DRAFT

2021 Massachusetts Ocean Management Plan

Volume 2
Baseline Assessment and Science Framework

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Baseline Assessment Update

Science Framework

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Baseline Assessment Update:
Report on Notable Changes and Trends
Since 2015

Chapter 1 - Introduction

The Oceans Act of 2008 and section 301 CMR 28.07 of the implementing regulations require that the Massachusetts Ocean Management Plan (ocean 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). The previous version of the ocean plan was promulgated in 2015,[48] and the review of the 2015 ocean plan was initiated by the Secretary in December 2020.[49]

An important part of the original ocean plan, which was promulgated in 2009, was its Baseline Assessment. 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 the economic value derived from 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 use (WDU) 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 and the Baseline Assessment Update published in 2015. Both of the previous documents are available online.[50,51]

1.1 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., Habitat, Fisheries, Transportation and Navigation, Sediment and Geology, Cultural Heritage and Recreational Uses, and Energy and Infrastructure) that were convened over 2019 and 2020 to review existing information and identify important trends in ocean resources and uses. In addition, the SAC assisted in the development of this document by reviewing the data sources, reviewing the analyses, and providing additional data sources as necessary.

48 https://www.mass.gov/service-details/2015-massachusetts-ocean-management-plan
49 https://www.mass.gov/service-details/review-and-update-of-the-2015-massachusetts-ocean-management-plan
50 https://www.mass.gov/service-details/2009-massachusetts-ocean-management-plan-superseded-by-the-2015-plan
51 https://www.mass.gov/service-details/2015-massachusetts-ocean-management-plan

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1.2 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 planning area, the Massachusetts coastal zone, and adjacent federal waters.

Chapter 2 - Water Column Features

This chapter summarizes trends and observations of interest in the physical characteristics of Massachusetts coastal and marine waters.

2.1 Upwelling, Fronts, and Waves

In Massachusetts Bay, at the Massachusetts A01 buoy, the highest yearly average for wave height from 2002-2020 occurred in 2018, at 3.6 feet (Figure 1).[52] The average wave height of the past three years (2018-2020) surpassed the mean of the time series (3.2 feet). Previously, average yearly wave height fell below the mean of the time series for six of seven years.

2.2 Sea Temperature

Between 2001 and 2020, the highest average monthly sea surface temperature at the Massachusetts A01 buoy occurred in August for every year except 2019 (Figure 2).[53] Instead of peaking in August in 2019, the highest average monthly sea surface temperature occurred in July. August 2018 experienced the highest average monthly sea surface temperature (20.2 ˚C), with July 2019 registering the next highest monthly average (19.9 ˚C). In the 2014-2019 time series, every year except 2014 registered higher monthly averages in June-August than 2014. June-December 2016, May-October 2018, and July-December 2019 had average monthly temperatures that exceeded the mean of each respective month for the 2001-2020 time series.

2.3 Water Quality

Chlorophyll a

Chlorophyll a is a green pigment found in all photosynthetic plants and cyanobacteria. Measurements of chlorophyll a concentration are used as indicators of the condition of a waterbody. While chlorophyll a is necessary component of an ecosystem, higher concentration can indicate that a waterbody is eutrophied; dominated by algae and/or cyanobacteria and subject to periods of low dissolved oxygen that threaten aquatic life.

In early 2015 and late 2019, at the Center for Coastal Studies (CCS) 7S station in Cape Cod Bay, the highest peaks of chlorophyll a (9.88 and 9.56 μg/L) were recorded within the 2007-2019 time series (Figure 3, middle panel). [54] In Nantucket Sound, at the CCS NTKS_6

[52] http://neracoos.org/datatools/historical/graphing_download
[53] http://neracoos.org/datatools/climatologies_display
[54] http://www.capecodbay-monitor.org

station, chlorophyll a levels above 3 μg/L were recorded at least once per year in every year from 2014-2019, except 2015 (Figure 4, middle panel). In June 2018, the maximum concentration was recorded (5.78 μg/L). Of note is that chlorophyll a concentrations in excess of 3 μg/L were not reached at the NTKS_6 station prior to 2014.

Dissolved Oxygen

When dissolved oxygen (DO) concentration is less than 4 mg/L, the area may be classified as hypoxic. Extremely hypoxic conditions occur in areas with less than 2 mg/L of DO.[55] Hypoxia occurs after an influx of nutrients creates an algal bloom and the algae die, sink to the bottom, and decompose, decreasing DO concentrations, especially in bottom waters. These hypoxic areas are a cohesive mass of water and move based on upwelling or downwelling events and their corresponding wind speed and direction.[56] Therefore, hypoxic zones can occur close to shore as well as in deeper waters. Lower DO concentrations may cause the movement of species away from the hypoxic area and may result in a decrease in feeding, reproduction, and spawning.

Massachusetts Bay (MB) and Cape Cod Bay (CCB) both follow a seasonal DO cycle (Xue et al. 2013).[57] MB experiences its highest concentrations of DO during the spring and its lowest concentrations during the fall (Figure 5). Generally, DO concentrations peak in April and gradually decrease until September. October has been observed to have the lowest DO concentrations, which then rise again until its peak in April. Cape Cod Bay (CCB) experiences different peaks in DO concentration than MB (Figure 6). DO concentrations in CCB were higher in May-September than MB. Dissolved oxygen concentrations in MB were higher in January-March than CCB.

In September 2019, several lobstermen and fishermen reported hundreds of dead lobsters, crabs, and finfish in their hauls. An examination of the deeper water around these catches discovered that DO levels were below 1 mg/L.[58] It is a known normal event for deeper water to have lower DO levels. However, concentrations below 1 mg/L are eventually lethal, and resulted in the death of those trapped lobsters and crabs. In data from CCS, the plummeting DO concentrations are seen in September 2019 (Figure 7), which aligns with the reports from the lobstermen and fishermen. The Massachusetts Water Resources Authority (MWRA) also found similar results at their monitoring stations. MWRA observed DO levels

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[55] https://www.epa.gov/nutrient-policy-data/documented-hypoxia-and-associated-risk-factors-estuaries-coastal-waters-and

[56] https://www.youtube.com/watch?v=K4fj8QH3cF0

[57] Xue P., Chen C., Qi J., Beardsley RC., Tian R., Zhao L., Lin H. 2013. Mechanism studies of seasonal variability of dissolved oxygen in Mass Bay: A multi-scale FVCOM/UG-RCA application. *Journal of Marine Systems* 131, 102-119. https://www.sciencedirect.com/science/article/abs/pii/S0924796313002935?via%3Dihub

[58] November 18, 2020, memo from Tracy Pugh, DMF Senior Marine Fisheries Biologist to Dan McKiernan, DMF Director.

following the normal cycle, before drastically decreasing in late August and early September. MWRA identified a large dinoflagellate bloom in August and September as the main driver behind hypoxic conditions.[59] *Karenia mikimotoi*, a relative newcomer to the area, was suspected since it has exhibited the ability to bloom and kill fish in other locations.
In the spring of 2020, the Lobster Foundation of Massachusetts created the Cape Cod Bay Study Fleet to increase monitoring capacity of the area by adding 25 data loggers.[60] The data from these loggers are analyzed by the Division of Marine Fisheries (DMF) and collaborators at Woods Hole Oceanographic Institution (WHOI). In September 2020, DMF, CCS, and WHOI were granted two years of funding by the National Sea Grant American Lobster Initiative to identify the primary influences on water quality in Cape Cod Bay. Study Fleet data showed that extremely hypoxic conditions (< 2mg/L) lasted no more than 45 hours, but hypoxic conditions (< 4mg/L) could last longer. The data from 2019 and 2020 were presented by Tracy Pugh of DMF to the Marine Fisheries Advisory Commission in December 2020.[61]

Harmful Algal Blooms

The abundance of *Karenia mikimotoi*, a dinoflagellate, has been observed in New England for a few decades, but was not found in MWRA samples until 2017.[62] In 2017, *K. mikimotoi* concentration was around 300,000 cells per liter. In 2019, its concentration was close to 850,000 cells per liter at the mouth of Boston Harbor, which temporarily caused the harbor to appear brown. The toxicity of *K. mikimotoi* is not well understood, but its potential contribution to anoxic and hypoxic episodes in Cape Cod Bay in September 2019 (see Dissolved Oxygen) was documented.

At MWRA monitoring stations, total dinoflagellate concentration increased substantially from 2018 to 2019, with the 2019 dinoflagellate concentration ranking third highest out of the 28 years of monitoring (Figure 8).[63] In 2019, large blooms of *Alexandrium catenella*, a known toxic dinoflagellate, required seven rapid-response surveys in two months. The 2019 blooms were comparable to blooms in 2005 and 2008. Large, sustained *Alexandrium* blooms, which normally originate off the coast of Maine, are notable because they can result in paralytic shellfish poisoning (PSP) in humans that consume affected shellfish. In 2020, none of the samples taken at 15 locations exceeded the "closed to all shellfishing" biotoxin levels of 80 µg/100g.[64]

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[59] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; pg. 50
[60] November 18, 2020, memo from Tracy Pugh, DMF Senior Marine Fisheries Biologist to Dan McKiernan, DMF Director.
[61] https://www.youtube.com/watch?v=K4fj8QH3cF0
[62] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; pg. 20
[63] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; pg. 20
[64] https://www.mass.gov/service-details/psp-red-tide-monitoring

Nutrients

In 2019, the MWRA's Deer Island Treatment Plant discharged 13,217 metric tons of nitrogen, exceeding for the first time MWRA's Contingency Plan caution level of 12,500 metric tons.[65] This warning level reflected the predicted nitrogen load of 2020 that had been calculated in 1996. MWRA did not consider the warning level exceedance an environmental concern because water quality monitoring indicated no decrease in water quality in the vicinity of the outfall. Nutrient concentrations followed similar ranges from previous years, and concentrations of nutrients decreased when distance from the outfall increased (Figure 9).

Data from CCS showed normal and improving total nutrient concentrations in Cape Cod Bay and Nantucket Sound.[66] The NTKS_6 station in Nantucket Sound showed total phosphorus concentrations of 1.73 and 1.88 μM in 2012 and 2013 respectively (Figure 4, bottom panel). Despite a slight peak in 2015, total phosphorus concentrations have stayed at or below 1 μM since the end of 2015. In Cape Cod Bay, peaks of total nitrogen and total phosphorus were recorded at 35.68 μM and 3.21 μM, respectively, in late 2010 and early 2012 (Figure 3, bottom panel). The levels at these buoys have not been exceeded since early 2012.

pH

The lowering of the ocean's pH, or ocean acidification, is driven by an increase of atmospheric CO_2. As more CO_2 dissolves into the ocean, pH and saturation state of carbonate decrease. Aragonite, which is the form of calcium carbonate used by various marine shellfish, becomes less available to marine calcifiers as pH decreases. In a study done on 18 different calcifiers, 10 species experienced a decrease in calcification as atmospheric CO_2 increased (Ries et al. 2009).[67] These 10 species included temperate corals, pencil urchins, whelks, soft and hard clams, conchs, periwinkles, and oysters. Of these 10 species, six of them had their shells dissolved in increasingly acidic (low pH) waters (pencil urchins, hard and soft clams, conchs, periwinkles, and whelks).

The relationship between eutrophication and acidification has also been studied. Areas of Buzzards Bay that experienced high levels of total nitrogen, resembling eutrophication, had extremely low carbonate saturation levels (Rheuban et al. 2019).[68] Continued development of coastal areas and the nutrients from human wastewater contribute greatly to eutrophication,

[65] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; pg. vi
[66] http://www.capecodbay-monitor.org
[67] Ries, J.B., Cohen A.L., McCorkle D.C. 2009. Marine calcifiers exhibit mixed responses to CO_2-induced ocean acidification. *Geology, 37(12)*, 1131-1134. Doi: 10.1130/G30210A.1.
[68] Rheuban, J.E., Doney, S.C., McCorkle, D.C., Jakuba, R.W. 2019. Quantifying the effects of nutrient enrichment and freshwater mixing on coastal ocean acidification. *Journal of Geophysical Research: Ocean, 124*, 9085-9100. https://doi.org/10.1029/2019JC015556

although stricter regulation of water quality can result in a rebound of carbonate saturation levels.

The MWRA has stations and programs that monitor the pH of Boston Harbor, Massachusetts Bay, and several rivers. The MWRA Harbor Monitoring Program has been taking bi-weekly readings of pH from several stations within Boston Harbor since 1995. Monthly measurements of pH at 11 stations in Massachusetts Bay has occurred since September 2006. Over the last few years, MWRA has been reexamining past studies where pH readings were taken but were not the focus of the study in order to bolster past pH data for future study.

The Cape Cod Cooperative Extension (CCCE) has real-time monitoring stations in Cotuit Bay, Barnstable; Wellfleet Harbor, Wellfleet; Duxbury Bay, Duxbury; and Pleasant Bay, Orleans. These stations collect pH data from March/April to November/December, and the archived data are online.[69] Currently, the data have not been collected over a long enough time frame to detect any trends.

The Massachusetts Ocean Acidification Commission was established by House No. 4133 in January 2018.[70] The commission was composed of 19 members, which included senate and house members, members of environmental groups, commercial fisherman, ocean acidification scientists, an aquaculturist, the commissioner of marine fisheries, the commissioner of environmental protection, and the director of CZM. The commission was tasked with identifying the main contributors to ocean acidification, determining how to mitigate these contributors, identifying any gaps in knowledge on ocean acidification and its effects on commercially viable species, identifying steps to increase monitoring and analysis of ocean acidification and its effects, and providing legislative recommendations based on the commission's discoveries. Four work groups were established to gather information and make recommendations on different aspects of ocean acidification. These work groups were monitoring and barrier beaches, fishing and aquaculture, scientific literature, and policy. Some of the recommendations included funding further research into the economic and ecological effects of acidification, improving acidification monitoring, revising nutrient pollution regulations amid its recognized contribution to acidification, and implementing updated pollution standards through the upgrade of treatment faculties and septic systems.[71]

69 https://www.capecodextension.org/marine/waterquality/
70 https://malegislature.gov/Bills/190/H4133
71 https://drive.google.com/file/d/1Pcx8r-rSu8T4mf-FBHLRQH48KdGXP1uj/view?usp=sharing

Salinity

From 2014-2019, the Massachusetts A01 buoy recorded some of the highest and lowest recordings of salinity for the entire 2001-2020 time series.[72] In 2016, every monthly average salinity measurement except for March was greater than the mean of the time series (Figure 10) due to the severe drought conditions and low river discharge to the system. The monthly average salinities from July-October 2016 represent the maxima of the whole time series. In 2015 and 2016, the two lowest recordings of total annual rainfall in coastal watersheds were reported (37.09 and 37.21 inches/year). It is not unexpected then that the entire year of 2015 recorded average monthly salinities that exceeded the mean of the time series. On the other hand, salinity recordings from May 2017 and May 2019 at the Massachusetts A01 buoy were the two lowest recordings for the entire time series across all months, suggesting that rainfall and river discharge in those two months were the highest of the last two decades. This result if supported by the United States Geological Survey (USGS) Merrimack River gauge that reported 16,880 cubic feet per second (cfs) and 15,430 cfs, for May 2017 and May 2019 respectively, both well above the 20-year average of 11,900 cfs.[73]

Sound

Continued efforts to map and monitor anthropogenic marine acoustics were laid out by the National Oceanic and Atmospheric Administration (NOAA) Ocean Noise Strategy Roadmap (Roadmap), which closed for public comment in July 2016. The Roadmap serves as a guide for addressing the effects of noise on different species and their habitat by outlining the science behind the goals of the Ocean Noise Strategy and recommending future steps for interagency actions to deal with noise impacts.[74] With the assistance of the Northeast Fisheries Science Center and Stellwagen Bank National Marine Sanctuary, NOAA and DMF identified inshore areas of Massachusetts Bay that are used for spawning by cod and haddock.[75] They also discovered certain vessel noises that operate on frequencies similar to spawning Atlantic cod and haddock. Continued research by NOAA and collaborators at Cornell University have observed low-frequency noise contributions throughout Massachusetts Bay.

[72] http://neracoos.org/datatools/climatologies_display
[73] https://waterdata.usgs.gov/
[74] https://cetsound.noaa.gov/road-map
[75] https://cetsound.noaa.gov/Assets/cetsound/documents/Roadmap/ONS_Roadmap_Final_Complete.pdf; pg. 81

Chapter 3 - Seabed Features

This chapter reports on changes to the geological and biological features of the Massachusetts seafloor and how they are managed through the ocean plan. A more comprehensive analysis can be found in the Sediment and Geology Technical Work Group Report.[76]

3.1 Geomorphology

Since the Baseline Assessment Update published in 2015, new data have been incorporated into the ocean plan's hard/complex seafloor SSU map. These data draw from:

- The updated CZM/DMF sediment database
- USGS interpreted sediment maps
- Artificial reefs
- Board of Underwater Archaeological Resources recreational shipwreck sites
- Automated Wreck and Obstruction Information System (AWOIS) with 100-meter radius buffer around each wreck and obstruction

The methods used to map the hard/complex seafloor SSU area in the 2015 ocean plan were generally followed again for the 2021 update. The updated 2021 hard/complex seafloor map includes hard seafloor, complex seafloor, artificial and biogenic reefs, wrecks, and obstructions (Figure 11). The complex seafloor classification was broken into complex hard bottom and complex soft bottom. The mapped area covered 744 km^2, which was a 2% reduction from the area mapped for the 2015 ocean plan (Table 1). This reduction was a result of additional data points, increased accuracy, refined mapping, and the removal of islands from any calculations.

Table 1. Hard/Complex Seafloor SSU area coverage in the planning area.

Bottom Type	2009 Planning Area	2015 Planning Area	2021 Planning Area	% Change (2015 vs. 2021)
Hard/Complex	904 km^2 (16%)	756 km^2 (14%)	744 km^2 (13%)	-2%
Hard	308 km^2 (6%)	578 km^2 (10%)	561 km^2 (10%)	-3%
Complex	755 km^2 (14%)	364 km^2 (7%)	385 km^2 (7%)	6%
Complex-Hard	160 km^2 (3%)	192 km^2 (3%)	201 km^2 (4%)	5%
Complex-Soft	596 km^2 (11%)	171 km^2 (3%)	185 km^2 (3%)	8%

The CZM/DMF sediment database—including new high-resolution data from USGS interpreted seafloor sediment maps as well as the Massachusetts Department of Environmental Protection

[76] https://www.mass.gov/files/documents/2021/01/27/sediment-geology-wg-2021.pdf

(MassDEP) wetlands sandy beach and rocky shore delineations—was used to update the ocean plan's surficial sediment map (Figure 12). A second map of seafloor sediment (albeit of lower confidence) beyond state waters out to 10 nautical miles using the CZM/DMF database and the USGS Continental Margin Mapping Program (CONMAP), was also created (Figure 13).

Exploration of offshore sand deposits for possible sand extraction was identified as a top science priority in the 2015 ocean plan. Out of nine potential sites identified by the 2015 ocean plan, five were selected for further study (Figure 14). CZM contracted Aptim Environmental & Infrastructure, Inc. (APTIM) in 2017 to begin preliminary qualification and quantification of offshore sand resources in the five selected study areas. The studies included geophysical characterization, sediment grab sampling to establish grain size, coring to establish the volume of sand, and analysis of videos/photos of the seafloor to identify biotic resources. The offshore sites underwent an historic data review, collection of 20 vibracores up to 4 meters long, collection of 25 surface grabs, and towed video footage of the seafloor. The preliminary total volume estimated from the five study areas was approximately 313,470,000 m^3 (410,003,400 y^3) (Table 2). This estimate is only preliminary, and would require additional, design-level geotechnical and geophysical data collection in order to produce a more accurate, actionable volume of available sand resources.

Table 2. Preliminary characterization of the selected offshore sand resources.

Region	Study Area	Average Grain Size (mm)	Average % Silt	Average Sand Thickness (m)	Area of Isopach (m^2)	Estimated Volume of Isopach (m^3)	Estimated Volume of Isopach (yd^3)
Merrimack River	1	0.30	2.50	1.76 to 3.84	35,665,334	99,730,000	130,442,000
Nantasket Beach	2A	0.11	11.75	2.54 to 4.18	1,070,310	3,600,000	4,708,600
Nantasket Beach	2B	*	*	*	*	*	*
Nantasket Beach	2C	0.11	12.28	2.67	1,348,929	3,600,000	4,708,600
Duxbury Beach	3A	0.17	1.69	0.84 to 5.68	14,398,272	46,940,000	61,395,200
Duxbury Beach	3B	0.16	10.59	0.71 to 4.55	17,497,037	46,000,000	60,165,700
Sandwich	4A	0.23	2.68	3.38	15,286,265	51,670,000	67,581,800
Sandwich	4B	*	*	*	*	*	*
Cuttyhunk	5A	0.19	4.66	1.61 to 7.33	12,180,335	54,470,000	71,244,100
Cuttyhunk	5B	0.17	6.49	0.76 to 2.04	5,338,989	7,460,000	9,757,300

*No cores or grabs collected in these study areas.

In 2014, the Massachusetts Geological Survey and University of Massachusetts conducted topographic profiles and grain size analyses for 18 public beaches along the Massachusetts coast that are threatened by erosion or have important infrastructure that is at risk (Table 3). The purpose of this work was to fully characterize the beaches so that beach-compatible material can be identified in off-shore borrow areas. Future work will be required to establish the compatibility of offshore sand resources for replenishment at specific beaches. The report from the University of Massachusetts established that finer-grain beaches (i.e., Low, Miacomet, Salisbury, and Plum Island) experienced significant loss of berm compared to other types of beaches. These observations may be used in future discussions about prioritizing beaches for nourishment.

Table 3. Public beaches in Massachusetts studied by the Massachusetts Geological Survey and University of Massachusetts in 2014 that are threatened by erosion or have important infrastructure that is at risk (from north to south)

Public Beach	Municipality
Salisbury Beach State Reservation	Salisbury
Plum Island Beach	Newburyport/Newbury
Long Beach	Rockport
Nahant Beach Reservation	Nahant
Revere Beach Reservation	Revere
Nantasket Beach Reservation	Hull
Peggotty Beach	Scituate
Humarock Beach	Scituate
Fieldston/Brant Rock	Marshfield
Long Beach	Plymouth
Low Beach	Nantucket
Miacomet Beach	Nantucket
Joseph Sylvia State Beach	Oak Bluffs
Ink Well Beach	Oak Bluffs
Surf Drive Beach	Falmouth
Barges Beach	Cuttyhunk
East Beach	Westport
Horseneck Beach State Reservation	Westport

*Note: Winthrop Shore Reservation, Winthrop and Town Neck Beach, Sandwich were not part of the study.

3.2 Sediment Transport

In 2018, CZM entered a cooperative agreement with USGS to conduct three sediment studies in Cape Cod Bay. First, a coupled ocean-wave-sediment transport model was created to better understand the nearshore sand dynamics from Manomet Point, Plymouth, to Corporation Beach, Dennis. These 45 km of shoreline function as one littoral cell and thus the results of the model can be used as a framework for addressing coastal management issues such as erosion. In particular, the model is expected to predict the relative importance of large storms (Nor'Easters, hurricanes, tropical storms) to the movement of sand among the system; from landside dunes out into the bay down to 20 m depth. The second study was an investigation into the ability of a previously developed shoreline change tool, the Digital Shoreline Assessment System, to accurately predict shoreline change (erosion and/or accretion). Model-derived shoreline forecasts previously produced for CZM at 10- and 20-year intervals were evaluated relative to actual shorelines. An additional component of the modeling included the application of a Kalman filter, a process whereby actual observed shoreline positions are combined with modeled positions to increase predictive ability. The third project was a seafloor mapping effort in Cape Cod Bay. The mapping project included the acquisition of swath bathymetry, backscatter, and seismic reflection profile data. The geophysical data were ground truthed with a series of videos, photographs, and surficial sediment grabs. The mapping work adds to the over 2,400 km^2 of Massachusetts seafloor that has already been mapped.

3.3 Sediment Quality

Growing concern for the accumulation of harmful chemicals and substances in the environment prompted studies into the quality of sediment. Certain known pollutants have been well studied, but emerging legacy pollutants and their unknown effects remain to be studied. Benzotriazoles (BZTs) are a legacy pollutant that have been in vigorous production for five decades, yet their role and effect in the environment are poorly studied and understood. BZTs are used as ultraviolet stabilizing additives for numerous plastics and polymers. There is also a class of BZTs used for its anticorrosive properties. In a 2015 study, identifiable levels of BZTs were found in Salem Sound (Figure 15), despite the fact that there were no production facilities nearby (Cantwell et al. 2015).[77] Wastewater treatment was theorized to limit the levels of BZTs in the sediment. However, complete removal of BZTs, or prevention of its entrance into the ocean at all, was found to be impossible even with secondary wastewater treatment. Though the levels in Salem Sound were low, the appearance of BZTs in an area where they were never historically produced shows that certain legacy pollutants can migrate.

[77] Cantwell, M.G., Sullivan, J.C., Katz, D.R., Burgess, R.M., Hubeny, J.B., King, J. 2015. Source determination of benzotriazoles in sediment cores from two urban estuaries on the Atlantic Coast of the United States. *Marine Pollution Bulletin* 101(1), 208-218. https://www.sciencedirect.com/science/article/abs/pii/S0025326X1530148X?via%3Dihub

In the 2019 MWRA Outfall Monitoring Overview, several long running sediment quality monitoring plans were examined and reevaluated.[78] Revisions began in 2018 with a workshop titled "2300 Days at Sea: Monitoring the Impacts of Outfall on Massachusetts Bay," which examined new environmental concerns. From this workshop, a framework was established to evaluate current monitoring plans and whether they could be reduced or replaced. The original questions that these monitoring plans set out to answer related to MWRA contamination of marine sediments were deemed to have been adequately answered. After the 2019 framework meeting and its subsequent workshop, the proposed changes to the monitoring program were to: (1) end monitoring of historically catalogued chemical contaminants in the sediment; (2) end monitoring of the sediment Redox Potential Discontinuity (RPD; the depth of the sediment-oxygenated layer), and (3) eliminate two sampling areas from monitoring of contaminant-related liver conditions in winter flounder.

Since 2002, several sediment contaminants, such as toxic metals, PAHs, banned organochlorine pesticides, and PCBs, have been measured by MWRA every third year. These measurements have indicated continually decreasing levels of contaminants in the sediment. This is seen in concentrations of PCBs, which have been decreasing since 2005 (Figure 16). Due to the decreasing levels, MWRA and the Outfall Monitoring Science Advisory Panel (OMSAP) have agreed that sediment-contaminant monitoring can end. However, there is an ongoing discussion about monitoring contaminants of emerging concern.

A major concern during outfall planning was that input of organic matter would increase eutrophication and make the RPD shallower. Since monitoring of RPD began, it has been discovered that the RPD became deeper over the course of the MWRA monitoring program. Benthic habitats immediately adjacent to the outfall have also shown good health, indicating that discharge into Massachusetts Bay has not adversely affected the sediment and its inhabitants. Due to these promising results, MWRA and OMSAP have agreed that RPD measurements can end, with certain sediment conditions still being monitored.

In the 1970s and 1980s, tumors and other precancerous conditions were common in the populations of winter flounder in Boston Harbor. During outfall planning, concerns about possible effects on winter flounder liver conditions were raised. MWRA has monitored the external health and liver-conditions for collected winter flounder. Liver tumors and tumor precursors have not increased in Massachusetts Bay since outfall planning. No tumors have been reported from the outfall site, and the prevalence of CHV, a tumor precursor, has decreased. MWRA and OMSAP have agreed to continue monitoring winter flounder liver conditions in Boston Harbor. However, the promising results from Nantasket Beach and eastern Cape Cod Bay have led to both sites being removed from the monitoring plan. Though legacy pollutants, like BZTs, are still found in the sediment, results from MWRA's sediment monitoring plan showcase continually decreasing concentrations of contaminants in sediment and stable health for benthic communities. The reduction of monitoring programs is an indication of increasing sediment quality.

[78] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; p. 51

3.4 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. CZM used the Coastal and Marine Ecological Classification Standard (CMECS)[79] 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 2015 and revised 2021 hard/complex seafloor SSU resources maps, CZM determined the percent of known taxonomic groups that were observed within the hard/complex seafloor SSU resource areas. Percentages were calculated by dividing the number of photos with a taxon/group identified within the hard/complex seafloor SSU resources areas by the total number of photos where the group/taxon had been observed (Table 4).

Table 4. The percent occurrence of select taxa in photographs occurring within the 2015 hard/complex seafloor SSU resource area and the revised 2021 hard/complex seafloor SSU resource area.

Taxa/Group	Number of Photos in Planning Area	Hard/ Complex Seafloor SSU Area (2015)	Hard Seafloor Only (2015)	Hard/ Complex Seafloor SSU Area (2021)	Hard Seafloor Only (2021)
Alcyoniina (Soft Coral)	63	78%	62%	78%	60%
Astrangia sp. (Stony Coral)	85	41%	38%	41%	38%
Attached Fauna	680	61%	51%	59%	50%
Attached Hydroids and Bryozoans	416	57%	47%	61%	46%
Attached Mussels and Mussel Reefs	315	92%	86%	88%	86%
Benthic Macroalgae	1,230	71%	66%	69%	66%
Bivalvia (Clam Bed)	948	12%	6%	10%	6%
Bivalvia and Soft Sediment Mussels	1,118	22%	14%	65%	57%
Brachiopoda	371	76%	53%	57%	53%
Canopy-Forming Algal Bed (Kelps)	96	90%	86%	89%	86%
Diverse Colonizers	29	100%	100%	93%	93%
Porifera (Sponge, Sponge Bed)	1,030	68%	53%	58%	33%
Tube-Building Fauna	735	13%	7%	10%	7%

The data in Table 4 suggest that the updated 2021 hard/complex seafloor SSU resource area includes the majority of seafloor where attached fauna and flora have been found via photographs, including important habitat formers such as kelps (89%) and mussels (88%). As expected, the

[79] https://iocm.noaa.gov/standards/cmecs-home.html

hard/complex seafloor SSU resource maps do not capture areas where clams and tube-dwelling fauna are found very well, 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 has been important in providing physical evidence of the habitat of various taxa that are included within the mapped hard/complex seafloor SSU resource areas.

