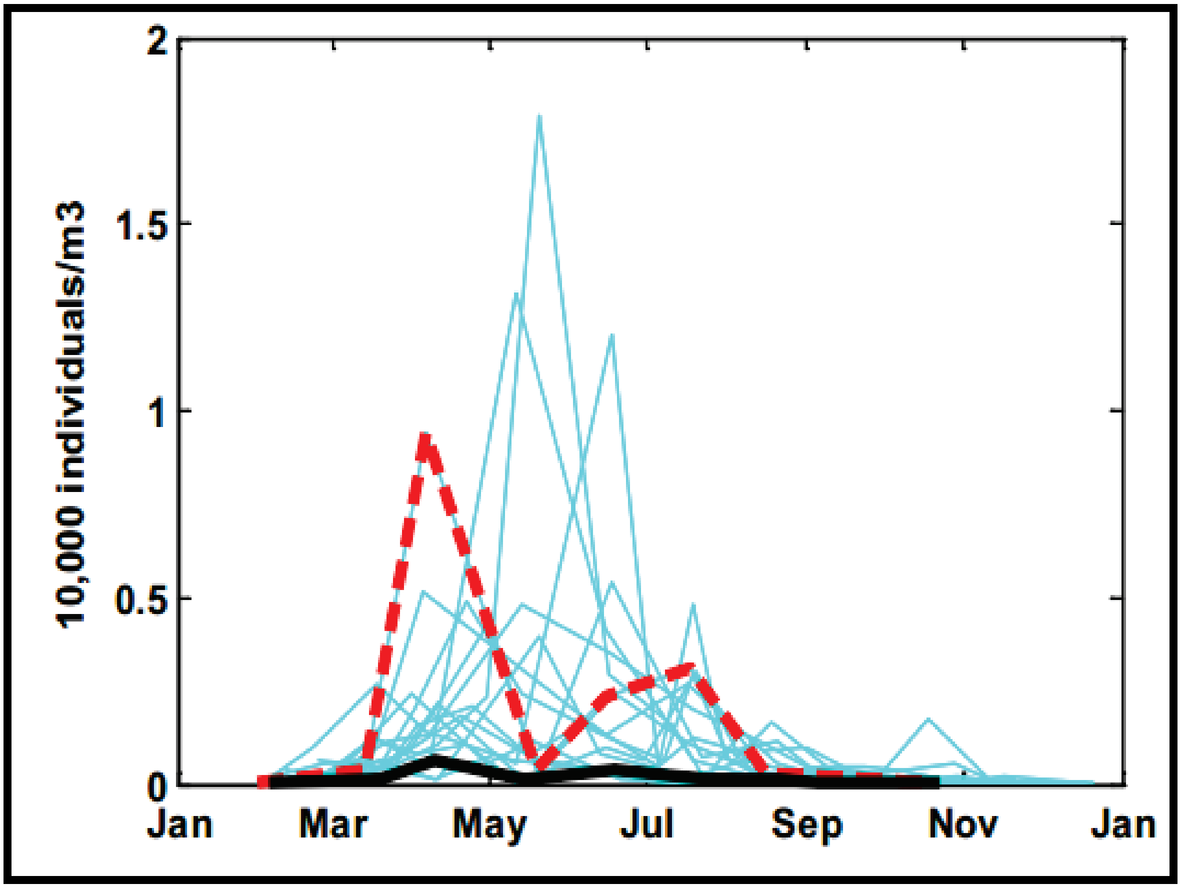


Figure 12. ***Calanus finmarchicus*** **abundance at MWRA nearfield sampling sites in Massachusetts Bay. Blue lines represent years 1992-2010, the dashed red line is 2011, and the solid black line is 2012. Figure reproduced from MWRA ENQUAD Report 2013-14, Figure 3-20.[68]**

[68] http://www.mwra.state.ma.us/harbor/enquad/pdf/2013-14.pdf

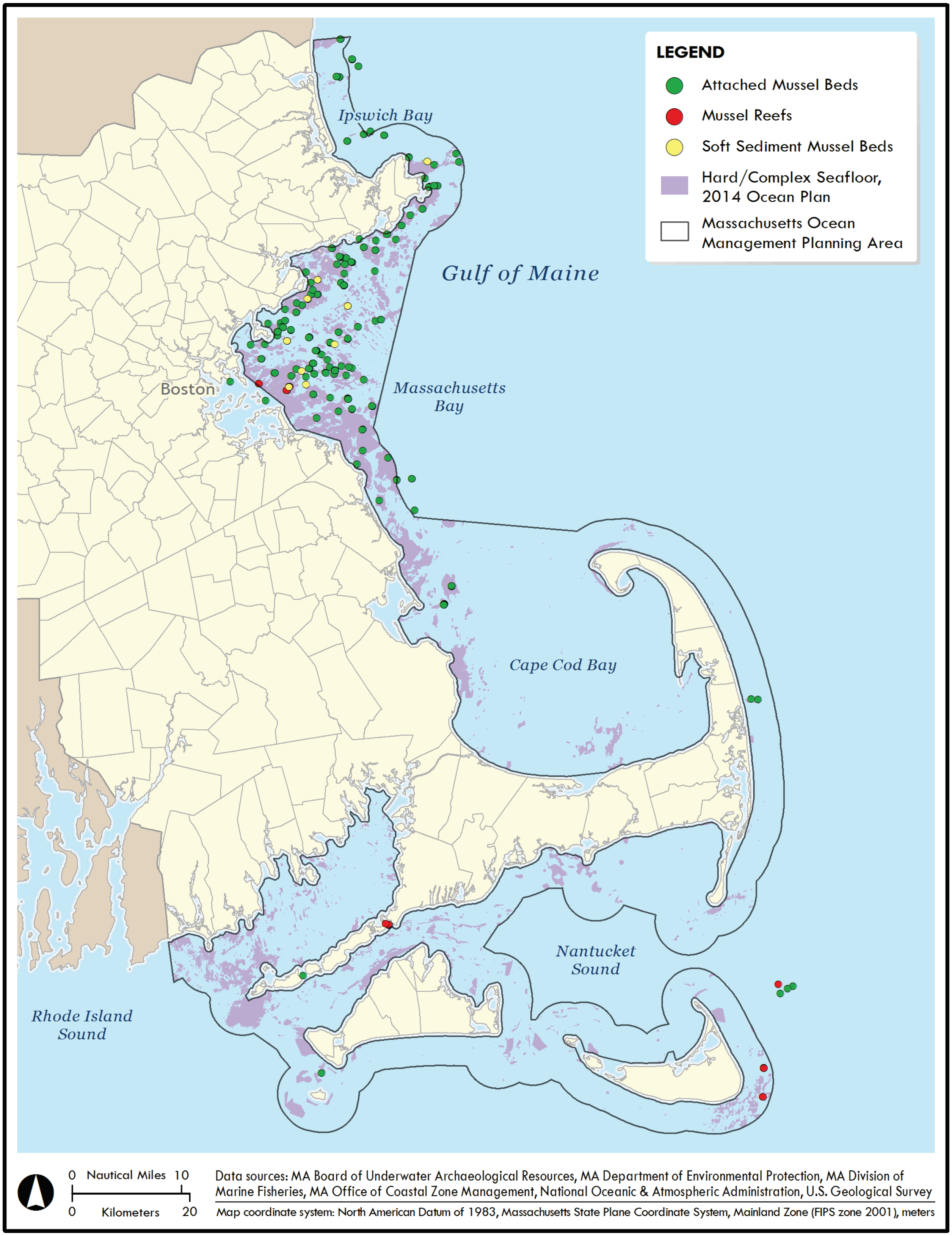


Figure 13. The location of mussel beds and reefs in Massachusetts waters as identified from opportunistic seafloor photos.

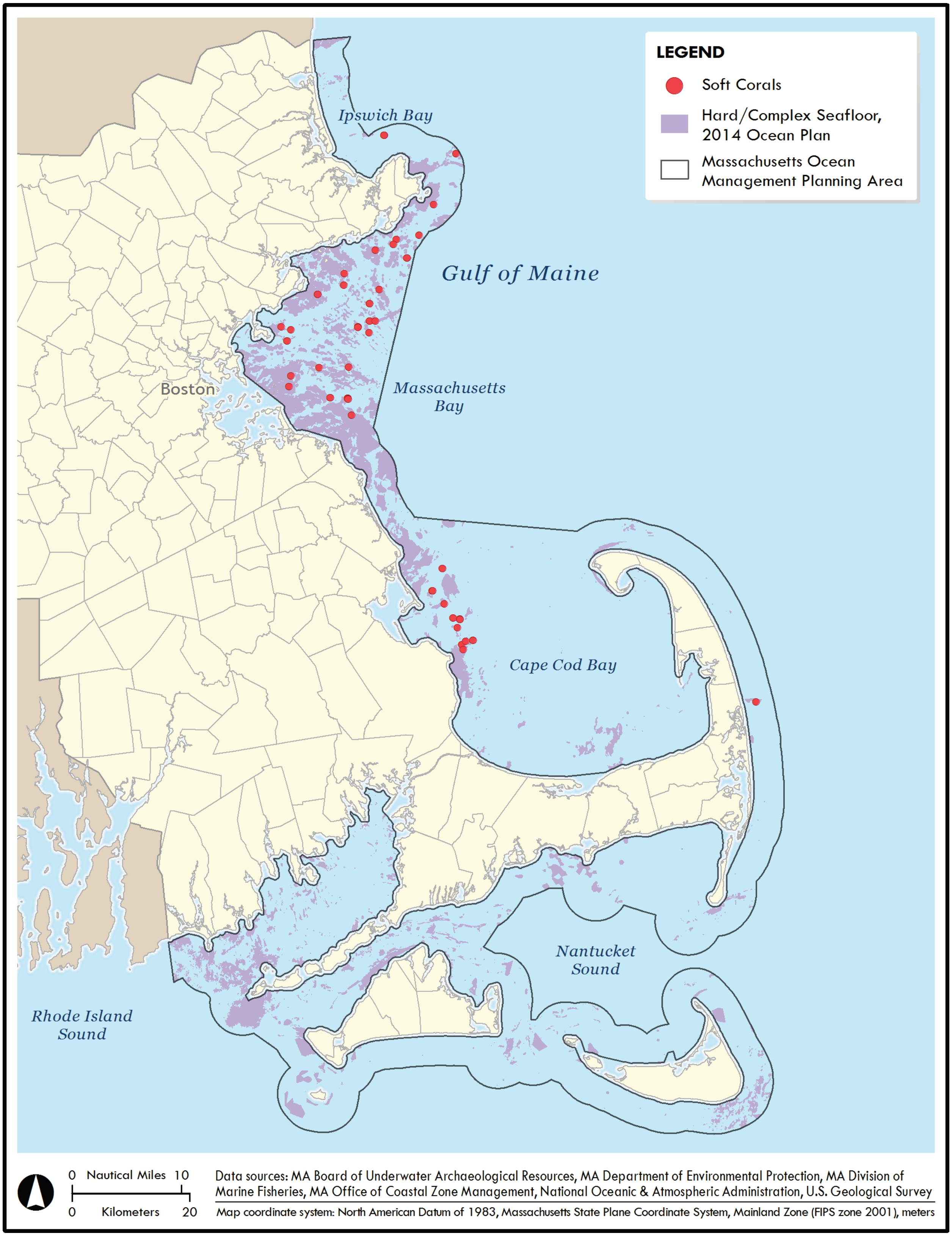


Figure 14. The location of soft corals in Massachusetts waters as identified from opportunistic seafloor photos.

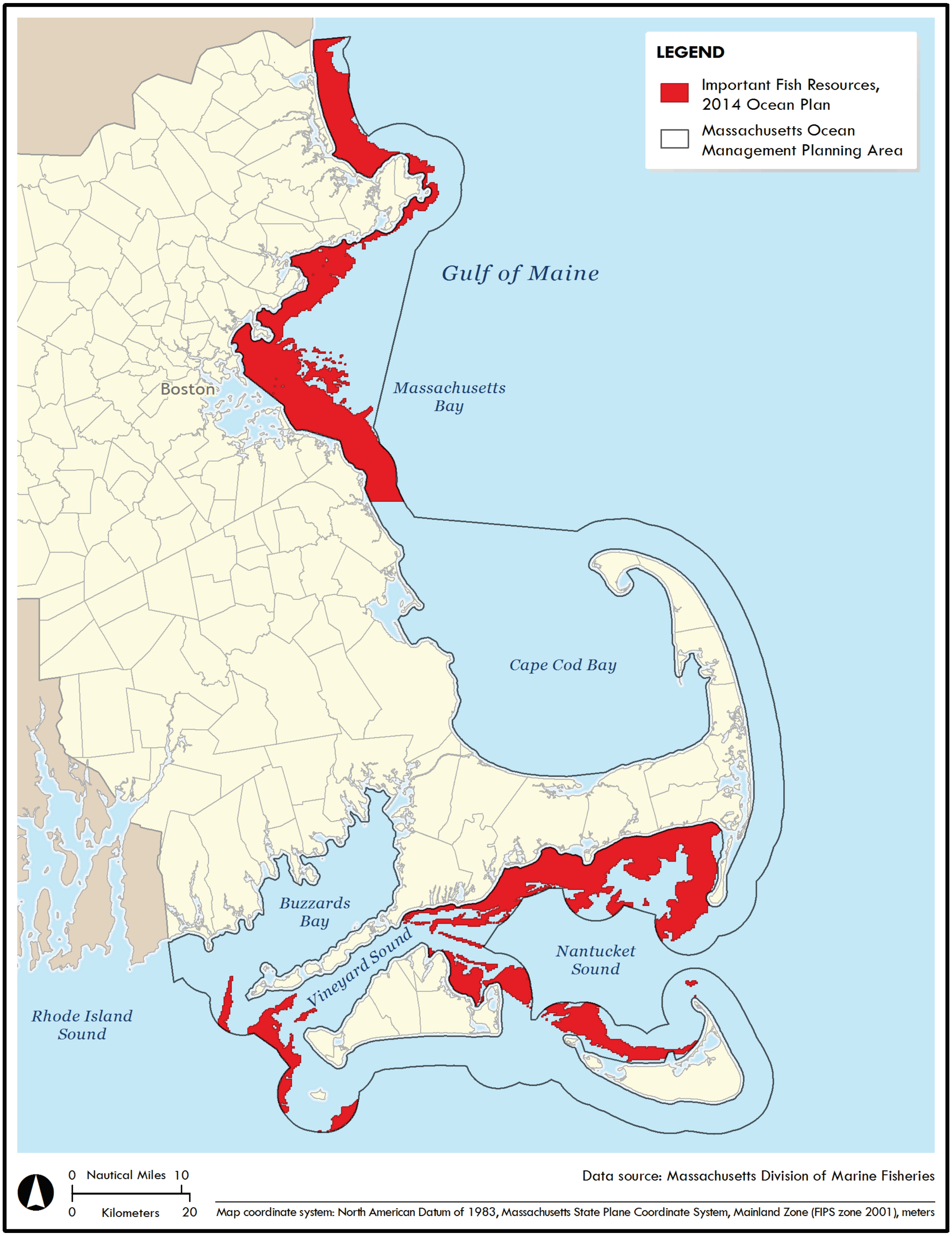
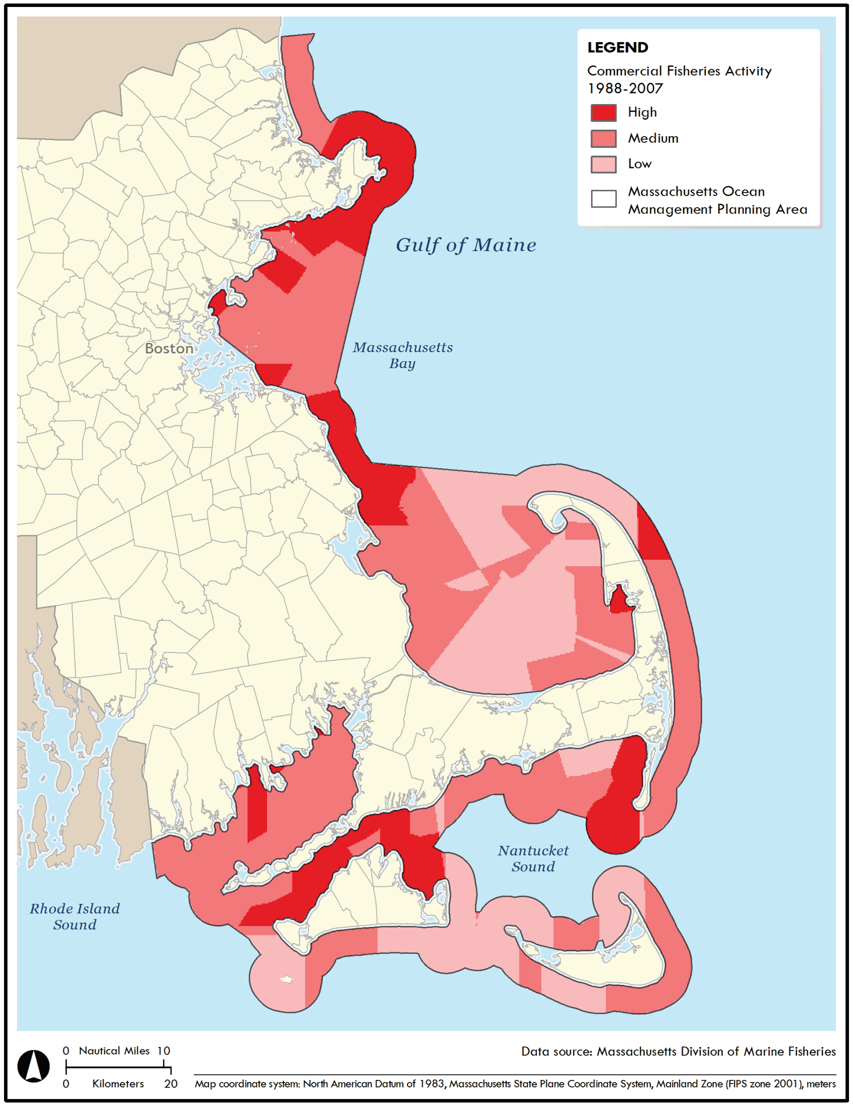


Figure 15. Revised 2014 important fish resources SSU area based on *MarineFisheries* trawl survey data from 1978-2012. The SSU area did not change from 2009.



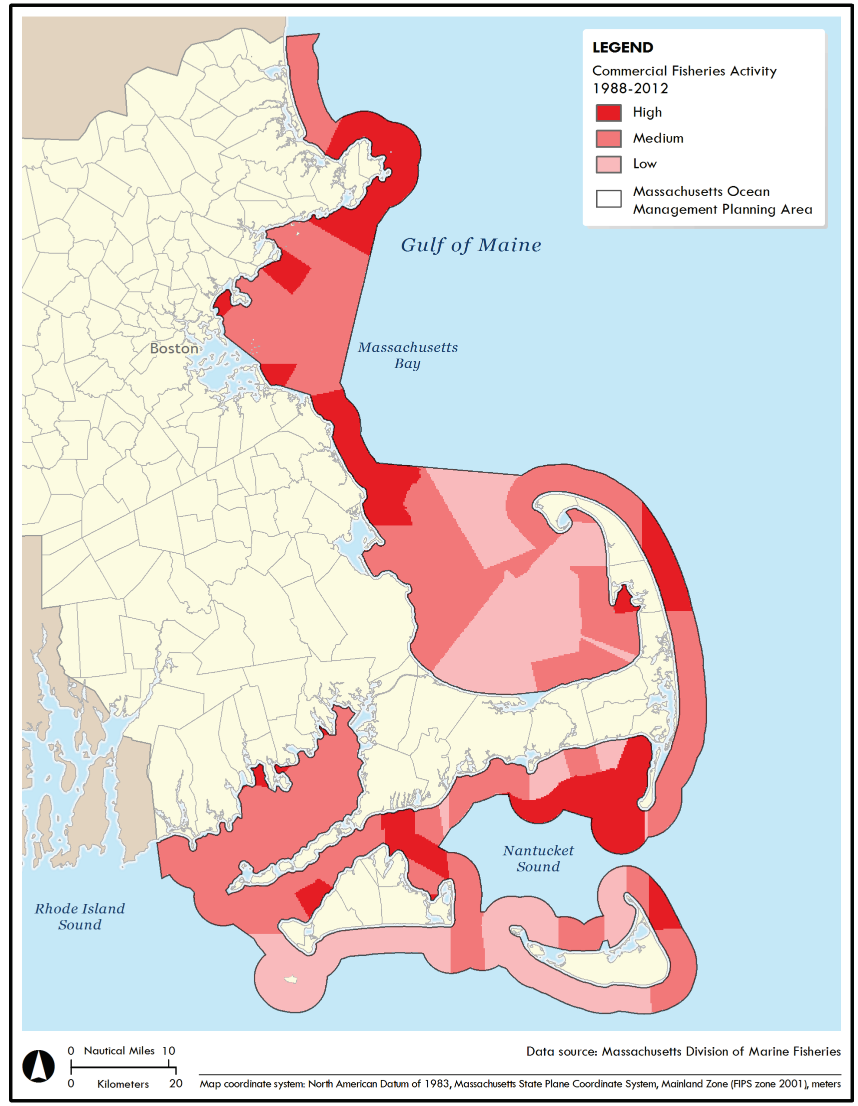


Figure 16. Commercial fishing effort and value in the 2009 ocean plan (left) and updated for the 2014 ocean plan (right). The largest changes were seen on the eastern side of Cape Cod and Nantucket and within Nantucket Sound.

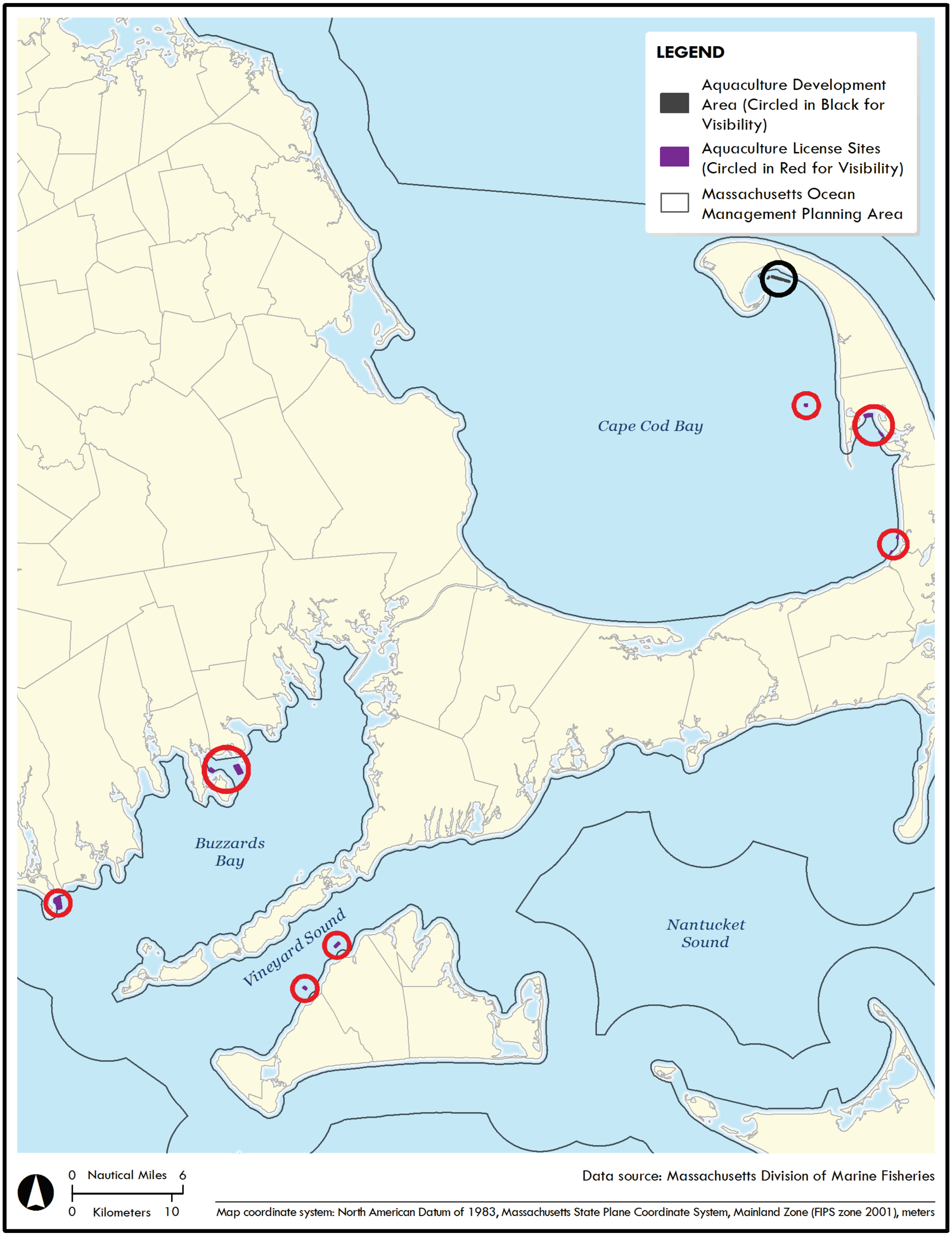


Figure 17. Aquaculture sites in the planning area; sites circled for visibility.

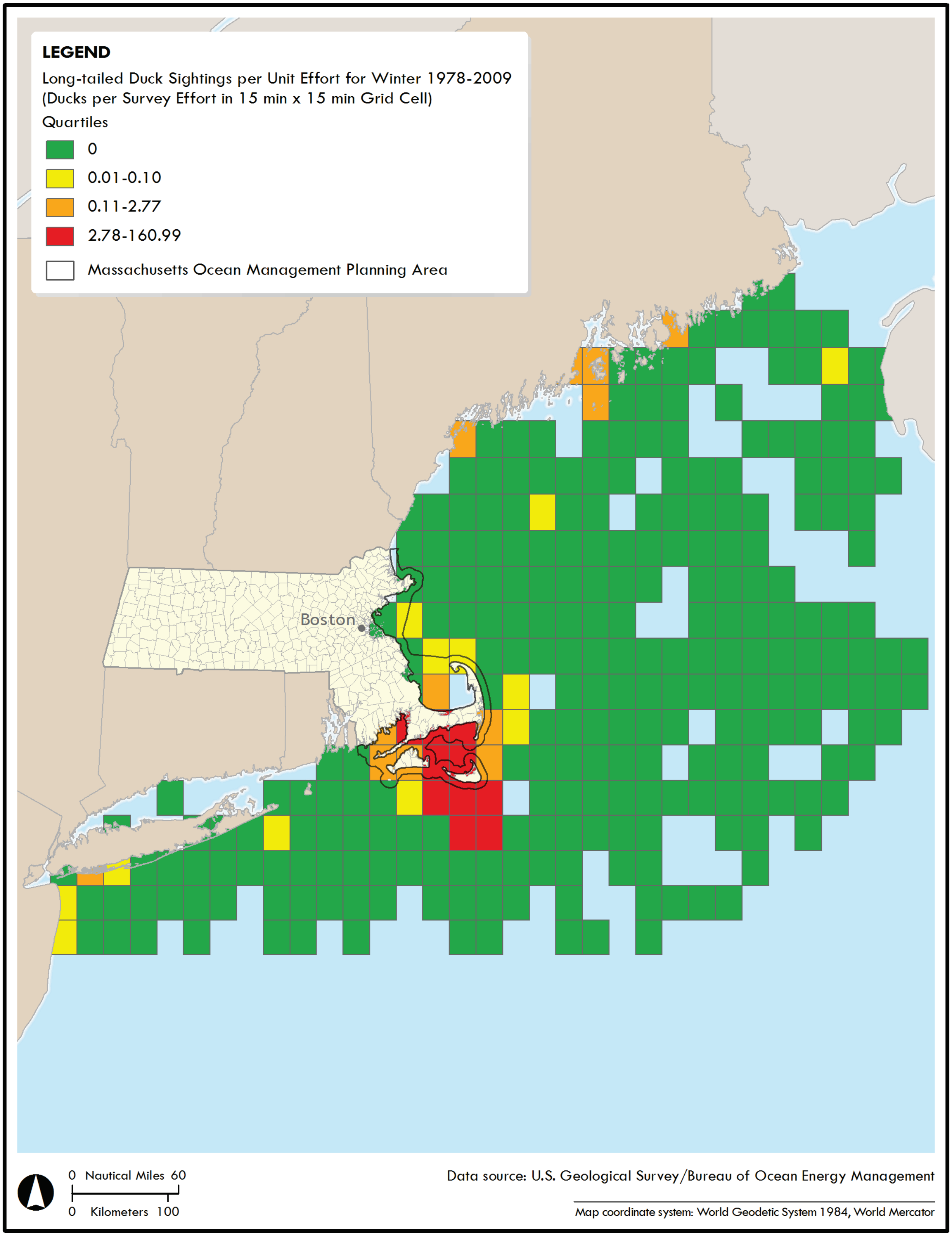


Figure 18. An example of how the USGS/BOEM Compendium of seabird studies demonstrates the importance of Massachusetts waters.

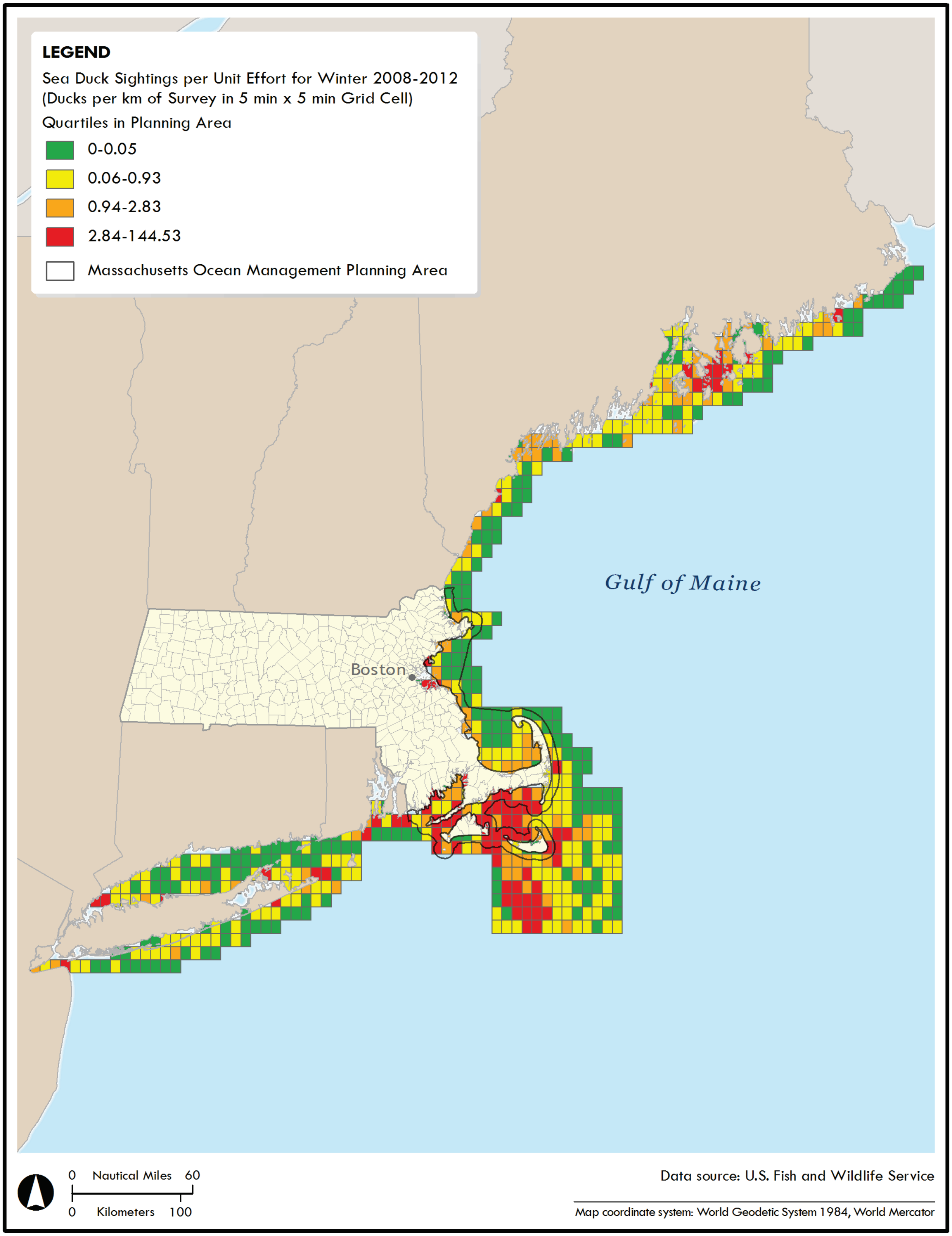


Figure 19. Combined sea duck (Long-tailed Duck, Common Eider, Surf Scoter, Black Scoter, White-winged Scoter) densities from the 2008-2012 USFWS aerial surveys.

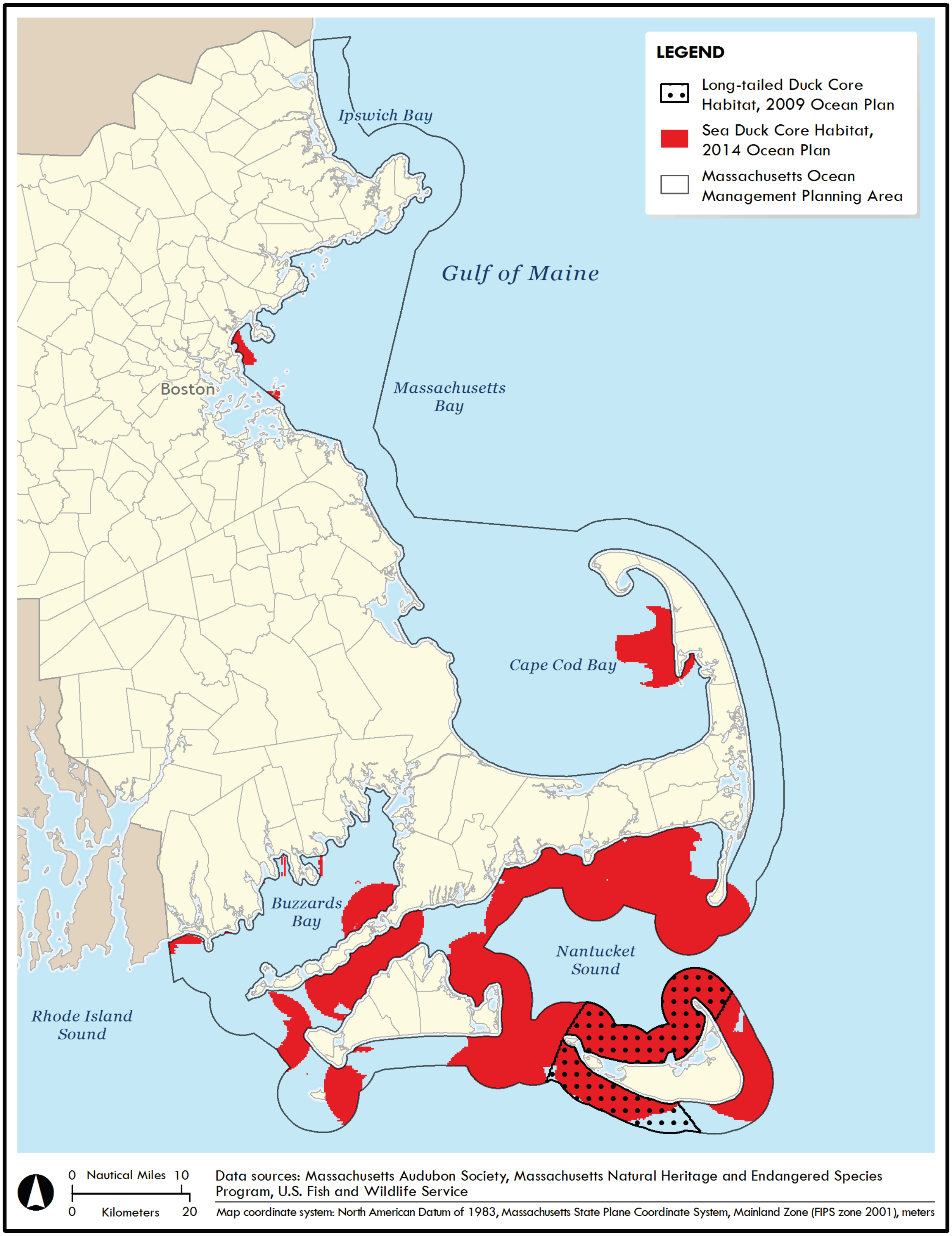


Figure 20. Sea duck core habitat SSU area for the 2014 ocean plan (in red). The stippled area represents the Long-tailed Duck core habitat SSU area in the 2009 ocean plan.