Chapter 4 – Habitat

This chapter summarizes trends and observations of interest in the use of Massachusetts coastal and marine waters as habitat, with a particular focus on habitats that are managed via the ocean plan. A comprehensive analysis of managed habitats can be found in the Habitat Technical Work Group Report.[80]

4.1 Marine Mammals

To support the 2021 ocean plan, CZM obtained whale sightings data, spanning 1998-2018, from the North Atlantic Right Whale Consortium (NARWC). Sightings Per Unit Effort (SPUE) data were calculated for North Atlantic right, humpback, and fin whales in Massachusetts and surrounding waters. The SPUE data were grouped into 5-minute x 5-minute (roughly 7 km x 9 km) grid cells (Figure 17). The SPUE data were interpolated using the Natural Neighbor tool in ArcGIS 10.2 (Figure 18). Off-effort whale sightings were also mapped, as they could be important if a vessel had a large number of sightings but no official survey effort. Off-effort sightings were plotted together with on-effort (on survey) sightings, but no distinction was apparent between the two methods in the detection of North Atlantic right whales (Figure 19). For each of the three whale species, interpolated maps of their distributions in each of the four seasons were produced (Figures 20-22). The seasonal maps indicate that whales have a seasonal presence in Massachusetts waters.

Analysis of the 1998-2018 data revealed that the prevalence of North Atlantic right whales (*Eubalaena glacialis*) in Massachusetts waters has increased in the last 10-15 years. An increase in North Atlantic right whales in Massachusetts was first detected in Cape Cod Bay in 2007, and sightings continued to increase consistently between 2013 and 2020. The recent analysis revealed an increase in sightings in northwestern Massachusetts Bay, between Boston and Gloucester. This phenomenon will be monitored to see if a long-term trend forms. The increasing prevalence of North Atlantic right whales in Massachusetts waters was also documented by acoustic receivers, which documented more calls within what was traditionally considered the peak season for observing North Atlantic right whales and in what was previously considered the off season for their presence.

4.2 Avifauna

The population of Roseate Terns (*Sterna dougallii*) increased from 3,000 pairs in 1988 to 4,300 pairs in 2000. After a brief period of decline from 2000-2010, the Roseate Tern population began increasing again. Continually increasing since 2013, the Roseate Tern population is currently approaching 4,100

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80 https://www.mass.gov/files/documents/2021/01/27/habitat-wg-2021.pdf

pairs, which is below the recovery goal of 5,000 pairs. Wind turbines within 25 km of nesting colonies have been classified as one of the greatest risks to Roseate Tern populations.[81] In response to this risk, tagged Roseate terns were used to map flight track densities in the northeast (Figure 23). Within their flight track, exposure to the five wind turbines of the Block Island Wind Farm was estimated and mapped (Figure 24). Offshore wind lease holders south of Massachusetts are developing avifauna monitoring and mitigation frameworks that include efforts to better understand what impacts wind farms might have on foraging and migrating birds, including Roseate Terns.

For the 2021 ocean plan, both the Roseate Tern core habitat SSU map and the Special Concern Tern core habitat map were updated after discussions with the Massachusetts Natural Heritage and Endangered Species Program (NHESP). The changes resulted in an increase of the Roseate Tern core habitat SSU area to 685,278 acres, an almost six-fold increase over the 2015 ocean plan (Figure 25), while the Special Concern tern core habitat SSU area increased to cover 794,104 acres, an almost four-fold increase compared to the 2015 ocean plan (Figure 26).

4.3 Eelgrass

For the 2021 ocean plan, the most current eelgrass datasets were obtained from MassDEP and DMF. The data were composed of aerial photographs, diver surveys, and vessel-based acoustic surveys. In reviewing how the eelgrass SSU map gets created, the Habitat Work Group recommended that the method for mapping eelgrass change from gridding to using a 100-m buffer around eelgrass polygons. The 100-m buffer was used to provide an adequate margin of safety for planning purposes, and also to reduce the incidence of inadvertent mapping of eelgrass where it is not present, the latter of which is an issue with the gridding method of mapping used in the 2015 ocean plan. The updated eelgrass SSU map covers an area of 24,703 acres, which is an 11% decrease from 2015 (Figure 27), but the decrease is likely a result of the change in methodology and not indicative of a 11% loss in eelgrass acreage.

By leveraging existing datasets, professional experience, and judgment from MassDEP, DMF, and CZM staff, recent work by U.S. Environmental Protection Agency (EPA) and the Great Lakes Environmental Center evaluated changes in the spatial distributions of eelgrass in 25 embayments managed by the MassBays National Estuary Partnership. Seagrass trends were estimated from colonial times through 2017, combining a habitat suitability model (to estimate the historic capacity of each embayment to support seagrass) with survey data. The information will be used by MassBays in setting targets for habitat restoration. This study found that all embayments lost significant eelgrass through 1995, after which very large losses of eelgrass occurred in Duxbury Bay and

[81] Burger, J., Gordon, C., Niles, L., Newman, J., Forcey, G., and Vlietstra, L. 2011. Risk evaluation for federally listed (roseate tern, piping plover) or candidate (red knot) bird species in offshore waters: A first step for managing the potential impacts of wind facility development on the Atlantic Outer Continental Shelf. Renewable Energy 36:338-351.

Wellfleet Harbor, while a number of smaller embayments stayed relatively stable or gained a few acres through 2017 (Giancarlo Cicchetti, personal communication).

4.4 Northeast Ocean Data Portal

The Northeast Ocean Data Portal, in collaboration with the Marine-life Data and Analysis Team (MDAT) from Duke University, developed hundreds of geospatial data products, across many species groups, that predict the distribution and abundance of a variety of marine species.[82] The diverse inhabitants of northeast waters—cetaceans, sea turtles, birds, or fish—can be mapped individually by taxa or via various functional groups. The portal's viewable and downloadable data include regional observations and modeled probabilities for 47 bird species, 30 marine mammal species, and 99 fish species. Depending on the range of these species, data exist as far south as the Atlantic coast of Florida and as far north as Newfoundland. In addition to annual maps of distribution and abundance, there are also seasonal maps for individual species. For fish species, distribution and abundance maps across several decades were produced. Several taxa were also mapped by their ecological guild or their conservation status. There are data available for 12 bird guilds, four marine mammal guilds, and three fish guilds.

4.5 Invasive Species

Most of what is known about invasive species distributions in Massachusetts comes from Rapid Assessment Surveys (RASs), highly collaborative efforts that have occurred every 3-5 years since 2000 to monitor and track the status of introduced species in New England. During the surveys, taxonomic experts use a combination of field surveys and laboratory work to identify invertebrate and plant species living on selected docks and piers. Because the RASs are located primarily outside of the Ocean Management Planning Area (which starts 0.3 nautical miles [NM] from shore and therefore is well away from any docks and piers), the distribution of invasive species within the planning area is not well known. However, given the life history characteristics of marine invasive species (e.g., wide dispersal of life stages via ocean currents and vessels), it is reasonable to assume that most of the invasive species identified via the RAS could inhabit the planning area.

In the most recent RAS in 2018, eight sites were sampled from New Bedford to South Freeport, Maine.[83] During the 2018 RAS, dock and pier-based surveys were supplemented by the EPA Region 1 dive team, who assisted by collecting and photographing subtidal organisms in the study areas. The results of the 2018 RAS identified 20 introduced species and 27 cryptogenic species (i.e., species whose origins are not yet resolved). In contrast to previous years, no new species were found. However, notable observations from the survey included the northern expansion of the red algae *Dasysiphonia japonica* into Maine, a southern expansion in range for the brown algae *Colpomenia*

[82] https://www.northeastoceandata.org; see "theme maps"
[83] https://www.mass.gov/files/documents/2020/07/22/ras-2018-report-final.pdf

peregrina to the Massachusetts Maritime Academy in Buzzards Bay, and a northern increase in range for the red algae *Grateloupia turuturu*. *G. turuturu*, discovered in Massachusetts during the 2007 RAS, was observed on the North Shore of Massachusetts for the first time in 2018. Although this is the first record of *G. turuturu* north of Boston for the RAS, monitoring efforts by others have previously reported the species as far north as Maine. *Tricellaria inopinata*, first observed in 2010 in Woods Hole, expanded its range and was recorded at all but one survey location in 2018. The European shrimp, *Palaemon elegans*, observed for the first time in the Northwest Atlantic in Salem during the 2010 RAS, was not observed at any site in the 2018 RAS, but is known to be expanding its range and is frequently recorded in other surveys (e.g., CZM's Marine Invader and Monitoring Information Collaborative). Outside of the RAS, the encrusting bryozoan, *Cribrilina (Juxtacribrilina) mutabilis*, was observed for the first time in the Northwest Atlantic in Casco Bay, Maine.[84] While not yet observed in Massachusetts, as a colonizer of eelgrass, this species has a high potential to expand into Massachusetts waters.

4.6 Shellfish

The Massachusetts Shellfish Initiative (MSI), a professionally diverse group including wild harvesters, aquaculturists, the restoration community, town and state officials, tribes, and the general public, met several times in 2019 and 2020 with a goal of sustaining the economic, environmental, and social aspects of the shellfish industry. [85] Through several meetings and reports, the MSI aimed to build support for shellfish resources and fisheries through the bolstering of public and stakeholder capacity, as well as through the creation of effective communication between local, state, and federal managers. The MSI also aimed to support the cultural and historic uses of shellfish, along with the maintenance of a balanced, sustainable relationship between shellfish management and economic opportunities by using ecologically sound management and enhancement of shellfish beds.

The 2020 MSI Assessment Report revealed trends in the management of shellfish resources, shellfish fisheries, shellfish aquaculture, public health, and shellfish planting and propagation. The key nearshore commercial shellfish fisheries (bay scallops, oysters, quahogs, razor clams, and softshell clams) were chosen for analysis based on their landings and value (see Table 7 and Table 8 in Chapter 7 below).[86] In total, the value of the studied nearshore species rose 41%, from $31.4 million in 2014 to $44.2 million in 2018. The value of the oyster fishery in 2018 was only behind the lobster and sea scallop fisheries. Oyster landings increased from 34.5 million pieces in 2014 to 51.1 million pieces in 2018, as a result of the increase in aquaculture reared oysters. The value of the oyster fishery followed this increasing trend, surging from $19.4 million in 2014 to $28.3 million in

[84] Trott, T.J. Enterline, C. 2019. First Record of the Encrusting Bryozoan *Cribrilina (Juxtacribrilina) mutabilis* (Ito, Onishi & Dick, 2015) in the Northwest Atlantic Ocean. BioInvasions Records. 8(3):598-607.

[85] http://www.massshellfishinitiative.org/uploads/1/0/4/9/104987295/final_msi_scoping_report.pdf

[86] http://www.massshellfishinitiative.org/uploads/1/0/4/9/104987295/assessment_committee_report_2020.pdf; pg. 63

2018. The Cape Cod and Islands geographic region accounted for a majority of oyster landings (33.31 million of 51.14 million pieces) in 2018.

4.7 Artificial Reefs

In 2021, there were five artificial reefs in Massachusetts, two in Boston Harbor, and one reef in each of the towns of Dartmouth, Yarmouth, and Harwich. In March 2016, 1,600 cubic yards of granite and repurposed concrete were placed at the 10-acre Harwich site, the state's newest artificial reef. The deployment was funded through the Massachusetts saltwater recreational fishing license program, established in 2011. Black sea bass, scup, and tautog were observed on the reef within months of the deployment.[87] DMF enacted regulations at 322 CMR section 8.09 prohibiting all commercial fishing activity on the Harwich reef and within a 100-meter buffer zone.[88] In 2019 and 2020, materials were added to a section of the 125-acre Yarmouth reef site. Over 2.5 acres of subtidal habitat was enhanced using 3,000 cubic yards of granite and repurposed concrete. The deployment and five years of monitoring were funded through the Department of Fish and Game In Lieu Fee Program. Underwater visual census and Baited Remote Underwater Video (BRUV) surveys were used to compare reef habitat species diversity and relative abundance with a nearby natural reef. DMF identified that both artificial reef sites have space available to accept future material placement.

In 2018 and 2019, DMF assessed lower Cape Cod Bay for suitable sites to permit as artificial reefs. A side scan survey of more than 5,000 acres of seafloor was used to identify more than 50 potential reef locations throughout lower Cape Cod Bay. Sediment imagery and diver survey groundtruthing further narrowed potential sites. This information will be used in permitting to justify the selection of two new, 15-acre artificial reef sites in lower Cape Cod Bay off of Brewster and Dennis. DMF is beginning the project's permitting phase in 2021.

[87] https://www.youtube.com/watch?v=zl4SnfLyC9k

[88] https://casetext.com/regulation/code-of-massachusetts-regulations/department-322-cmr-division-of-marine-fisheries/title-322-cmr-800-coastal-fisheries-and-conservation-management/section-809-restrictions-on-fishing-in-certain-artificial-reef-areas

Chapter 5 – Archaeological Landscape and Cultural Heritage

This chapter summarizes trends and observations of interest in the archaeological landscape and cultural heritage of Massachusetts's coastal andmarine waters, with particular focus on the area that is managed via the ocean plan. A comprehensive analysis of the managed underwater archaeological landscape and submerged cultural heritage can be found in the Cultural Heritage and Recreational Uses Technical Work Group Report.[89]

Underwater cultural heritage within the Massachusetts Ocean Management Planning Area (planning area) is represented by a diverse range of submerged cultural landscapes, areas, and site types in which thousands of years of human history are preserved. Included among them are the surviving elements of formerly terrestrial paleolandscapes submerged by post-glacial sea level rise that have Indigenous cultural and archaeological sensitivities, as well as submerged shipwrecks, disposal areas, and aircraft dating from the period following European contact and colonization of Massachusetts over 400 years ago.

As noted in the 2015 Massachusetts Ocean Management Plan (the 2015 ocean plan), management of underwater cultural heritage has evolved to view and understand places and their associated resources through a more comprehensive "cultural landscape" interpretive lens. This lens is analogous and complementary to ecosystems-base management and considers the rich, complex relationships between people and place across the land-sea boundary. Given that humans are terrestrial beings, it is important to acknowledge and understand that underwater cultural heritage resources within the planning area have onshore origins and share a connection with patterns of human settlement and activity on the lands along the Massachusetts coast and in the state's interior.

Ocean planning and management of underwater cultural heritage generally involves a sequence of tasks: 1) Inventory (discovery and recording); 2) Evaluation (scientific and public importance); 3) Planning (determining appropriate use); 4) Protection (safeguarding resources); and 5) Utilization (accommodating proper use).[90] Within the planning area and throughout the Commonwealth's waters, under Massachusetts General Law (MGL) c.6.s.179-180, and c.91.s.63, and 312 Code of Massachusetts Regulations (CMR) 2.0, the Massachusetts Board of Underwater Archaeological Resources (BUAR) has statutory jurisdiction and is the sole trustee of the state's underwater cultural heritage, charged with the responsibility of encouraging the discovery and reporting, as well as the

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[89] https://www.mass.gov/files/documents/2021/01/27/culture-rec-wg-2021.pdf

[90] General Accounting Office (GAO). 1987. Cultural Resources: Problems Protecting and Preserving Archaeological Resources. Washington, DC: General Accounting Office.

preservation and protection, of Massachusetts's underwater archaeological resources. The Commonwealth holds title to these resources and retains regulatory authority over their use. No person, organization or corporation may remove, displace, damage, or destroy underwater archaeological resources located within the Commonwealth's submerged lands except in conformity with permits issued by the BUAR. BUAR Special Use Permits are granted to qualified archaeologists to conduct marine archaeological identification, evaluation, and mitigative investigations as part of state and federal environmental review processes for proposed projects in state waters. Similarly, under federal law (36 Code of Federal Regulations [CFR] 800), projects requiring federal licensing, funding, or permitting must also consult with the State Historic Preservation Office (SHPO) to consider the project's potential for adverse effects to historic properties (i.e., cultural and archaeological resources). In Massachusetts, the SHPO operates from within the Massachusetts Historical Commission (MHC) and is distinctly separate from the BUAR. Any proposed projects or activities in the planning area that may result in disturbances to the seafloor must anticipate the existence of underwater cultural heritage landscapes, areas, and sites, and if they are identified through BUAR-permitted surveys, must take steps to avoid them. Information on the BUAR's work, on BUAR-related statute and regulations, on BUAR permitting, and on BUAR's survey requirements (published as policy guidance documents) are publicly available for review and reference at BUAR's website.[91]

5.1 INDIGENOUS UNDERWATER CULTURAL HERITAGE AND ARCHAEOLOGICAL SITES

Recent marine geoarchaeological research (2012-2019) completed by the University of Rhode Island in collaboration with BOEM and the region's Tribal Historic Preservation Offices (THPOs) in nearby Rhode Island[92,93,94,95,96] and surveys of proposed offshore wind energy project areas in

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[91] https://www.mass.gov/orgs/board-of-underwater-archaeological-resources

[92] US Department of the Interior, Bureau of Ocean Energy Management (BOEM). 2015. Developing protocols for reconstructing submerged paleocultural landscapes and identifying ancient native American archaeological sites in submerged environments: summary report of the initial project workshop. Final Report. 169 p. OCS Study BOEM 2015-048. Obligation No.: M12AC00016.

[93] Caccioppoli, B., Robinson, D., King, J., Gibson, C. 2018. Developing protocols for reconstructing submerged paleocultural landscapes and identifying ancient Native American archaeological sites in submerged environments; field report: 2013-2016. Final Report 74 p. OCS Study BOEM 2018-056. Obligation No.: M12AC00016.

[94] King J.W., Robinson D.S., Gibson C.L., Caccioppoli B.J. 2020. Developing protocols for reconstructing submerged paleocultural landscapes and identifying ancient Native American archaeological sites in submerged environments. Final Report. 24 p. OCS Study BOEM 2020-023. Obligation No.: M12AC00016

[95] Robinson, D.S., Gibson, C.L., King, J.W. 2018. Developing protocols for reconstructing submerged paleocultural landscapes and identifying Native American archaeological sites in submerged environments: best practices. Final Report. 65 p. OCS Study BOEM 2018-055. Obligation No.: M12AC00016.

[96] Robinson, D.S., Gibson, C.L., Caccioppoli, B.J., King, J.W. 2020. Developing protocols for reconstructing submerged paleocultural landscapes and identifying ancient Native American archaeological sites in submerged environments: geoarchaeological modeling. Final Report. 175 p. OCS Study BOEM 2020-024. Obligation No.: M12AC00016.

Massachusetts waters by marine archaeological consultants working under BUAR Special Use Permits within the past five years have produced new knowledge and approaches that have proven effective for identifying preserved elements of culturally and archaeologically sensitive paleolandscapes inundated by post-glacial sea level rise. Using a combination of marine remote-sensing and geological sediment sampling technologies and analysis techniques, performed in consultation with and with participation by local Indigenous communities and their THPOs, researchers have demonstrated that some geological elements of drowned paleolandscapes (e.g., topographically low and protected margins of fluvial, lacustrine, and wetland features that were part of an ancient landscape where the Continental Shelf is now that was exposed and available for human occupation prior to post-glacial sea level rise) have survived the largely destructive inundation processes associated with sea level rise. These preserved paleolandscape features have been found to contain archaeological materials and possess sufficient contextual integrity as stratified geoforms to contribute to the cultural significance of areas identified as Traditional Cultural Properties (TCP) important to the region's Indigenous communities. Determined eligible as a TCP in 2010 by the U.S. Department of the Interior, Nantucket Sound is an example of an essential component of a larger traditional cultural landscape important to the ongoing practices, beliefs, and traditions of the indigenous Wampanoag peoples of the Cape and Islands region. Features include landscape forms central to events associated with Wampanoag stories, as well as archaeological and historic sites associated with the ongoing practices and traditions of these Indigenous communities. While these submerged paleocultural landscapes and areas are now generally recognized to exist within the planning area, and regional sea level rise and offshore geologies are broadly defined and understood, additional remote sensing and coring data generated by site-specific studies conducted at higher resolutions capable of defining and characterizing paleoenvironments in adequate detail to enable the identification and protection of Indigenous underwater archaeological resources are necessary and recommended research priorities. The region's archaeological, geoscience, and Indigenous research communities should work collaboratively in all aspects of this research to ensure optimal research and management results.

5.2 SHIPWRECKS AND NON-INDIGENOUS UNDERWATER CULTURAL HERITAGE AND ARCHAEOLOGICAL SITES

The BUAR maintains a database and files documenting over 3,500 reported shipwrecks in Massachusetts coastal waters. Unlike geo-referenced positions of terrestrial heritage sites on shore, nearly all published shipwreck inventories suffer from imprecise and incomplete location and descriptive data and have not been validated through ground-truthing. For example, in the 2009 Massachusetts Ocean Management Plan (the 2009 ocean plan), only shipwrecks listed in the NOAA Automated Wrecks and Obstructions Information System (AWOIS) database were included. As noted in the 2009 ocean plan, the AWOIS database is not a comprehensive listing of shipwrecks, but rather is a listing of wrecks identified as navigational hazards by NOAA. Furthermore, the location data for these wrecks were found to be often imprecise, and the list of vessels was composed mainly of steel-hulled ships lost after 1900. The 2015 ocean plan presented expanded shipwreck information that included the results of archaeological sensitivity assessments for shipwrecks completed by the University of Connecticut[97] and the BUAR that used each reported shipwreck's locale to populate areas along the coast organized by city or town and categorized and color-coded as "high" (red), "moderate" (yellow), or "low" (blue) sensitivity. These areas were projected from their coastal municipal boundaries out to the seaward edge of Massachusetts's territorial sea. The resulting sensitivity map showed a strong correlation between larger numbers of reported shipwrecks/greater relative archaeological sensitivity, and Massachusetts's largest and most historically active ports and areas along the coast that projected out into the sea and presented a navigational hazard (e.g., Gloucester, Rockport, Salem, Marblehead, Swampscott, Lynn, Boston, Hull, Cohasset, Scituate, Marshfield, Provincetown, Truro, Wellfleet, Orleans, Chatham, Harwich, Nantucket, Martha's Vineyard, and Gosnold [Elizabeth Islands]).[98]

The 2015 ocean plan also included a map depicting the Commonwealth's 40 "Exempted" shipwreck sites (2015 ocean plan, Volume 2, Figure 27), that because of their location, condition, history, or resource value have been preserved for recreational activities, mainly diving (since 1985), and do not require an BUAR permit for casual artifact collection. The AWOIS and Exempted Sites databases and maps were included as an additional layer to the hard/complex seafloor SSU area of the 2015 ocean plan, so that they could be included in site-specific environmental assessments conducted for development and management purposes. For the 2021 ocean plan, this data presentation has been retained (Figure 11); however, a draft version of a more comprehensive database of publicly available shipwreck information has been developed by BUAR and CZM (Figure 29) that will be edited, corrected, and ground-truthed with information provided by the recreational diving community and then finalized as one of the 2021 ocean plan science priorities, so that it may be considered for potential inclusion as a new shipwreck specific SSU in the next update of the ocean plan.

[97] Robinson, D.S., 2008. Massachusetts Vessel Casualties (1614-1978): A Statistical Analysis. University of Connecticut.

[98] Robinson, D.S., 2008. Massachusetts Vessel Casualties (1614-1978): A Statistical Analysis. University of Connecticut.

Chapter 6 – Human Uses

6.1 COMMERCIAL FISHING

The Fisheries Technical Work Group analyzed commercial fishing activity to support the update of the High Commercial Fishing Effort and Value WDU map for the 2021 ocean plan. Though data existed for 1988-2019, a truncated time series of 2010-2019 was analyzed because the work group believed that the past decade of fishing activity better represents current existing uses of the planning area.[99] The 2010-2019 time series relied on the mandatory trip-level reporting program that the Division of Marine Fisheries (DMF) implemented in 2010. Since individual species level could impact the value, and therefore its weighting, an "adjusted-price" analysis was used for the 2010-2019 time series. The "adjusted-price" analysis converted live pounds to values by multiplying them by the landings weighted average price per live pound reported in each year. The 2010-2019 time series was also analyzed without lobster landings, so that other fisheries overshadowed by the lobster fishery could be identified and located. The shellfish component of the 2010-2019 time series relied on dealer reported shellfish transactions from the Standard Atlantic Fisheries Information System (SAFIS). Each transaction was assumed to be one trip, with the total number of trips and landings value being tallied by the Designated Shellfish Growing Area (DSGA) and averaged over available years. To account for different scales of fisheries in each part of the state, the planning area was separated into two regions: north of Cape Cod and south of Cape Cod (Figure 30). The total area had 23 strata, according to depth and region (Figure 31).

Due to the large influence of the lobster fishery and oyster aquaculture landings, the effort and value levels of the area north of Cape Cod are higher than the area south of Cape Cod (Figure 32). American lobster landings heavily influenced the trends seen in the 2010-2019 time series. Lobster landings and value in state waters were double that of the next species in most years. The lobster fishery has primarily shifted away from south of Cape Cod to north of Cape Cod, which allows for the northern stability seen in the figures. Withholding lobster landing data changes the mapping of the area north of Cape Cod (Figure 32). The area south of Cape Cod does not change as much with the removal of lobster landings because of the various other species contributing to southern fisheries. There was a greater than 300% increase in oyster effort and value observed between 2010 and 2019. This was mostly attributed to the boom in oyster aquaculture seen since 2012. This rapid increase in oyster effort and value exceeds all fisheries except lobsters.

6.2 RECREATIONAL FISHING

Over a million recreational anglers regularly fish in the waters of the planning area, primarily by hook and line. Recreational fishing for lobsters and crab using pots and recreational shellfishing with

[99] https://www.mass.gov/files/documents/2021/01/27/fisheries-wg-2021_0.pdf; pg. 4

various hand-gears in the nearshore areas are also popular. Recreational fishing is conducted from the shore and from vessels, including personal vessels and for-hire vessels. In 2019 there were 7.4 million angler trips in Massachusetts, up from 6.7 million in 2018. During the trips in 2019, 10.6 million fish were harvested, and 15.5 million fish were released alive.[100] Target species include striped bass, black sea bass, bluefish, cod, cusk, haddock, halibut, scup, tautog, and bluefin tuna, among others.

Recreational fishing catch and effort data are collected annually by NOAA via the Marine Recreational Information Program (MRIP) established in 1983. In response to a federal mandate to improve estimates of saltwater fisheries data, in 2011 the Commonwealth of Massachusetts established the Recreational Saltwater Fishing Permit, administered by DMF. DMF also administers the Recreational Fisheries Project to preserve, enhance, and promote marine recreational fisheries in Massachusetts. Data on abundance, length frequency, and age classes of key finfish populations are gathered and input to stock assessments in order to design and evaluate management options. DMF also assesses the habitat and prey needs of key species; measures harvest and release of key species; promotes and enhances recreational fishing access through the purchase and maintenance of access sites (most of which is funded by recreational fishing permit sales) and disseminates information on all aspects of recreational species and fisheries to the public. However, none of these programs collect spatial data of sufficient resolution to quantify the catch in specific areas important to the recreational fishery industry.

Recreational fishermen surveyed by DMF provided information on concentrations of recreational fishing activity in the 2015 ocean plan. Using data from 28 respondents, a heat map was generated and used to identify areas of concentrated recreational fishing in the 2015 ocean plan. The recreational fishing subcommittee of the Marine Fisheries Advisory Commission (MFAC) recommended that in the future, the survey should be repeated with a sample of at least 2,000 fishermen in order to generate statistically robust data. For the 2021 ocean plan, the WDU will be represented with the same map that was used in the 2015 ocean plan (Figure 33). The Fisheries Technical Work Group suggested that the 150,000-person angler database generated from the recreational fishing license program could be used to target the survey sample and that angler cell phones or vessel GPS devices could be used to generate spatial information.[101]

Shellfishing was also recognized as an important recreational fishing activity that occurs primarily outside of the ocean planning area. As part of the Massachusetts Shellfish Initiative, a survey was sent to all coastal municipalities with open shellfish beds to the assess the extent of recreational shellfishing. The results of the survey identified that over the last 10 years, 12 communities increased the number of recreational shellfish harvest permits issued annually, 16 remained unchanged, and

[100] Fisheries of the United States 2019
[101] https://www.mass.gov/doc/fisheries-work-group-report-2021/download

only two communities decreased the number of recreational harvest permits.[102] In most cases, the increases were due to an increase in shellfish propagation and planting effort by the communities.

6.3 IMPORTANT FISH RESOURCE AREAS[103]

The assessment of important fish resource areas by the Fisheries Work Group relied on fisheries-independent otter trawl survey data collected by DMF in September and May of each year. Each trawl survey measured changes in the relative abundance and biomass of commercially and recreationally important species over time. A composite method, used in previous ocean plans, and a vulnerability method was used for analysis. The vulnerability method sought to identify any species that were potentially vulnerable to specific types of construction activities. For the composite method, 22 species were selected based on their catchability. The trimean averaging technique ([1st quartile + 2*median + 3rd quartile] / 4) was used to calculate the biomass of each species over the full 1978-2018 time series and the truncated 2008-2018 time series. In order to be included in the analysis a survey stratum needed to have at least eight years of non-zero catches for the full time series and two years of non-zero catches for the truncated time series. As in previous analyses, the selected strata were analyzed based on their location, keeping strata north and south of Cape Cod separate. Each stratum was normalized by dividing the trimean by the sum of the trimeans for all included strata within a season, giving each species approximately the same influence.

The composite method map shows four separate time periods: 1978-2007, 1978-2012, 1978-2018, and 2008-2018 (Figure 34). The 2008-2018 map depicts an increasing importance of the deeper strata north of Cape Cod, as deeper waters had a higher average biomass of species caught in the DMF trawl surveys as compared to shallower waters. Though there were high scup and tautog landings in stratum 11 (south of Cape Cod), there were sizable declines in stratum 15, a shallow area in Nantucket Sound. Of note was that only deeper strata south of Cape Cod were classified as "important" in the 2008-2018 time series—suggesting that the long-term increase in seawater temperature is affecting where fish are distributed in Massachusetts. The area of the Important Fish Resource Area SSU resource in the 2021 ocean plan is 185,170 acres, which is less than the 253,681 acres mapped in the 2009 and 2015 planning area (Table 5).