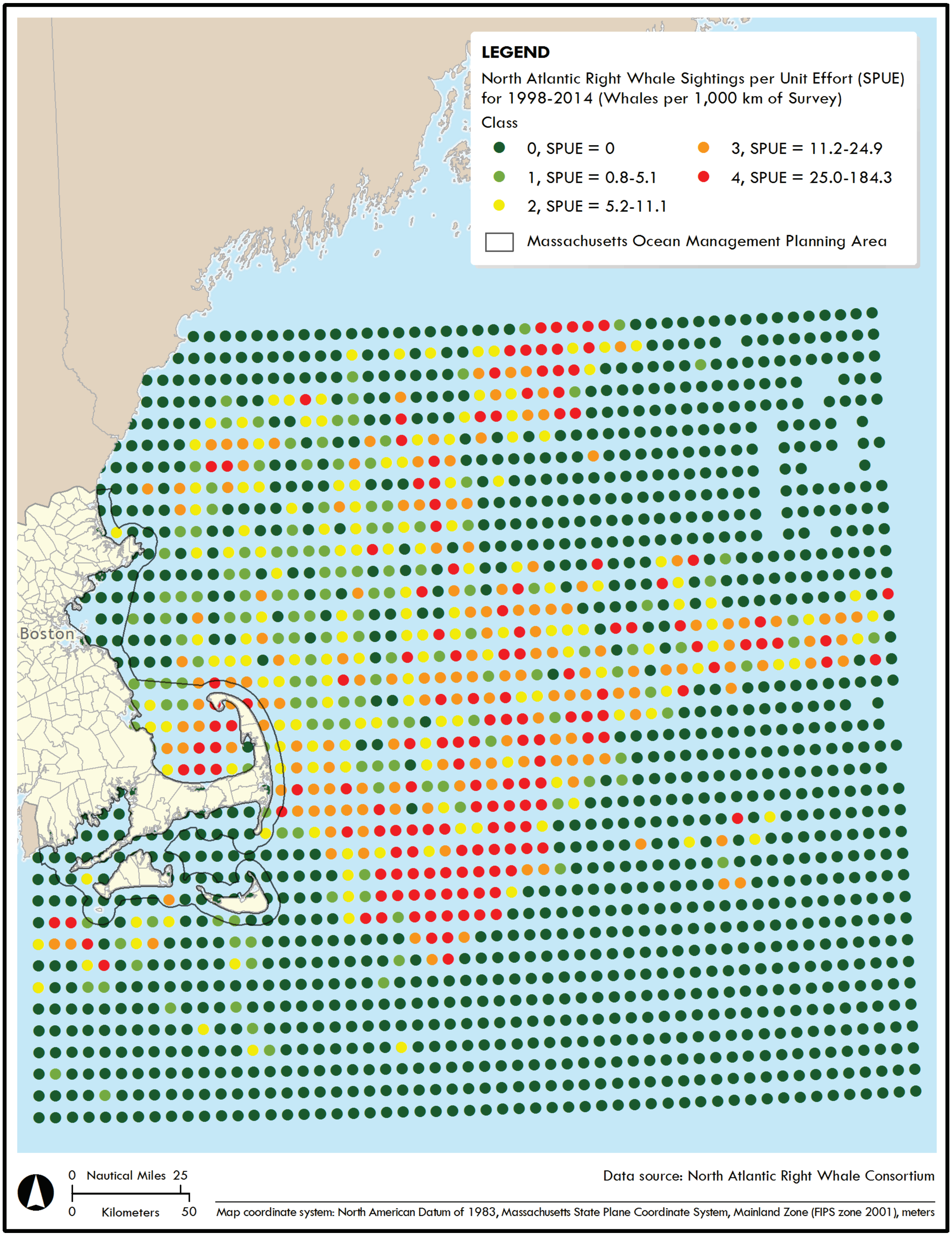


Figure 21. North Atlantic right whale sightings per unit effort for 1998-2014.

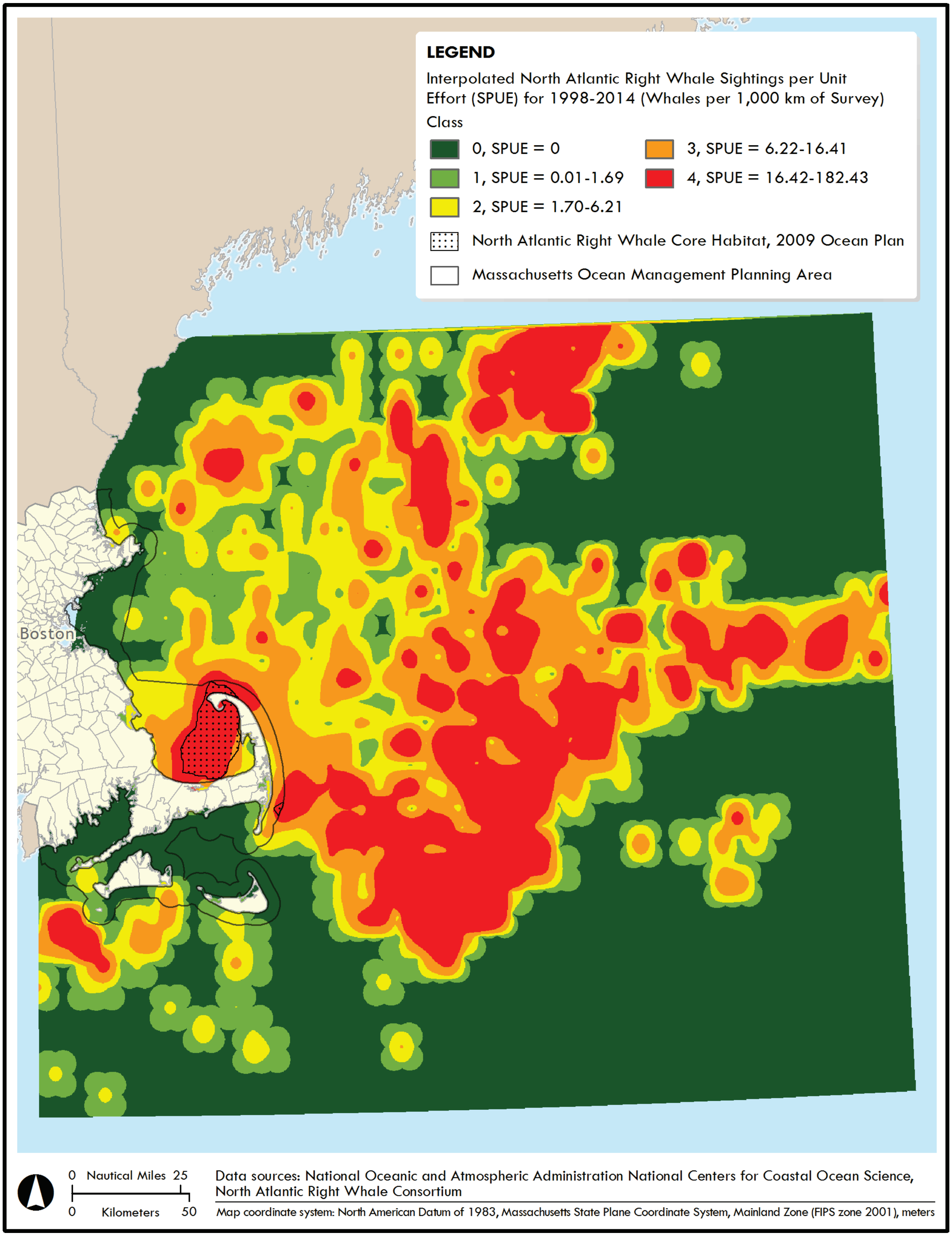


Figure 22. Interpolated North Atlantic right whale sightings per unit effort for 1998-2014. The stippled area is the North Atlantic right whale core habitat SSU area in the 2009 ocean plan.

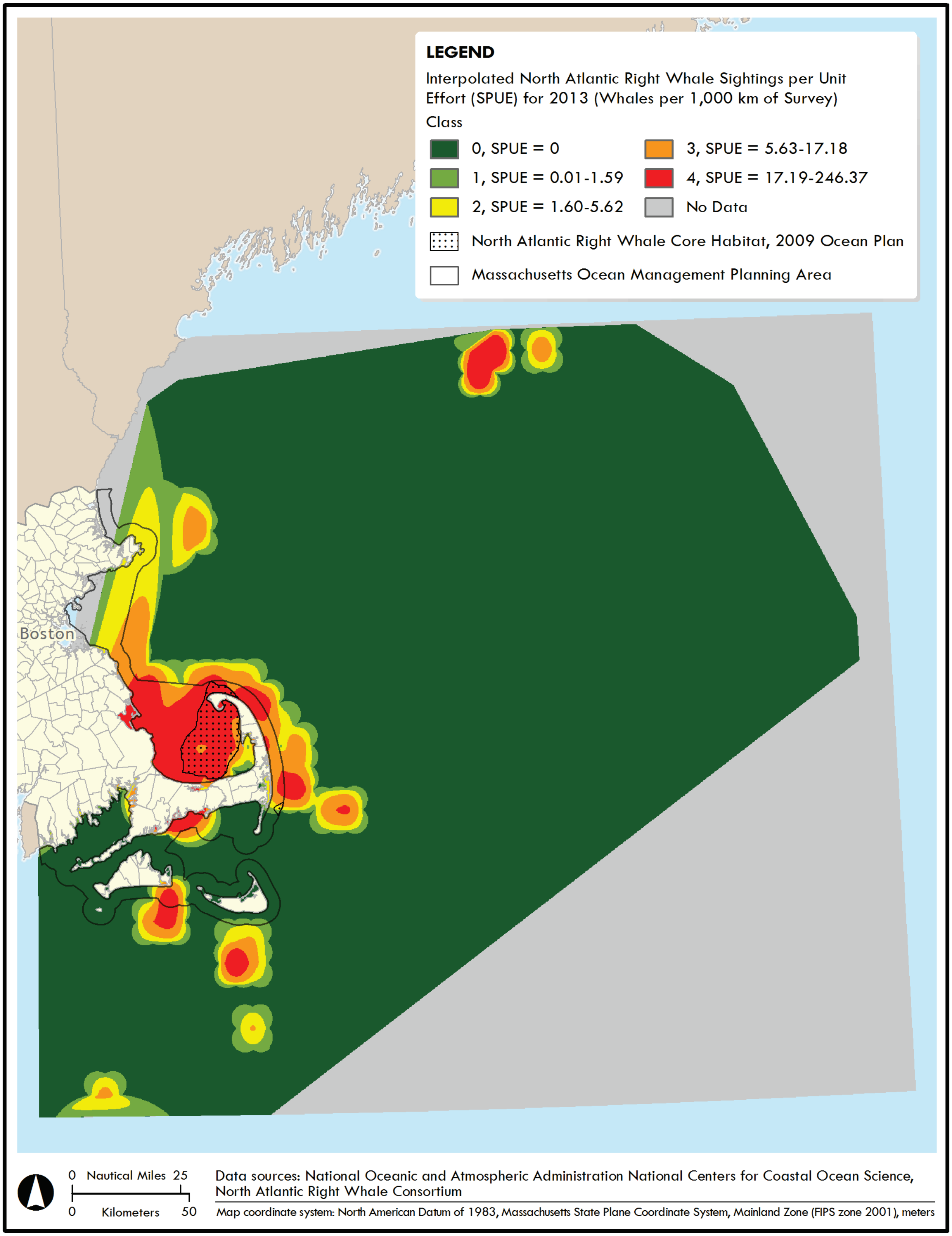


Figure 23. Interpolated North Atlantic right whale sightings per unit effort for 2013. The stippled area is the North Atlantic right whale core habitat SSU area in the 2009 ocean plan.

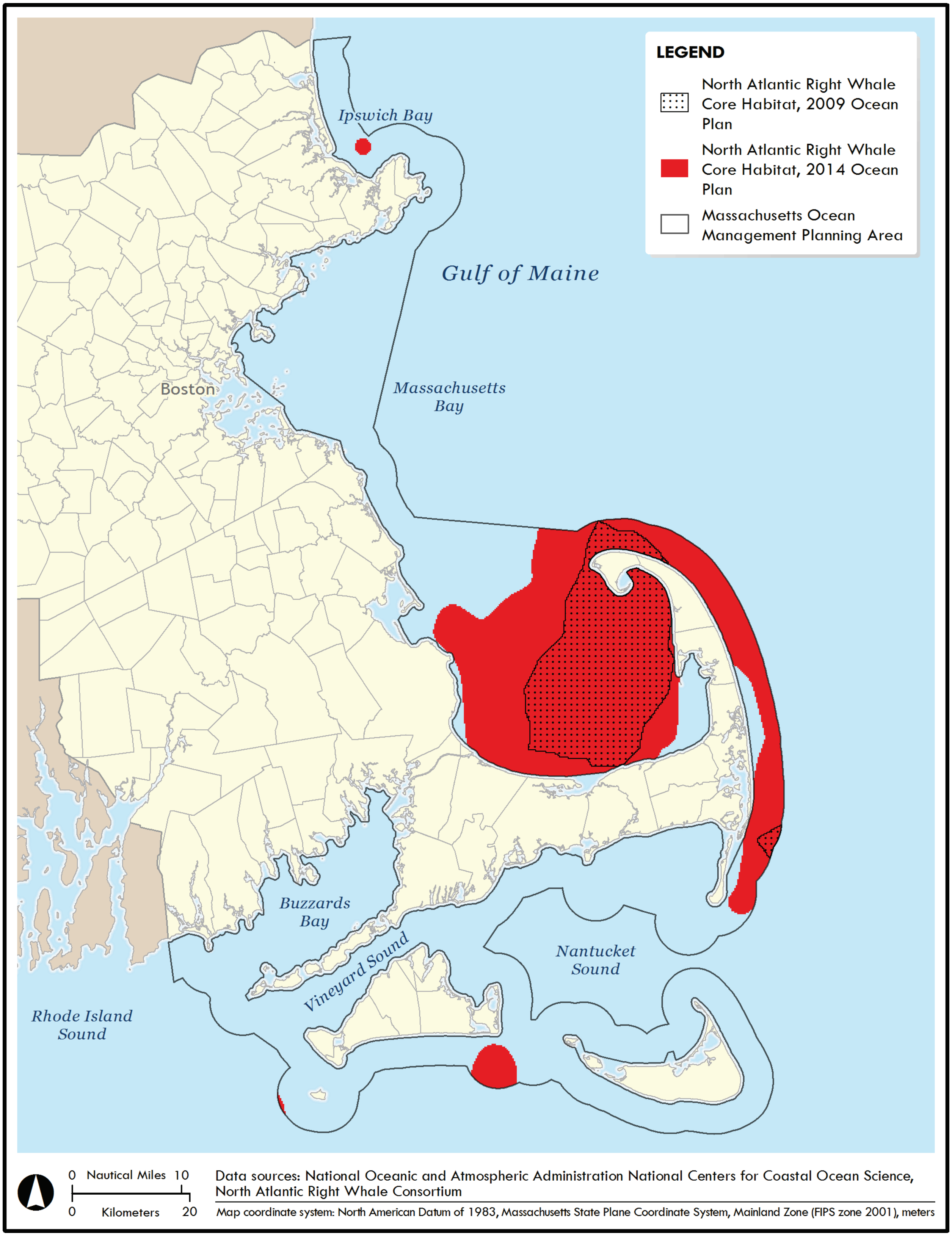


Figure 24. North Atlantic right whale core habitat SSU area for the 2014 ocean plan (in red). The stippled area represents the North Atlantic right whale SSU area in the 2009 ocean plan.

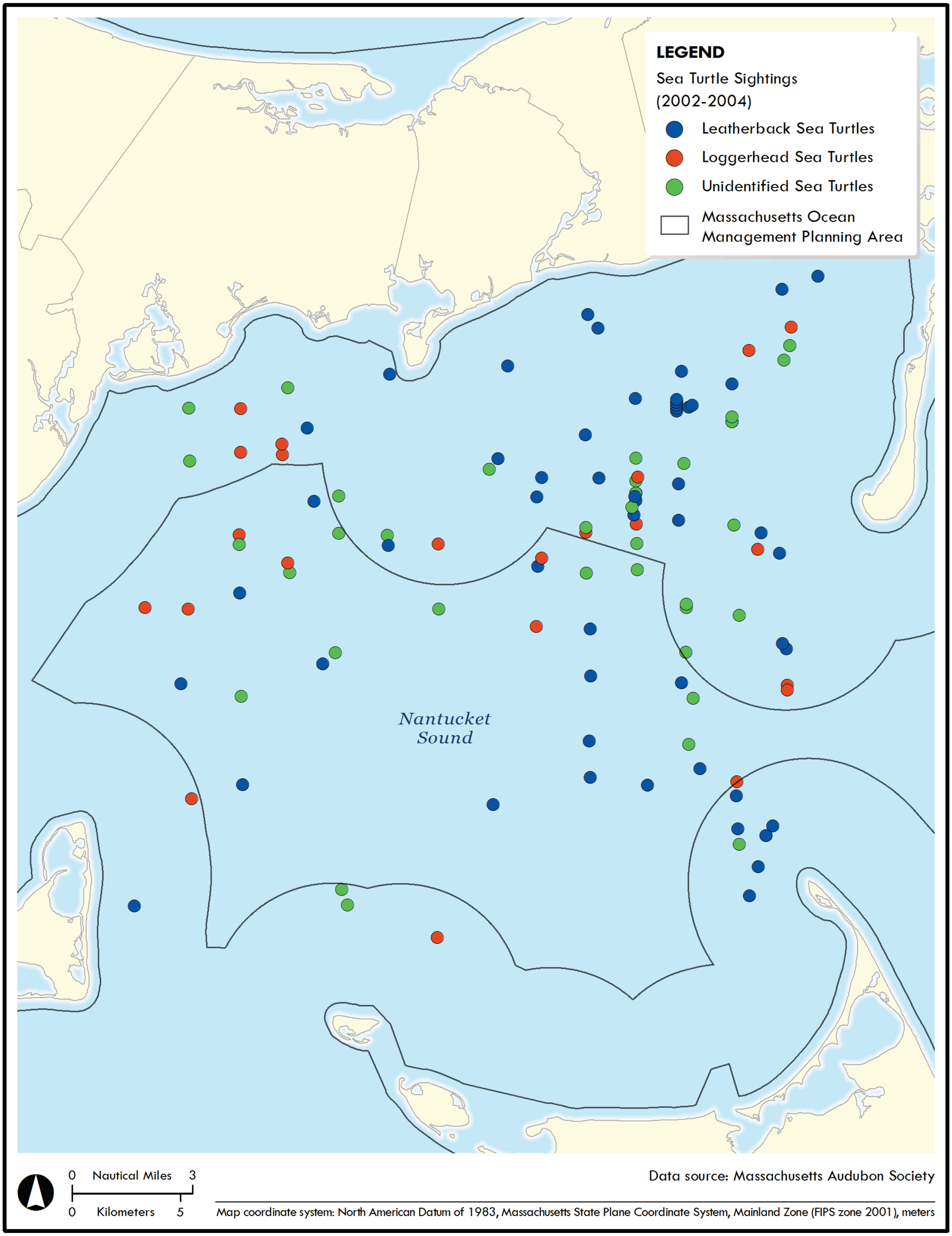


Figure 25. Mass Audubon sea turtle sightings in Nantucket Sound from aerial surveys in 2002-2004. Blue = Leatherback Turtle, Red = Loggerhead Turtle, Green = Unidentified sea turtle.

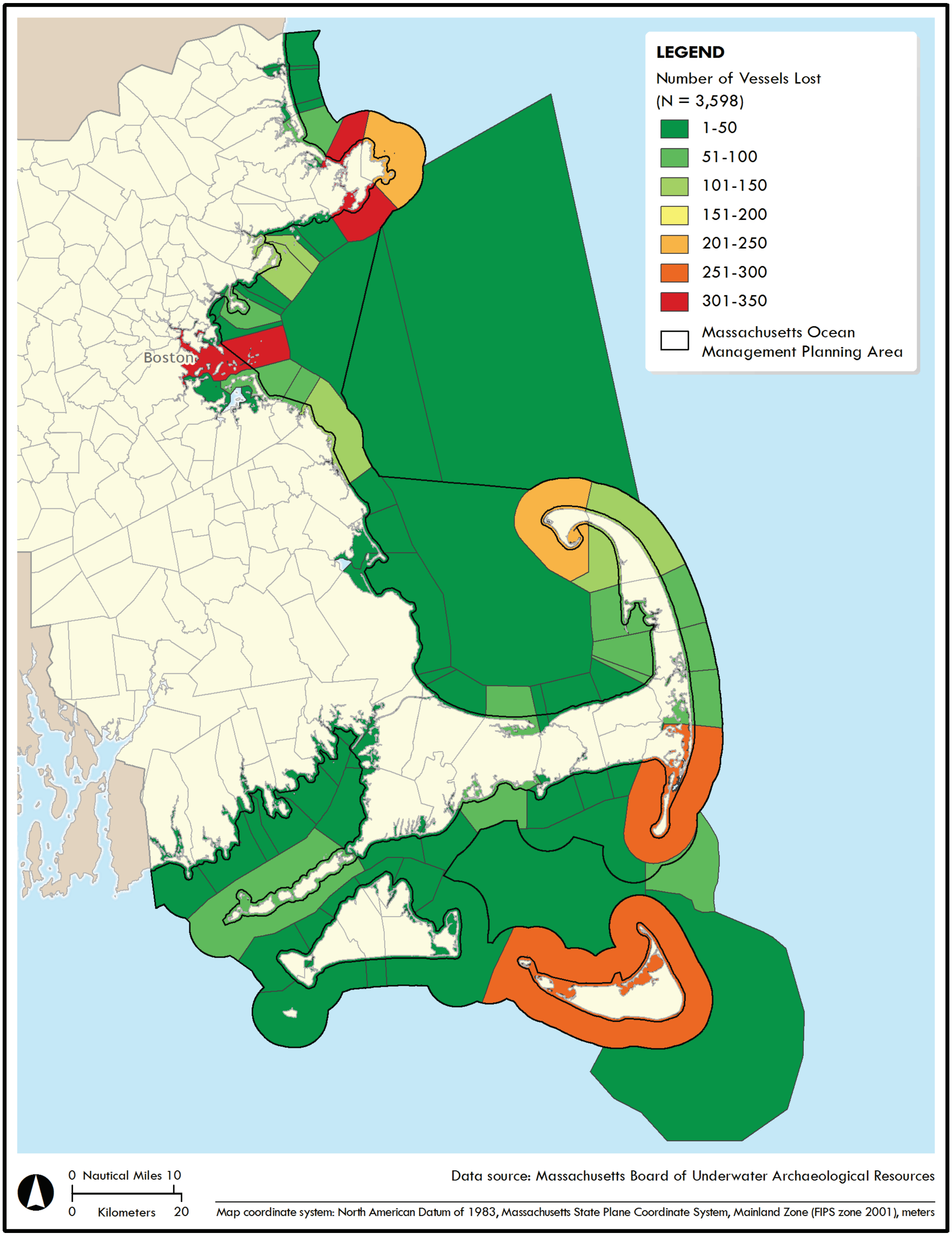


Figure 26. Sensitivity map depicting Massachusetts reported vessels lost as recorded by nearest town (1640s to present).

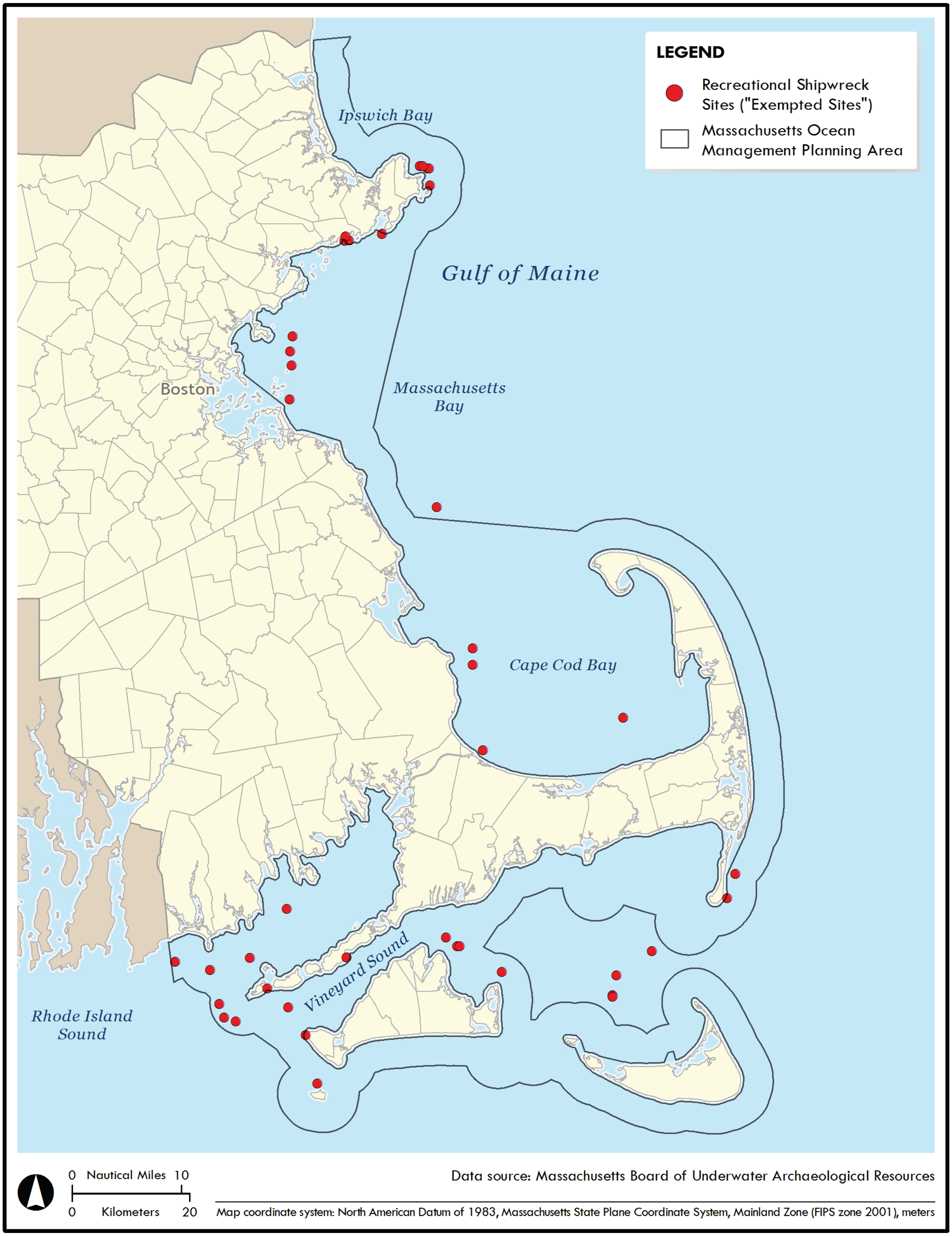


Figure 27. Shipwreck sites designated in 1985 as "Exempted Sites" for public access and use.

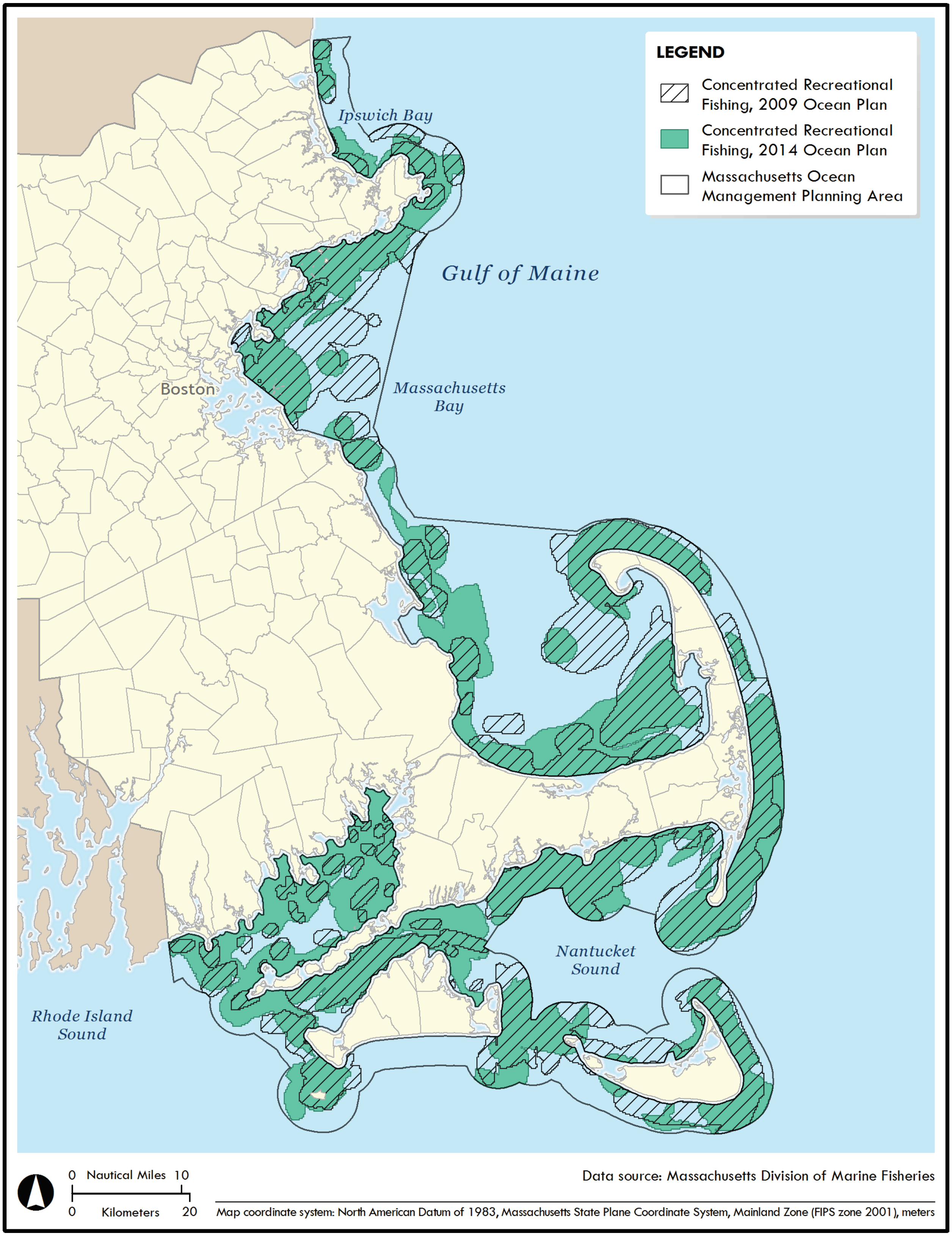


Figure 28. Concentrated recreational fishing water-dependent use area for the 2014 ocean plan (in green) and the 2009 ocean plan (striped).

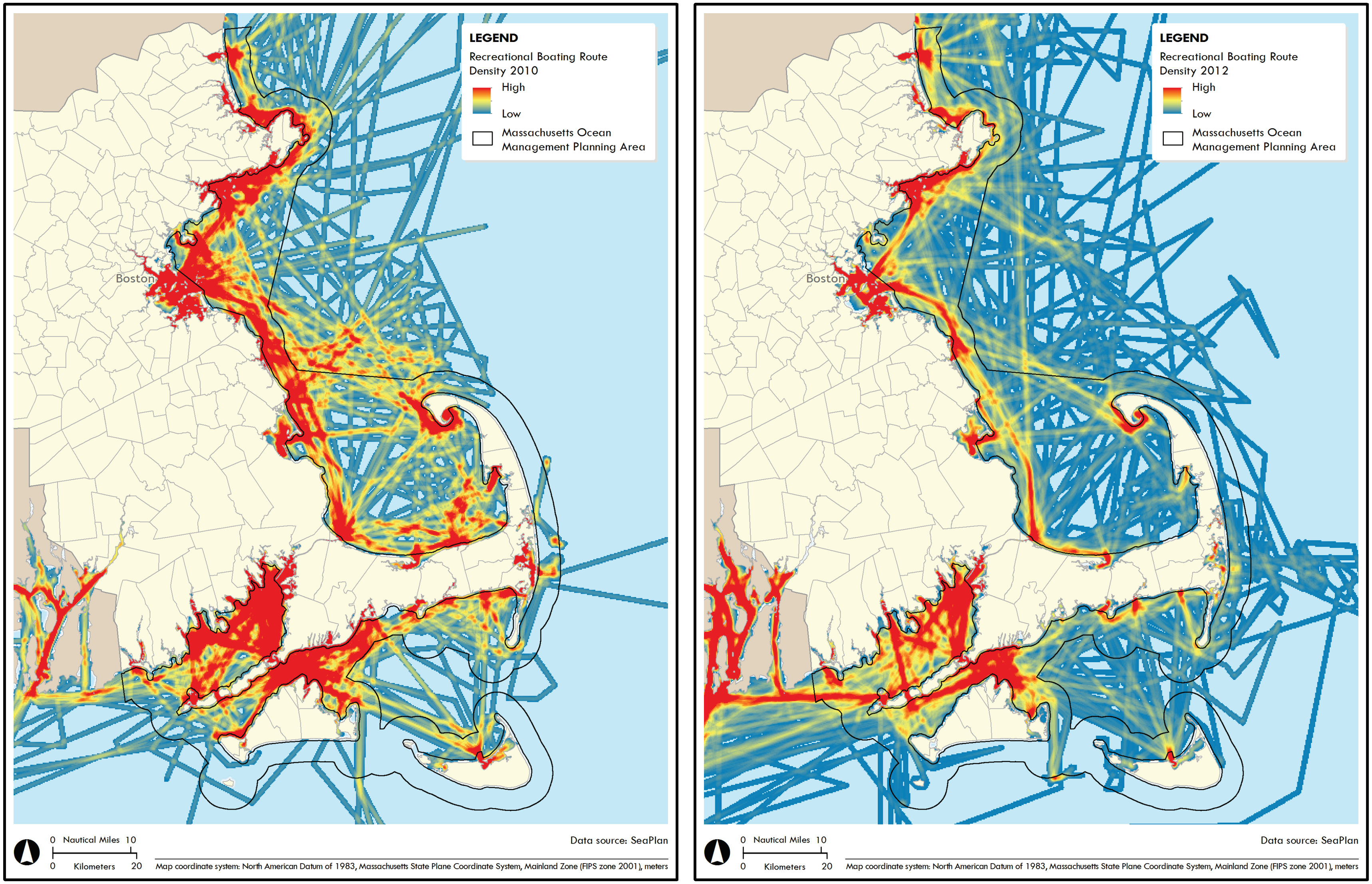


Figure 29. Recreational boating patterns resulting from the 2010 (left) and 2012 (right) recreational boating surveys conducted by SeaPlan.

Figure 30. Concentrated recreational boating for the 2014 ocean plan.

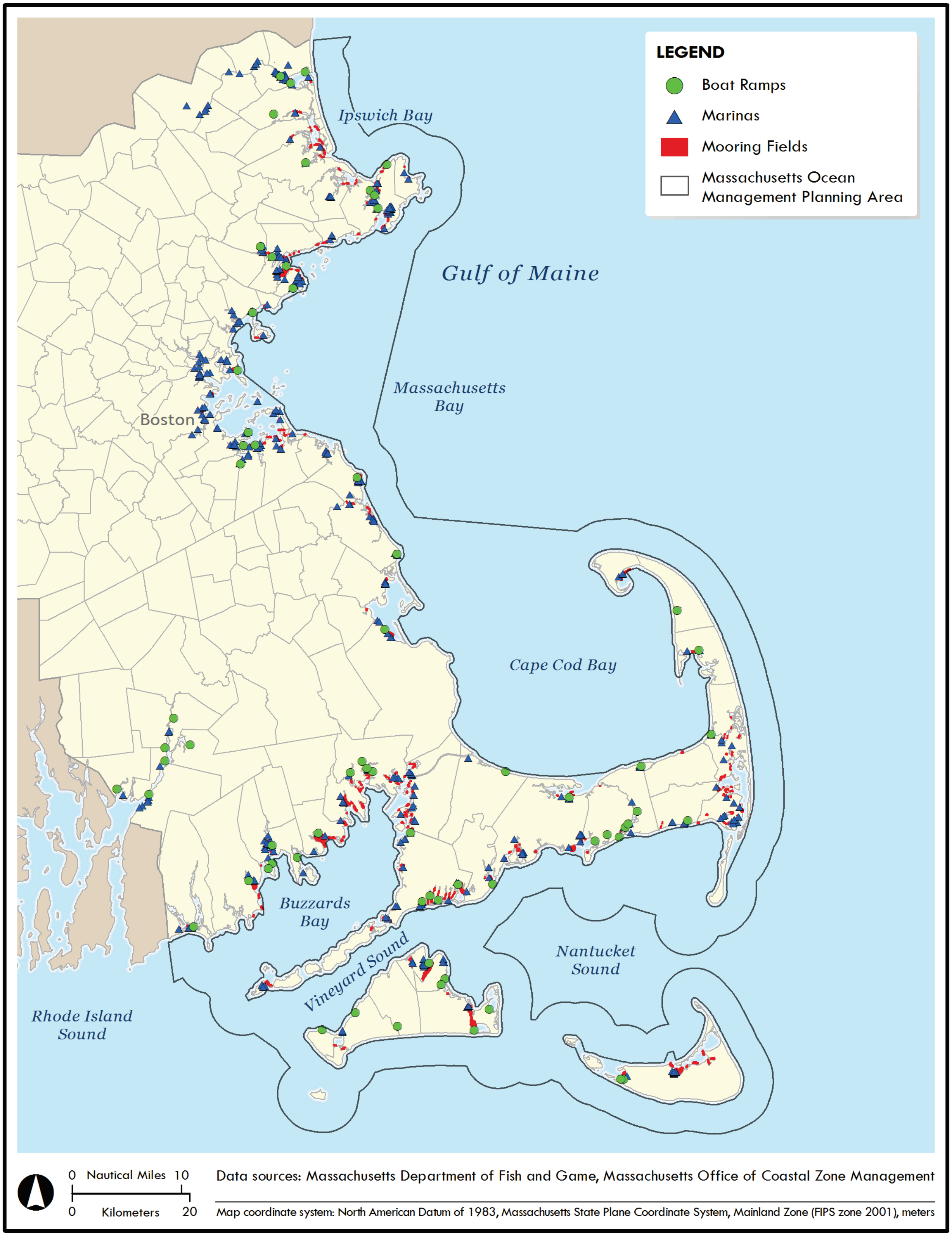


Figure 31. Coastal boat ramps, marinas, and mooring fields in Massachusetts.