Table 5. Size of Important Fish Resources SSU Area and % of planning area covered

	Area (acres)	% of planning area covered
Area in 2009 and 2015 ocean plans	253,681	18
Area calculated using 1978-2018 data	314,694	23
Area calculated using 2008-2018 data—used in 2021 ocean plan	185,170	12

102 http://www.massshellfishinitiative.org/documents.html/#assessment

103 https://www.mass.gov/files/documents/2021/01/27/fisheries-wg-2021_0.pdf ; pg. 13

Sea scallop, cod recruitment, skates, whelk, spiny dogfish, black sea bass recruitment (juveniles), lobster, and flounders were species considered vulnerable to the cable laying process. With the exception of spiny dogfish, these species were also considered vulnerable to pipeline construction and sand mining. The list of fisheries species that are vulnerable to pipelines and sand mining also included loligo squid, horseshoe crabs, and Jonah crabs. Since the listed species for each activity are similar, the maps for cables (Figure 35) and pipeline/sand mining (Figure 36) are also similar. The major difference between the two maps is that Nantucket Sound is included in the pipeline/sand mining map, which is due to the presence of horseshoe crabs and squid there. These species are not considered vulnerable to cables but are considered vulnerable to pipelines/sand mining.

6.4 STATUS OF STOCKS

Data from NOAA's Status of Stocks Reports from 2013 and 2020 were used to observe changing trends in New England fish stocks from 2013 to 2020 (Table 6).[104] Atlantic cod stocks in Gulf of Maine (GOM) and Georges Bank (GB) remained on the overfishing and overfished list, as they were in the 2009 and 2015 ocean plan. Since 2013, the stocks of Cape Cod (CC)/GOM yellowtail, GOM haddock, GOM windowpane, witch flounder, GOM thorny skate, and GB/Southern New England (SNE) winter skate have been removed from the overfishing list. In 2020, stocks of Southern Georges Bank (SGB)/Mid-Atlantic (MA) red hake and GOM Atlantic mackerel have been added to the overfishing list. Since 2013, stocks of CC/GOM yellowtail have been removed from the overfished list. Between 2013 and 2020, five stocks were added to the overfished list: SNE/MA yellowtail, GB winter flounder, SGB/MA red hake, GOM/GB white hake, Atlantic herring, and GOM Atlantic mackerel. This resulted in a net removal of four stocks from the overfishing list and a net gain of four stocks onto the overfished list from 2013-2020. GB/SNE barndoor skate (2016), GOM smooth skate (2018), and GOM/GB American plaice (2019) were classified as fully rebuilt.

[104] https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates

Table 6. Commercially harvested groundfisheries from the 2013 and 2020 NOAA Status of Stock Reports. GOM = Gulf of Maine, GB = Georges Bank, SGB = Southern Georges Bank, SNE/MA = Southern New England/Mid-Atlantic, CC = Cape Cod

<table>
<tr><th>Stock Status</th><th>2013 (as of 9/30/13)</th><th>2020 (as of 12/31/20)</th><th>Stocks rebuilt since 2015</th></tr>
<tr><td>Stocks on the overfishing list</td><td>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</td><td>Atlantic cod - GB
Atlantic cod - GOM
Yellowtail - GB
Red hake - SGB/MA
Atlantic mackerel - GOM</td><td rowspan="2">2016: Barndoor skate - GB/SNE

2018: Smooth Skate - GOM

2019: American plaice - GOM/GB</td></tr>
<tr><td>Stocks on the overfished list</td><td>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</td><td>Atlantic salmon
Atlantic cod - GB
Atlantic cod - GOM
Atlantic wolffish
Yellowtail - GB
Yellowtail - SNE/MA
Windowpane - GOM/GB
Winter flounder - SNE
Winter flounder - GB
Ocean pout
Atlantic halibut
Thorny skate - GOM
Witch flounder
Red hake - SGB/MA
White hake - GOM/GB
Atlantic herring
Atlantic mackerel - GOM</td></tr>
</table>

6.5 TRAWL SURVEYS

Several notable observations were recorded in the DMF's 2019 spring and fall trawl surveys.[105] During the spring survey, from May 6-23, the first spring Greenland halibut was recorded at station 39 off of Halibut Point, Rockport (Figure 37). East of Rockport, 384 female American lobsters were recorded, the largest quantity of the spring survey. South of Westport in Buzzards Bay (station 56), the largest quantity of Northern puffer was recorded. In Nantucket Sound, Vineyard Sound and Buzzards Bay, scup, longfin squid, Northern sea robin and young of the year (YOY) cod were frequently caught in the survey trawls. During the fall survey, from September 3-25, the spiny butterfly ray was recorded for the first time in Western Nantucket Sound, at station 57 (Figure 37). East of Horseshoe Shoal at station 91, a loggerhead sea turtle made its first appearance in over 40 years of the trawl survey. In Nantucket Bight, 78 Northern kingfish were recorded, the largest quantity of the fall trawl survey. Nantucket Sound, Vineyard Sound, and Buzzards Bay all had abundant scup, longfin squid, and butterfish in fall tows.

6.6 AQUACULTURE

The aquaculture industry continues to expand in Massachusetts. For example, oyster culture has increased by 50% by weight from 2014- 2018. However, the number of acres of shellfish growing areas (i.e., approved, conditionally approved, restricted, or conditionally restricted areas) has remained static over the same time period at 1.7 million acres (Hickey et al., 2015).[106] The increase in aquaculture has led to three distinct initiatives that seek to bring attention to, and address issues associated with the advancement and improvement of the aquaculture industry in Massachusetts. In response to a perceived space conflict among aquaculturists, wild harvesters, and water quality restoration projects (e.g., bivalve culture to remove estuary nitrogen), the Cape Cod Commercial Fishermen's Alliance, the Massachusetts Aquaculture Association, The Nature Conservancy (TNC), and the University of Massachusetts Boston created the Massachusetts Shellfish Initiative (MSI) in early 2019. The goal of the MSI is to "maximize the economic, environmental, and social benefits of Massachusetts' nearshore shellfish resources." The MSI Task Force includes CZM, DMF, Massachusetts Department of Agriculture (DAR), the Massachusetts Department of Environmental Protection (MassDEP), and Massachusetts Environmental Policy Act (MEPA). An assessment report of the status of the shellfish industry across municipalities was developed in 2020 and recommendations published by the MSI Task Force in the strategic plan.[107]

Most shellfishing activities take place landward of the ocean planning area. A map depicting fixed fishing facilities is included as a new WDU in the ocean plan. The fixed fishing facilities map

[105] 2019 Annual Performance Report. https://www.mass.gov/doc/2019-resource-assessment-annual-performance-report/download
[106] Shellfish Planting Guidelines 2015. https://www.mass.gov/files/2017-07/shellfish-planting-guidelines_0.pdf
[107] MSI 2021-2025 Strategic Plan 2021. http://www.massshellfishinitiative.org/uploads/1/0/4/9/104987295/msi_strategic_plan.pdf

includes existing aquaculture license sites that overlap with the ocean planning area and all fish weirs (Figure 38). All the existing aquaculture license sites within the ocean planning area are used for shellfish aquaculture. There are 94 active aquaculture license sites occupying 227 acres within the ocean planning area, located in the towns of Chilmark, Eastham, Edgartown, Fairhaven, Orleans, Provincetown, Truro, Wellfleet. All but the sites in Chilmark and Westport are inshore licenses that extend more than 1,500 ft from shore, so they extend into the ocean planning area. One offshore site in Cape Cod Bay is linked to an inshore license holder, but it is not currently producing shellfish. In total, both within and outside of the planning area, there are 628 aquaculture license sites, occupying 1,332 acres, held by 424 permittees in Massachusetts.

There are three Aquaculture Development Areas (ADA) in the ocean planning area, located in Provincetown, Truro, and Westport. An ADA is an area selected by a municipality for the purpose of aquaculture. It can be an aquaculture license held by the municipality or simply a planning area. The ADA is subdivided into smaller individual license sites available for growers and may not have active aquaculture activity over the whole licensed area. Individual licensees need to apply to DMF for a state permit for their aquaculture operations. Fish weirs are fish traps located in a single location over the fishing season and so they are permitted for specific sites. The length of a weir varies between 300 ft to 3,600 ft and averages 2,100 ft. As of January 2021, there are 30 weir sites permitted to 5 companies (Figure 38) and these are included in the fixed fishing facilities WDU map. The WDU includes the area of the weir site which was generated using the starting point, weir length, weir direction, and a standard width of 500 ft. to create a surface area for each weir.

In anticipation of emerging interest in deep-water aquaculture within the ocean planning area, siting and management provisions may be considered in a future ocean plan in a similar manner as sand mining, cables, and pipelines. This was outside the scope of work, so an aquaculture working group was established to determine how the state could best address aquaculture in the Ocean Plan.

6.7 RECREATIONAL BOATING

Recreational boating—the use of a noncommercial vessel for leisure activities such as fishing and travel—is an important and popular activity in Massachusetts coastal waters with 136,106 boats registered in Massachusetts in 2019.[108,109] The ocean plan recognizes the importance of recreational boating by mapping areas of concentrated recreational boating. Spatial data for the map in the 2015 ocean plan were gathered from two surveys of recreational boaters using motorized vessels conducted in 2010[110] and 2012[111] by Seaplan, and the Urban Harbors Institute, as well as a more

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108 https://www.statista.com/statistics/240634/registered-recreational-boating-vessels-in-the-us/
109 https://www.boatma.com/boating_in_ma.html
110 2010 Massachusetts Recreational Boaters Survey https://scholarworks.umb.edu/cgi/viewcontent.cgi?article=1000&context=uhi_pubs
111 2012 Northeast Recreational Boater Survey: A Socioeconomic Spatial Characterization of Recreational Boating in the Coastal and Ocean Waters of the Northeast U.S.

limited survey of 2013 expert recreational boaters conducted by the Massachusetts Marine Trades Association (MMTA). The datasets were analyzed to include the areas with the highest concentration of boaters as hotspots for the development of the Water Dependent Use: Concentrated Recreational Boating map in the 2015 ocean plan The map confirms 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, with popular navigation routes from Boston to Provincetown and from Cape Cod to Buzzards Bay via the Cape Cod Canal. The surveys also revealed that the most popular activities conducted by boaters included cruising, fishing, and sightseeing, with July and August being the busiest months for this activity.

Since 2015, no new surveys were conducted to update the data in the 2015 ocean plan. Both the Transportation and Navigation Technical Work Group and the Cultural Resources and Recreational Uses Technical Work Group recommended keeping the data and map from the 2015 ocean plan for the concentrated recreational boating activity WDU in the 2021 ocean plan (Figure 39). The Northeast Ocean Data Portal (portal) hosted by the Northeast Regional Ocean Council (NROC) includes recreational boating hotspots as well as up to 20 associated activities for the northeast region. The data include recreational boating in Massachusetts. When the data in the portal are updated, CZM will work with the team to have access to the data pertaining to Massachusetts waters.[112]

Access to coastal waters is an important component of recreational boating. Although marinas, moorings, and public boat ramps are mostly located outside of the planning area, the location of this infrastructure influences the patterns of boating within the planning area. In 2018, CZM developed an online coast guide that includes location of boat ramps, public beaches, and other public access points in Massachusetts.[113] The guide includes more than 1,900 sites along the Massachusetts coast that are owned by government agencies and nonprofits and open to the public. The sites vary from long, sandy beaches and rocky shores to small rights-of-way and public landings. There are 341 marinas for recreational boating along the coastline of Massachusetts.

6.8 WHALE WATCHING

Whale watching is a popular activity in Massachusetts and makes up a significant component of the marine tourism and recreation industry. The number of rare and endangered species of whales that visit Cape Cod Bay, and the proximity to Stellwagen Bank National Marine Sanctuary (SBNMS),

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https://www.openchannels.org/sites/default/files/literature/2012%20Northeast%20Recreational%20Boater%20Survey.pdf

[112] Northeast Ocean Data Portal (Recreation). https://www.northeastoceandata.org/data-explorer/?recreation|boating

[113] Coast Guide Online https://mass-eoeea.maps.arcgis.com/apps/MapSeries/index.html?appid=35ba833bdc704d49b71a71c511224eb6

make this one of the top-ten whale watching destinations in the world, attracting over a million people annually.[114]

Most whale watching data are related to whale watching as a commercial activity. Commercial whale watching vessels are typically over 65 feet in length and hold at least 100 passengers, although some may carry over 300 passengers on a trip. These large commercial whale watch operators are expected to have a spatial footprint and industry characteristics that are unique to that sector. The whale watch season in Massachusetts runs from April through October, peaking in July and August. There are 13 whale watch operators in Massachusetts. They operate out of Newburyport, Gloucester, Boston, Plymouth, Hyannis, and Provincetown and fan out to different locations in offshore waters that serve as hotspots for marine mammals. These areas coincide with prominent underwater features such as Stellwagen Bank and Jeffrey's Ledge. Intensely used whale watching areas vary with season and often differ from year to year, as vessels follow the changing migratory patterns of different species. Because the Gulf of Maine is considered a major feeding ground for several species, operators may observe more variability in congregation patterns among seasons within a specific year as a result of shifting food sources. In the spring and fall operators search for humpback, fin, and minke whales near Tillies Bank, and in the summer near the southwest corner of the SBNMS. Operators out of Provincetown and Nantucket are able to spot fin, minke, and right whales closer to the shore of Cape Cod in the spring and on the backside of Cape Cod in the fall.

Upon leaving port, operators follow a single navigation corridor out to the target destination. These transit paths create a fan pattern out of the respective ports. Transit time to the open ocean varies depending on home port and destination (which varies with the season). Typical trips out of Gloucester and Newburyport transit straight out toward Jeffreys Ledge or follow the coastline south into SBNMS. Trips out of Boston Harbor follow one of three primary transit paths along restricted channels (Nantasket Channel, Hypocrite Channel, and North Channel). Operators sailing out of Provincetown may travel in any direction off Race Point depending on the location of whales. Operators out of Plymouth and Hyannis travel straight out to the SBNMS, and operators out of Nantucket travel north towards Chatham.

The 2015 ocean plan incorporated data from the 2010 and 2012 recreational boating surveys which provided information on activities conducted by recreational boaters, including wildlife viewing. In 2015, NROC and partner organizations hosted a workshop for whale watch operators in the northeast, including six from Massachusetts, to gather data on this industry. The results were published in the Northeast Coastal and Marine Recreational Use Characterization Study,[115]and were used to develop maps of commercial whale watching in the portal.

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[114] 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

[115] Characterization of Coastal and Marine Recreational Activity in the U.S. Northeast. 2015. http://archive.neoceanplanning.org/wp-content/uploads/2015/10/Recreation-Study_Final-Report.pdf

The maps in the portal were updated based on input from whale watch industry experts in 2020. Whale watch owners, operators, naturalists, and data managers attended multiple webinars hosted by NROC to review and discuss updates to the original portal data to best depict where whale watching takes place in the northeast region, while also providing information about seasonality, species, and overall industry trends. The new regional map in the portal was derived using vessel transit counts (i.e., density maps) and individual vessel tracks for whale watching vessels derived from public vessel identification information and Automatic Identification System (AIS) database.[116] For the 2021 ocean plan whale watching activity in and adjacent to the ocean planning area, including hotspots and vessel transit routes, were mapped using the regional data provided downloaded from the portal (Figure 40).

6.9 DIVING

Recreational diving is a popular and thriving activity in Massachusetts across the planning area. Most recreational diving takes place in inshore waters at depths ranging from 10-130 ft. There are 44 diving clubs in Massachusetts.[117] Although there is no comprehensive database on recreational diving in Massachusetts, SCUBA diving often takes places in areas offering opportunity for viewing interesting features and habitats (e.g., reefs), photography, and recreational fishing (e.g., lobsters and scallops). In addition to its importance as a recreational activity, diving has been instrumental in providing information on submerged wrecks and other historic artifacts, fish censuses and invasive species monitoring. Most of the diving sites are accessed by boat but a substantial number are accessible from shore.

The 2015 ocean plan includes a map of 40 sites associated with underwater archaeological resources that because of their location, condition, history, or resource value are best left in the public domain. These 40 underwater archaeological sites are designated as "Exempted sites" (See Chapter 5). The map from the 2015 ocean plan will be retained in the 2021 ocean plan (Figure 28). However, gathering comprehensive spatial data on this activity is a science priority with the goal of establishing a water-dependent use for concentrated recreational diving in a future ocean plan.

6.10 MARITIME TRANSPORTATION AND NAVIGATION

The planning area provides access for a variety of commercial transportation uses. While technically outside of the planning area, the ports of Boston, New Bedford, Fall River, and Gloucester are the destination and origin of vessels transporting people, food, fuel, liquid and dry bulk cargoes, and container goods through the planning area. Thus, the construction and maintenance of navigational pathways to ensure the safe transit of these vessels through the planning area and how these

[116] https://www.northeastoceandata.org/files/metadata/Themes/Recreation/CommercialWhaleWatchingAreas.pdf

[117] http://archive.neoceanplanning.org/wp-content/uploads/2015/10/Recreation-Study_Final-Report.pdf

navigational lanes interact with other uses of the planning area is an important component of the ocean management plan. Figure 41 illustrates some of the major navigation and transportation related features in the planning area.[118]

Harbor Maintenance, Dredging, and Disposal

Coastal harbors play a vital role in driving the Commonwealth's blue economy. Dredging is essential to remove shoaling that impedes navigation to and from harbors and marinas in Massachusetts. Most of the dredging that occurred since 2015 has taken place in waters shoreward of the ocean planning area and is mainly associated with the larger ports: Port of Boston and Port of New Bedford. Since 2015, maintenance dredging and improvement dredging in the Boston Harbor has resulted in the removal of 1.942 million cubic yards and 14.415 million cubic yards, respectively. Over fourteen million cubic yards of this material were applied for beneficial reuse to cover the offshore Industrial Waste Site.

Since 2015, there have been numerous dredging events that resulted in nearshore or offshore sediment disposal at sites permitted by the U.S. Army Corps of Engineers. Material placed close to shore is often used for beach nourishment, which is considered a beneficial reuse. From 2015 to 2020, almost16 million cubic yards (cy) of dredged sediment was directed toward beneficial reuse (Table 7).

Table 7. Dredged sediment used beneficially 2015-2020

Region	Volume placed (cy)	Volume dredged (cy)
North Shore		
Boston Harbor	14,415,500	14,112,000
South Shore	448,348	104,348
South Coast	18,260	18,260
Cape Cod	992,123	1,019,048
Islands	118,382	118,382

The Port of Boston is a strategic regional gateway for international trade and cruise tourism (See Section 7.5). One of the most important projects to ensure continued growth of port facilities is the Boston Harbor Deep Draft Navigation Improvement Project. The $350 million project included dredging of the Reserve and Main Ship Channel which began in July 2018. Approximately 12.5 million cubic yards of silt, blue clay, till, and weathered rock were removed. This was the only dredging project that included aspects in the ocean planning area: the Broad Sound North Entrance Channel, which was deepened to -50 feet mean lower low water (MLLW), and the lower Main Ship Channel through President Roads, which was deepened to -48 feet MLLW, allowing larger container

[118] https://www.mass.gov/doc/transportation-navigation-work-group-report-february-23-2021/download

vessels to more efficiently and safely transit Boston Harbor to berth at Conley Terminal. All dredge spoils were deposited at the Massachusetts Bay disposal site in federal waters.

The Port of New Bedford is one of the most vibrant commercial/industrial ports in Massachusetts, ranking as the top major fishing port in the U.S. based on value ($431 million in 2018, up from $390 million in 2017), and among the top ports in the U.S. by landings (NMFS 2018).[119] The Port of Gloucester also ranked highly, with $53 million value of product in 2018.

The Port of New Bedford offers deepwater access for maritime vessels. However, with the emergence of offshore wind energy off Massachusetts waters over the past five years, the City of New Bedford, in collaboration with the Commonwealth, is making significant improvements to its New Bedford Marine Commerce Terminal, including dredging of the terminal area, to enable it to serve as a hub for offshore wind energy construction and operations support and other marine commerce uses.

The Massachusetts Dredging Program[120] was authorized by the 2018 Economic Development Bond Bill and is the Commonwealth's first standalone grant program with focused funding to support saltwater dredging in public tidelands. One-year construction grants are competitively awarded with a focus on shovel-ready projects that contribute to the economic significance, recreational value, public safety, and/or coastal resilience of Massachusetts's coastal harbors. Since 2019, $11 million has been awarded for 13 projects that resulted in the removal of 386,000 cubic yards of material from 95 acres of public tidelands. Projects supported navigation for more than 500 commercial vessels and 5,000 moorings and dockings. The latest round of funding was awarded in 2021.[121]

Material dredged from ports and harbors is often disposed of in nearshore or offshore sediment disposal at sites permitted by the U.S. Army Corps of Engineers. Material placed close to shore is often used for beach nourishment, which is considered a beneficial reuse. Between 2015 and 2020, over 14.1 million cubic yards of dredged sediment was directed toward beneficial reuse (Industrial Waste Site).

Cruises and Ferry Services

In addition to commercial shipping, the ports of Massachusetts also offer facilities for cruise ships and passenger handling, serving as important ports of call and providing facilities for the growing cruise ship industry. Flynn Cruiseport Boston contributes $290 million to the local economy and supports nearly 1,100 direct jobs. In 2019, 402,346 passengers on 138 ships went through the terminal between March and November, an increase of 3% over the previous year.[122]

[119] Fisheries of the United States. https://media.fisheries.noaa.gov/dam-migration/fus_2018_report.pdf
[120] https://www.mass.gov/service-details/about-the-massachusetts-dredging-program
[121] Ibid.
[122] Massachusetts Port Authority 2019 Annual Report

In Massachusetts, several ferries transport commuters between key points along the mainland coast and the islands. Some ferry routes are outside the ocean planning area as they service areas within a Boston Harbor, e.g., Charlestown Navy Yard to Long Wharf, while others are mid-distance and carry passengers from one harbor to another, e.g., Hingham to Rowes Wharf, Salem Harbor to Long Wharf, Boston Harbor to Provincetown, Provincetown to Plymouth, and the longer distance ferries from Hyannis and Falmouth (Woods Hole) to Nantucket and Martha's Vineyard respectively, and from New Bedford/Fairhaven to Cuttyhunk, to Martha's Vineyard, and to Nantucket, among others.

6.11 ENERGY GENERATION AND TRANSMISSION

Power Generation

The total capacity of generating plants in Massachusetts is approximately 12,000 MW.[123] According to ISO New England's 2019 Forecast Report of Capacity, Energy, Loads, and Transmission (CELT), peak demand and overall electricity use will be declining in Massachusetts over the next 10 years. More specifically, 50/50 summer peak demand is predicted to decrease from 11,946 MW in 2019 to 11,416 MW in 2028 (-0.5%) and overall electricity use in Massachusetts is predicted to decrease from 58,178 gigawatt-hours (GWh) in 2019 to 54,470 GWh in 2028 (-0.7%).[124]

Since 2015, there have been several major changes in energy generation in Massachusetts:

- On May 31, 2017, Brayton Point Power Station, a 1,538 MW coal- and oil-fired power plant in Somerset, Massachusetts, permanently retired.
- In May 2018, Footprint Power Salem Harbor Station, a 674 MW natural-gas-fired power plant in Salem, Massachusetts, began commercial operation.
- On May 31, 2019, Pilgrim Nuclear Power Station, a 690 MW nuclear power plant in Plymouth, Massachusetts, permanently retired.
- In May 2019, Canal 3 Generating Station, a 333 MW simple-cycle natural gas and diesel-fired power plant in Sandwich, Massachusetts, began commercial operation.

Energy Transmission

Since 2015, several offshore wind energy projects have been proposed for construction in the Massachusetts Wind Energy Area, located around 25 miles south of Martha's Vineyard. An important part of these projects is the laying of submarine cables to transmit power to land. The

[123] ISO-NE 2019 Forecast Report of Capacity, Energy, Loads, and Transmission https://www.iso-ne.com/system-planning/system-plans-studies/celt/.

[124] ISO-NE 2019 Forecast Report of Capacity, Energy, Loads, and Transmission. Forecast Data. https://www.iso-ne.com/system-planning/system-plans-studies/celt/.

2015 ocean plan included an analysis of potential transmission corridors from the offshore wind energy lease areas to landside connection points in Massachusetts with minimal impacts to coastal resources and existing uses. The proposed offshore export cable route through Muskeget Channel for the Vineyard Wind 1 project closely approximates this analysis and has recently been approved as part of the Vineyard Wind 1 offshore wind project.

In August 2019, the Harbor Electric Energy Company (HEEC), a subsidiary of Eversource, installed a new cable across Boston Harbor to provide primary power for the MWRA's Deer Island Wastewater Treatment Plant. HEEC's project involved installing the approximately 4.2-mile long 115-KV electric power cable on land and across Boston Harbor and the decommissioning and partial removal of the existing distribution line.

Offshore Renewable Energy

There are nine offshore wind areas south and west of Massachusetts leased by the U.S. Bureau of Ocean Energy Management (BOEM) to several private companies to generate power from offshore wind. Since 2015, proposed projects are in various stages of planning and surveying including geological and geophysical surveys, turbine spacing, export cable construction, scour protection, sedimentation models, and biological studies. On May 11, 2021, BOEM issued a Record of Decision for the first commercial scale offshore wind energy project in the U.S., allowing Vineyard Wind to start construction on its 62 13-MW turbines to deliver 800 MW of electricity to Massachusetts. The offshore export cable will run through Muskeget Channel and Nantucket Sound and will make landfall at Covell's Beach in Barnstable with an interconnection to the electrical substation in West Barnstable.

In December 2019, and in response to interest by the states, BOEM held its first regional task force meeting to begin consideration of additional wind energy areas on the Outer Continental Shelf in the Gulf of Maine. The task force is made up of representatives from the states of Maine, Massachusetts, and New Hampshire. In November of 2020, the state of Maine announced its intention to request a BOEM research grant for a floating offshore wind research array in the Gulf of Maine.

6.12 WASTEWATER, STORMWATER, AND INDUSTRIAL FACILITIES DISCHARGES

Wastewater

Twenty-three municipal wastewater treatment facilities and the New England Aquarium discharge treated wastewater to the coastal zone of Massachusetts. The largest facility, operated by MWRA is located on Deer Island and has had a general decrease in per capita discharge flow from 2012 to 2019 relative to flows from 1999 to 2011.

The 2014 Act Improving Drinking Water and Wastewater Infrastructure enacted by state legislature resulted in changes to the Ocean Sanctuary Regulations in 2017 to allow for the permitting of ocean outfalls to discharge treated municipal wastewater to ocean sanctuaries. The Town of Wareham, with assistance from the Buzzards Bay Coalition (BBC), has been collecting data to support the relocation of the Wareham water pollution control facility's outfall from the Agawam River to the Cape Cod Canal at the site of the Massachusetts Maritime Academy outfall. Modeling of an outfall discharging a minimum of 3 MGD and up to 10 MGD of effluent (treated to 3 mg/l total nitrogen (TN)) demonstrated the concentration of TN in the receiving waters would increase by <1% and 2% respectively. The proposed Wareham facility would likely have the capacity to treat wastewater from the western part of Bourne (Town of Plymouth), and potentially the Town of Marion, in addition to the Town of Wareham. The communities and BBC have partnered to model the outfall relocation to understand potential impacts to downstream estuarine resources. In addition, BBC has collected two years of baseline water quality and benthic monitoring (required by Ocean Sanctuary regulations) and continues to gather data to inform future water quality and habitat assessments.[125]

Five Cape Cod communities (Bourne, Sandwich, Falmouth, Mashpee, and Barnstable) have been discussing the potential use of the Joint Base Cape Cod (JBCC) wastewater treatment facility as a regional wastewater treatment and disposal opportunity. In addition to upgrades to JBCC, other alternatives for treated wastewater disposal include an ocean outfall, potentially in the Cape Cod Canal, are being considered. A report prepared by consultant Wright Pierce[126] estimated that in the mid-term (10-year) timeframe, up to 2.2 MGD of wastewater disposal capacity might be needed, and in the long-term (20-year) timeframe, up to 4.5 MGD disposal capacity might be needed for these five communities.

Stormwater and Combined Sewer Overflows

Since 2015 MWRA completed construction of its Combined Sewer Overflow (CSO) abatement plan and brought the plan's 35 projects into operation. CSO discharges have been eliminated or effectively eliminated (i.e., eliminated up to and including the 25-year storm along the South Boston beaches) at 40 of the 84 outfalls addressed in the plan. Outfalls that discharged CSO to Constitution Beach, the beaches of South Dorchester Bay and the Neponset River are permanently closed. The projects have reduced Typical Year CSO discharge volume from approximately 3.3 billion gallons to approximately 450 million gallons, and approximately 88% of the remaining

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[125] Review of the (2015) Massachusetts Ocean Management Plan. 2020. https://www.mass.gov/files/documents/2021/01/08/ocean-plan-review-2020.pdf

[126] Shared Wastewater Management Study Towns of Bourne, Falmouth, Mashpee, Sandwich, and Joint Base Cape Cod (2019). https://www.townofbourne.com/sites/g/files/vyhlif316/f/uploads/jbcc_shared_wastewater_mgmt_study_august2019.pdf

discharge volume is treated at four upgraded MWRA CSO treatment facilities.[127] MWRA continues to assess wastewater system performance and evaluate performance improvements to meet strict Federal District Court Order limits on remaining CSO discharges. A MWRA report on compliance with the court ordered levels of control is due in December 2021. The cities of Lynn and Gloucester continue to address their CSOs through their respective Long Term Control Plans.