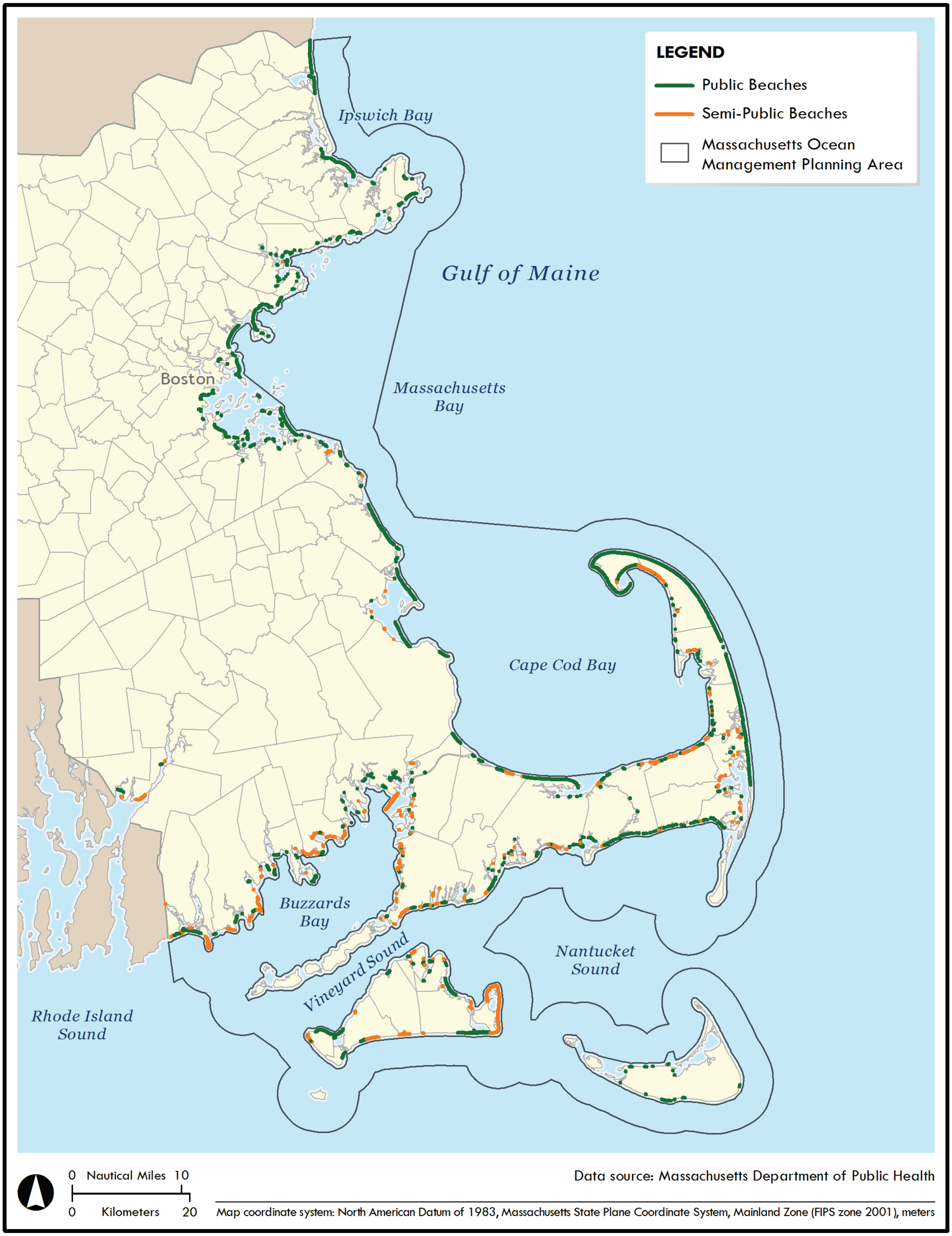


Figure 32. Marine public and semi-public beaches in Massachusetts.

Figure 33. Wildlife viewing locations reported by recreational boaters in 2012.

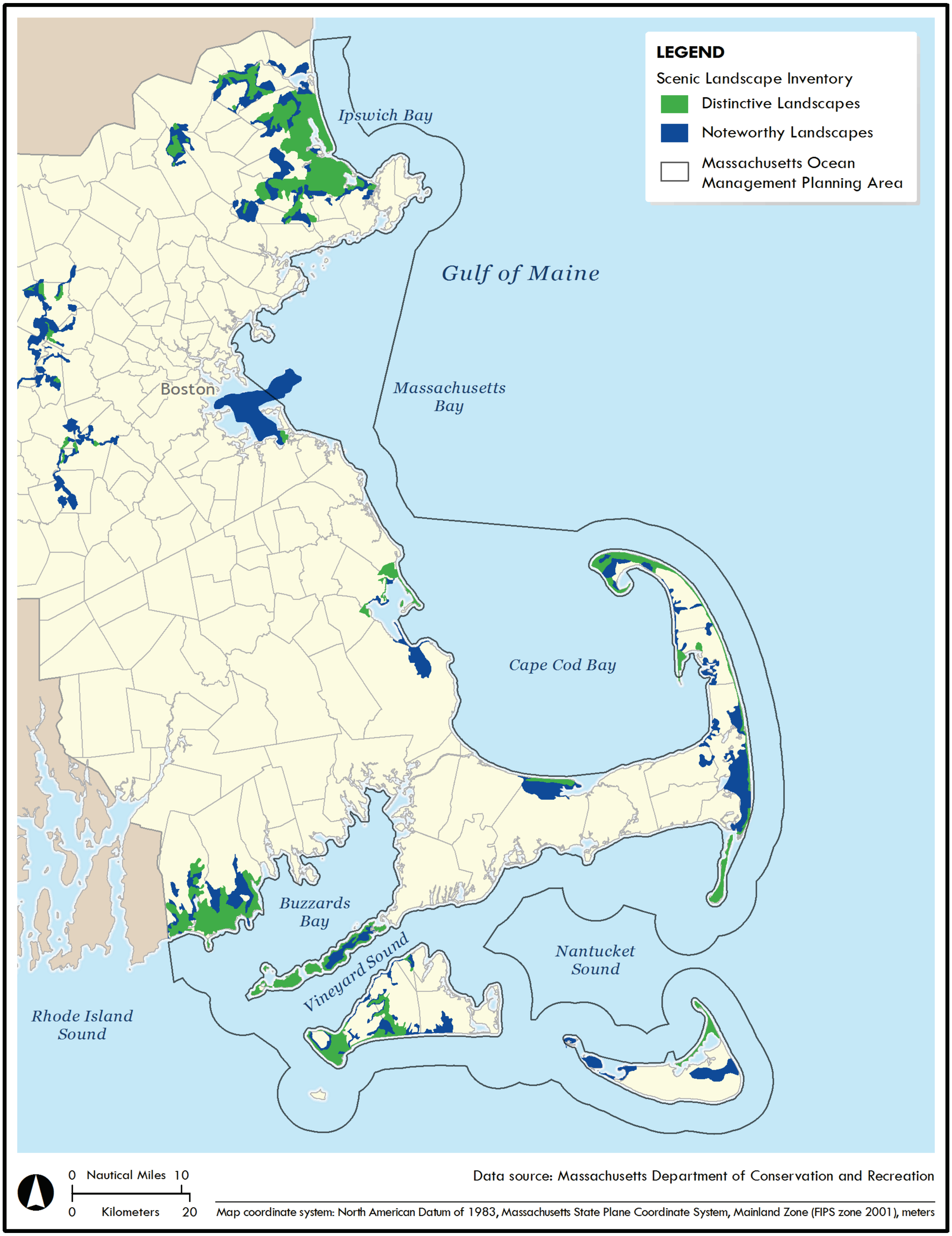


Figure 34. Scenic landscape inventory 2012. Distinctive areas have the highest scenic quality, while noteworthy landscapes are of a lesser, but important, visual quality.

Figure 35. National Register of Historic Places in coastal Massachusetts.

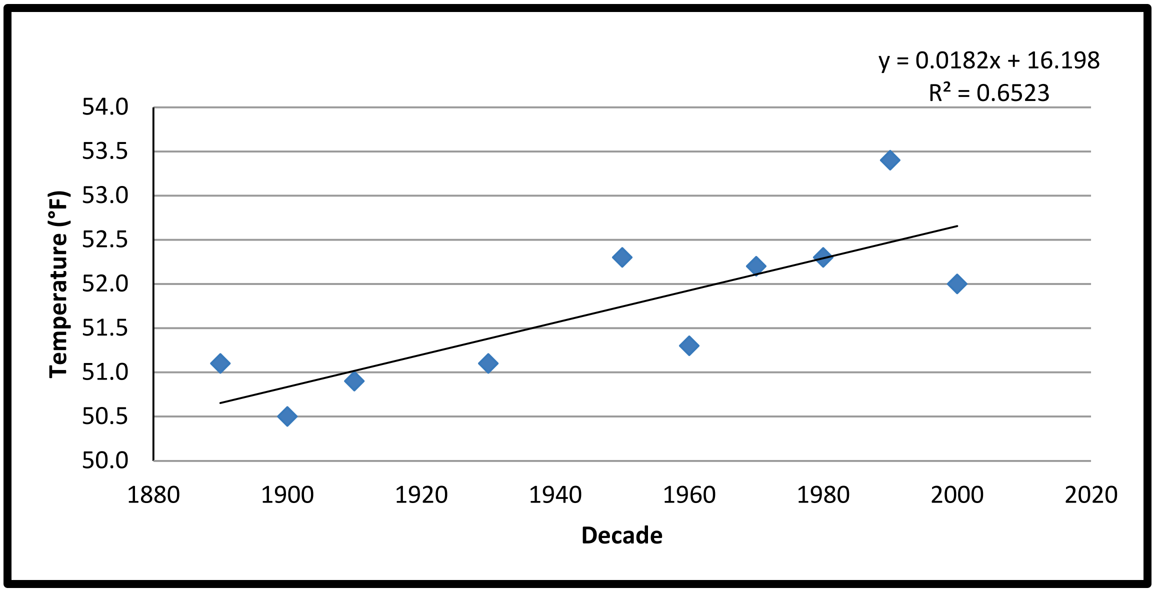


Figure 36. Decadal mean sea surface temperature at Woods Hole, Massachusetts, from the 1880s to the 2000s.

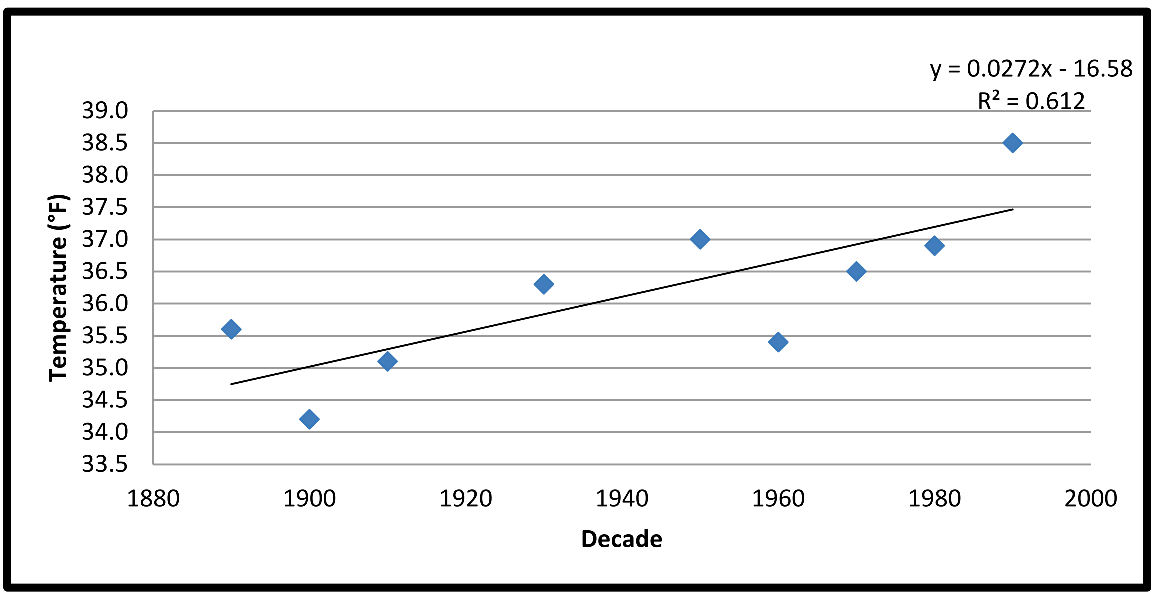


Figure 37. Winter (December-February) decadal mean sea surface temperature at Woods Hole, Massachusetts, from the 1880s to the 2000s.

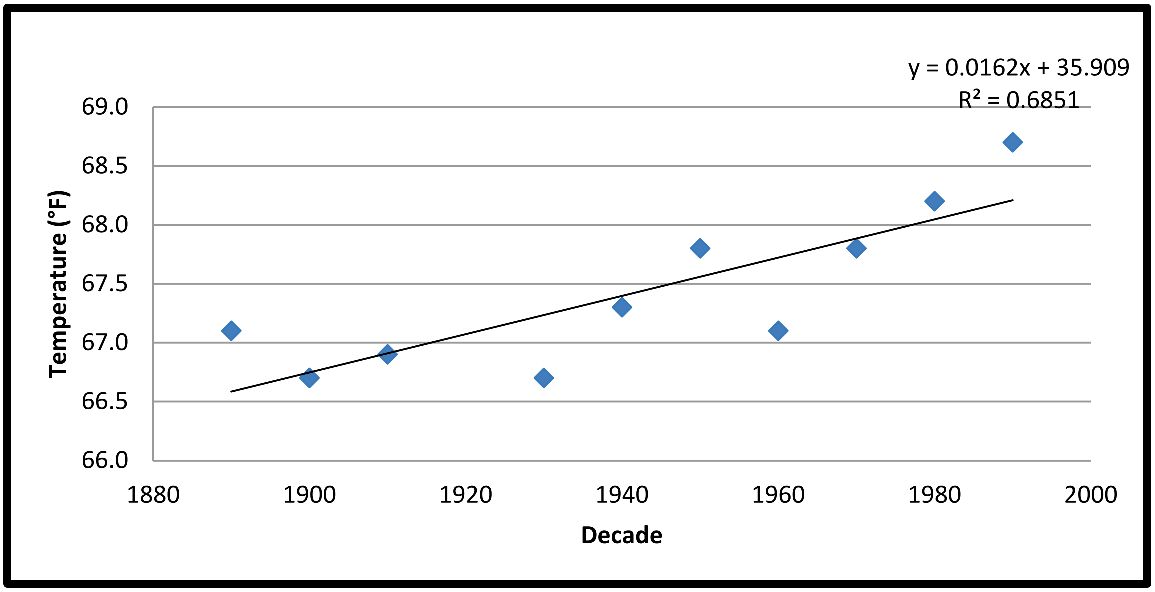


Figure 38. Summer (June-August) decadal mean sea surface temperature at Woods Hole, Massachusetts, from the 1880s to the 2000s.

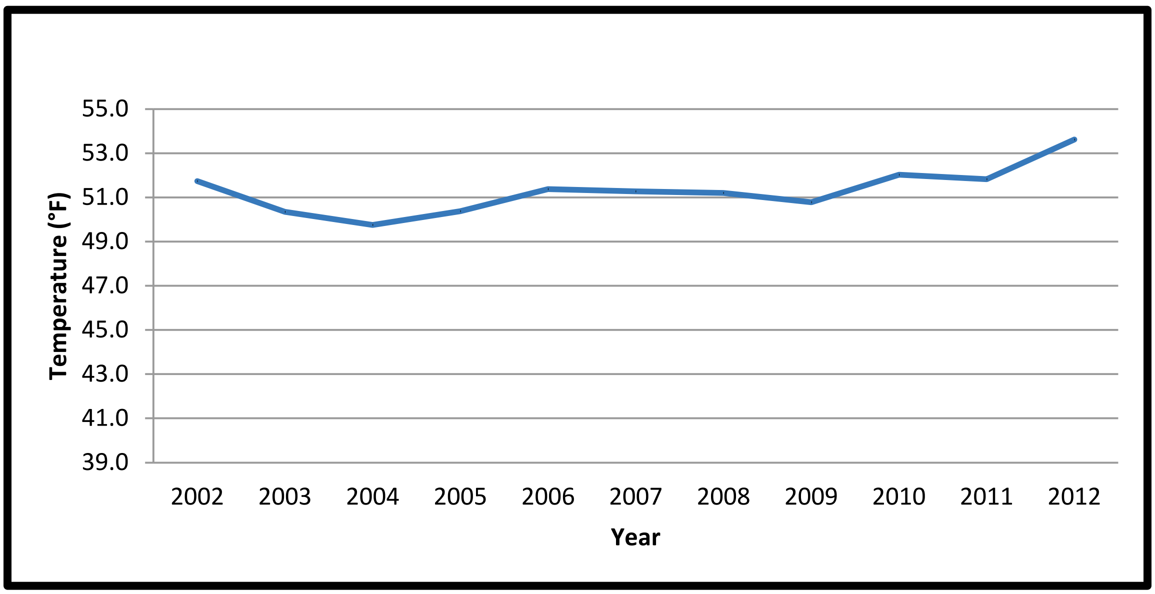


Figure 39. Annual average sea surface temperature at the Massachusetts A01 buoy from 2002-2012.

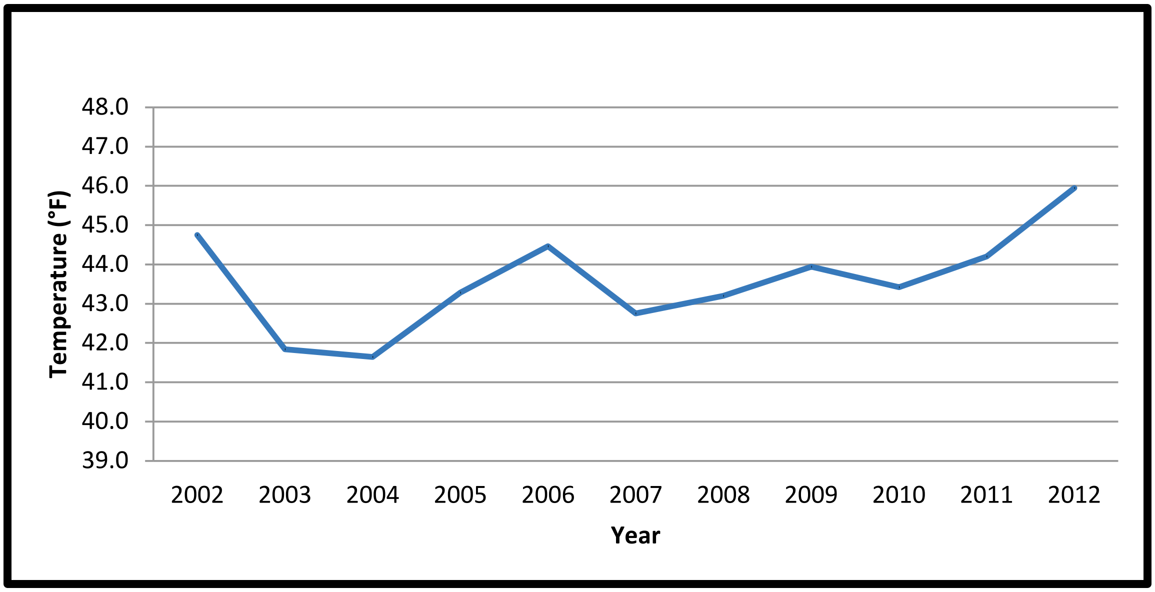


Figure 40. Annual average sea bottom (50 m depth) temperature at the Massachusetts A01 buoy from 2002-2012.

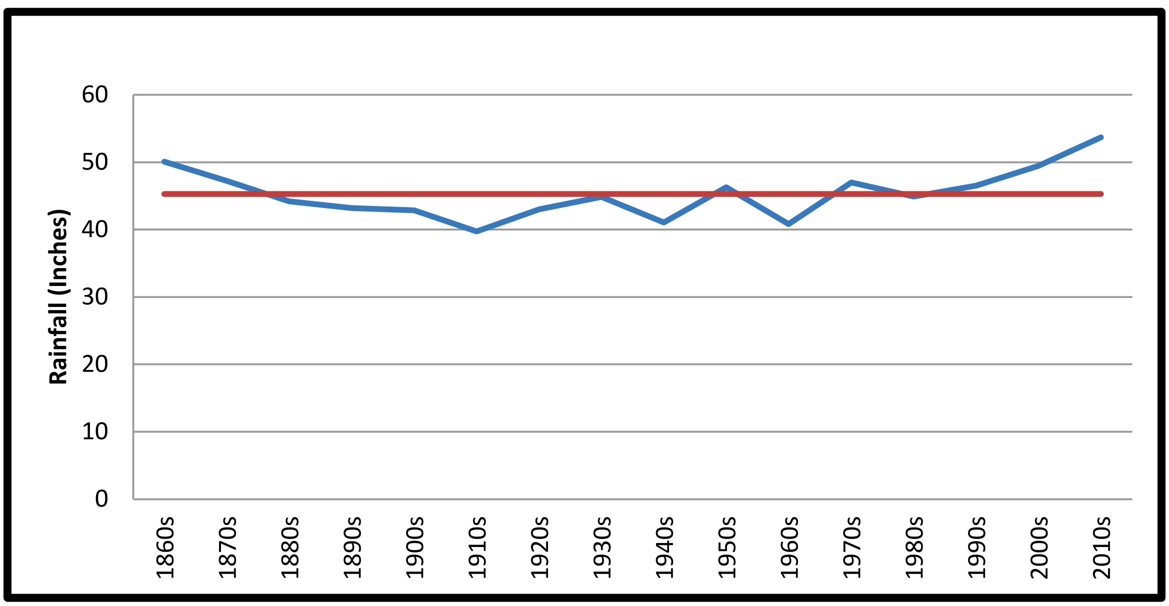


Figure 41. Decadal average rainfall in coastal Massachusetts watersheds from the 1860s to 2000s. The straight red line is the long-term average of 45 inches.

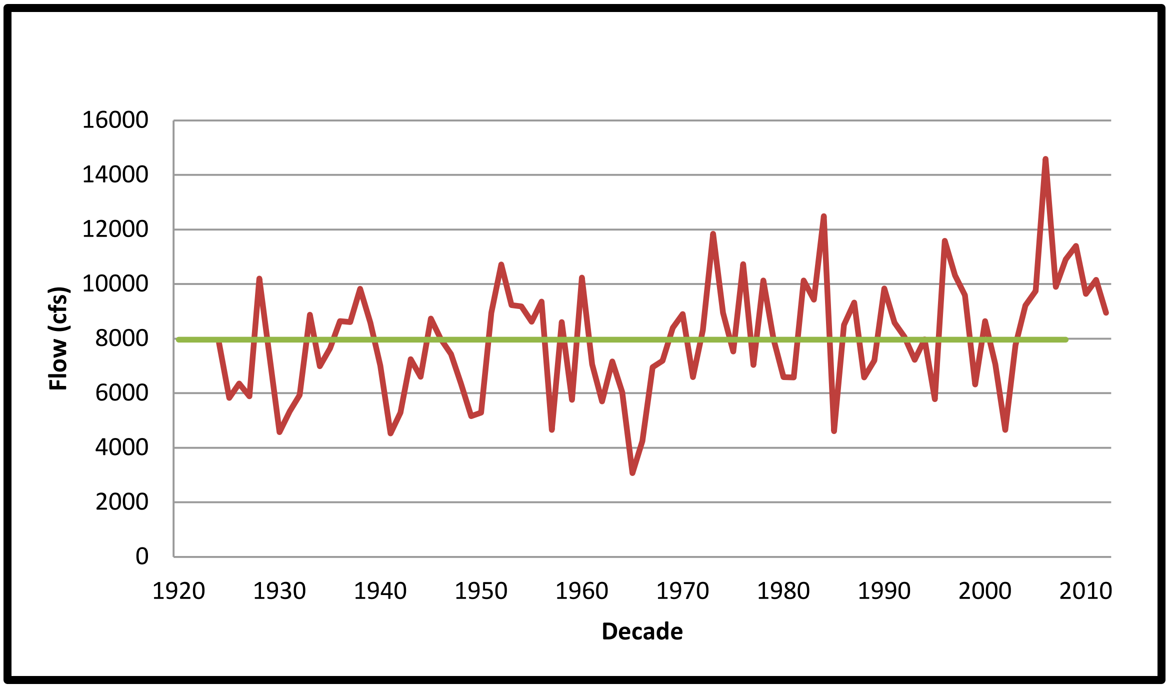


Figure 42. Merrimack River annual average flow in cubic feet per second (cfs) from 1924-2012 at USGS gauge 01100500. The straight green line is the long-term average flow of 7,959 cfs.

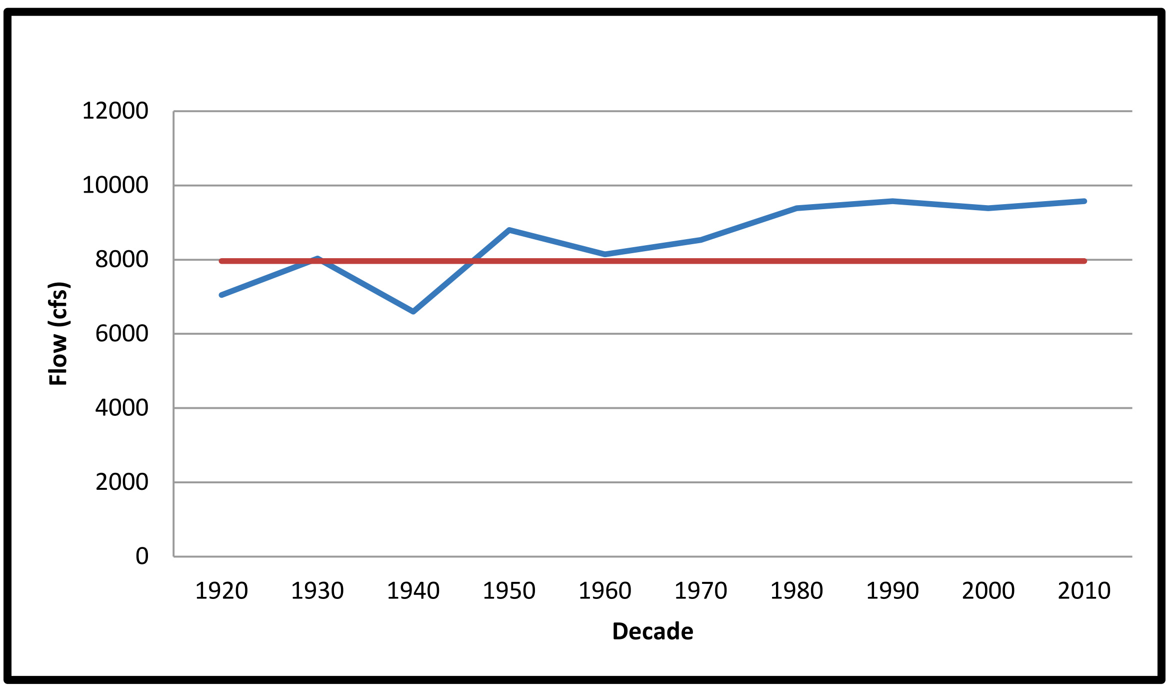


Figure 43. Merrimack River decadal average flow in cubic feet per second (cfs) from the 1920s to the 2000s at USGS gauge 01100500. The straight red line is the long-term average flow of 7,959 cfs.

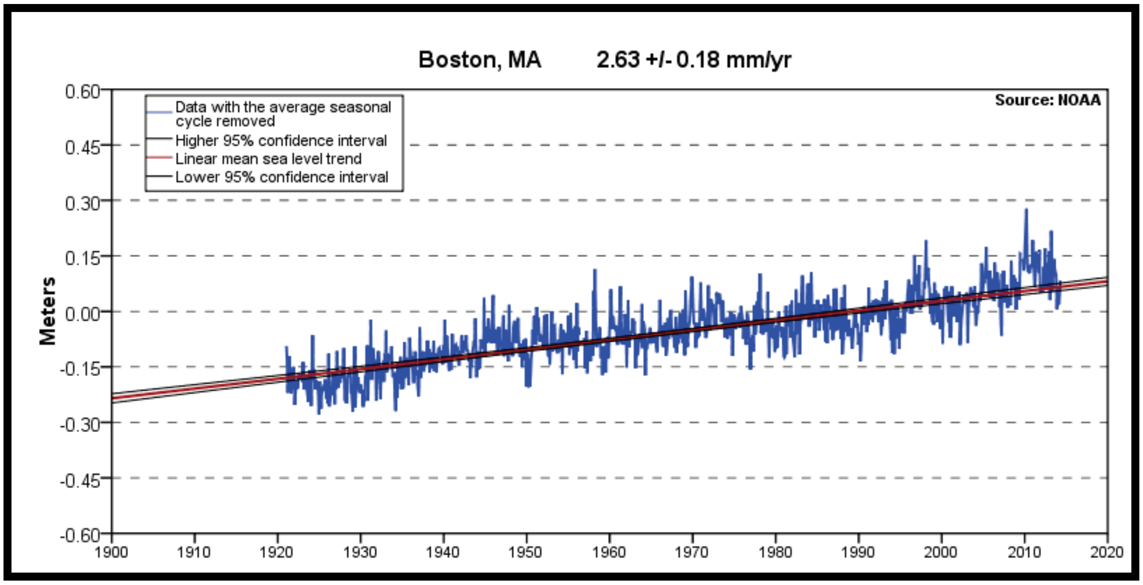


Figure 44. Long-term mean sea level data for NOAA Boston tide gauge station with linear trend and confidence interval.[69]

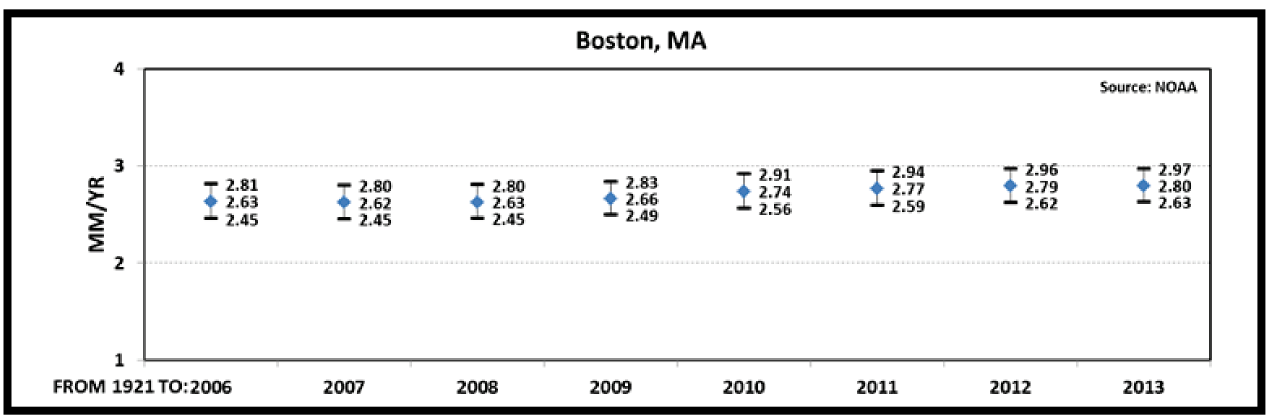


Figure 45. Mean sea level rates (blue diamonds) and 95% confidence intervals (in millimeters per year) calculated from 1921 to recent years (2006-2013) at the NOAA Boston tide gauge station. Values are the trend of the entire data period up to that year.

[69] http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8443970

Science Framework

Table of Contents

Chapter 1 - Introduction

As directed by the Oceans Act of 2008, the 2009 Massachusetts Ocean Management Plan was developed according to the principle that it should capture and adapt to evolving knowledge and understanding of the ocean environment. The Oceans Act further underscored the need for ocean plan evolution by requiring the review of the plan and its implementation process at least once every five years.

The Executive Office of Energy and Environmental Affairs (EEA) recognized that to continue to effectively manage the Commonwealth's ocean resources into the future, known science and data needs and gaps had to be addressed. The 2009 ocean plan consequently included a blueprint for identifying and addressing these science and research needs—the Science Framework (provided in Volume 2 of the 2009 ocean plan). The Science Framework was developed in consultation with the Ocean Science Advisory Council, an advisory body established in the Oceans Act to advise EEA with plan development, as well as with key input from six technical work groups, comprised of scientists and technical or subject matter experts from state and federal agencies, academia, nonprofits, and the private sector. The Science Framework also reflected feedback and comments received during the public comment period. The stated goal of the original Science Framework was to: *Identify and prioritize the scientific research and data acquisition necessary to advance ecosystem-based management in Massachusetts waters, and identify necessary steps and responsibilities for these tasks, based upon the Oceans Act and the ocean plan*. Consistent with this goal, the Science Framework defined eight priority science actions for a five-year window to coincide with the expected plan review and update, and also indentified longer term priorities.

This document—the Draft Massachusetts Ocean Management Plan, September 2014—presents the first formal amendment of the 2009 ocean plan for public review and comment. The 2014 draft ocean plan includes an update to the 2009 Science Framework.

Significant progress has been made on the science and data priorities in the 2009 ocean plan, resulting in new data and information that directly and indirectly support implementation of the plan's management framework. Chapter 2 of the Science Framework summarizes progress on each of the eight five-year priorities and covers work on the long-term science and data needs. Overall, efforts since 2009 have resulted in the availability of new information and tools, including: (1) higher resolution data and more accurate maps of seafloor surficial sediments and benthic infauna; (2) two surveys on the spatial patterns and economic impacts of recreational boating activity; (3) new maps of abundance and distribution of 22 important fish species over four-decade time periods at specific trawl locations; and (4) an updated version of the Massachusetts Ocean Resource Information System (MORIS) online mapping tool, which allows users to access, search, display, and download all of the maps in the ocean plan as well other data and maps such as aerial photographs, political boundaries, natural resources, human uses, bathymetry, and Google base maps.

The 2014 draft ocean plan affirms the goal of the 2009 ocean plan to identify and prioritize the scientific research and data acquisition necessary to advance the ecosystem-based management approach of the plan. Chapter 3 of the Science Framework describes the prioritized actions to address known science and data needs over the next five-year time horizon and for the longer term. The advancement of these actions depends on the availability of resources. Consequently, their inclusion in the Science Framework should be considered a recommendation for prioritization rather than a commitment to their implementation. Proposing a blueprint that specifically identifies science priorities for the ocean plan has proven to be very effective in bringing visibility and developing partnerships to address known data and information needs over the last five years. By defining a specific agenda for essential investigations, surveys, research, and data tools, limited available resources have been focused and leveraged through collaborations with partners to make meaningful progress on the priority actions. EEA acknowledges the tremendous support to date and encourages other organizations and institutions to continue to collaborate on both programmatic and project-specific partnerships to address shared goals to further ocean planning in the future, as now outlined in the 2014 Science Framework.

Chapter 2 - Progress on 2009 Science Framework Priorities

The development of the Massachusetts Ocean Management Plan, which was released in 2009, included rigorous efforts to acquire, develop, and synthesize the best available data and science and to seek a high level of peer review and evaluation of this information. With the understanding that the ocean plan is an evolving document—revisited and revised periodically as better information and science are developed, policy goals evolve, and experience in applying the management and administrative framework is gained—the Executive Office of Energy and Environmental Affairs (EEA) recognized the need to identify and prioritize a science and data agenda to advance ocean management. The 2009 Science Framework defined eight priority science actions for a five-year window and a set of longer-term priorities. Progress and work since 2009 on each of these priority actions, as well as on the long-term priorities, are summarized below.

Priority 1 - Refine Important Fish Resources Area Maps

In the 2009 ocean plan, the important fish resources special, sensitive, or unique (SSU) area was derived from 30 years of Massachusetts Division of Marine Fisheries (*MarineFisheries*) spring/fall resource assessment survey data. The analysis of the resource assessment data included 22 species important to commercial and recreational fisheries in Massachusetts and vulnerable to the trawl survey gear. The data analysis was based on the survey areas developed for the long-term assessment sampling design, which are defined by zones (or strata) of state water that are grouped by depth ranges and regions of the state's ocean areas. The analysis ranked the different survey areas by aggregating summary statistics of many species to determine high, medium, and low fish resources areas, largely based on the biomass of species caught in each stratum.

In the development of the 2009 ocean plan, it was recognized that identification of an important fish resources SSU area by the depth strata provided a solid foundation for the delineation of the initial SSU maps, but that the development of higher resolution information would improve the siting and management of ocean-based projects in or near these areas. Within each of the assessment survey areas, the *MarineFisheries* database has data on the specific trawl locations, or survey samples. The 2009 Science Framework recommended that the biomass (or in some cases, the abundance) of each of the 22 species be analyzed according to the actual locations of the trawl samples (as identified by the starting and ending coordinates of each trawl). With this approach, the mapped location of fish resources within the survey areas would more accurately reflect actual distribution of the species. The 2009 Science Framework also noted that within the important fish resources SSU areas, there are variations in the species composition.

Significant progress has been made on this priority data need. First, *MarineFisheries* has re-analyzed the resource assessment trawl data from 2009-2014 to update the important fish resources SSU area map. These changes are described and the new map provided in Volume 1 of the 2014 draft ocean plan. *MarineFisheries* has also produced a series of abundance maps based on the biomass (or number) for 22 species caught at specific trawl locations over four time periods: 1978-1986, 1987-1995, 1996-2003, and 2004-2012. *MarineFisheries* is currently working with The Nature Conservancy to produce a custom ArcGIS query tool to help manage and view the 30 years of trawl data. Continued work on this task is recommended in the 2014 priorities described in Chapter 3 of the Science Framework.

Priority 2 - Classify Benthic and Pelagic Habitats

When developing the 2009 ocean plan, only depth and surficial sediment data were available to characterize marine waters. The depth data were used to derive seafloor terrain and rugosity (a measure of roughness), which together with seafloor sediment were used to produce 51 unique classes of seafloor. Since that time, the Massachusetts Office of Coastal Zone Management (CZM) has been working to develop new seafloor terrain models (for determining geoforms), has received the most recent version of bathymetry data from the U.S. Geological Survey (USGS), and has worked with *MarineFisheries* to augment the number of seafloor data points in the surficial sediment database by four-fold. CZM is also working with USGS to identify the stability of sediments, as well as with the University of Massachusetts (UMass) Dartmouth and USGS on an assessment of water column characteristics. CZM is also developing a database of the locations of various fauna and flora species identified in the 11,000 photos of the seafloor taken by USGS, CZM, *MarineFisheries*, UMass Dartmouth, and Woods Hole Oceanographic Institution.

A substantial portion of the additional sediment data and seafloor photos, as well as all of the infauna data, developed since 2009 came from three ocean research cruises; one each in 2010, 2011, and 2012. In each year, through a regional competition, CZM and *MarineFisheries* were awarded an eight-day research survey aboard the U.S. Environmental Protection Agency (EPA) Ocean Survey Vessel *Bold*. On these ocean research surveys, several hundred samples of sediment and infauna and several thousand seafloor images from the New Hampshire border to Nantucket and Martha's Vineyard were obtained and analyzed. These data have allowed CZM to refine the hard/complex seafloor SSU area. The information has also significantly advanced the understanding of the species and habitats that are protected by the hard/complex seafloor SSU area. Finally, the data have directly supported major enhancements to the state's marine surficial sediment map.

CZM and *MarineFisheries* are also examining the application of marine habitat classification frameworks for the Massachusetts Ocean Management Planning Area (planning area).