Industrial

In 2021, Massachusetts had active permits for treated stormwater discharges from nine petroleum products terminals including: Citgo Petroleum, Conoco Phillips, Distrigas, Exxon Mobil, Global Petroleum, Global REVCO, Global Chelsea Sandwich, Gulf Oil, and Sprague Energy. These terminals are all located in the Boston Harbor region. Several power plant intake/discharge systems have been discontinued and only Braintree Electric Light, General Electric, Mystic Station, Taunton Municipal Light Plant, and Wheelabrator Saugus continue to operate cooling water intake systems with estuary discharges. Gillette and Sprague Twin Rivers are the only facilities using seawater intakes and discharges for their industrial processes.

Desalination Plants

There are two desalination facilities in the state. The Swansea Water District (SWD) has had a National Pollutant Discharge Elimination System (NPDES) permit since 2008 but did not begin withdrawing water until 2013. The NPDES permit allows SWD 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 at least 6 milligrams per liter. The first environmental monitoring report (2013) included information on water quality, ichthyoplankton, fish and crabs, infauna and benthic invertebrates, and sediment type in the vicinity of the intake and discharge. In 2019 and 2020, MassDEP required SWD to conduct additional monitoring at the location of the discharge and downstream to ensure that benthic habitat was not being degraded by the high salinity discharge.

The Taunton River Desalination Plant (TRDP) has a NPDES permit to withdraw up to 10 MGD and discharge up to 5.4 MGD of brackish water from the Taunton River, with salinity within two parts per thousand of the ambient salinity of the river. Because the Taunton River is one of the state's most important anadromous fish habitats, TRDP used multiple redundant fish exclusion devices and conducted a robust monitoring program in the vicinity of TRDP since 2007. The City of Brockton, the TRDP's only client, has not requested water from the plant in large quantities, with maximum daily withdrawals ranging from 5-8 MGD from 2015-2108, well below the permitted daily

[127] CSO Post Construction Monitoring and Performance Assessment MWRA https://www.mwra.com/cso/pcmpa-reports/01_041518-063018.pdf

withdrawal of 10 MGD. In 2020, CZM worked with DMF, Department of Conservation and Recreation Interbasin Transfer Act staff, MassDEP, and Executive Office of Energy and Environmental Affairs (EEA) Water Policy staff to update the Water Management Act permit and the Interbasin Transfer Act authorization for TRDP requiring the plant to withdraw no more than 5 million gallon per week (flow rate of less than 6,000 gallons per minute) for six weeks in the spring (April 25-June 8) that are important to white perch and river herring spawning.

6.13 SHORELINE PROTECTION AND FLOODPLAIN MANAGEMENT

Dynamic coastal environments shift in response to changes in currents, wave energy, sediment resources (sand, gravel, and cobble), and sea level. Although the Massachusetts shoreline is outside the planning area, activities within the planning area can directly and indirectly impact coastal processes. Coastal erosion and land loss, flooding associated with storms, and tidal inundation are already major challenges that coastal communities face. Erosion and flooding can lead to the loss of lives and major damages to property and infrastructure in developed coastal areas. Therefore, proposed activities in the planning area should consider potential impacts on coastal areas due to changes in ocean circulation, wave direction and energy, marine sediment transport, and water levels.

The Commonwealth works through CZM's StormSmart Coasts program, inter-agency efforts, and high-level committees and reports such as the 2006-2007 Coastal Hazards Commission, Climate Change Adaptation Advisory Committee (2009-2011), Coastal Erosion Commission (2014), and State Hazard Mitigation and Climate Adaptation Plan (2018) to address coastal floodplain, shoreline management, and climate adaptation issues. Primary components of this work include: (1) mapping coastal landforms and assessing change; (2) synthesizing technical information and developing actionable decision support tools; and (3) providing direct technical and financial assistance to communities to improve understanding of coastal hazards and risk, promote proactive planning, and implement best practices to reduce vulnerability and increase resilience along the coast.

Chapter 7 – Economic Impact of the Marine Sector

In an analysis by NOAA in 2018, the ocean economy of Massachusetts is broken down into six different sectors: living resources, marine construction, ship and boat building, marine transportation, offshore mineral extraction, and tourism and recreation. Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, and Suffolk counties are included in the NOAA analysis of Massachusetts' Ocean Economy. In the most recent data from 2018, the ocean economy accounted for 3% of the state's total employment, ranking 11th out of 30 coastal states with a total of 103,918 people employed in ocean economy sectors.[128] Total gross domestic product (GDP) for the ocean economy reached $7.4 billion in 2018. The percent contribution of each sector to Massachusetts ocean economy GDP is seen in Table 8.

Table 8. Percent contribution to the Massachusetts ocean economy Gross Domestic Product (GDP) by sector.[129]

Sector	2015	2016	2017	2018
Living Resources	10.1	14.8	14.6	14.4
Marine Construction	2.2	1.9	1.7	2.4
Ship and Boat Building	0.5	0.6	0.7	0.6
Marine Transportation	30.3	25.8	25.9	22.4
Offshore Mineral Extraction	0.5	0.7	0	0
Tourism and Recreation	56.4	56.3	57.1	60.1
Total GDP ($ billion)	7.8	7.4	7.6	7.9

7.1 COASTAL TOURISM AND RECREATION

The coastal tourism and recreation sector accounted for the highest employment and largest contribution to GDP of the ocean economy between 2015 and 2018 (Table 8). In 2018, the sector provided 80,082 jobs, which was 80.3% of total employment in the ocean economy.[130] Employment in this sector in Massachusetts ranked 7th out of 30 coastal states. The sector generated $4.7 billion in GDP, or 60.1% of the entire ocean economy GDP in 2018. Tourism and recreation also had $2.2 billion in wages, or 58.8% of total ocean economy wages.

128 https://coast.noaa.gov/enowexplorer/#/employment/total/2018/25000
129 https://coast.noaa.gov/enowexplorer/#/gdp/total/2018/25000
130 https://coast.noaa.gov/enowexplorer/#/employment/tourism/2018/25000

A study of passengers on for-hire whale watching vessels was conducted by Emerson College and the Office of National Marine Sanctuaries and the National Marine Sanctuary Foundation in 2018 and 2019.[131] The study focused on Stellwagen Bank National Marine Sanctuary (SBNMS) in the Gulf of Maine. The study sought to describe the important economic contributions that whale watching made to local economies over the time period. Massachusetts is a hotspot for people interested in whale watching, with roughly 80% of New England whale watching occurring at SBNMS. Of the 1,827 survey respondents, 93% stated that their primary purpose for visiting New England was for wildlife viewing, with 40% of those same respondents saying they particularly chose a vessel that travelled to SBNMS. This highlights the volume of tourists who came to New England specifically for whale watching in SBNMS. When asked if seeing more whales would encourage them to stay in New England longer, respondents, on average, stated they would stay 0.71 more days and take 0.94 trips to SBNMS if more whales could be seen. With a current upward trend in whale sightings off the coasts of New England (see the Marine Mammals section above), whale watching passengers may stay in New England longer, further supporting local economies. Whale watching was earmarked as a recurring activity when respondents were in the region. On average, 1.5 trips were taken to New England each year for an average of 5.6 days (1.2 of those days being for wildlife viewing). It was reported that 79% of total annual passengers (269,000 out of 347,475) visited SBNMS, showing its vital position in the whale watching industry. Overall, an Economic Impact Analysis for Planning model (IMPLAN) found that passengers who choose whale watching operations that visit SBNMS contributed about $692 million in output, $394 million in value added, $258 million in income, and 5,300 full- and part-time jobs to the total United States economy. For the 14 coastal counties that comprise the local economy, the IMPLAN model found the same individuals contributed $182 million in output, $107 million in value added, $76 million in income, and 1,400 full- and part-time jobs.

7.2 COMMERCIAL FISHERIES

Commercial fisheries are a major contribution to the living resources sector of the ocean economy of Massachusetts. The living resources sector has ranked third (behind tourism/recreation and marine transportation) out of all sectors in contribution to employment and ocean economy GDP between 2015 and 2018.[132] The living resources sector employed 10,492 people, earning a rank of 4th out of 30 coastal states. This rate of employment was 7.5% of the entire ocean economy. This sector also contributed $1.1 billion to the ocean economy GDP, ranking 3rd out of 30 coastal states. Wages for this sector reached $492.3 million, ranking 2nd out of 30 coastal states, exceeding the total of $297 million in 2015.

The 2020 MSI Assessment Report identified the trends of important shellfish species in Massachusetts, along with reviewing the management of shellfish resources, shellfish fisheries,

[131] https://sanctuaries.noaa.gov/science/conservation/2020-stellwagen-bank-whale-watching.html
[132] https://coast.noaa.gov/enowexplorer/#/employment/livingresources/2018/25000

shellfish aquaculture, public health, and shellfish planting and propagation. The key nearshore commercial shellfish fisheries (bay scallops, oysters, quahogs, razor clams, and softshell clams) were chosen for analysis based on their landings (Table 9) and value (Table 10).[133] In total, the value of the studied nearshore species rose 41%, from $31.4 million in 2014 to $44.2 million in 2018. The value of the oyster fishery in 2018 was only behind the lobster and sea scallop fisheries. Oyster landings increased from 34.5 million pieces in 2014 to 51.1 million pieces in 2018, as a result of the increase in farmed oysters. The value of the oyster fishery followed this increasing trend, surging from $19.4 million in 2014 to $28.3 million in 2018. The Cape Cod/Islands geographic region accounted for the majority of oyster landings (33.31 million of 51.14 million) in 2018.

Table 9. Commercial landings of shellfish fisheries, 2014-2018

	2014	2015	2016	2017	2018
Bay Scallop (Meat Pounds)	176,207	97,088	96,968	170,860	119,462
Oyster (Pieces)	34,455,290	38,506,920	39,290,996	50,569,102	51,133,233
Quahog (Live Pounds)	5,040,504	4,777,370	4,469,958	4,220,300	4,555,101
Razor Clam (Live Pounds)	486,507	336,088	361,078	547,120	728,322
Softshell Clam (Live Pounds)	2,009,057	2,045,058	3,277,268	3,702,887	3,652,841

Table 10. Commercial ex-vessel value by species, 2014-2018

	2014	2015	2016	2017	2018
Bay Scallop	$2,524,330	$1,431,364	$1,876,959	$2,125,376	$1,637,595
Oyster	$19,420,109	$22,637,293	$22,508,427	$28,333,754	$28,310,863
Quahog	$3,689,809	$4,373,455	$4,721,349	$4,549,027	$4,882,495
Razor Clam	1,821,976	$1,437,366	$1,471,317	$2,410,407	$3,226,260
Softshell Clam	$3,990,163	$4,470,983	$6,193,667	$6,242,089	$6,177,161
Total	*$28,126,387*	*$34,350,461*	*$36,771,719*	*$43,660,653*	*$44,234,374*

[133] http://www.massshellfishinitiative.org/uploads/1/0/4/9/104987295/assessment_committee_report_2020.pdf; pg. 63

7.3 RECREATIONAL FISHING

Recreational fishing, or sport fishing, is fishing for pleasure or competition and includes the for-hire industry. Saltwater recreational fishing is among the nation's favorite pastimes, and it remains a key contributor to the national economy. In 2016, recreational fishing supported 472,000 jobs and generated nearly $68 billion in sales nationally.

In 2016 Massachusetts generated the greatest economic impact in the New England region from recreational fishing: employment impacts from expenditures (10,000 jobs), sales impact ($1.1 billion) and income impacts ($495.5 million).[134] The greatest value-added impact was also generated by Massachusetts ($715.7 million). Massachusetts recorded 2.4 million trips by recreational fishermen in 2016.[135]

7.4 PORTS AND HARBORS

A report published in October 2020 by the Cape Cod Commission and the Urban Harbors Institute at the University of Massachusetts Boston sought to identify the potential economic impact of Cape Cod harbors on local businesses.[136] This report aimed to identify the potential economic impact in order to inform decisions based on harbor-related funding. Chatham, Dennis, Falmouth, and Provincetown were the towns selected for the study because of their diverse, lucrative harbors and population sizes. A survey was issued to businesses throughout the pilot towns, with questions centering on harbor dependency and possible reliance on efficient, effective harbor infrastructure. Limited survey response may have led to an undercount during economic analysis, but the data still provided a baseline for understanding the economic impact of selected harbors. Using an IMPLAN model, it was found that survey respondents directly employed 2,328 people across 58 industries, which amounts to $164 million in total direct labor income. Indirect and induced employment created 1,219 and 917.5 more openings, amounting to $53.3 million and $42.6 million in labor income, respectively. Direct employment from survey respondents added $228 million to the regional economy, along with an estimated output of $444 million. A majority of employers did not respond to the survey, meaning their addition to this analysis would increase these amounts. In terms of harbor-dependency, 46 survey respondents (49.4%) claimed they were dependent on a well-functioning harbor. Of those respondents, 32 of them stated that customers travelled to their business by boat, indicating further dependency on properly maintained harbors. Those identified harbor-dependent businesses were responsible for 80.1% of direct employment for survey respondents, with the labor income of those direct employees totaling $145.3 million and a value added of $199.5 million.

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134 Fisheries Economics of the United States. 2016. https://media.fisheries.noaa.gov/dam-migration/feus2016-report-webready4.pdf

135 Ibid.

136 https://www.capecodcommission.org/our-work/harbor-study/

An economic impact study on the Port of Boston was completed in 2018.[137] It utilized responses from telephone surveys of port tenants and firms providing services to marine terminals, cruise vessels and passengers, and seafood processing operations. Activities at Port of Boston created a total of 19,720 jobs, with 9,014 being direct, 7,531 being induced, and 3,176 being indirect. In total, $1.6 billion in personal wage and salary income was created by port activity. The 9,104 direct employees accounted for $544.2 million of this total. In terms of revenue, $1.8 billion was generated by maritime services in the Port of Boston, with $353.6 million spent on in-state purchases. State and local taxes amounted to $185.8 million, with federal taxes reaching $445.5 million. A further economic output of $5.5 billion was related to cargo activity. Significant economic growth was recorded in the Port of Boston since 2012. Total employment grew by 3,364 jobs, and direct business revenue increased by $559.2 million. The large economic output that was created by cargo activity is mirrored in its growth of jobs, where an addition of 1,397 jobs was seen since 2012. Also, 1,128 total jobs were added to the seafood processing operations, indicating the growth seen in that sector.

7.5 MARINE ENERGY INFRASTRUCTURE

The potential economic impact associated with offshore energy facilities has been estimated since the last ocean plan. The Vineyard Wind offshore wind energy project prepared an Environmental Impact Statement, that reported the possible economic impacts of the project.[138] Employment is one contributing economic factor, with temporary jobs available during construction and decommissioning, and long-term jobs available during the operation and maintenance of the offshore facilities. Locally sourced employment is planned to be used by the Vineyard Wind project, with a range of 35-55% of jobs being sourced from within the United States. It was estimated that at least 85% of direct jobs and 63% of indirect/induced jobs would originate from southeastern Massachusetts as a result of the project. Locally sourced supplies and materials are also planned to be used, with $177 million spent within Massachusetts, of which 60% are planned to be from southeastern Massachusetts. Construction jobs are predicted to be filled with mainly local labor. Job compensation (and benefits) for these employees is projected to be in the range of $88,000-$96,000. The construction of the offshore wind facility would stimulate the state's ocean economy since there is reliance on local tug and other vessel charters, dockage, fueling, inspection/repairs, and crew work. Vineyard Wind reported that the proposed project may have minor impacts on recreation, tourism, and commercial fisheries in the area, which would entail minor indirect economic impacts. A minor beneficial impact on employment is expected. During the operation and maintenance of the facility, direct jobs last for the lifespan of the project (up to 30 years). Similar employment and economic impacts are seen when comparing construction and decommissioning. Vineyard Wind has Host Community Agreements (HCAs) set up with the towns of Barnstable and Yarmouth and has established the Windward Workforce Program for recruiting local employment. The Offshore Wind

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[137] https://www.massport.com/media/3213/massport_final_report_6-03-2019-report-final.pdf
[138] https://www.boem.gov/vineyard-wind

Industry Accelerator Fund and the Resiliency and Affordability Fund were also set up to garner interest and support for investments in ports, manufacturing facilities, technology development for offshore wind, clean energy projects, and coastal energy resiliency.

Two areas for commercial-scale wind projects—one located off Gosnold Island and one located off Martha's Vineyard—were included in the first ocean plan and carried forth in the 2015 ocean plan. Due to several factors, the 2021 ocean plan eliminated the Gosnold and Martha's Vineyard Wind Energy Areas. The 2015 ocean plan called for an evaluation of their status as designated Wind Energy Areas, in part because the 2012 Wind Energy Plan for Dukes County designated exclusionary areas within large sections of the Gosnold and Martha's Vineyard Wind Energy Areas. The Martha's Vineyard Commission (MVC) has legal authority under the Oceans Act to define the appropriate scale of offshore renewable energy projects within its jurisdiction. Given the restrictions of the MVC's county wind plan, the availability of new data and information, and stakeholder concerns expressed during the review of the 2014 draft ocean plan, the 2015 ocean plan acknowledged that commercial-scale wind energy projects are not suitable for these areas. In addition, advances in offshore wind technology have made it possible to site large and efficient turbines farther from land where they can capture greater wind resources at longer durations than at locations closer to shore. Thus, these two areas were unlikely to be developed by the offshore wind industry.

A tidal energy test structure was permitted for the Cape Cod Canal in 2016 and installed on U.S. Army Corps of Engineers property in late 2017. The platform has been used by several instrumentation developers to test sensors for current velocity and environmental conditions. The first tidal turbine to be tested will be a twin turbine system cross flow design from Aegis. As part of this test and to validate the site monitoring plan, University of Massachusetts Dartmouth researchers will use an acoustic camera to determine how fish interact with the turbines.

Chapter 8 – Climate Change

8.1 SEA TEMPERATURE CHANGE

Data from the Massachusetts A01 Buoy, obtained from NERACOOS, remains the strongest source of continuous surface and bottom sea temperature data for areas north of Cape Cod with a time series spanning from 2001-2020. Over this time period there was a notable maximum in the winter sea surface temperature of bottom waters (45.6˚F) in 2015 (Figure 42). Another maximum was recorded in 2016 for annual sea bottom temperature (45.8˚F) for the entire time series (Figure 43). Until a longer continuous time series becomes available for northern Massachusetts waters, long-term trends cannot be confidently described.

8.2 CHANGES IN PRECIPITATION

Annual rainfall data since 1855, as compiled by DCR[139], show an increasing trend in the past three decades that has not been seen since the 1850s-1880s (Figure 44). Since the 1990s, annual rainfall has exceeded the long term mean of 44.0 inches/year. The 2000s experienced the maximum for the entire time series (48.9 inches/year), closely followed by the 2010s (47.4 inches/year). The 1850s-1880s are the only other continuous stretch of decades that exceeded the long-term mean.

The increases in precipitation are also evident in the patterns of river flow reported at the USGS river gauges for the Merrimack and Charles rivers.[140] The Merrimack and Charles rivers are the two largest rivers that discharge into the planning area. Since the 1970s, average decadal flow for the Merrimack River has exceeded the mean of 7963 cubic feet per second (cfs), with the average flow in the 2000s representing the maximum for the time series (9386 cfs) (Figure 45). A similar pattern is seen in the Charles River, with the 2000s registering the maximum (354 cfs) for that time series (Figure 46).

8.3 SEA LEVEL RISE

NOAA tide gauges in Boston Harbor, Woods Hole, and Nantucket Island record long-term location-dependent levels of sea level rise.[141] The tide gauge in Boston Harbor reported an increase in sea level of about 2.87 mm/year (0.113 inches/year) since 1921 (Figure 47) which equates to 0.94 feet per 100 years. The stations in Woods Hole and Nantucket Island reported similar long-term increases in sea level since 1965 of 2.95 mm/year (0.116 inches/year) and 3.79 mm/year (0.149

[139] https://www.mass.gov/info-details/water-data-tracking ; https://w2.weather.gov/climate/xmacis.php?wfo=box
[140] https://waterdata.usgs.gov/ma/nwis/current/?type=flow&group_key=huc_cd&site_no_name_select=siteno
[141] https://tidesandcurrents.noaa.gov/map/index.html

inches/year), respectively. These rates equate to 0.97 and 1.24 feet per 100 years, respectively (Table 11).

Table 11. Mean sea level trends for NOAA's Massachusetts tide gauges at Boston Harbor, Woods Hole, and Nantucket Island

Station	Mean sea level trend and 95% confidence interval		Time Period
	(millimeter/year)	(inch/year)	
Boston, MA	2.87 ± 0.15	0.113 ± 0.006	1921-2020
Woods Hole, MA	2.95 ± 0.17	0.116 ± 0.0067	1932-2020
Nantucket Island, MA	3.79 ± 0.33	0.149 ± .013	1965-2020

8.4 CHANGES IN WIND PATTERNS

Wind speeds appear to be increasing in Massachusetts Bay. Over a 20-year period from 2001-2020, the six-year period from 2015-2020 had the highest average monthly wind speeds during all months but June and December at the Massachusetts A01 buoy. The highest average wind speeds in January, February, and October were in 2015; the highest average wind speed in March was in 2017; the highest average wind speeds in October and November were in 2018; and the highest average wind speeds in April, May, July, August, and September were in 2020 (Figure 48). To date, 2021 appears to be an average year in terms of wind speed.

8.5 INCREASING FREQUENCY AND INTENSITY OF STORMS

Between 2017 and 2019, the New England region saw three high wind events associated with extratropical cyclones in October and November that caused significant damage. Storms developing in this time of the year in New England are unique in that they have predominantly cold-weather characteristics yet can also be fueled by warm-season moisture, causing some to propose that they might become more frequent as fall temperatures continue to increase over time. Researchers found no significant increase in frequency or intensity of mid-autumn windstorms from 1979 to 2019 in relation to their central pressure or wind speeds but did find a significant positive relationship between increasing precipitation and 10-meter height wind gusts greater than 58 miles per hour.[142]

8.6 OCEAN ACIDIFICATION

See pH subchapter in Chapter 2 (pg. 6).

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142 https://doi.org/10.1002/met.1952

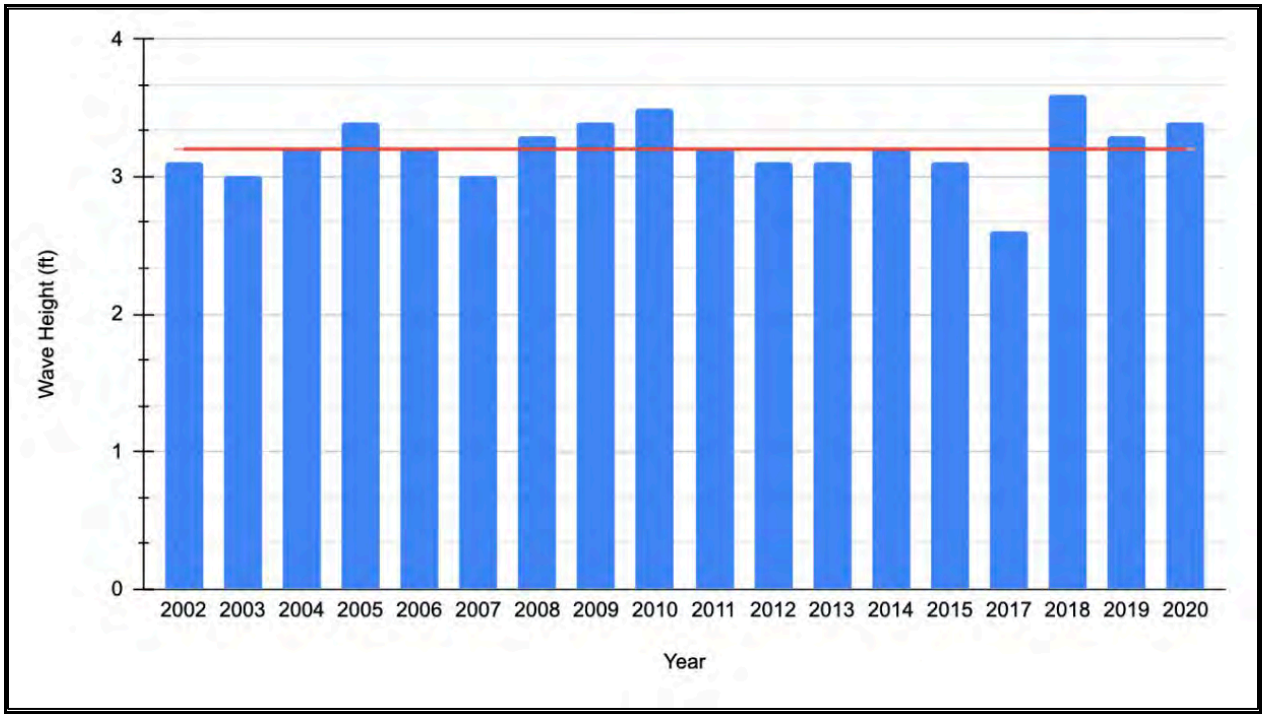

Figure 1. Annual mean wave height (feet) at the Massachusetts Bay A buoy.[143] The red line represents the 2002-2020 mean of 3.2 feet. There was no wave height data for the buoy during 2016 or the first half of 2017.

[143] http://neracoos.org/datatools/historical/graphing_download

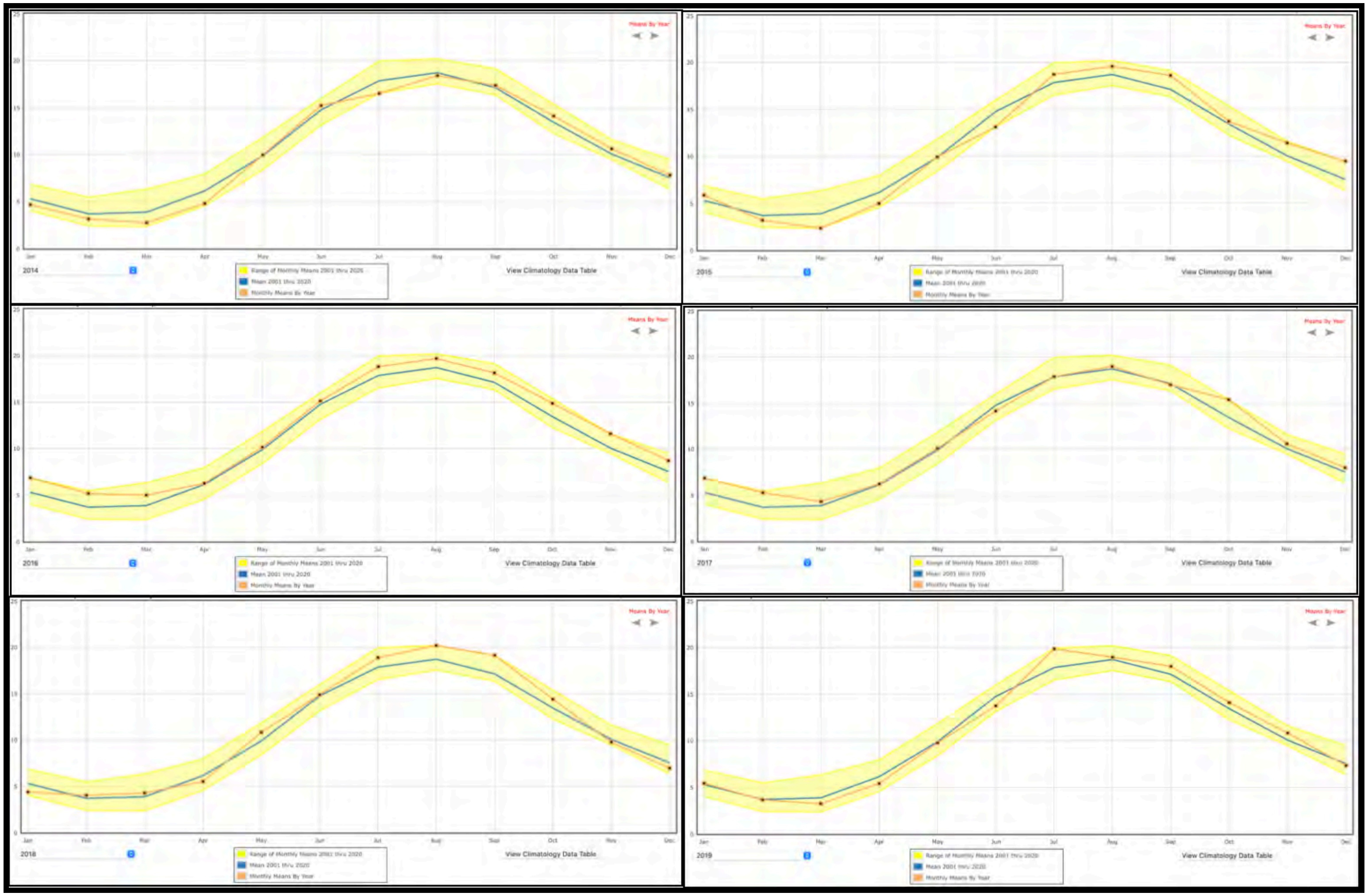

Figure 2. Monthly sea surface temperatures (˚C) at Mass. Bay A buoy from 2014 (top left) to 2019 (bottom right).[144] The yellow shading is the range of temperatures from 2001-2020, and the blue line is the mean of the time series. The orange dots represent monthly averages for the respective years.