Currently, the classification scheme is limited to the data that are available, namely surficial sediment, geoform, depth, and in some areas, infauna. CZM has begun applying portions of National Oceanic and Atmospheric Administration (NOAA) Coastal and Marine Ecological Classification Standard (CMECS) to areas of Massachusetts that have sufficient data. CZM anticipates that the Commonwealth's seafloor classification scheme will include surficial sediment, the geoforms underlying this sediment, a description of the temporal stability of the sediment, a limited number of depth classes, a description of the physical characteristics of the water column (e.g., mean temperature, current velocity, and salinity) in a given location, and descriptions of the dominant macrofauna, macroalgae, and/or infauna. CZM and *MarineFisheries* are partners in a Northeast Regional Ocean Council (NROC) initiative focused on coordinating and advancing regional habitat classification efforts by unifying mapping, characterization, and classification approaches in terms of methodologies, structure, data requirements, and leveraged data acquisition. Continued work on this task is recommended in the 2014 Science Framework priorities described in Chapter 3. More information on CZM's Seafloor and Habitat Mapping Program can be found at: www.mass.gov/eea/agencies/czm/program-areas/seafloor-and-habitat-mapping.

Priority 3 - Develop New Spatial and Economic Data on Recreational Uses

In the 2009 ocean plan, information on the spatial extent and intensity of recreational boating and fishing was limited. Improving the extent and quality of data and information on these important water-dependent uses was recognized as a high priority.

Since that time, several major efforts have been undertaken to gather spatial and economic data on recreational boating activity. A partnership of many organizations led by SeaPlan (formerly the Massachusetts Ocean Partnership) and including CZM and the Massachusetts Marine Trades Association (MMTA), conducted two surveys (2010 and 2012). A 2010 survey invited 10,000 randomly selected Massachusetts registered boat owners to participate in a six-month study on recreational boating activity in Massachusetts coastal and ocean waters. Through monthly surveys, more than 22% of these boaters provided detailed information on their boating trips, including expenditures, recreational activities, and routes. Survey respondents plotted over 1,000 of their boating routes in Massachusetts state waters from May to October 2010. Results gave an indication of recreational boating patterns in Massachusetts and provided an approximate estimate of the economic contribution of this activity to the Massachusetts economy—an estimated $806 million in 2010.

Using a similar methodology in 2012, 68,000 randomly selected registered boaters in the Northeast (NY, CT, RI, MA, NH, and ME) were invited to participate in a six-month study aimed at gathering data on recreational boating activity in the region's coastal and ocean waters. In addition to gathering spatial and economic data, the 2012 survey collected data on interstate boating traffic in Massachusetts waters and boating-based uses, such as recreational fishing, diving, and swimming. Outcomes of this survey include: (1) maps that display recreational boating patterns and important areas for a variety of recreational uses, such as fishing, diving, swimming, etc., and (2) data on the economic impact of saltwater recreational boating to each state and the Northeast. Boaters mapped over 1,000 routes in Massachusetts state waters between May and October 2012. Results confirmed the 2010 data for spatial patterns and habits of recreational boaters in Massachusetts and indicated an overall contribution of $839.5 million by recreational boaters to the Commonwealth's Gross Domestic Product (GDP) in 2012.

In 2013, MMTA asked experienced mariners to mark charts with routes commonly used by recreational boaters in Massachusetts. Over 500 routes were mapped through this survey.

These data are being used in the 2014 draft ocean plan to identify areas of the highest recreational boating activity, as well as areas where boaters concentrate on specific recreational activities. For more information, see www.seaplan.org/project/2010-massachusetts-recreational-boater-survey and www.seaplan.org/project/2012-northeast-recreational-boater-survey. Work to further characterize recreational fishing is recommended in the 2014 Science Framework priorities described in Chapter 3.

Priority 4 - Develop New Spatial and Economic Data on Commercial Fishing

Information related to commercial fishing was used in the 2009 ocean plan in several ways, including in compatibility analysis and as a designated water-dependent use for protection in the siting of ocean-based proposed projects or activities. Although the Oceans Act specifies that the ocean plan not regulate commercial fishing, development of the plan's management approach required careful consideration of commercial fishing as a significant water-dependent use that can be adversely impacted by certain ocean-based development or activities. Potential impacts vary according to the type of fishing gear (mobile or fixed, e.g.), location within the water column and seafloor, season, and many other factors. More information on commercial fishing patterns, gear types, target species, and effort distribution was identified as a priority for the 2014 ocean plan update.

In 2011, the Massachusetts Clean Energy Center (MassCEC), in collaboration with CZM, contracted Applied Science Associates (ASA) to characterize the spatial distribution of catch, effort, and value for selected species and gear types in the Gulf of Maine and Georges Bank. For this project, Vessel Trip Reports (VTRs) from 2000 to 2009 were analyzed. VTRs are submitted by federally permitted fishing vessels to NOAA's National Marine Fisheries Service (NMFS) and contain information on the area fished, gear type used, and species caught. Ten-year averages of the following datasets were created through this project: (1) total effort by ten-minute square for nine gear types, (2) total value by ten-minute square for nine gear types, (3) catch by ten-minute square for 13 species and species assemblages, and

(4) value by ten-minute square for 13 species and species assemblages. These data may be used to identify the areas with the highest catch, effort, and value for select species and gear types for the marine waters around Massachusetts and into the Gulf of Maine. For example, some of the highest catch and value areas for Atlantic cod from 2000 to 2009 are located off of the North Shore of Massachusetts.

In 2012, as part of the Northeast regional ocean planning initiative (described in Volume 1, Chapter 3), NROC commissioned a project that sought to describe how New England's commercial fishing industries, including party/charter businesses, utilize the region's ocean space. The project was a first phase of ongoing work to characterize commercial fishing, and using NMFS information from its Vessel Monitoring System (VMS) and VTR datasets, initial map products were developed that were configured to spatially represent specific fisheries and time-spans. These maps were shared with members of the fishing industry, scientists, and managers, and then refined based on feedback and information gleaned over the course of 50 community meetings. A project report summarizes the results of this initial phase, and work will continue to produce more complete information. Details on this project can be found on the Northeast Regional Planning Body website at http://neoceanplanning.org/projects/commercial-fishing.

Work to further characterize commercial fishing is recommended in the 2014 Science Framework priorities described in Chapter 3.

Priority 5 - Understand Cumulative Impacts and Ocean Resource Vulnerability

Another important action recommended in the 2009 Science Framework was to better identify, characterize, and quantify impacts of anthropogenic stressors on coastal/marine ecosystems. SeaPlan, working with the National Center for Ecological Analysis and Synthesis (NCEAS) and CZM, produced an assessment of cumulative impacts in coastal Massachusetts and adjacent federal waters. The NCEAS methodology used expert judgment to characterize the vulnerability of the ecosystem to various human impacts. The vulnerability component was then combined with the intensity of the human use in any given location to produce a relative cumulative impact score for each location (grid cell) in the study area. The end result was a cumulative impact map highlighting the areas of highest impact. Cumulative impacts assessment approaches and resulting products, such as the map of cumulative impacts of existing uses in Massachusetts and adjacent federal waters from this project, have known limitations. One important concern is the reliance on expert interpretation and opinion, due to the inadequacy and gaps in data and scientific literature to support more empirical characterizations. Other concerns revolve around spatial resolution and temporal aspects. For more information on the project described above, see www.seaplan.org/project/cumulative-impacts. The application of cumulative effects models and assessments is included as a long-term research and data priority in the 2014 draft ocean plan.

Priority 6 - Monitor Climate Change across Massachusetts Coastal Waters

Increasing the understanding of the effects of climate change on the resources and uses of the planning area is critically important to effective ecosystem-based management. Long-term climate change is linked to increases in ocean temperature and in the amount of carbon dioxide dissolved in seawater. Seawater temperature is important to marine organisms because it often serves as a cue for life history events (e.g., spawning, migration); it can affect the rate of feeding, development, and metabolic processes; and it helps define the spatial extent of preferred habitat of many species. The amount of carbon dioxide dissolved in seawater is critical to some shelled organisms because excessive carbon dioxide can decrease pH, which decreases the amount of minerals in seawater (e.g., aragonite) that are necessary to form and repair shells. Consequently, EEA participation in efforts to monitor climate change in the planning area was identified as a priority action in the 2009 Science Framework.

To advance progress on this priority, CZM is actively involved in regional efforts to track and report on long-term seawater temperature, pH, dissolved carbon dioxide, salinity, and sea level. Such regional programs and project-specific initiatives include: the Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS), the Northeast Coastal Acidification Network (NECAN), NROC/NERACOOS Sentinel Monitoring for Climate Change, and the Gulf of Maine Council's (GoMC) Ecosystem Indicator Partnership.

NERACOOS provides weather and ocean data and is advancing efforts to use these data for harmful algal bloom predictions and warnings and coastal flooding and erosion forecasting. Several NERACOOS buoys record seawater temperature, including two in Massachusetts Bay (buoy A01 and buoy 44013) and one in Nantucket Sound (buoy 44020). The University of New Hampshire maintains an oceanographic buoy off of Appledore Island that carries several sensors, one of which measures the pressure of carbon dioxide in the ocean. The Appledore Island buoy is part of NERACOOS and thus the carbon dioxide data are readily accessible. See www.neracoos.org.

NECAN is working on a phased process to synthesize the regional science on ocean acidification, communicate information to regional managers and stakeholders, and develop the strategic design for a network of acidification observation stations for the Northeast. See www.neracoos.org/necan.

The Sentinel Monitoring for Climate Change is a joint strategic planning exercise to establish an integrated regional sentinel monitoring network to observe, assess, and interpret the status and trends of key indicators at select sites and geographic subregions. This initiative is organized by work groups (focused on pelagic, benthic and estuarine, and nearshore habitats) that have been tasked to identify a suite of sentinel ecosystem variables and indicators, compile information on existing observing activities, identify gaps in the present observing system, and contribute to the synthesis of an integrated regional plan. See www.neracoos.org/sentinelmonitoring.

The GoMC Ecosystem Indicator Partnership works to develop and track indicators for the Gulf of Maine and integrate regional data for a web-based reporting system for marine ecosystem monitoring. The current indicators in the Ecosystem Indicator Partnership for climate change are sea level, air temperature trends, and precipitation trends. More information can be accessed at www.gulfofmaine.org/2/esip-homepage.

CZM has also supported a pilot project that installed carbon dioxide sensors on existing acoustic monitoring buoys along the Boston Harbor Traffic Separation Scheme. These buoys are designed to warn mariners when whales are in the area, and the Stellwagen Bank National Marine Sanctuary and Cornell University are investigating the use of these buoys as platforms for other sensors, such as the carbon dioxide sensors.

Continued work on this task is recommended in the 2014 Science Framework priorities described in Chapter 3.

Priority 7 - Develop an Indicator Framework

To address the Oceans Act requirement to review the ocean plan at least once every five years, an iterative and adaptive approach to track plan implementation and measure progress toward achieving the Act requirements is needed. In 2009, CZM worked with the Urban Harbors Institute, UMass Boston, and SeaPlan to develop a list of indicators or metrics that can be used to track specific environmental and socioeconomic conditions and assess management actions. The team subsequently worked with a group of experts from various organizations, and through discussions and two workshops, screened a comprehensive list of indicators to select 20 preliminary management, environmental, and socioeconomic indicators.

Continued work to further advance a performance framework is a priority in the 2014 draft ocean plan. The proposed Monitoring and Evaluation Framework is described in Chapter 3 of Volume 1 of the 2014 draft plan and further work to develop and operationalize the Monitoring and Evaluation Framework is recommended as a priority in Chapter 3 of the 2014 Science Framework. The list of indicators developed for the 2009 ocean plan will be revised and updated based on available data, to ensure that these metrics will provide relevant and helpful information to measure progress in ocean plan implementation.

Environmental and socioeconomic indicators will be examined to help track current conditions in the planning area. This effort is intended to guide the review and update of the ocean plan and its Baseline Assessment (also in Volume 2 of the ocean plan).

Priority 8 - Develop a Data Network for Sharing Information on Massachusetts Ocean Resources and Uses

Two other objectives from the 2009 ocean plan's Science Framework are to enhance data availability and inform managers, stakeholder, and the public of science- and data-related advancements. In February 2011, CZM released the updated version of the MORIS online mapping tool, which can be used to search and display spatial data pertaining to the Massachusetts coastal zone. Users can interactively view various data layers (e.g., tide gauge stations, marine protected areas, access points, eelgrass beds, etc.) over a backdrop of aerial photographs, political boundaries, natural resources, human uses, bathymetry, or other data including Google base maps, and can create and share maps and download the actual data for use in a Geographic Information System (GIS). While designed for coastal management professionals, MORIS can be used by anyone interested in these data and maps. See www.mass.gov/eea/agencies/czm/program-areas/mapping-and-data-management/moris for additional information on MORIS, and for a stand-alone version of MORIS that contains all of the maps in the ocean plan, see http://maps.massgis.state.ma.us/map_ol/mass_ocean_plan.php.

In June 2011, a group of public and private entities, including CZM, collaborated on the Northeast Ocean Data Portal, a website that can be used as a decision support and information system for people engaged in ocean planning in the region from the Gulf of Maine to Long Island Sound. The website provides access to data, interactive maps, tools, and other information needed for decision making. The data categories available through the mapping tool are: administrative and regulatory boundaries, ocean uses, biological resources, physical oceanography, demographics, and cartography. The primary audiences for this effort include regional managers, ocean stakeholders, and technical staff. The Northeast Ocean Data Portal builds on existing efforts in the region and provides additional capacity for both state- and regional-level ocean planning. See www.northeastoceandata.org. Continued efforts to advance integrated geo-spatial data management through MORIS enhancements and integration with other ocean data portals and platforms is a long-term priority in the 2014 draft ocean plan..

Long-Term Priorities

The 2009 ocean planning process identified several long-term research and data support priorities that would be useful for effective ocean management. Below is a summary of the work that EEA, its agencies, and its partners have done on these long-term priorities. In most cases, much of the effort is ongoing through active applied research programs and partnerships.

Ecosystem Mapping, Characterization, and Monitoring

- **Map the Massachusetts seafloor in shallow waters (< 10 meters [m] deep)** - Light Detection and Ranging (LIDAR) data available from the U.S. Army Corps of Engineers has been utilized by CZM and others to generate seamless topographic/bathymetric mapping along 710 miles of the Massachusetts coastline. In 2009, USGS mapped Red Brook Harbor, Bourne, using the shallow-draft vessel *Raphael* and a 234-kilohertz interferometric sonar system to collect bathymetry and backscatter data, and at the same time, assessed the shallow-water mapping capability of the geophysical systems deployed for the project. The Provincetown Center for Coastal Studies has also done shallow water mapping and characterization in parts of Cape Cod Bay. CZM continues to actively engage federal agencies, academic institutions, and others to assist in shallow water mapping.

- **Ground-truth benthic and pelagic habitat maps** - As described above in Priority 2, CZM and *MarineFisheries* engaged in three research cruises (2010, 2011, and 2012) on U.S. EPA's Ocean Survey Vessel *Bold*. The seafloor imagery and grab samples captured during these cruises were used to refine surficial sediment maps, create maps of infauna communities, and refine the hard/complex seafloor SSU area management layer. In addition, CZM has been working with USGS and UMass Dartmouth to identify hydrodynamic conditions in Massachusetts waters that could potentially delineate pelagic habitat.

- **Survey and assess key species** - CZM is actively engaging academic institutions and nonprofits to assist in underwater surveys using cameras, video, and sonar to delineate patches of biogenic habitat made by various plants, algae, and mollusks. In addition, through the Habitat Work Group, CZM was able to acquire the most recent GIS information depicting eelgrass patches; the distribution and abundance of North Atlantic right whales, humpback whales, and fin whales; as well as distribution and abundance of several species of terns and diving ducks.

- **Identify associations between sediment types, water column types, and species** - As stated above, CZM has made significant strides toward identifying well-defined surficial sediment types. As CZM works with partners such as USGS, *MarineFisheries*, and NOAA and acquires more information on water column types and the species that inhabit them, work toward these associations can continue.

- **Continue observations of key oceanographic parameters** - As described above in Priority 6, CZM is an active member of NERACOOS (serves on the Board of Directors) and has been a key supporter of continued, long-term oceanographic data collection via buoys, gliders, and directed research cruises.

- **Continue observations of river discharge and tidal height; investigate ground water discharge importance** - Through the Massachusetts Water Resources Commission, EEA supports a long-term partnership with USGS in funding river discharge monitoring stations. CZM also continues to work closely with the Massachusetts Department of Environmental Protection (MassDEP) on issues of nutrient disposal and migration to coastal waters via ground water discharge.

Characterization and Mapping of Human Uses and Interactions

- **Periodically revise spatial and economic data on commercial and recreational uses** - CZM has acquired VTR data from NOAA that can be used to delineate the use and economic importance of marine waters to Massachusetts commercial fishermen. CZM, with the assistance of SeaPlan, has acquired significant information on the use of Massachusetts waters by recreational boaters, including popular boating hotspots and the activities engage in by when boating. In addition, NROC has developed regional maps of fishing activity.

- **Develop a marine cadastre** - A marine cadastre is an authoritative source for ocean-based data and maps and other integrated information. It also refers to a comprehensive register of real property boundaries. Historically, a cadastre was a series of printed maps, or an atlas. In today's digital age, the new standard is for online data servers and mapping sites. As detailed above in Priority 8, significant progress has been made on MORIS, the Commonwealth's online mapping tool for coastal and ocean data. Recognizing this progress, there is still a need for more work on some aspects of legal boundaries, including towns and regional planning agencies with regulatory authority.

- **Digitize and import shellfish aquaculture sites into MORIS** - *MarineFisheries* has acquired the coordinates for shellfish aquaculture sites, digitized them, and developed a GIS layer for marine aquaculture.

- **Update the Board of Underwater Archeological Resources database** - The Board of Underwater Archeological Resources (BUAR) database is being updated on an ongoing basis using volunteer time. The BUAR has been working with the owner of a proprietary shipwreck database to discuss how some of those data points could be incorporated into an ocean planning data layer.

- **Develop a methodology for assessing the value of ocean viewsheds** - Work was done in the 2009 ocean plan to examine potential impacts of ocean-based development on lands within a project's viewshed through an assessment of land cover, potential visual interactions with important public spaces and open space, cultural and historical resources, and other identified sites. Site-specific visual assessments are recommended for specific projects.

Develop Models and Other Decision-Support Tools

- **Develop coupled hydrodynamic models** - CZM, with the assistance of SeaPlan, the UMass Dartmouth School for Marine Science and Technology, and USGS, has acquired a 30-year hindcast of oceanographic parameters from a Finite Volume Coastal Ocean Model (FVCOM) hydrodynamic model. CZM is currently working with USGS to bin hindcast data into useable temporal and spatial pieces that can then be coupled with biological or physical data to help make predictions about the occurrence of important marine phenomena.

- **Develop conceptual ecological models** - While no specific actions have been taken on this task, advancing efforts to assess and define areas of significant ecological importance remains a long-term priority. The work of the Northeast regional planning body is expected to help address this need, and CZM and *MarineFisheries* will actively participate and support efforts by partner organizations on this action.

- **Determine the economic value of ecosystem goods and services** - SeaPlan funded work to develop a model that predicted the costs and benefits of using a parcel of Massachusetts marine waters strictly for specific uses: groundfishing, protection of endangered whales, wind energy development, or some combination of the three. CZM provided significant feedback on various iterations of the model.