[144] http://neracoos.org/datatools/climatologies_display

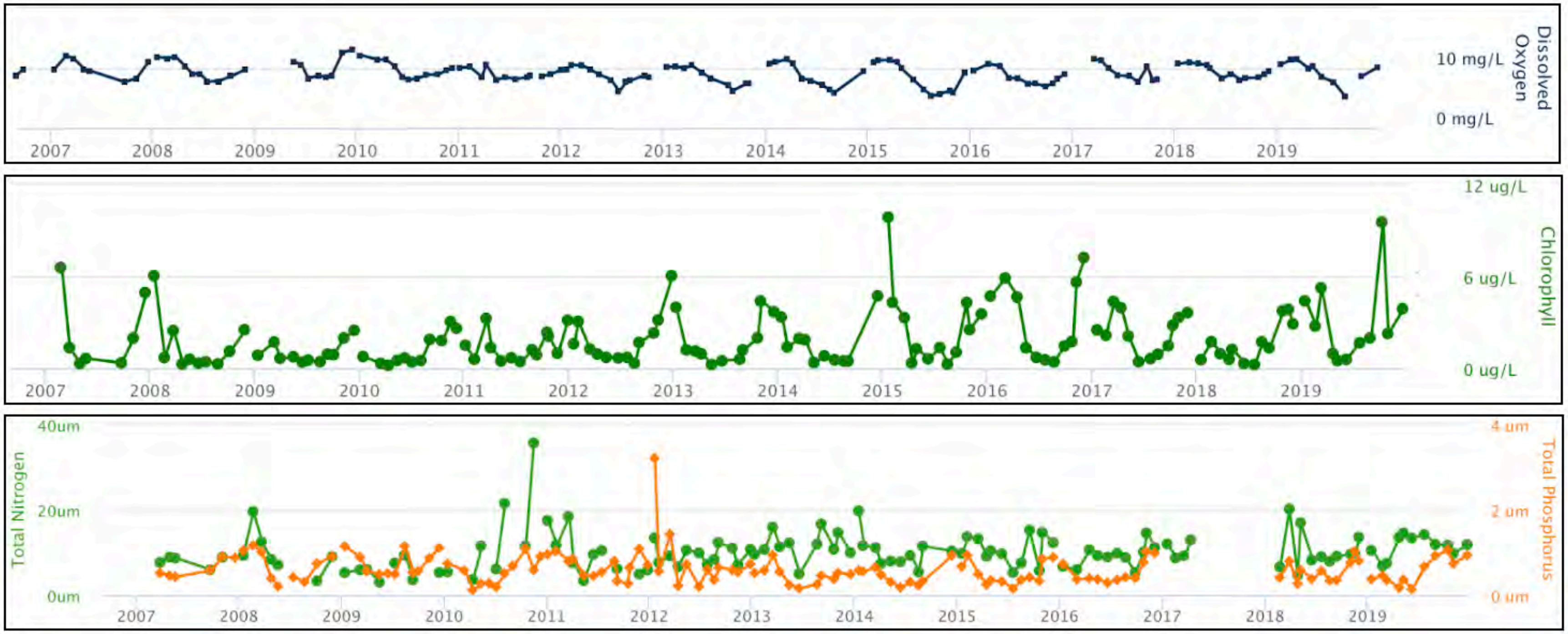

Figure 3. Dissolved oxygen (top), chlorophyll a (middle), and total nitrogen/total phosphorus (bottom) from the Center for Coastal Studies 7S station in Cape Cod Bay, August 2006 - December 2019.[145] In the bottom graph, nitrogen is green, and phosphorus is orange.

[145] http://www.capecodbay-monitor.org

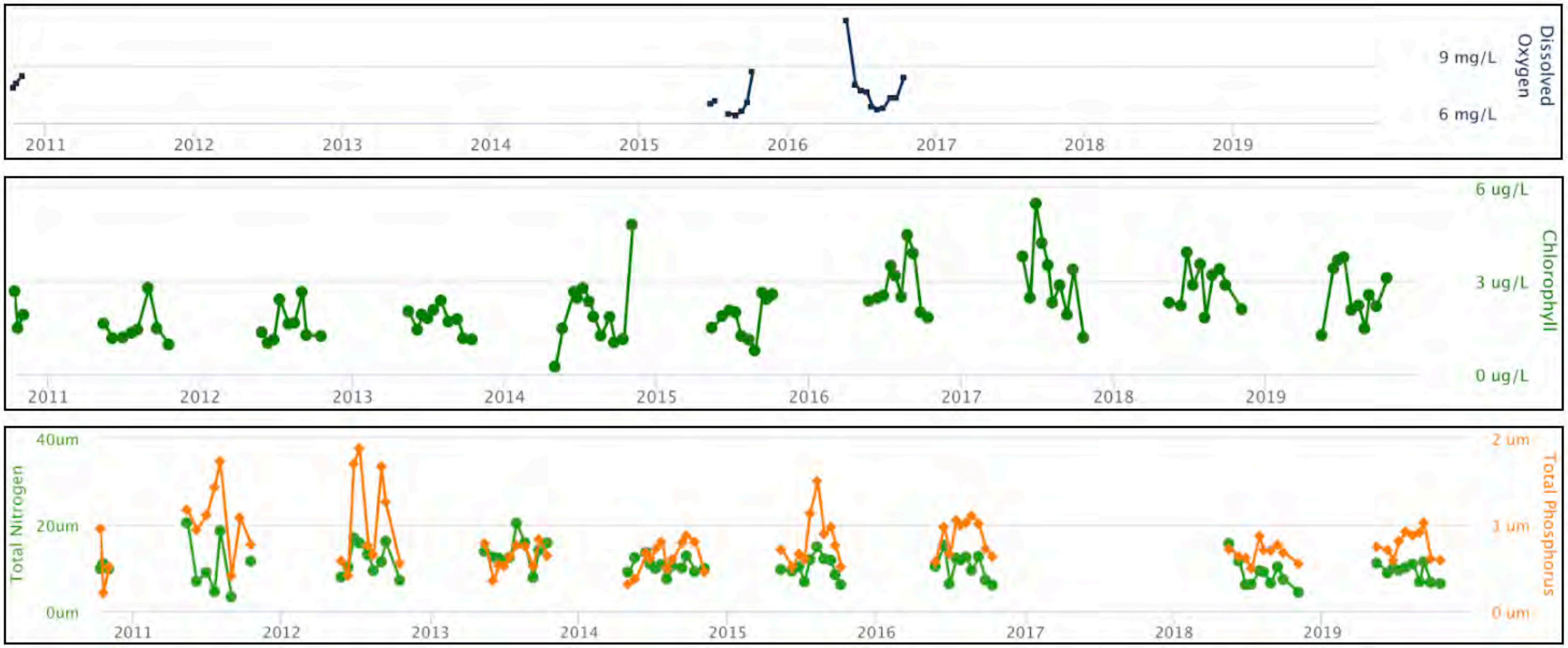

Figure 4. Dissolved oxygen, chlorophyll a, and total nutrients (total nitrogen/total phosphorus) from the Center for Coastal Studies NTKS_6 station in Nantucket Sound, October 2011 - December 2019.[146] Despite lacking dissolved oxygen data, NTKS_6 occupied a similar location within Nantucket Sound when compared to the 7S station in Cape Cod Bay. In the bottom graph, nitrogen is green, and phosphorus is orange.

[146] http://www.capecodbay-monitor.org

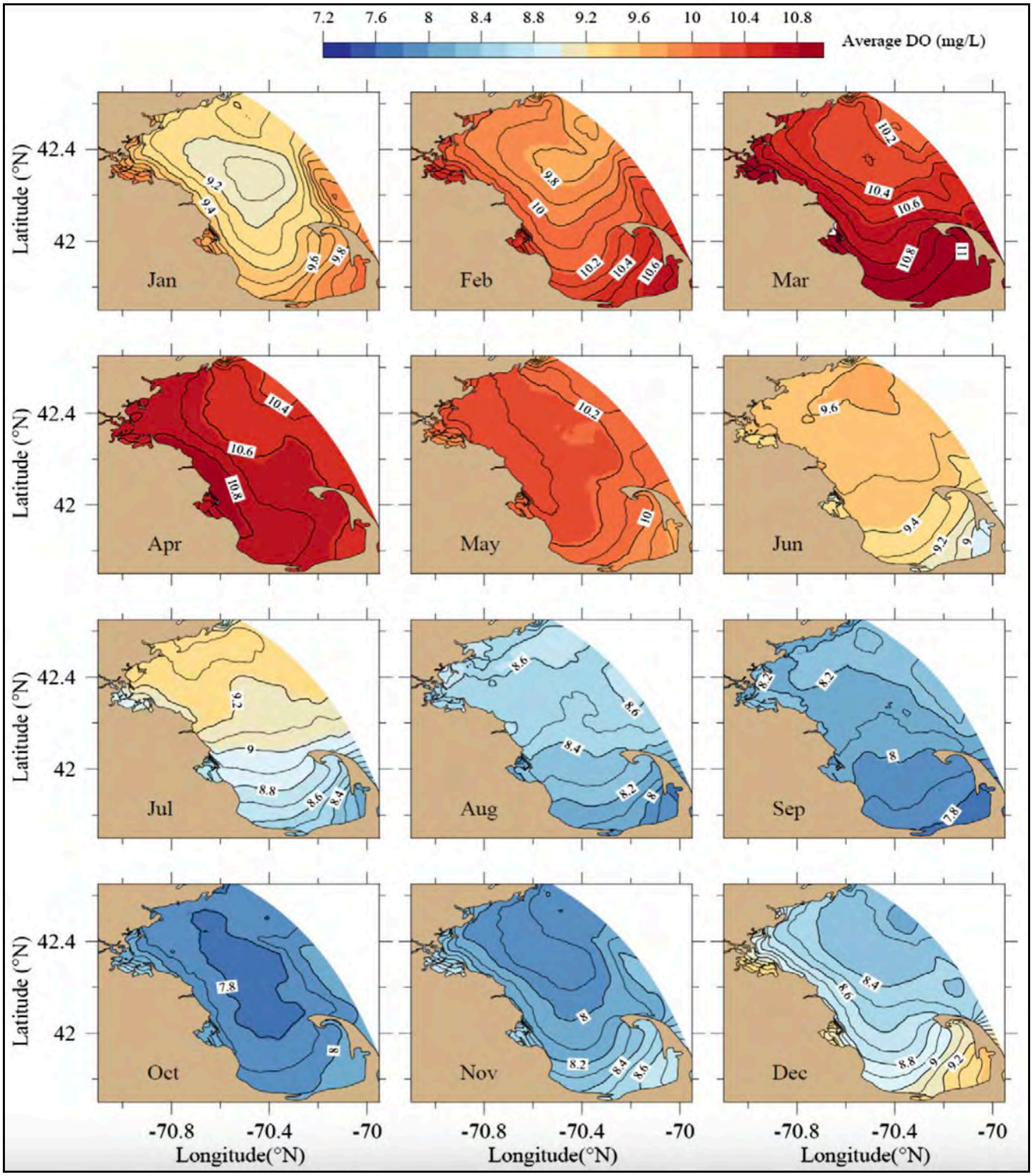

Figure 5. Vertically averaged, monthly mean dissolved oxygen concentration in Massachusetts Bay from 1995-2010.[148]

148 Xue P., Chen C., Qi J., Beardsley RC., Tian R., Zhao L., Lin H. 2013. Mechanism studies of seasonal variability of dissolved oxygen in Mass Bay: A multi-scale FVCOM/UG-RCA application. *Journal of Marine Systems* 131, 102-119. http://dx.doi.org/10.1016/j.jmarsys.2013.12.002

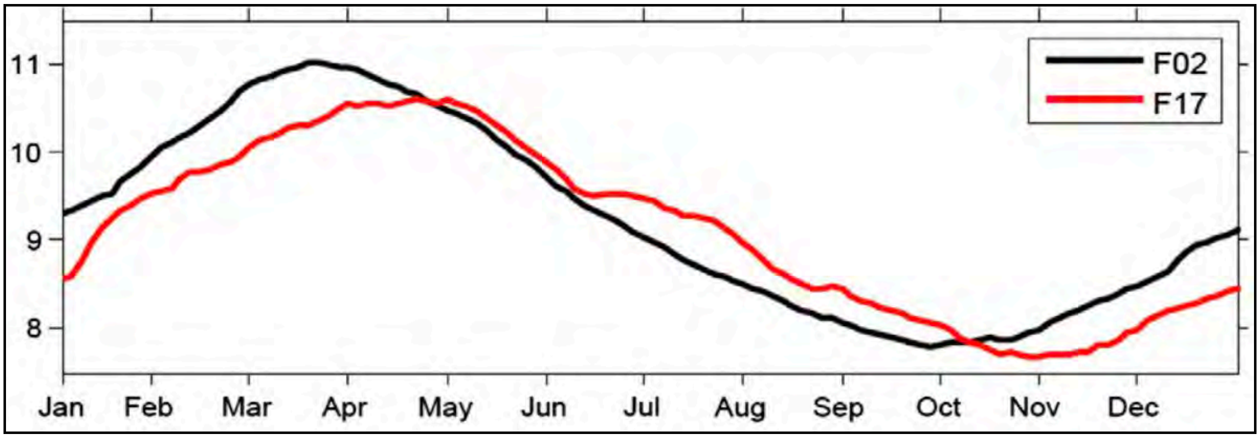

Figure 6. Vertically averaged, monthly means of dissolved oxygen concentration at the Center for Coastal Studies northern Massachusetts Bay station (F17, red line) and the southern Cape Cod Bay station F02 (black line).[149]

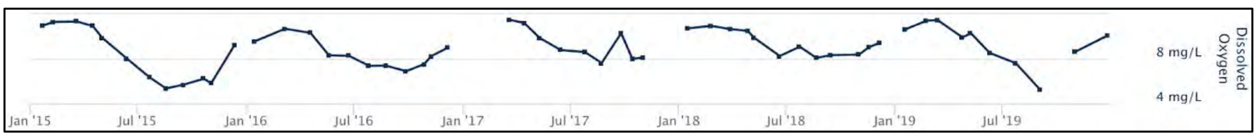

Figure 7. Dissolved oxygen concentration from 2015-2019 at the Center for Coastal Studies station 7S in Cape Cod Bay. Dissolved oxygen concentration decreased significantly in September 2019.[150]

[149] Xue P., Chen C., Qi J., Beardsley RC., Tian R., Zhao L., Lin H. 2013. Mechanism studies of seasonal variability of dissolved oxygen in Mass Bay: A multi-scale FVCOM/UG-RCA application. *Journal of Marine Systems* 131, 102-119. http://dx.doi.org/10.1016/j.jmarsys.2013.12.002

[150] http://www.capecodbay-monitor.org

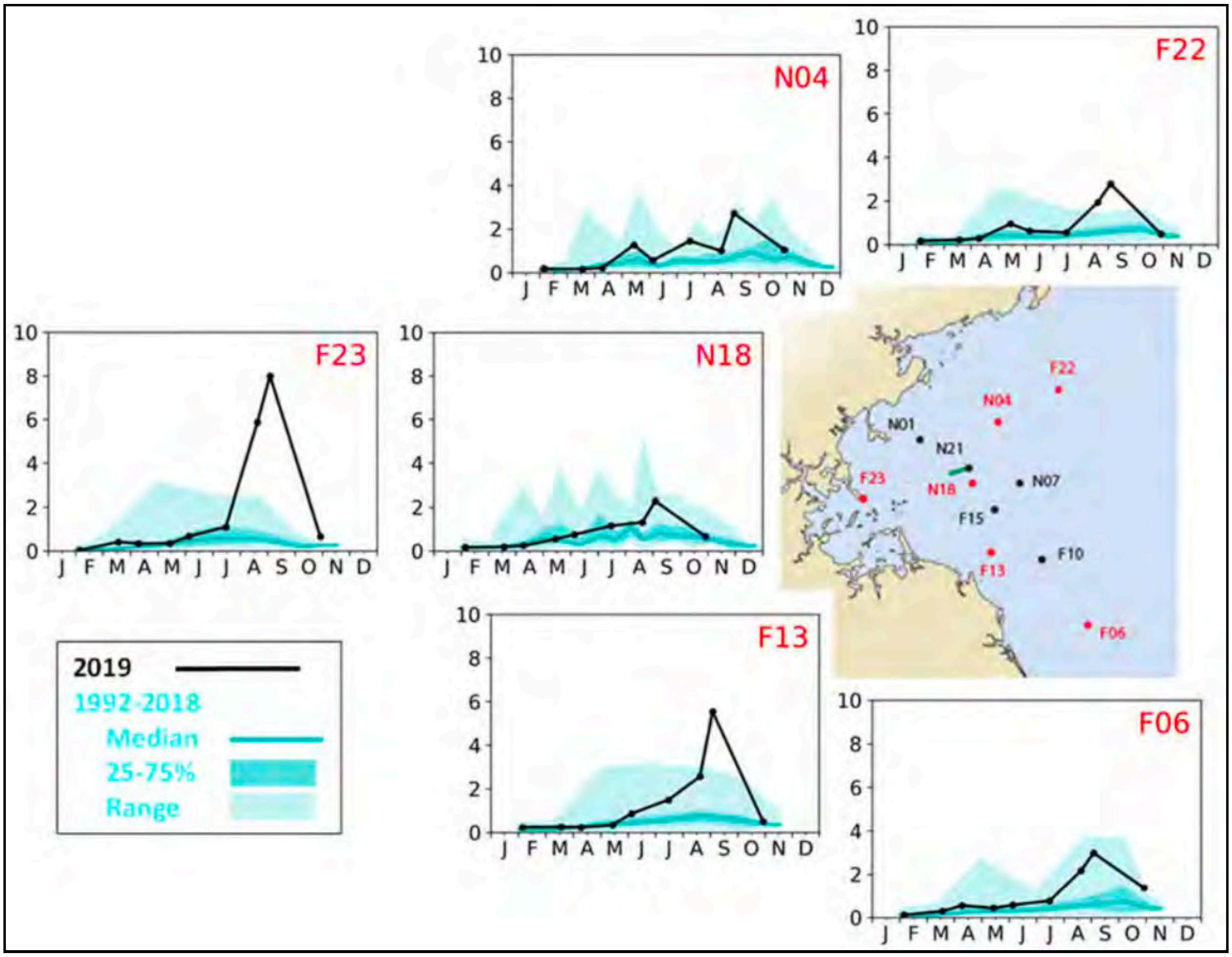

Figure 8. Total dinoflagellate concentration (100,000 cells per liter) at MWRA near field (N) and far field (F) monitoring stations in 2019, compared to the 1992-2018 median concentration and range.[151] The black line is the 2019 results, while the blue line is the median of the data from 1992-2018 and the blue shaded area is the range over the same time period. The inset map identifies the monitoring station locations.

151 https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; pg. 21

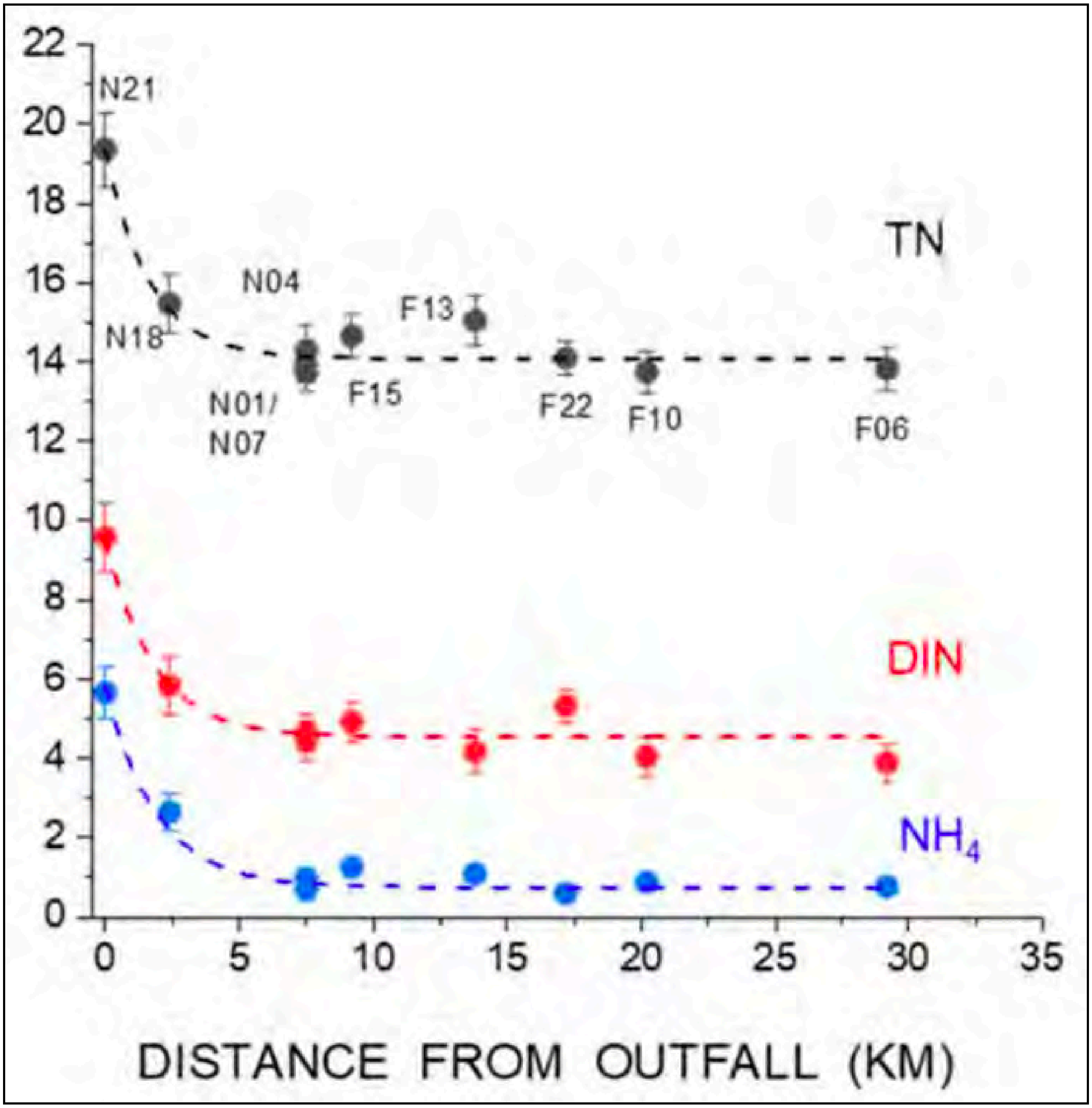

Figure 9. Depth-averaged total nitrogen concentrations (µM) as a function of distance from the MWRA outfall.[152] Total nitrogen and monitoring stations are in black, dissolved inorganic nitrogen (DIN) is in red, and ammonium (NH_4) is in blue. The error bars are 95% confidence limits.

[152] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf; pg. 46

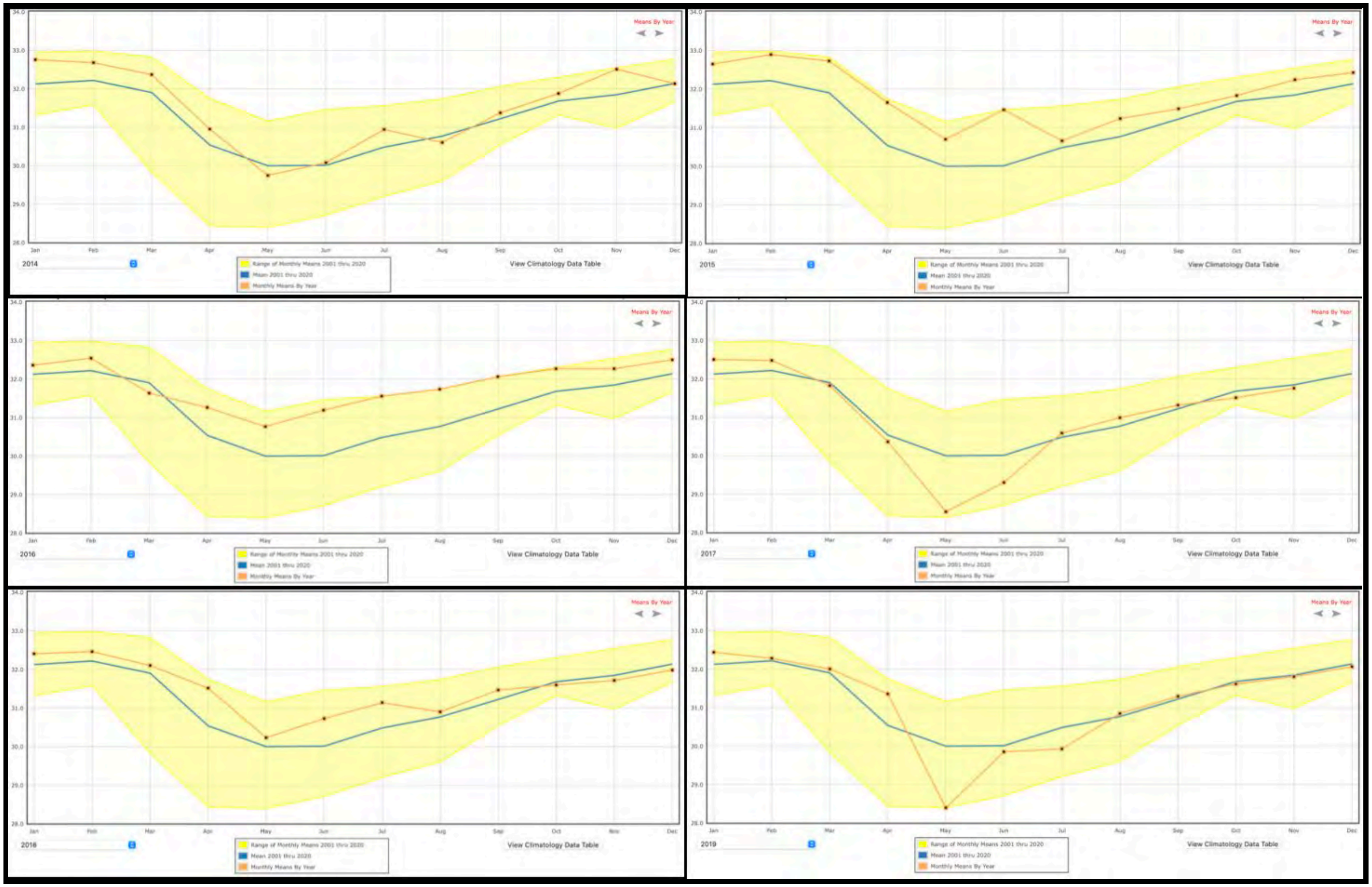

Figure 10. Monthly surface salinity (psu) at the Massachusetts Bay A01 buoy from 2014 (top left) to 2019 (bottom right).[153] The yellow shading is the range of salinities from 2001-2020, and the blue line is the mean while the orange dots represent monthly averages for the respective years.

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153 http://neracoos.org/datatools/climatologies_display

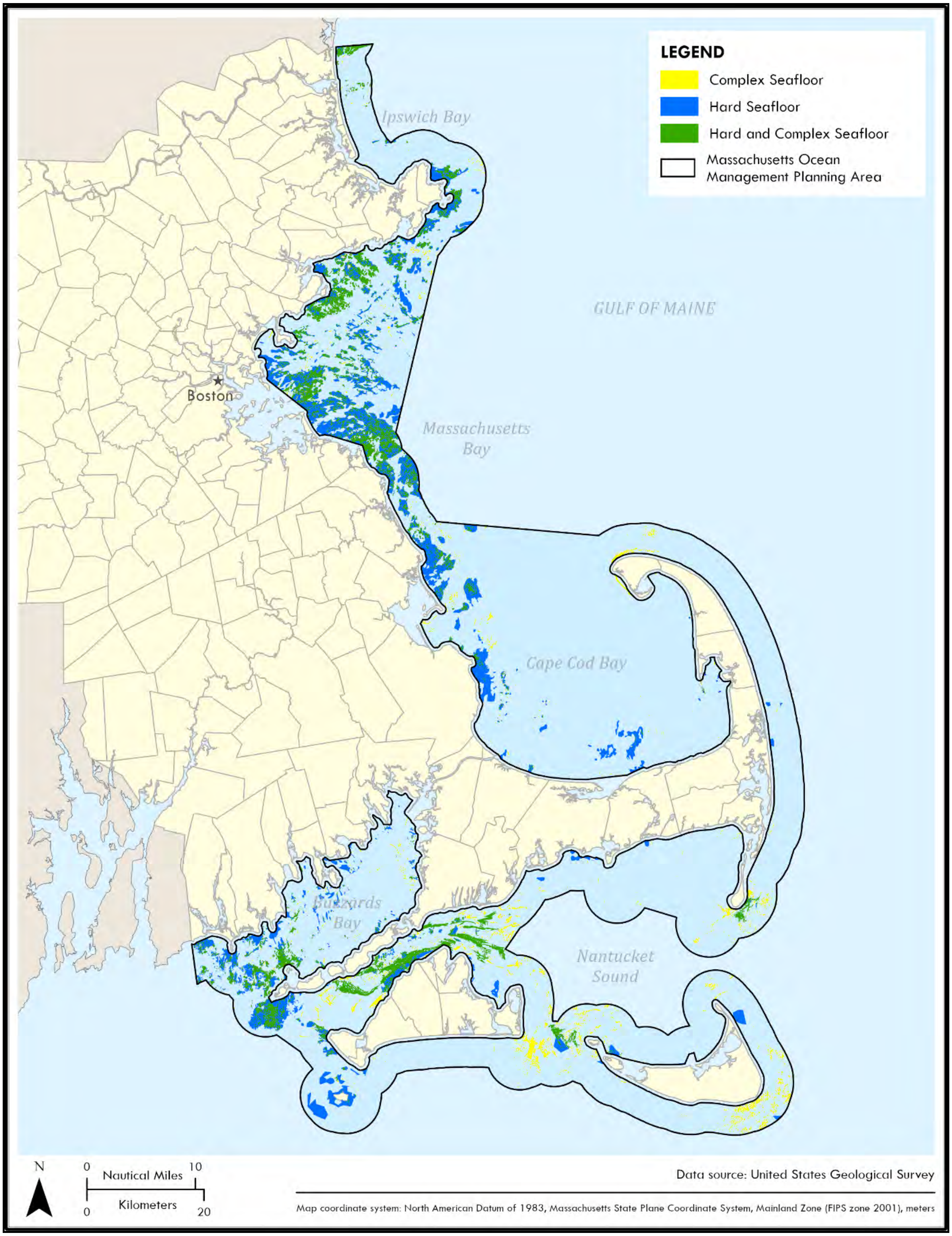


Figure 11. Hard/complex seafloor in the ocean management planning area.

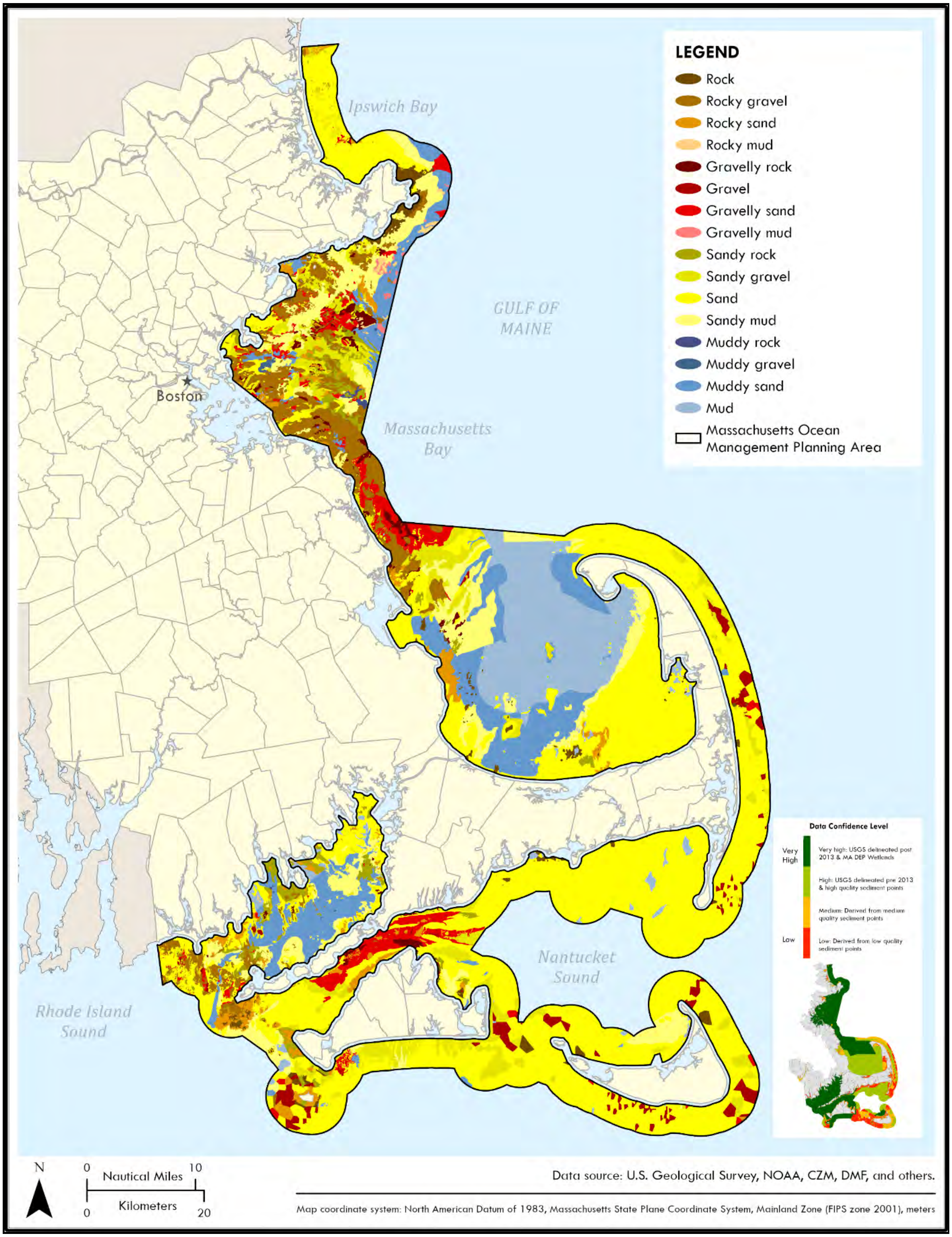


Figure 12. Surficial sediment map for Massachusetts waters.

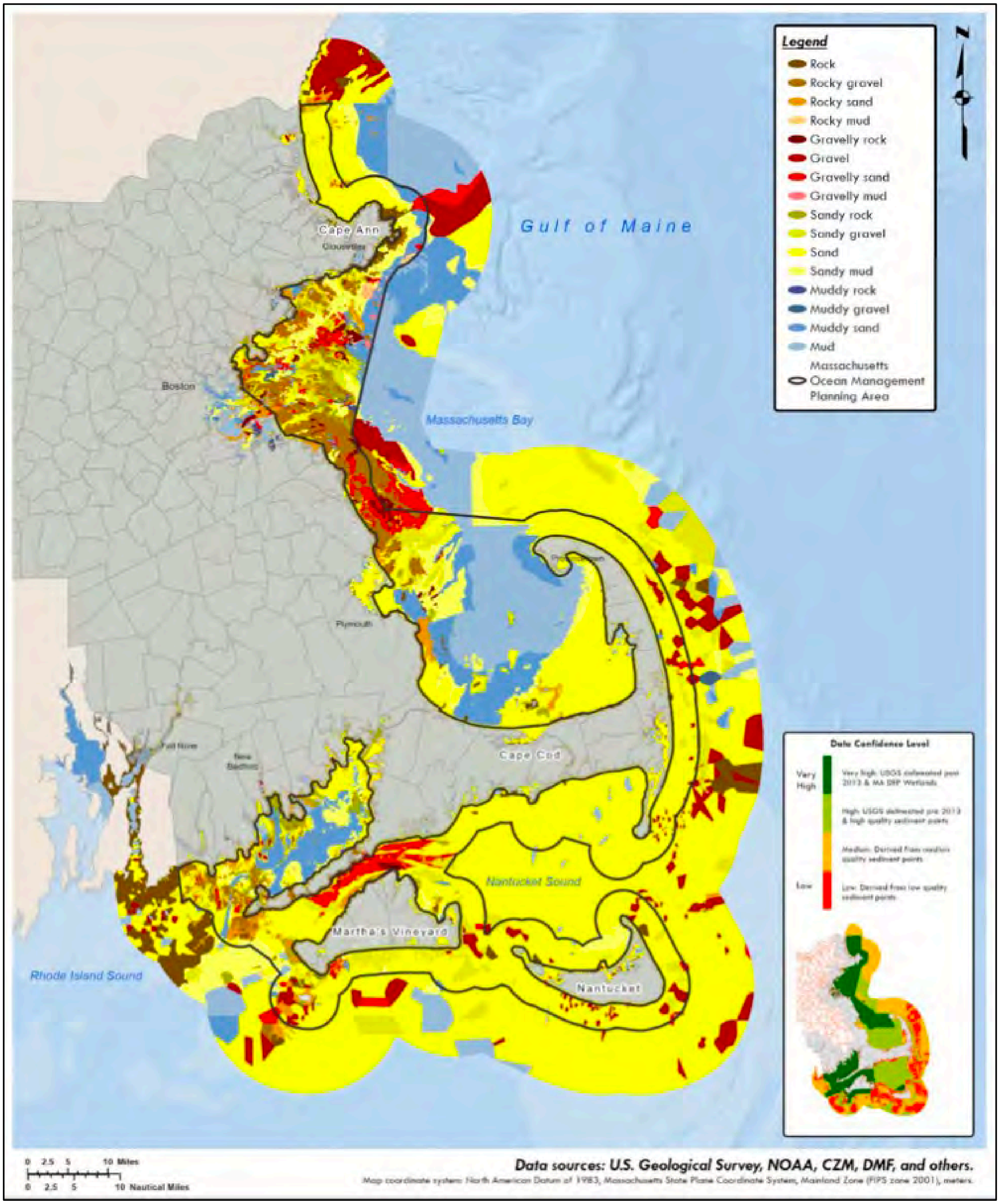


Figure 13. Surficial sediment map out to 10 nautical miles from the Massachusetts coastline.

Figure 14. Five study areas for possible sand extraction within the Massachusetts ocean planning area.

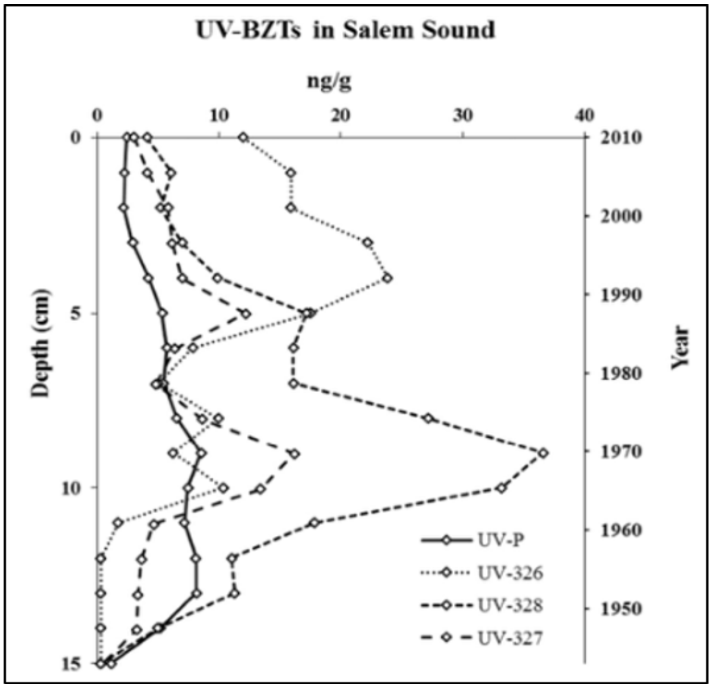


Figure 15. UV-BZT levels in Salem Sound.[154]

[154] Cantwell, M.G., Sullivan, J.C., Katz, D.R., Burgess, R.M., Hubeny, J.B., King, J. 2015. Source determination of benzotriazoles in sediment cores from two urban estuaries on the Atlantic Coast of the United States. *Marine Pollution Bulletin* 101(1), 208-218. http://dx.doi.org/10.1016/j.marpolbul.2015.10.075

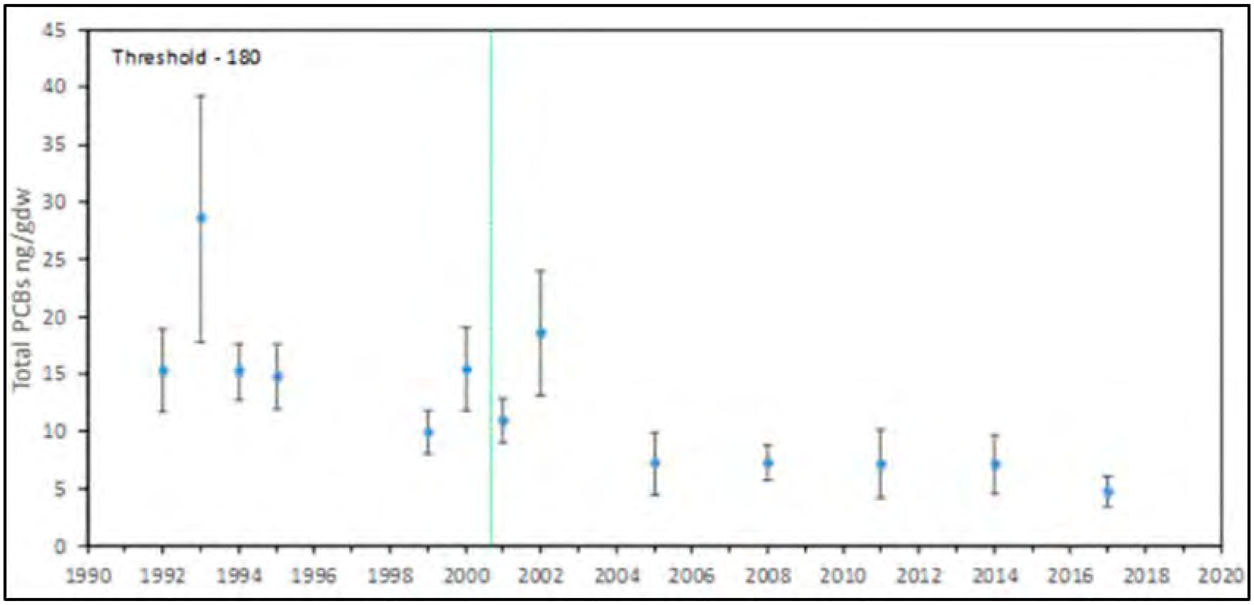


Figure 16. Average PCB concentrations collected by MWRA in sediments at its nearfield stations, 1992-2017.[155] Error bars are +/- one standard deviation. The green line signifies the startup of the MWRA Massachusetts Bay outfall.

[155] https://www.mwra.com/harbor/enquad/pdf/2020-11.pdf ; pg. 52

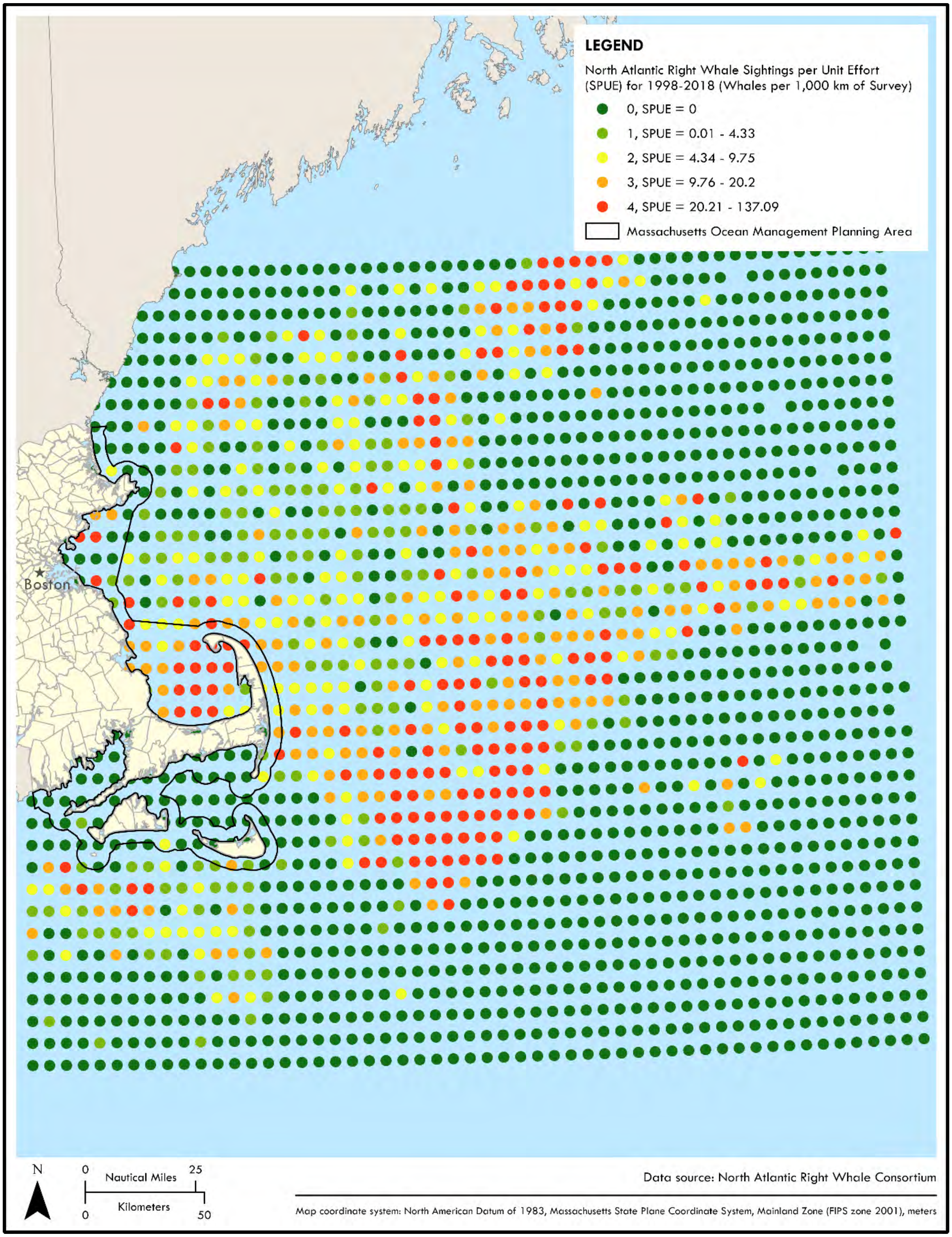


Figure 17. North Atlantic right whale Sightings Per Unit Effort (SPUE) data (1998-2018), classified into five quantiles and assigned to the centroids of 5-minute x 5-minute grids.

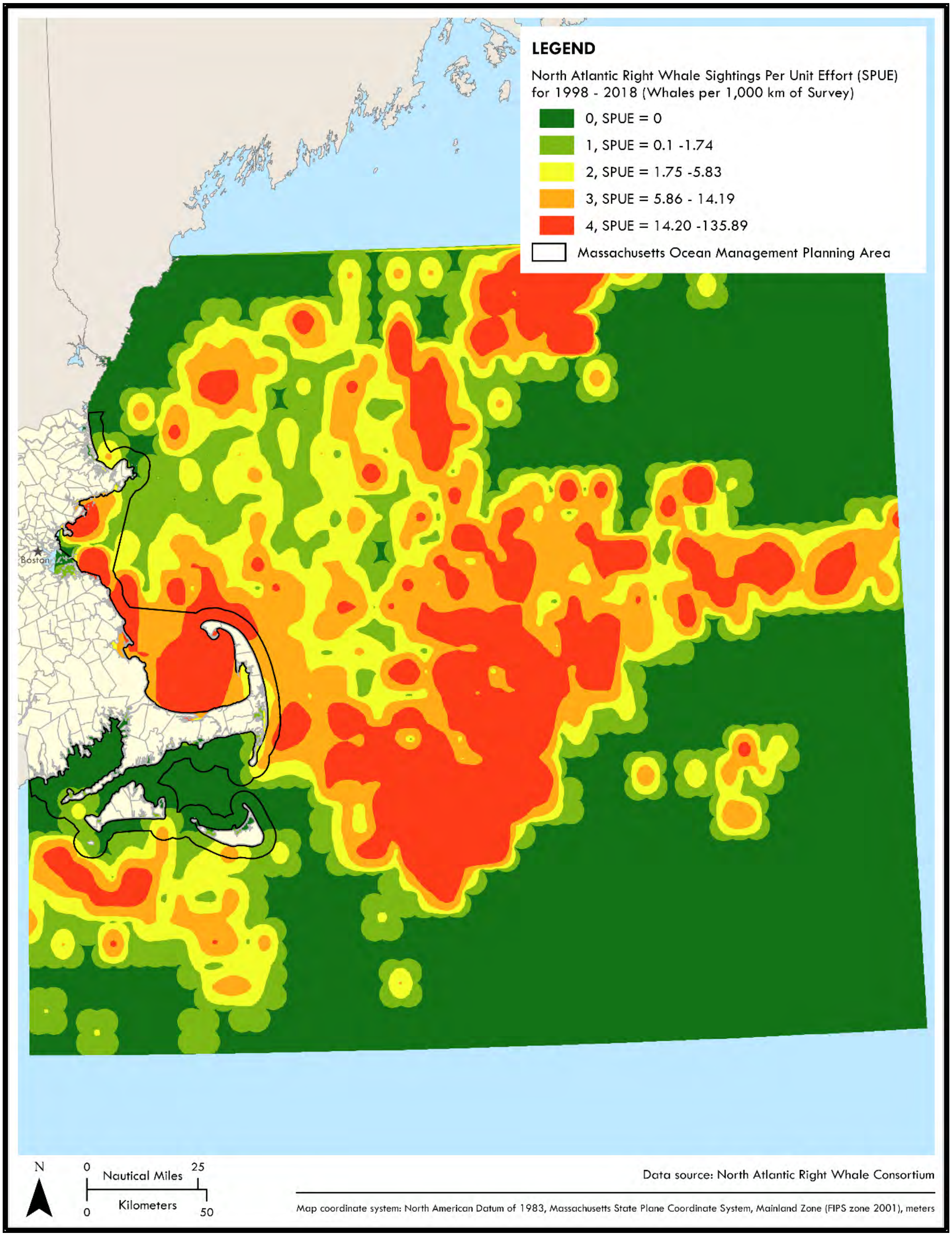


Figure 18. North Atlantic right whale interpolated Sightings Per Unit Effort (SPUE) data (1998-2018).

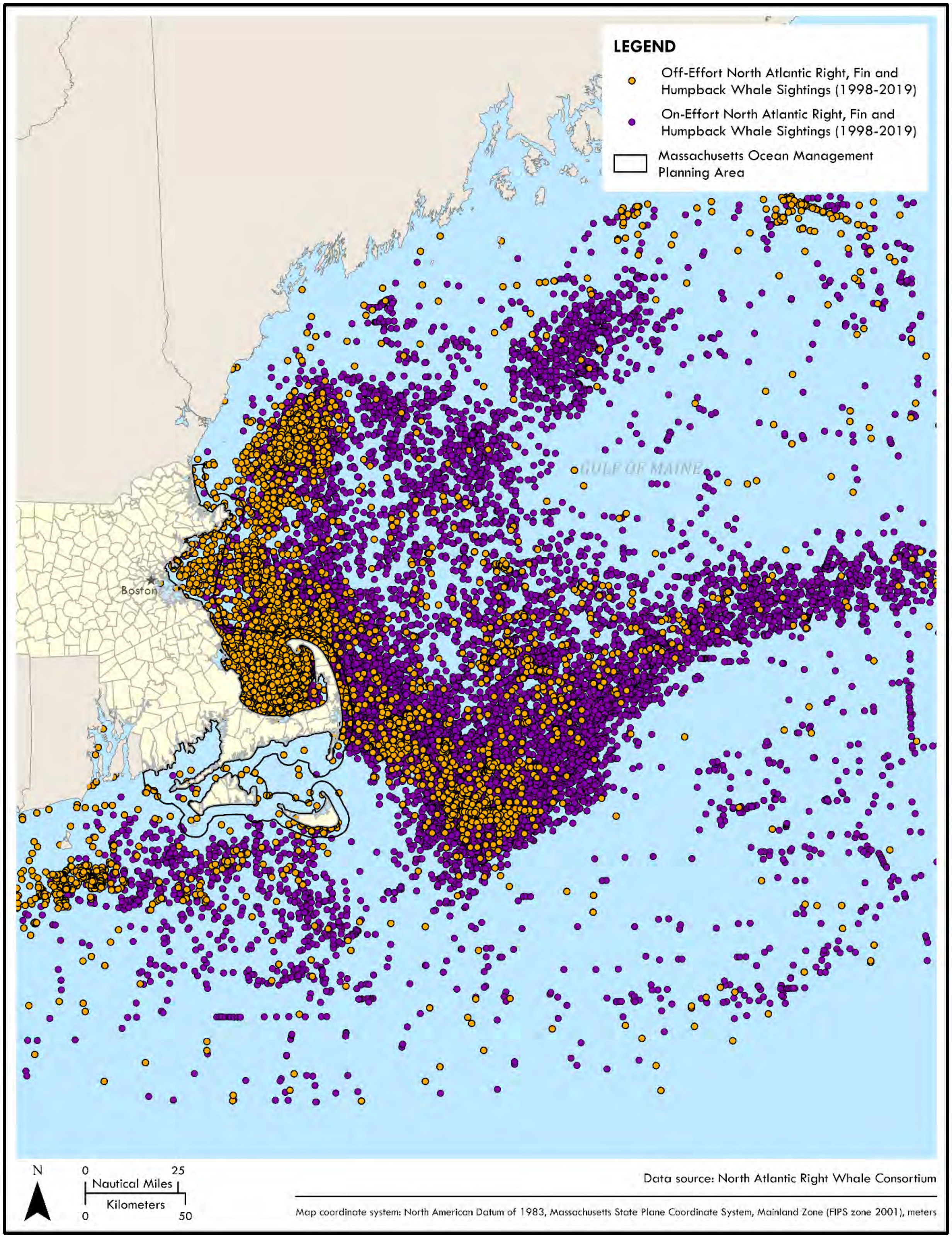


Figure 19. On-effort (purple) and off-effort (orange) sightings of North Atlantic right, fin, and humpback whales (1998-2019).

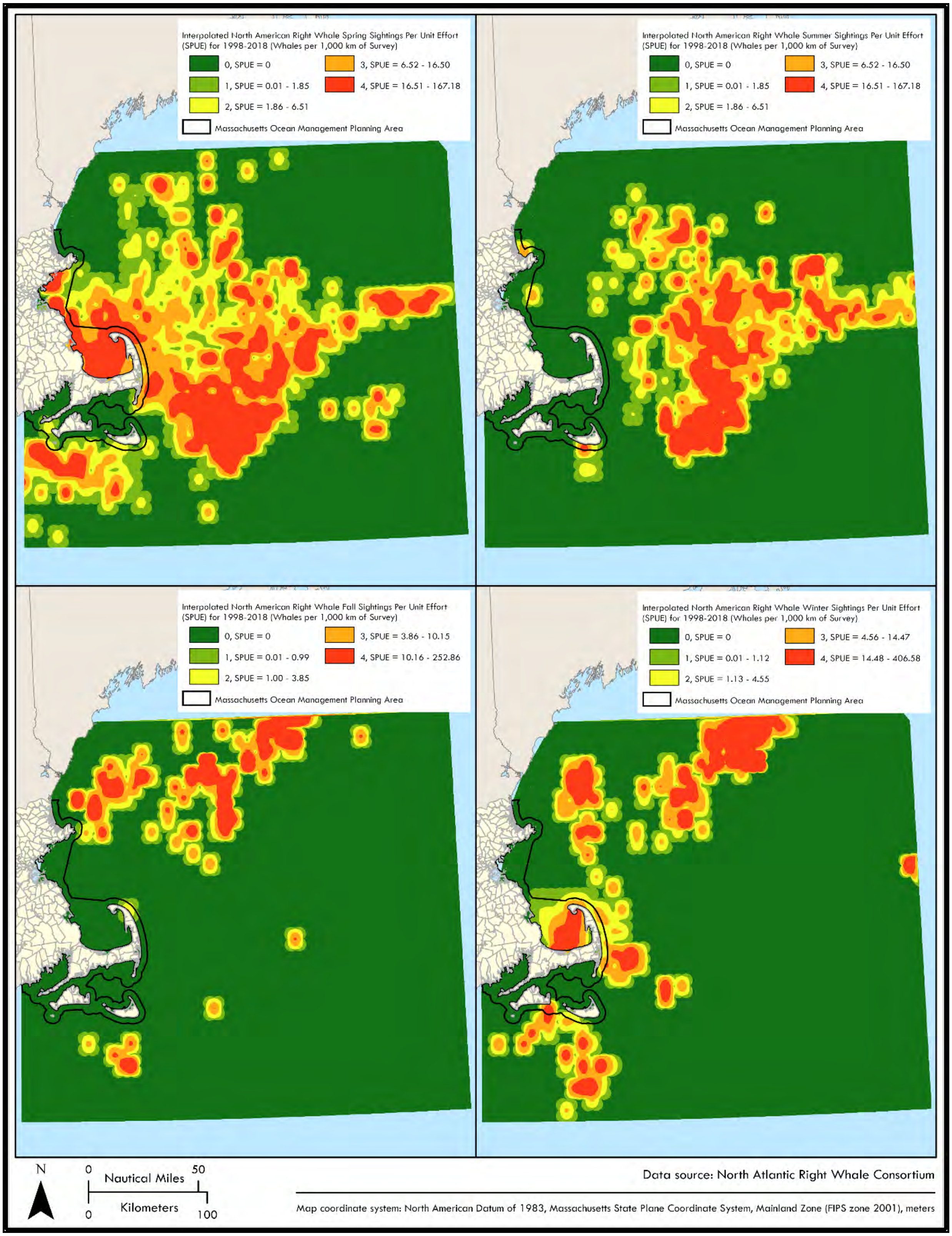


Figure 20. Sightings Per Unit Effort of North Atlantic right whales (1998-2018) by season (spring, summer, winter, fall).

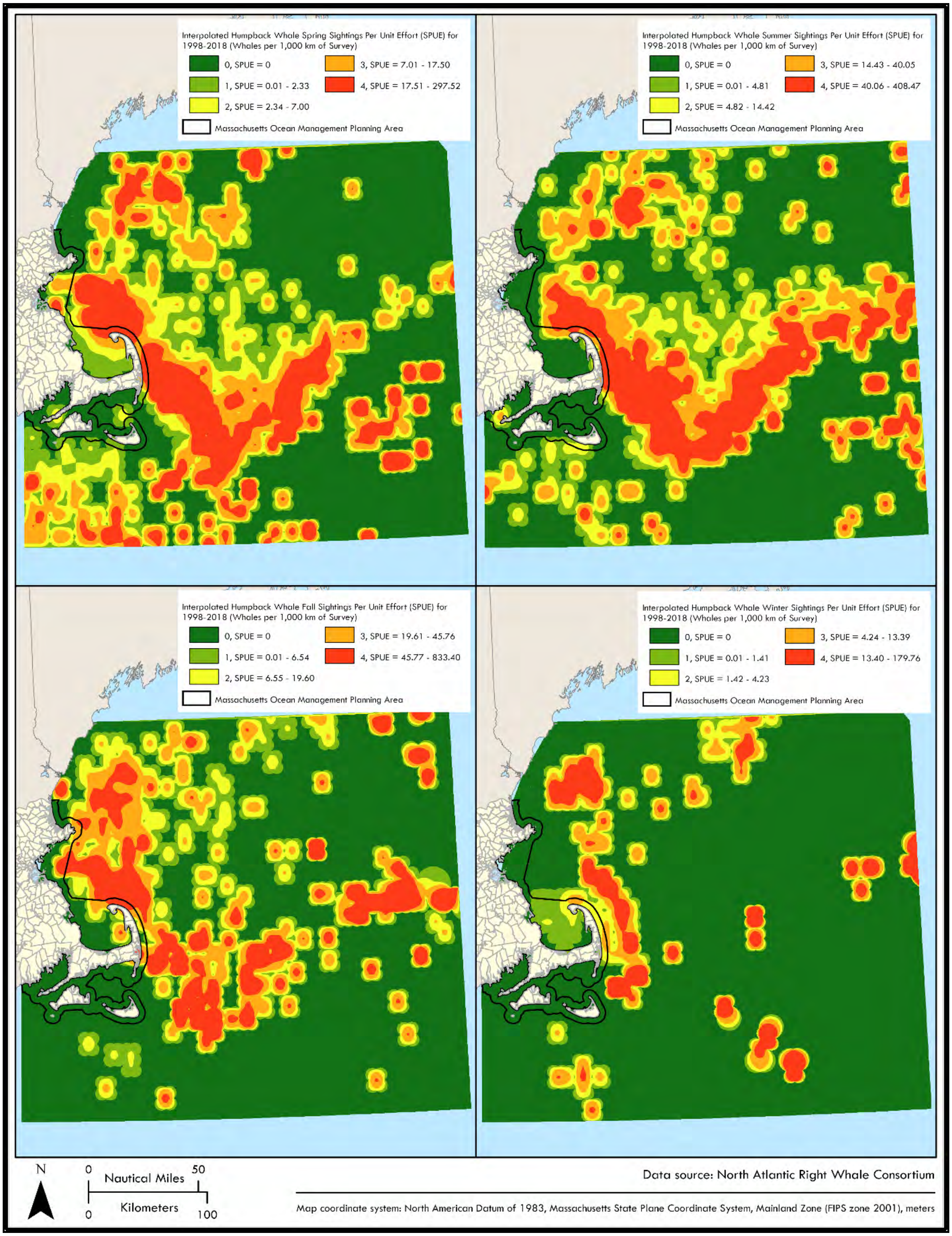


Figure 21. Sightings Per Unit Effort of humpback whales (1998-2018) by season (spring, summer, winter, fall).