- **Develop risk, impact, and scenario-support tools** - While no specific actions have been taken on this task, developing these tools remains a long-term priority. The work of Northeast regional planning body is expected to help address this need at some level, and CZM and *MarineFisheries* will actively participate and support efforts by partner organizations on this action.

Adaptive Management

- **Conduct research on species sensitivity to oceanographic changes associated with climate change** - EEA follows and advocates for research that furthers understanding of how climate change is affecting species' life histories and ranges, recruitment of shelled organisms, and changes in wetlands distributions.

- **Identify technology and/or Best Management Practices to improve compatibility between uses** - CZM continues to develop and implement policies to assist project proponents in minimizing their environmental impacts. Recent examples include requiring proponents for state permits in the ocean planning area to use:
    - Horizontal directional drilling underneath wetland habitats such as eelgrass.
    - Dynamically positioned construction vessels (instead of anchored vessels) to avoid anchor sweep disturbance.
    - Sand-filled burlap bags instead of hard cover for ensuring appropriate burial depth of infrastructure.
    - CZM's collection of georeferenced seafloor photos in conjunction with the CZM surficial sediment map, and backscatter and sub-bottom profile data from the CZM/USGS Cooperative, to help propose a construction footprint that avoids sensitive marine resources.

Integrated Data Management and Communication Network

- **Continue to increase data discoverability** - CZM has developed a Google Earth database of over 10,000 seafloor photos that not only serves up georeferenced photos of the seafloor but also provides an analysis of the surficial sediment, depth of the photo location, and source of the photo.

CZM has also classified these photos using NOAA's CMECS into a searchable MS Excel database. The database allows a user to quickly identify all known locations of important seafloor biota.

- **Ensure and increase data interoperability** – CZM continues to work with the Massachusetts Office of Geographic Information to ensure that MORIS has best available maps and data from the ocean plan. Data on MORIS is drawn from the GeoServer mapping software. GeoServer is a free, open-source, map-serving platform that serves data using Open Geospatial Consortium formats. CZM also works with the Northeast Ocean Data Portal Working Group on data sharing and interoperability issues. Finally, EEA and its agencies support ongoing dialogue with marine project proponents—from pre-permitting discussions, through data collection and permit issuance, to post-project surveys—including discussions of how a proponent can best provide CZM with seafloor characterization data so that they can be incorporated into existing databases.

- **Continue activities to communicate information and results** - The five-year ocean plan review process provides CZM with an opportunity to have multiple informational sessions with partners and interested parties. In addition, CZM participates in ongoing collaborations with various partners to achieve the Science Framework priorities. Completed data products can be accessed through CZM's Seafloor and Habitat Mapping website (www.mass.gov/eea/agencies/czm/program-areas/seafloor-and-habitat-mapping) or the MORIS online mapping tool (www.mass.gov/eea/agencies/czm/program-areas/mapping-and-data-management/moris).

Chapter 3 - Priority Science and Data Actions for 2014 Draft Ocean Plan

As detailed above in Chapter 2, significant progress has been made on the science and data priorities in the 2009 ocean plan, resulting in new data and information that directly and indirectly supports the implementation of the plan's management framework. This document—the Draft Massachusetts Ocean Management Plan, September 2014—presents the first formal amendment of the 2009 ocean plan for public review and comment. The 2014 draft ocean plan contains an updated blueprint that identifies and prioritizes the scientific research and data acquisition needs to support and advance the ecosystem-based management approach of the ocean plan, called the Science Framework.

This chapter of the Science Framework describes priority actions to address known science and data needs over the next five-year time horizon, as well as for the longer term. The advancement of these actions depends on the availability of resources. Consequently, their inclusion in the Science Framework should be considered a recommendation for prioritization rather than a commitment to their implementation. Additionally, to make meaningful progress on these priorities, other organizations and institutions are encouraged to collaborate with EEA agencies on both programmatic and project-specific partnerships to address shared goals. By defining a specific agenda for essential investigations, surveys, research, and data tools, limited available resources can be focused and leveraged through collaborations with partners to make meaningful progress on the priority actions.

These Science Framework priorities were developed based on advice, recommendations, and guidance from six technical work groups (Habitat, Fisheries, Regional Sediment Management, Recreational and Cultural Services, Transportation and Navigation, and Energy and Infrastructure) and the Ocean Science Advisory Council.

The updated Science Framework defines 10 priority science actions for the next five-year implementation window, along with longer-term priorities. The five-year priorities are summarized below, followed by a list of the long-term science and data objectives.

Priority 1 - Further Characterize Marine Sand Deposits and Support Development of Regional Sediment Budgets

The 2009 ocean plan called for further work to advance the identification of potential areas with suitable sand resources for beach nourishment, and the scope for the 2014 draft ocean plan called for work to advance the planning for and identification of appropriate potential locations for offshore sand areas, taking into account important criteria including compatible sand resources, potential environmental impacts, interactions with existing water-dependent uses, and consideration of other key factors. In the development of the 2014 draft ocean plan, an optimization and screening analysis (detailed in Chapter 2 of Volume 1) was used to identify exclusionary areas and areas of particular concern based on special, sensitive, or unique (SSU) natural resource areas, seafloor geology, and navigational and other areas of significant impact or incompatibility. As a result of this analysis, the 2014 draft ocean plan proposes several preliminary sand resource areas for further investigation with the goal of siting one to three pilot offshore sand areas for beach nourishment projects in the next five years.

The initial characterization work, which combined surficial sediment data and available information on sand deposits, will be refined through a tiered investigation that follows these steps: (1) the Division of Marine Fisheries (*MarineFisheries*), National Marine Fisheries Service (NMFS), and the fisheries work group will be consulted and discussions will help inform the following steps; (2) existing data on geology, benthic infauna, and fisheries resources within and outside of state waters will continue to be acquired and analyzed; (3) in areas where acoustic data and information on bathymetry, seafloor hardness/roughness, and sub-surface sediment exists, a sediment coring survey will be conducted to confirm the sand deposit thickness and characterize sediment grain size; and (4) in areas where acoustic data does not exist, both surveys with both multi-beam and sidescan sonar, and seismic-reflection profiling and sediment coring surveys will be conducted to confirm the sand deposit thickness and characterize sediment grain size. This information will be used in coordination with site-specific information from the pilot beach nourishment project sites to identify a candidate site(s) within the preliminary sand resource areas. Sediment budgets and transport analysis models will then be developed to better predict and assess the effects of sand removal from this site(s). Finally, biological and physical monitoring plans to track recovery after sand removal will be developed for sand deposits selected as donor sites for beach nourishment.

In addition to this work, EEA recognizes the importance of the development of regional sediment budgets to quantify sources and sinks of sediment along sections the Massachusetts coast. A sediment budget is an accounting system for all the sand and sediment material within a defined study area, which is generally based on littoral cells or compartments that define the limits of sediment movement both on the shore, in the near-shore, and into off-shore areas.

Potential partners for the tasks in this priority action include: the Massachusetts Office of Coastal Zone Management (CZM), U.S. Geological Survey (USGS), Bureau of Ocean Energy Management (BOEM), University of Massachusetts and its Massachusetts Geological Survey Office, *MarineFisheries*, Department of Conservation and Recreation, Department of Environmental Protection, Provincetown Center for Coastal Studies, Woods Hole Sea Grant and Cape Cod Cooperative Extension, and local towns or cities.

Priority 2 - Characterize Potential Wind Energy Transmission Corridors

The scope for the 2014 draft ocean plan called for work to advance important steps in the planning and siting of offshore wind energy transmission corridor(s) to bring renewable energy from the potential projects in lease areas in federal waters across state waters to landside grid tie-in location(s), with the goal of minimizing environmental impacts and conflicts with existing water-dependent uses. Through an optimization and screening analysis (detailed in Chapter 2 of Volume 1) that identified exclusionary areas and areas of particular concern based on SSU areas, seafloor geology, and navigational and other areas of significant impact or incompatibility, the 2014 draft ocean plan identifies several preliminary areas for offshore wind transmission cables for further investigation with the goal of synchronizing transmission planning and siting with the next stages in the BOEM process, including leasing, site assessment, and National Environmental Policy Act (NEPA) analysis.

Steps needed to further investigate and characterize the preliminary areas include: (1) consultation with *MarineFisheries*, NMFS, and the fisheries work group; (2) continued acquisition and analysis of existing data on geology, benthic infauna, and fisheries resources within and outside of state waters; and (3) ocean surveys to gather both acoustic data (multi-beam bathymetry, sub-bottom profiling, sidescan sonar, and magnetometry) and sediment cores. Work that will be conducted to better characterize resources landward of the Massachusetts Ocean Management Planning Area (planning area) in areas where cables might make landfall and utilize upland routes includes mapping and delineating wetland resources (eelgrass, salt marsh, beaches, and dunes) and other potential impediments (such as water and sewer pipes, gas lines, and electric and telecommunication cables).

Potential partners for the tasks in this priority action include: CZM, the Massachusetts Clean Energy Center (MassCEC), BOEM, USGS, and *MarineFisheries*.

Priority 3 - Further Map Marine Habitats

Efforts to characterize and classify marine habitats have been underway for more than a decade through programs and projects by CZM, *MarineFisheries*, USGS, the National Oceanic and Atmospheric Administration (NOAA), and other partners. Massachusetts has made progress toward a statewide marine habitat map through the acquisition of sediment data and the creation of a surficial sediment map, acquisition of the most accurate bathymetry, development of models of benthic terrain, development of maps of epifaunal communities, and acquisition of water column characteristics (current velocity, temperature, salinity) from a hydrodynamic hindcast model. With the existing data, CZM can now characterize the abiotic structure of the seafloor (bathymetry, sediment type, rugosity, benthic position), and with ongoing analysis, will be able to characterize pelagic waters. CZM will continue to add data to and ground-truth the surficial sediment map, particularly in areas where the map was developed without the use of sidescan sonar data (e.g., southern Cape Cod Bay). This information directly supports the mapping of the hard/complex seafloor SSU area. Additional information from models such as those being developed by USGS will be able to provide estimates of the stability of sediments and benthic habitats and their susceptibility to disturbance from storms.

Eelgass beds are a defined SSU resource and have critical importance and value as marine and estuarine habitats. Eelgrass is very susceptible to disturbance and changes in environmental conditions. The location of eelgrass areas, or beds, is therefore highly variable, and the monitoring of eelgrass areas is a high priority. Information on the areal extent and the health and condition of eelgrass beds is used by managers in the review of most coastal construction projects.

Another important marine habitat mapping priority is to continue and advance work to map areas of habitat formed by marine fauna and flora (know as biogenic habitat), such as oyster beds and reefs, *Crepidula* (slipper shell) reefs, worm reefs, mussel beds and reefs, and kelp beds. These habitat areas can be mapped with the use of underwater cameras, divers, and/or sidescan sonar. Obtaining accurate, georeferenced maps of the locations, extent, and interannual variability of these important habitat-forming species will help agencies avoid or minimize damage to these habitats through the permitting process for ocean uses. CZM has begun this work by mapping the known locations of biogenic habitat as determined from seafloor photographs or video. Future work will focus on defining the extent and temporal variability of habitat patches.

Potential partners for the tasks in this priority action include: CZM, USGS, *MarineFisheries*, NOAA, and the Provincetown Center for Coastal Studies.

Priority 4 - Monitor Climate Change across Massachusetts Ocean Waters

Tracking and addressing climate change is a specific directive in the Oceans Act. Within the context of the Science Framework, the ocean plan addresses this charge through two primary tracks. On one track, CZM is actively involved in regional efforts to monitor and report on long-term seawater temperature, pH, dissolved carbon dioxide, salinity, and sea level. Such regional programs and project-specific initiatives include: the Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS), the Northeast Coastal Acidification Network (NECAN), Northeast Regional Ocean Council (NROC)/NERACOOS Sentinel Monitoring for Climate Change, and the Gulf of Maine Council's (GoMC) Ecosystem Indicator Partnership. The other track focuses on the periodic updating of data for habitats, species distribution and abundance, and other information that forms the basis for mapping and tracking SSU resources areas. In this effort, long-term data sets begin to show patterns and trends that can be examined in relationship to climate drivers, such as surface and water column temperatures, primary productivity, and thermal and hydrodynamic fronts. Consultations with scientists and resource managers will assist in interpretation of any trends. CZM will continue to track and report climate changes through the ocean plan's five-year review process.

Potential partners for the tasks in this priority action include: CZM, NERACOOS, NECAN, NROC, the GoMC Ecosystem Indicator Partnership, and the ocean planning technical work groups.

Priority 5 - Develop Data Tools and Products to Improve Interpretation and Refinement of the Important Fish Resources SSU Area

MarineFisheries has re-analyzed their long-term resource assessment trawl data to produce a series of abundance maps based on the biomass (or number) for 22 species caught at specific trawl locations over four time periods: 1978-1986, 1987-1995, 1996-2003, and 2004-2012. The development of a custom web-based and/or ArcGIS query tool to help manage and view this information is a priority and would advance an improved understanding of actual distribution and abundance of the fish species and species composition within the mapped important fish resources SSU area.

The fisheries work group recommended an assessment of the compatibility or conflict of various fisheries species with specific potential development scenarios. The goal of this assessment is to create a database of fish species (or groups of species, known as guilds) and their vulnerabilities to specific ocean-based projects (e.g., renewable energy, sand extraction, cable and pipeline burying) addressed in the ocean plan.

Potential partners for the tasks in this priority action include: *MarineFisheries*, NMFS, CZM, and The Nature Conservancy.

Priority 6 - Advance Work on an Effort-Corrected Sea Turtle Database

Patterns of endangered sea turtle distribution and abundance is an acknowledged gap in the ocean plan. More understanding of the spatial and temporal dimensions of endangered sea turtle habitat in the planning area will support future efforts to identify and protect SSU estuarine and marine life and habitats and improve siting and management of projects that could potentially lead to entanglements or other potential impacts. A priority in the next five years is to obtain aerial survey data on sea turtle sightings, build a geo-database, synthesize the data, and develop effort-corrected density maps.

Potential partners for the tasks in this priority action include: CZM, Mass Audubon, *MarineFisheries*, NMFS, and The Nature Conservancy.

Priority 7 - Develop Higher Resolution Maps and Characterization of Recreational and Commercial Fishing

Recreational fishing is an important water-dependent use that has significant public value. Both federal and state agencies have comprehensive catch and effort data on this activity but little is known of the spatial patterns and hotspots where recreational fishing takes place.

The fisheries work group examined various options to better characterize spatial patterns of recreational fishing, including: (1) repeating a 2009 survey of recreational fishermen; (2) using data collected in May-July 2013 from the Marine Recreational Information Program that included information on harvesting locations; and (3) using information compiled by SeaPlan during the 2012 Recreational Boating survey of recreational boaters (about 300 responses corresponding to recreational fishing).

The work group recommended that *MarineFisheries* conduct a survey of expert recreational fishermen to update the map from the 2009 ocean plan. This survey was carried out in November 2013 and data from 26 respondents were used to update the map of concentrated areas for recreational fishing for the 2014 draft ocean plan. The Work Group further recommended that *MarineFisheries* and CZM work together to identify options for compiling and analyzing spatial information and further characterizing recreational fishing for the next revision of the ocean plan. Work to better characterize recreational fishing is also anticipated as part of the Northeast regional ocean planning initiative.

Although the Oceans Act specifies that the ocean plan shall not regulate commercial fishing, this ocean use must be considered carefully in plan development and implementation because it can be adversely impacted by certain ocean-based development or activities. *MarineFisheries* maintains and updates comprehensive data and maps on commercial fishing by effort and value within state statistical reporting areas. This information can be augmented by other existing and new data sources to improve characterization and understanding of specific fisheries, time-spans, fisheries interactions, effects of regulations, and port-side influences. Building on a first phase of spatial mapping by NROC, additional phases of work to better characterize commercial fishing are also anticipated as part of the Northeast regional ocean planning initiative.

Potential partners for the tasks in this priority action include: *MarineFisheries*, NMFS, CZM, NROC, and the New England Fisheries Management Council.

Priority 8 - Revise and Update the State Inventory of Submerged Wrecks

The goal of this project is to convert the Commonwealth's inventory into a geo-referenced database that would include a significant ground-truthing component. Part of this effort would also require investigating the acquisition of higher resolution/more accurate wreck and historical artifact data from other sources. These data are essential to develop a comprehensive database of submerged historical artifacts that would inform the ocean plan's management framework and related permitting processes.

Potential partners for the tasks in this priority action include: the Board of Archaeological Resources (BUAR) and CZM.

Priority 9 - Develop a Paleo-landscape and Predictive Model of Ancient Native American Land Use

Data collected by USGS from work conducted in Buzzards Bay and Vineyard Sound indicate that it is possible to detect and re-create now submerged and buried ancient post-glacial landscapes. Creating a paleo-landscape would require additional sediment cores and data mining and analyses to supplement existing USGS data. This effort would be conducted in conjunction with further work on seafloor characterization (including Priority 1 and 2), but specific data analyses and refinement would need to be performed by experts in the field to ultimately create an accurate paleo-landscape. Development of a reliable model will also require active collaboration with Native American peoples.

Potential partners for the tasks in this priority action include: BUAR, CZM, the University of Massachusetts, Mashpee Wampanoag Tribal Council, Wampanoag Tribe of Gay Head (Aquinnah), and Narragansett Indian Tribe of Rhode Island.

Priority 10 - Refine and Implement the Ocean Plan Review Approach

A recommendation of the 2009 ocean plan was to develop an ocean plan evaluation framework. CZM will develop a means to: (1) assess progress in administration and implementation of the ocean plan (e.g., use of siting standards in the permitting process, implementation of the ocean development fee, coordination with the Ocean Advisory Commission and/or the Science Advisory Council), (2) review all data pertinent to updating the ocean plan (both mapped and unmapped) during each five-year review cycle, and (3) assess observed significant trends/changes in conditions pertinent to the update of the ocean plan's Baseline Assessment. The ocean plan work groups will be asked to help evaluate whether new information is available to create new ocean resources and use maps or to amend existing resource and use areas.

Potential partners for the tasks in this priority action include: CZM, SeaPlan, the Ocean Advisory Commission, Ocean Science Advisory Council, and ocean planning technical work groups.

Long-Term Actions

In addition to the five-year science priority actions described above, longer-term research and data goals were recommended by the technical work groups and Ocean Science Advisory Council:

- Support ecosystem modeling with a focus on climate change and trends in habitat and/or range shifts for individual species or groups. Evaluate options for advancing approaches/methods to further identify ecologically important areas. The evaluation should include consideration of cumulative effects models and assessments.

- Characterize the economics of Massachusetts-specific fisheries, including both large and small ports. Analyze the influence on spatial patterns of state and regional commercial fishing maps. Identify important in-state corridors for smaller fishing vessels.

- Conduct an assessment of potential and emerging impacts of climate change on the ocean and coastal environments. Identify vulnerabilities and threats from ocean acidification, ocean warming, and sea level rise. Include marine habitats, water-dependent uses, and cultural and recreational interests (i.e., historic properties, recreational infrastructure).

- Develop a database and identify spatial patterns of important recreational uses, such as diving, ocean-based wildlife viewing, surfing, and non-motorized boating (e.g., kayaking). Include information on transit routes to these locations.

- Support studies to investigate and generate maps of marine underwater noise and its potential effects on marine animals.

- Continue to advance integrated geo-spatial data management to enhance discoverability and access, user interface and data interaction, and integration with other portals and platforms