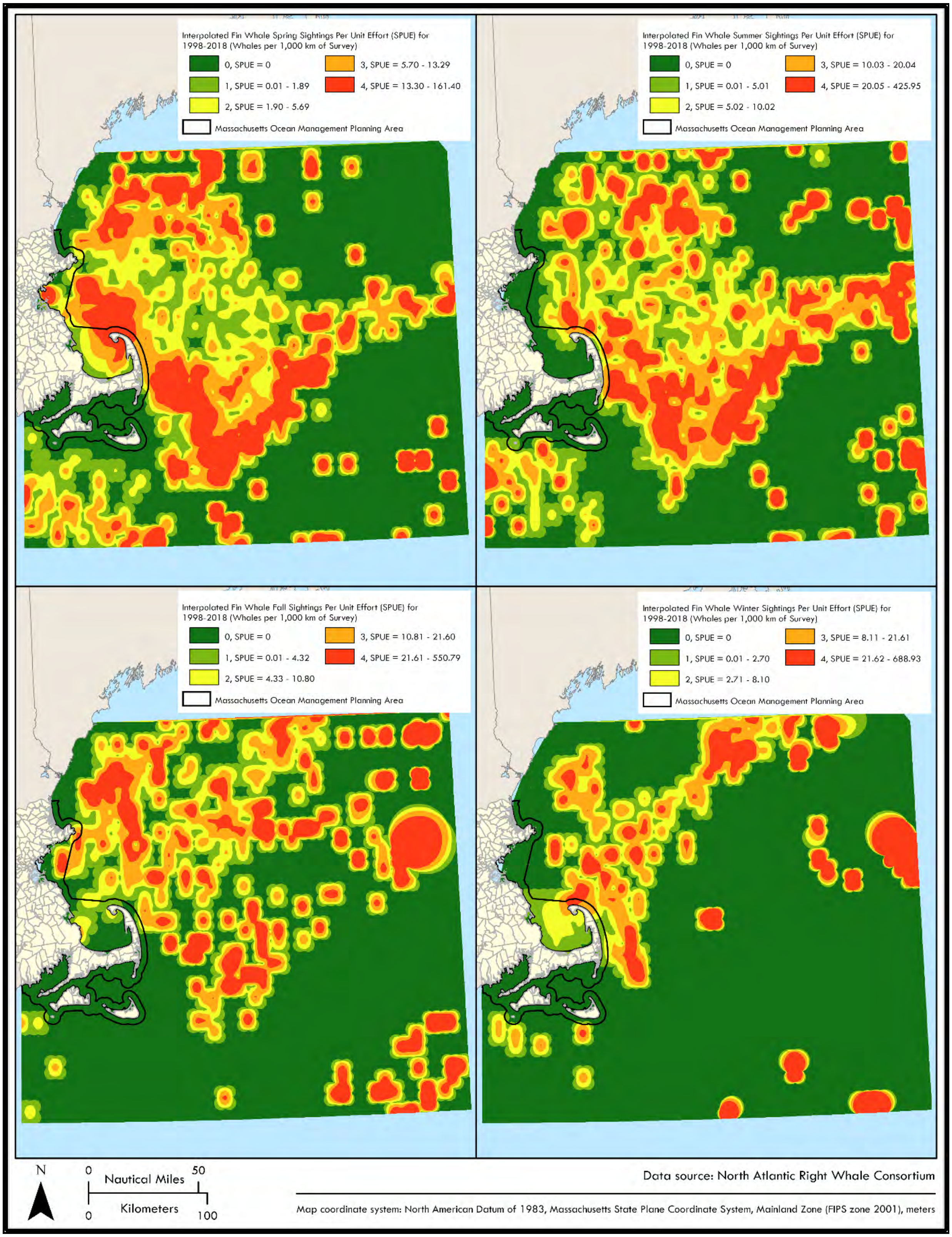


Figure 22. Sightings Per Unit Effort of fin whales (1998-2018) by season (spring, summer, winter, fall).

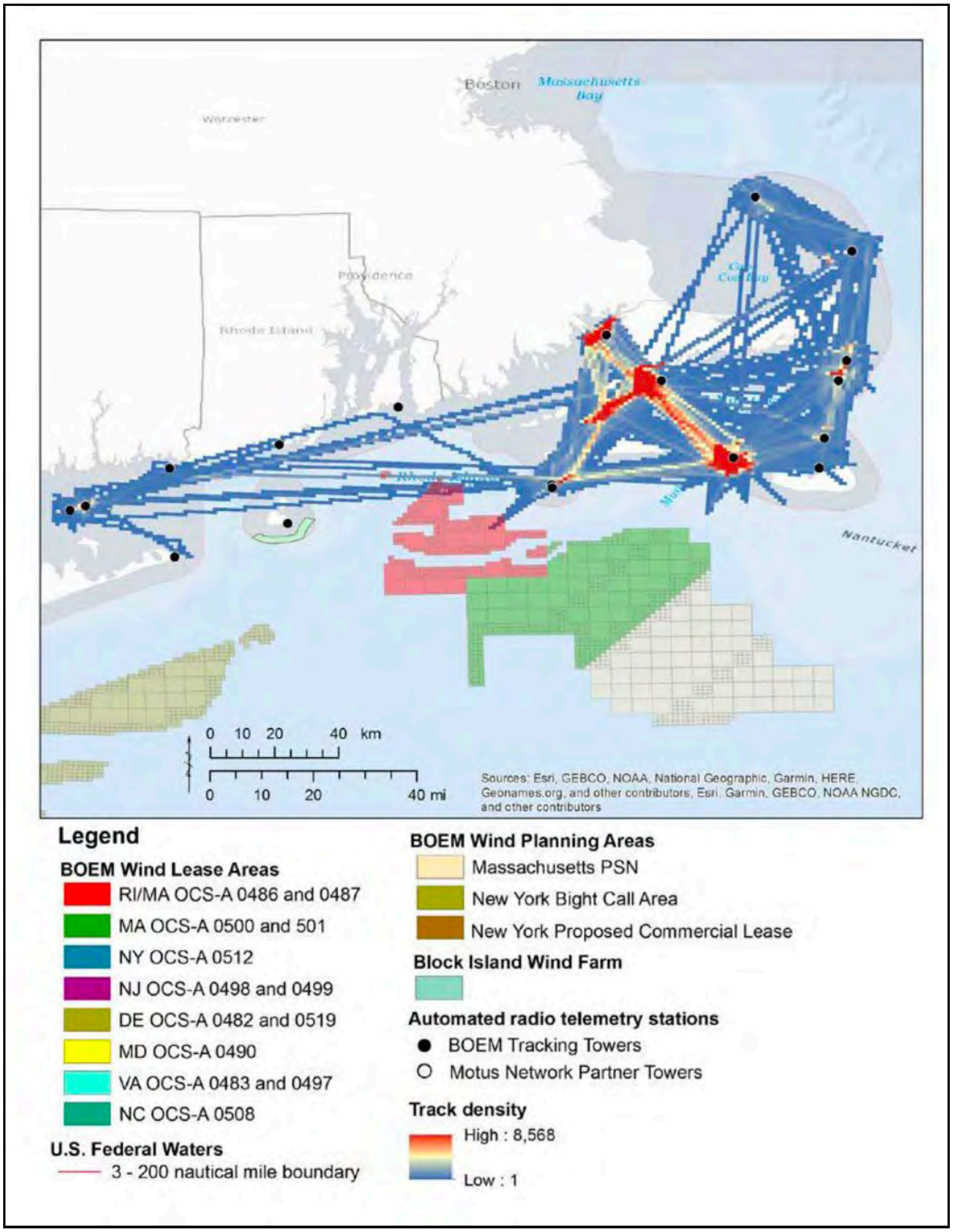


Figure 23. Track densities (# 10-minute tracks/km^2) representing tagged Roseate Tern flight paths (n=60) from colonies in Buzzards Bay during and after breeding periods in 2016 and 2017.[156]

[156] Loring P.H., Paton P.W.C., McLaren J.D., Bai H., Janaswamy R., Goyert H.F., Griffin C.R., Sievert P.R. 2019. Tracking Offshore Occurrence of Common Terns, Endangered Roseate Terns, and Threatened Piping Plovers with VHF Arrays. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-017. 140 p. Figure 15, p. 65/158.

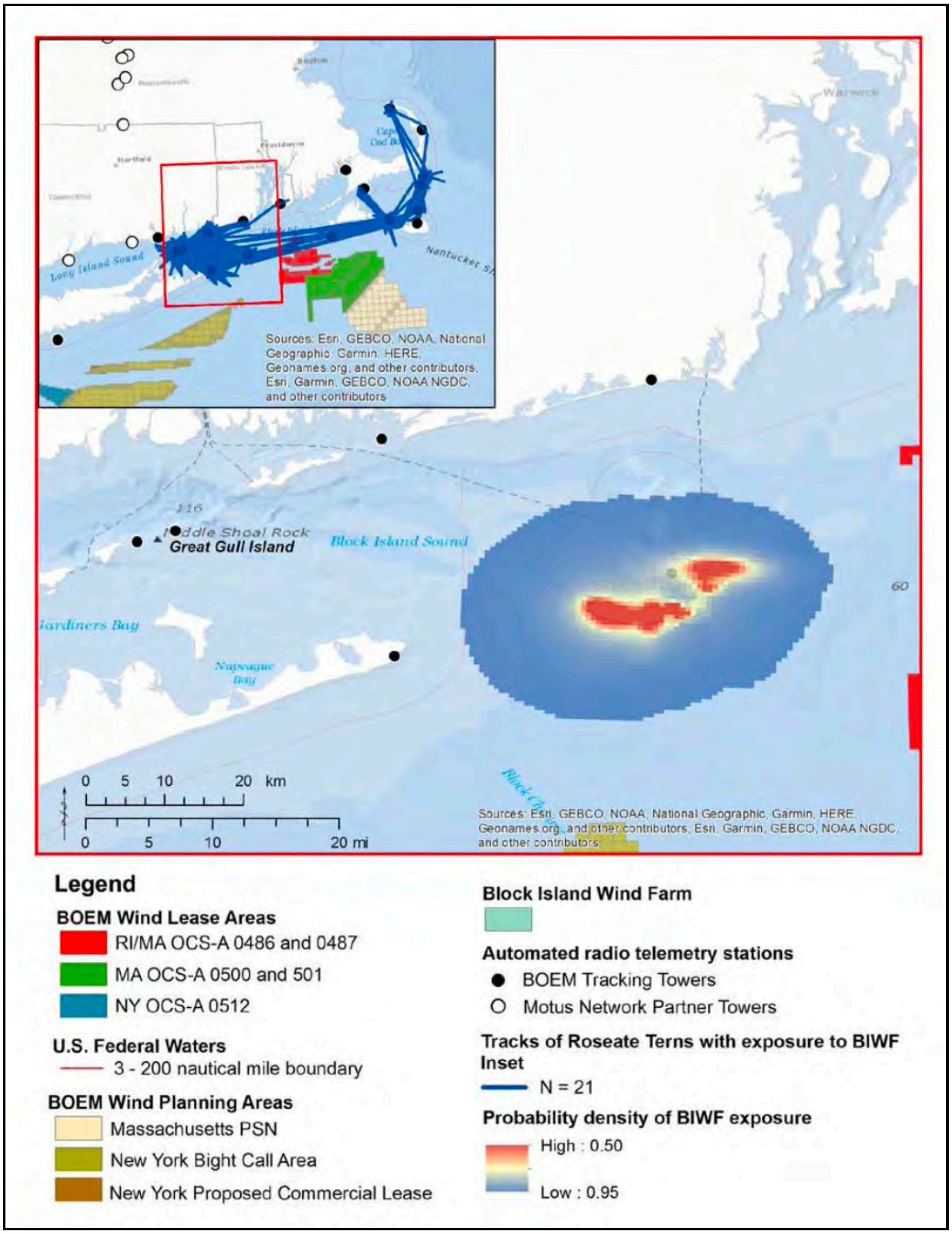


Figure 24. Roseate Tern tracks from birds tagged on Great Gull Island, 2015-2017 (inset) and probability density of Roseate Tern exposure to Block Island Wind Farm.[157]

[157] Loring P.H., P. Paton, J.D. McLaren, H. Bai, R. Janaswamy, H.F. Goyert, C.R. Griffin, and P.R. Sievert. 2019. Tracking offshore occurrences of Common Terns, endangered Roseate Terns, and Threatened Piping Plovers with VHF arrays. OCS Study BOEM 2019-017. Appendix K Summary of Exposure of Common and Roseate Terns at the Block Island Wind Farm. Figure K-3, p. 124/145.

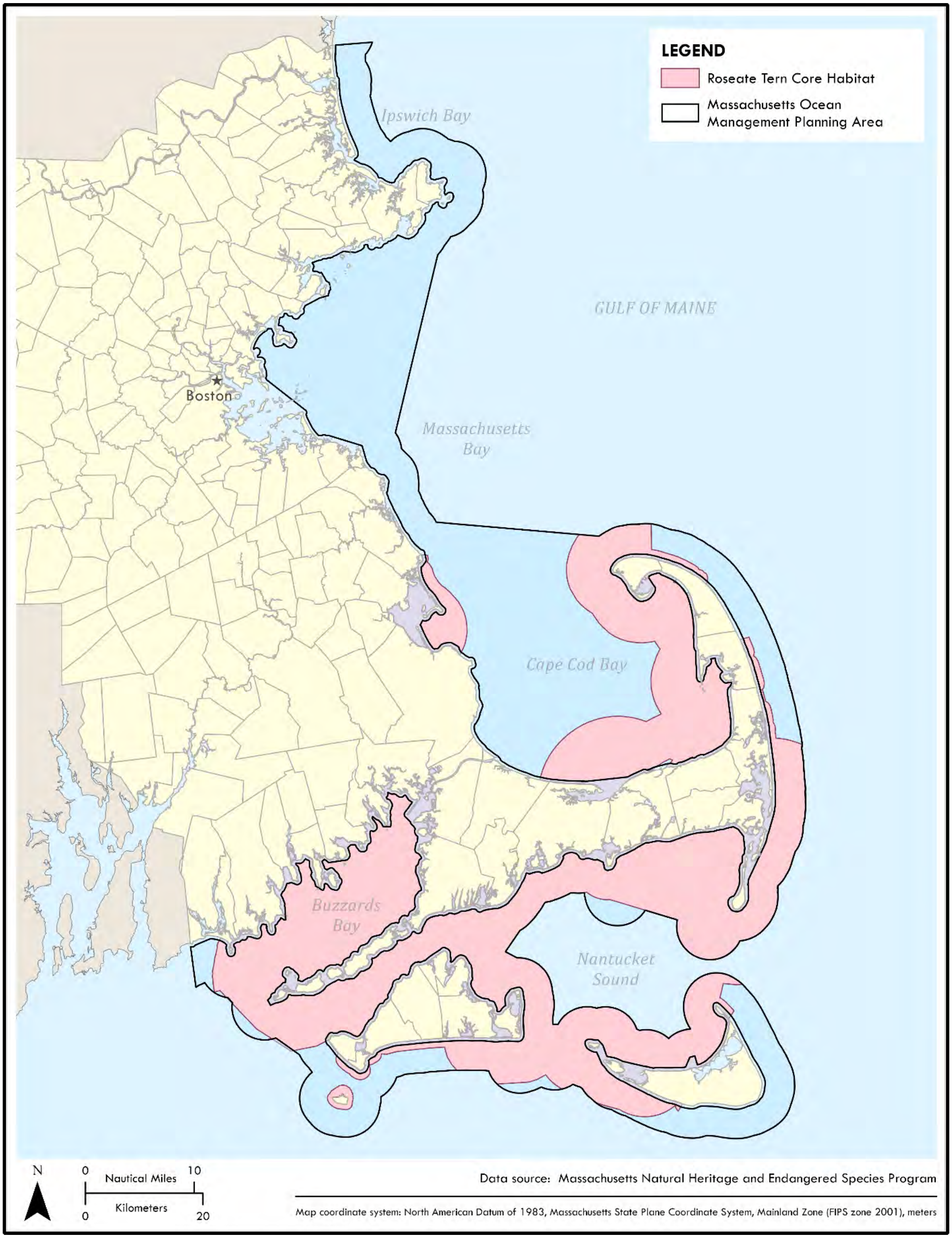


Figure 25. Roseate Tern core habitat SSU map.

Figure 26. Special Concern tern core habitat SSU map.

Figure 27. Eelgrass in the ocean planning area (dark green) and out of the ocean planning area (light green). The dark green area is the eelgrass SSU area.

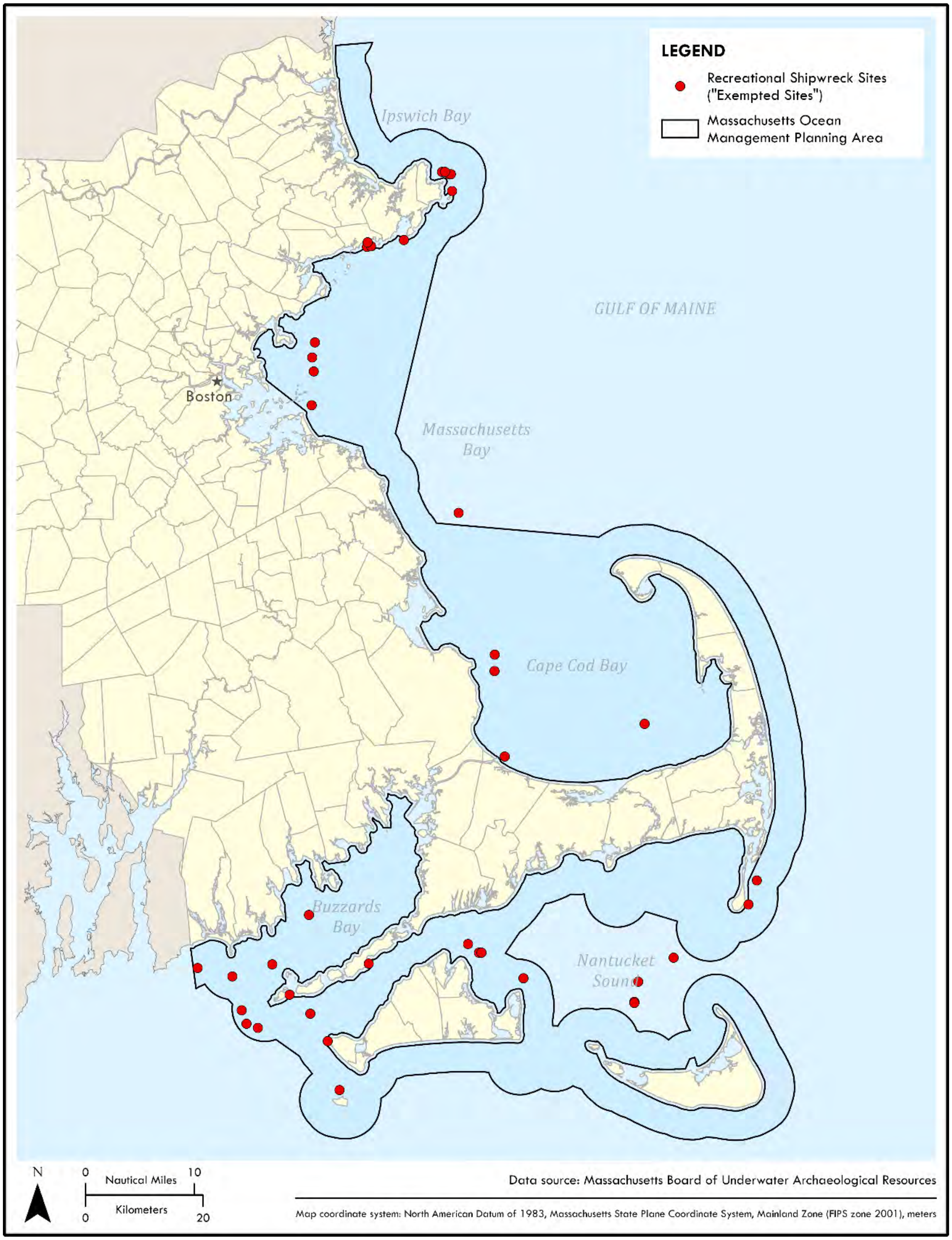


Figure 28. Shipwreck sites designated in 1985 as "Exempted Sites" for public access and use.

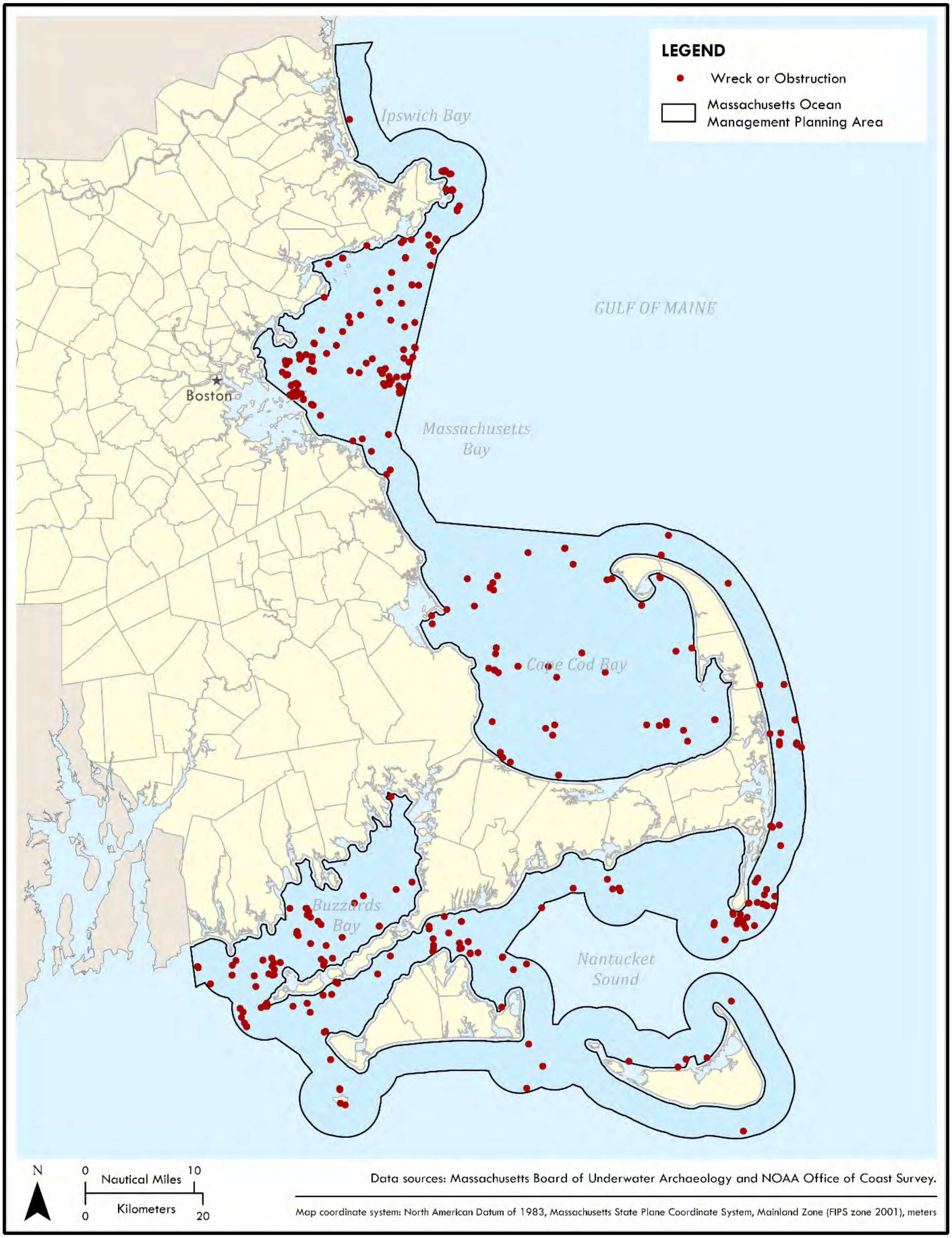


Figure 29. Wrecks and underwater obstructions in the ocean planning area.

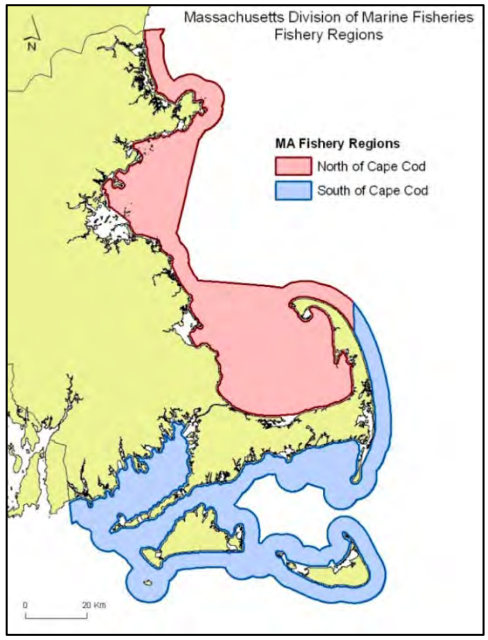


Figure 30. Regions used in the analysis of commercial fisheries and important fish resource areas.

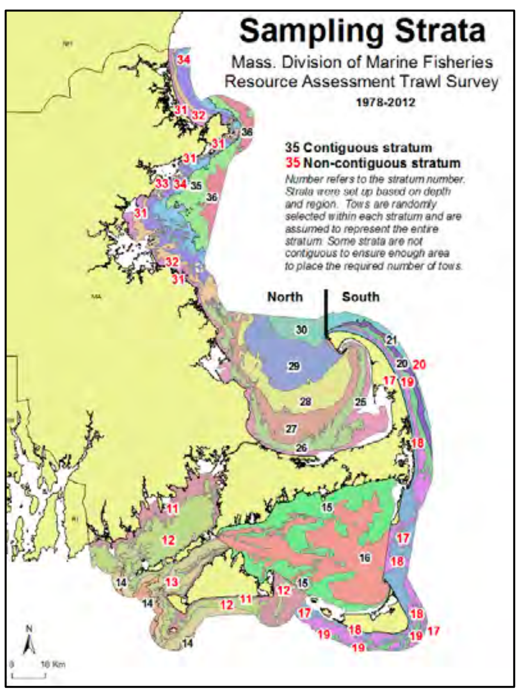


Figure 31. Contiguous and non-contiguous sampling strata. Black line indicates the north-south break.

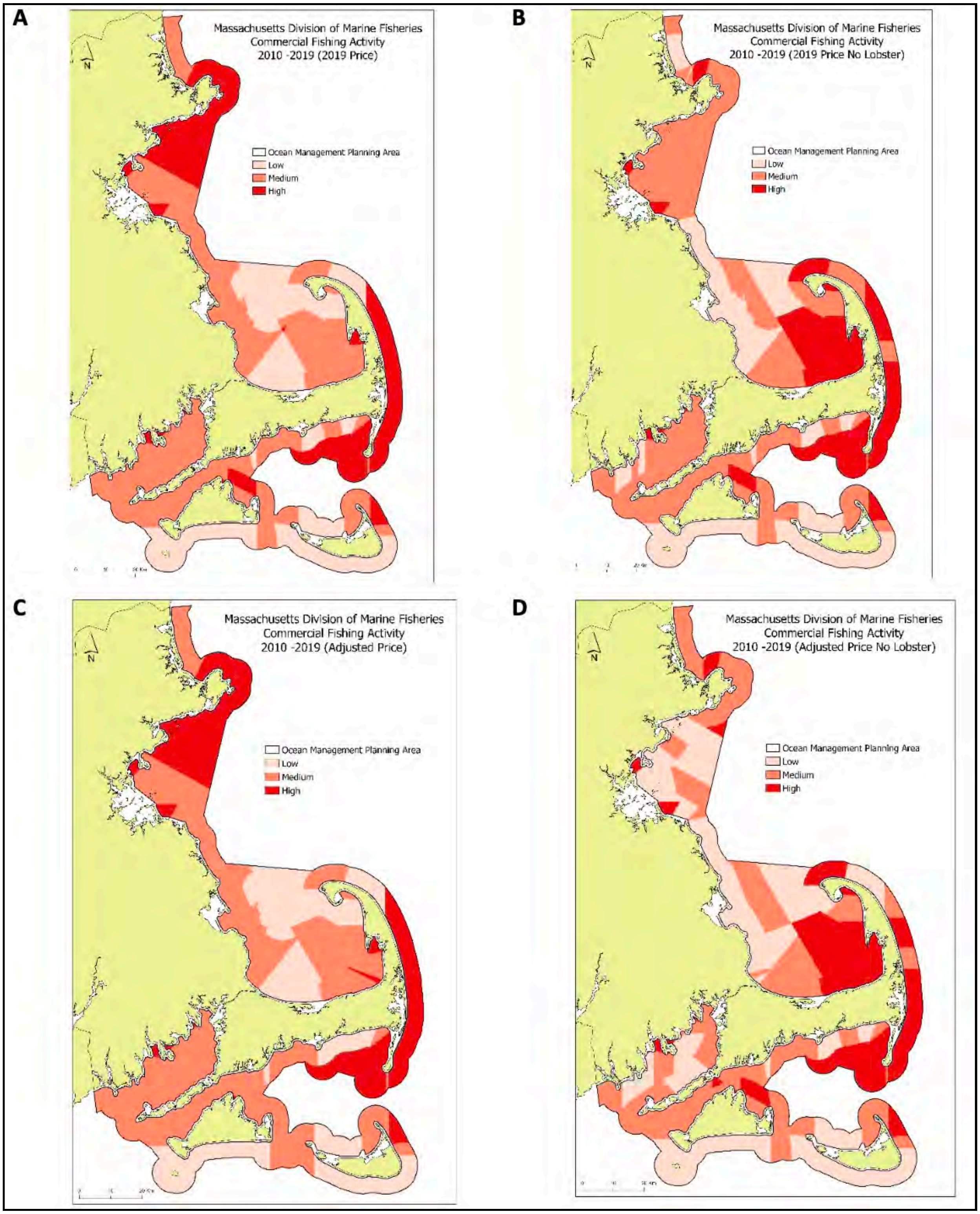


Figure 32. (A) 2010-2019 data with 2019 price, (B) 2010-2019 data with 2019 price and no lobster, (C) 2010-2019 data with adjusted prices, (D) 2010-2019 data with adjusted prices and no lobster. High, medium, and low values are scaled and relative to each region (north or south of Cape Cod).

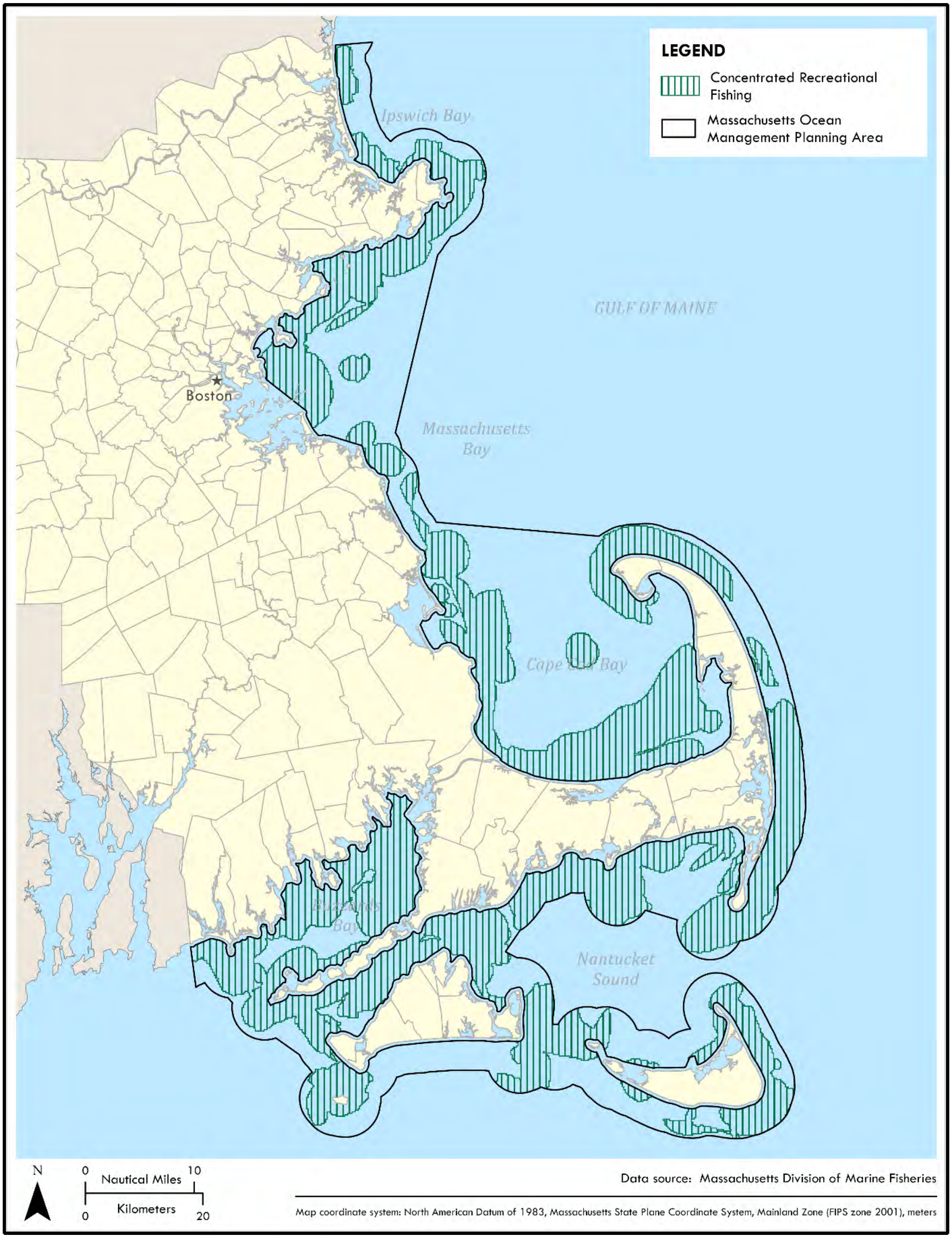


Figure 33. Concentrations of water-dependent use area: Concentrated recreational fishing.

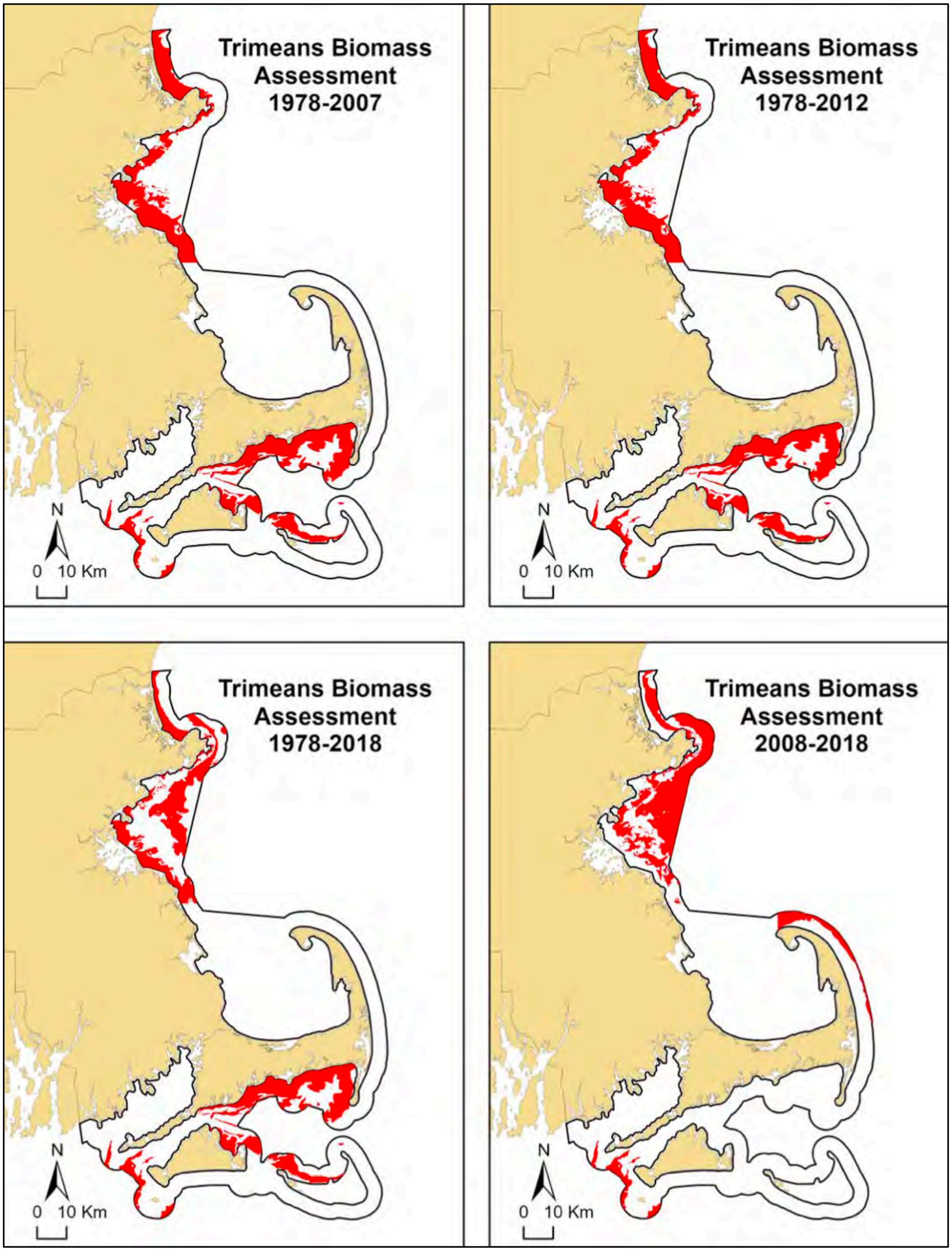
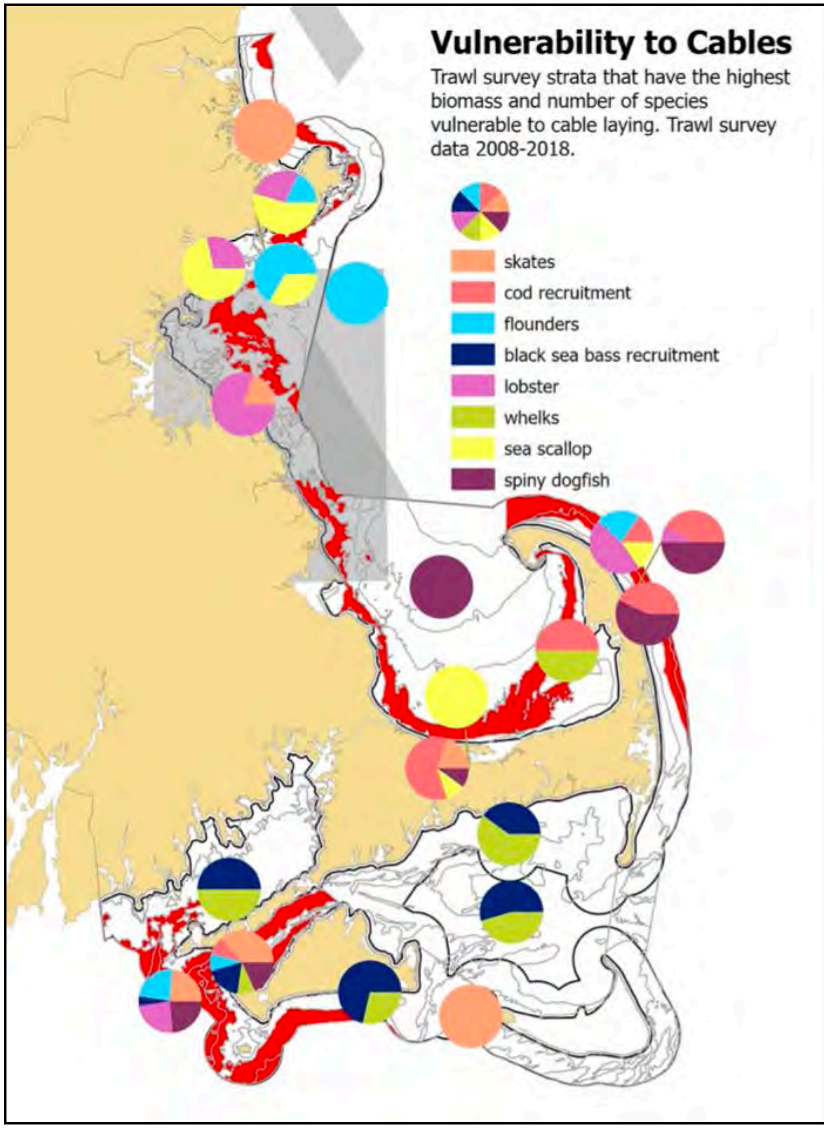


Figure 34. Highest 25% of trimean values are the Important Fish Resource Areas from 1978-2007 (top left), 1978-2012 (top right), 1978-2018 (bottom left), and 2008-2018 (bottom right). The ocean planning boundary is in black.



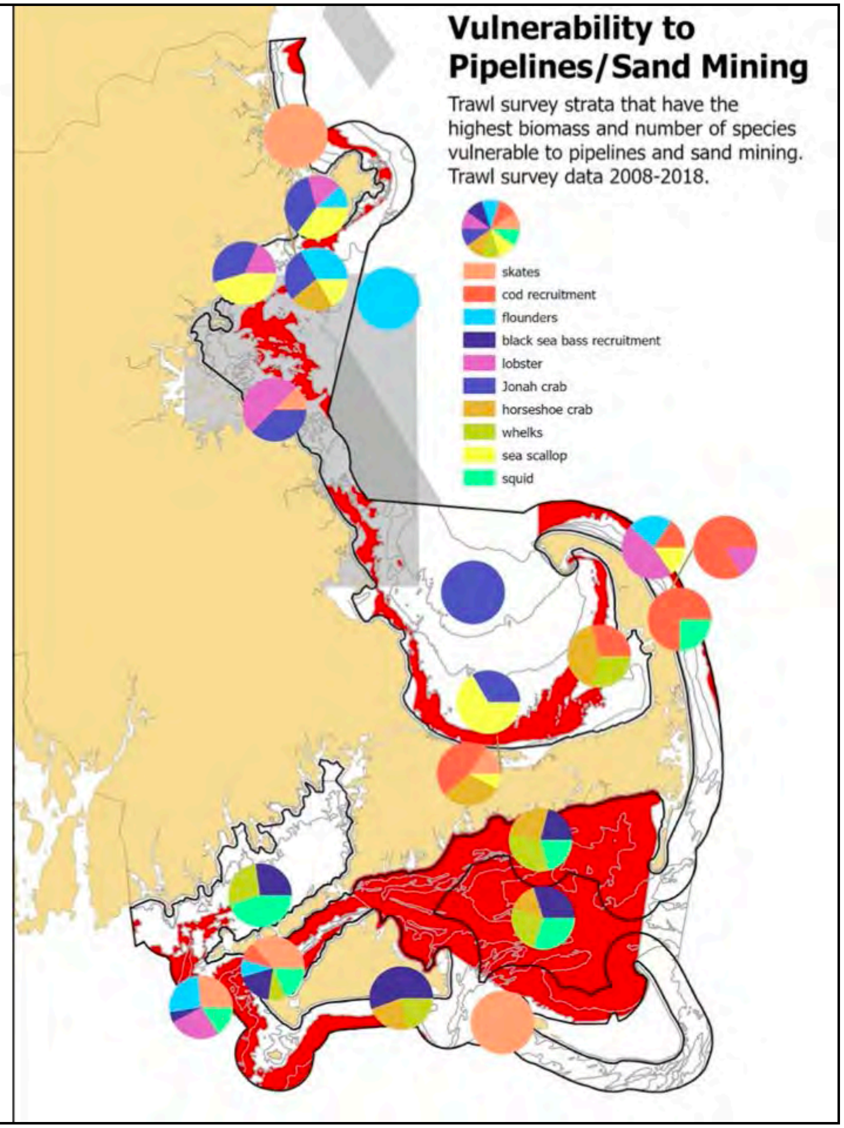


Figure 35 (left). Vulnerability map for cables. Spawning groundfish closures are in grey.
Figure 36 (right). Vulnerability map for pipelines/sand mining. Spawning groundfish closures are in grey.

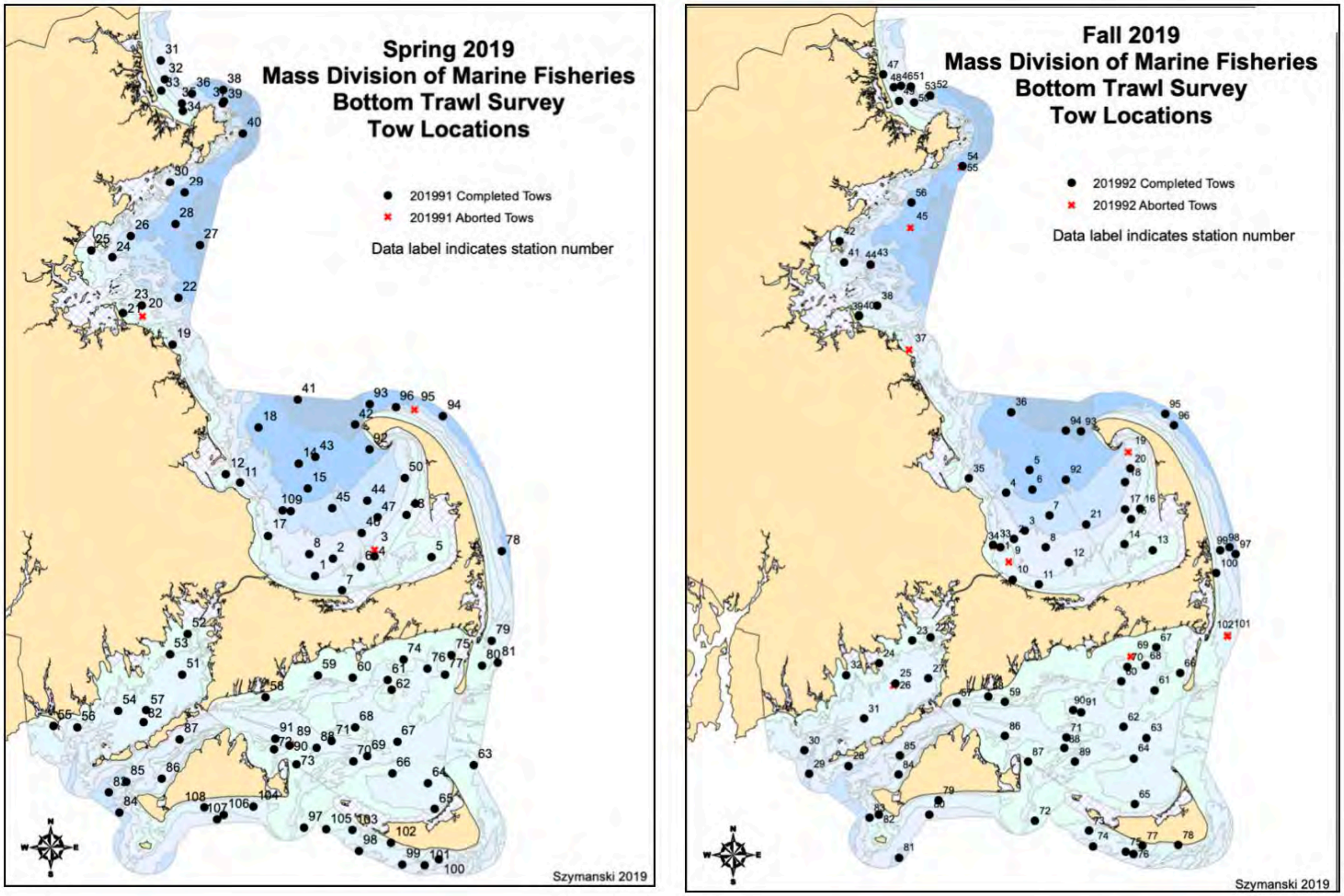


Figure 37. Locations of Massachusetts DMF bottom trawl survey tow locations in the spring (left) and fall (right) of 2019. [158]

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[158] https://www.mass.gov/doc/2019-resource-assessment-annual-performance-report/download

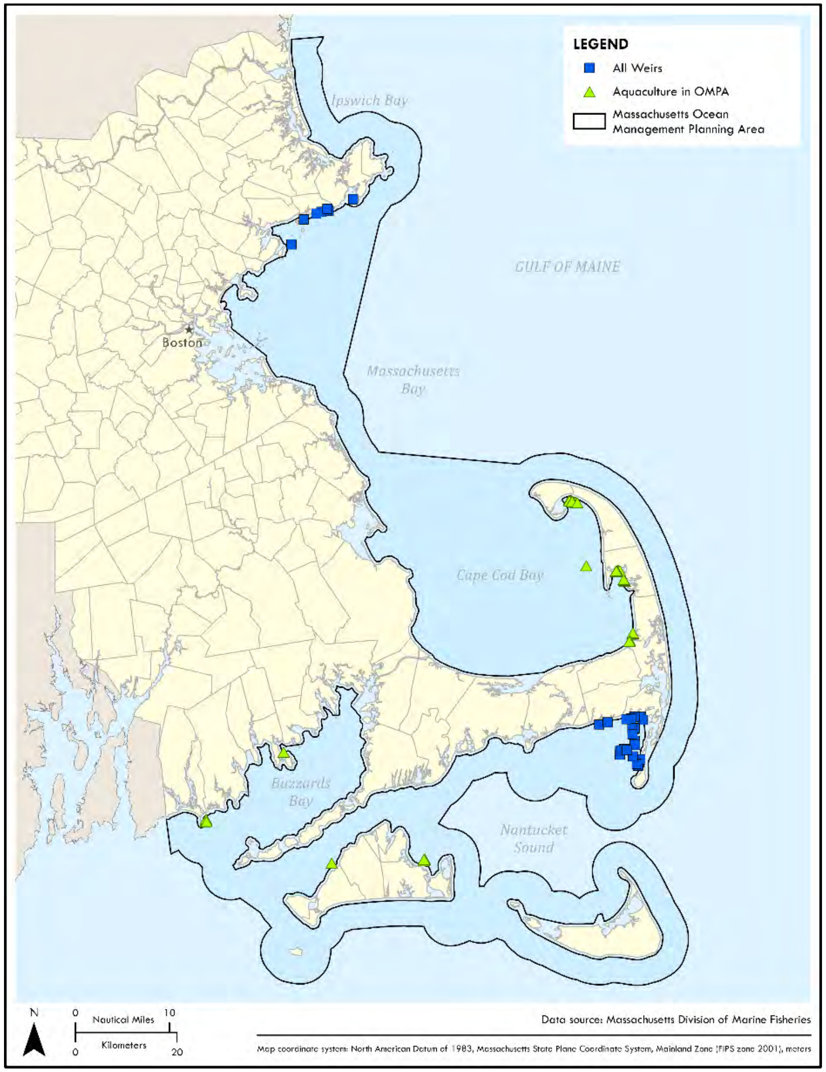

Figure 38. Fish weirs and aquaculture sites within the ocean planning area. (Note that there are 94 aquaculture sites mapped but because of their size there is significant overlap that is not discernable at the scale of this map).

Figure 39. Concentrated Recreational Boating Activity in Massachusetts.

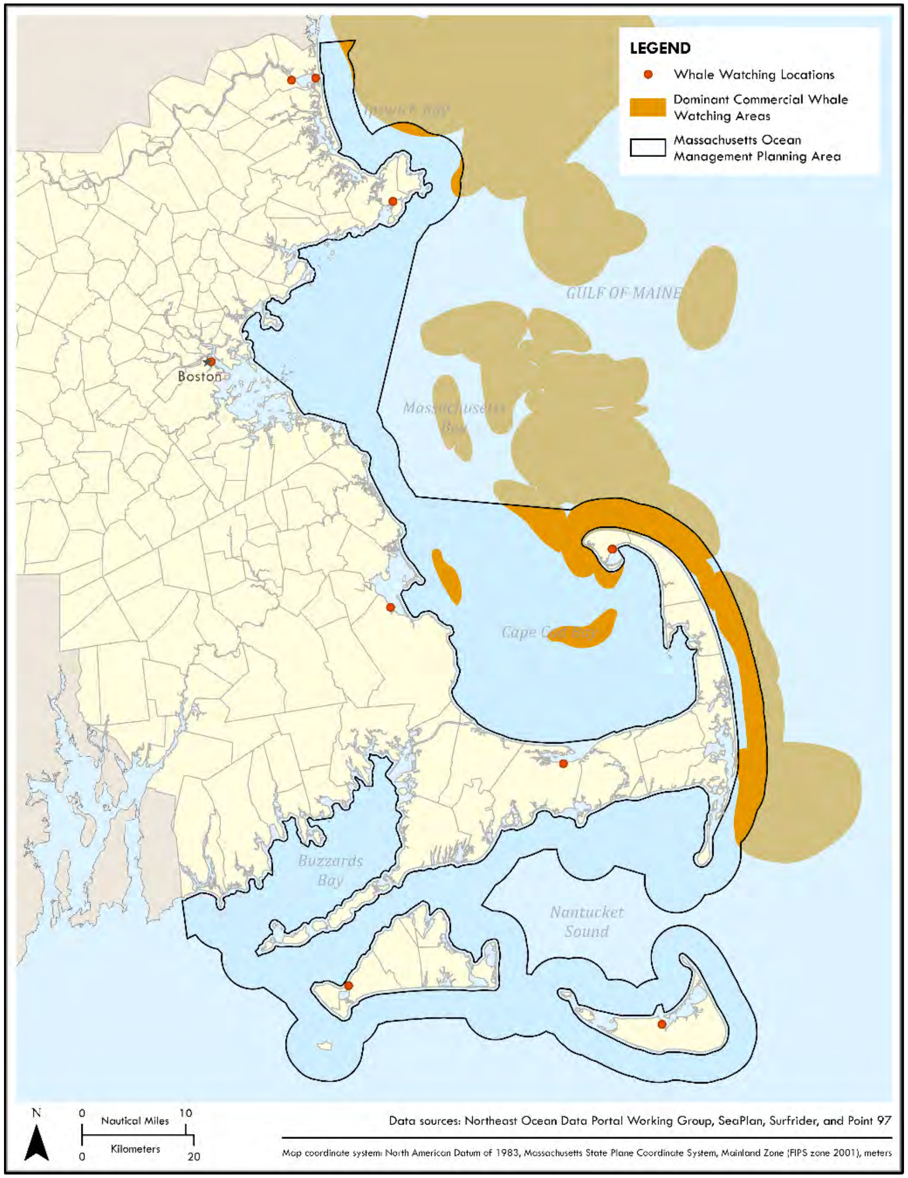

Figure 40. Whale watching hotspots in and adjacent to the ocean planning area.

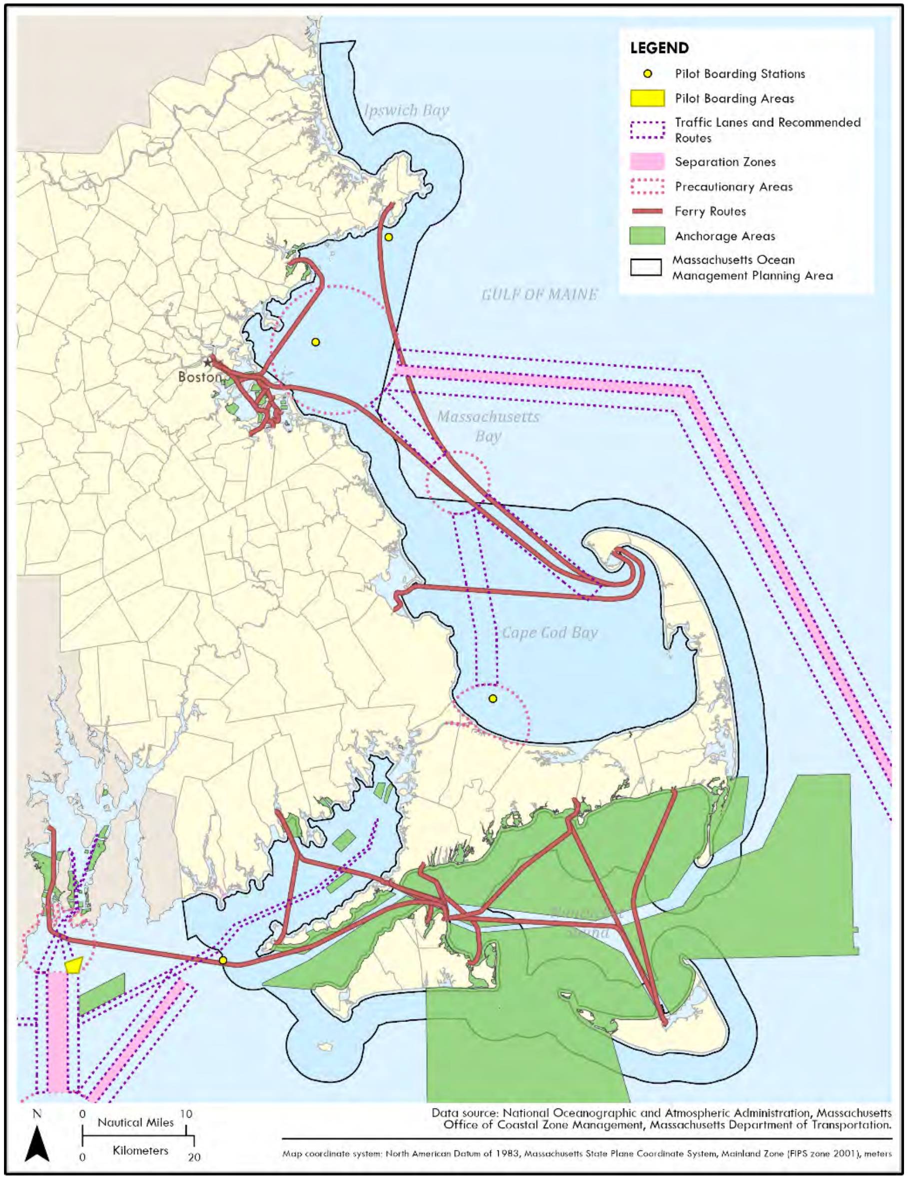

Figure 41. Transportation and navigation uses in and adjacent to the planning area.

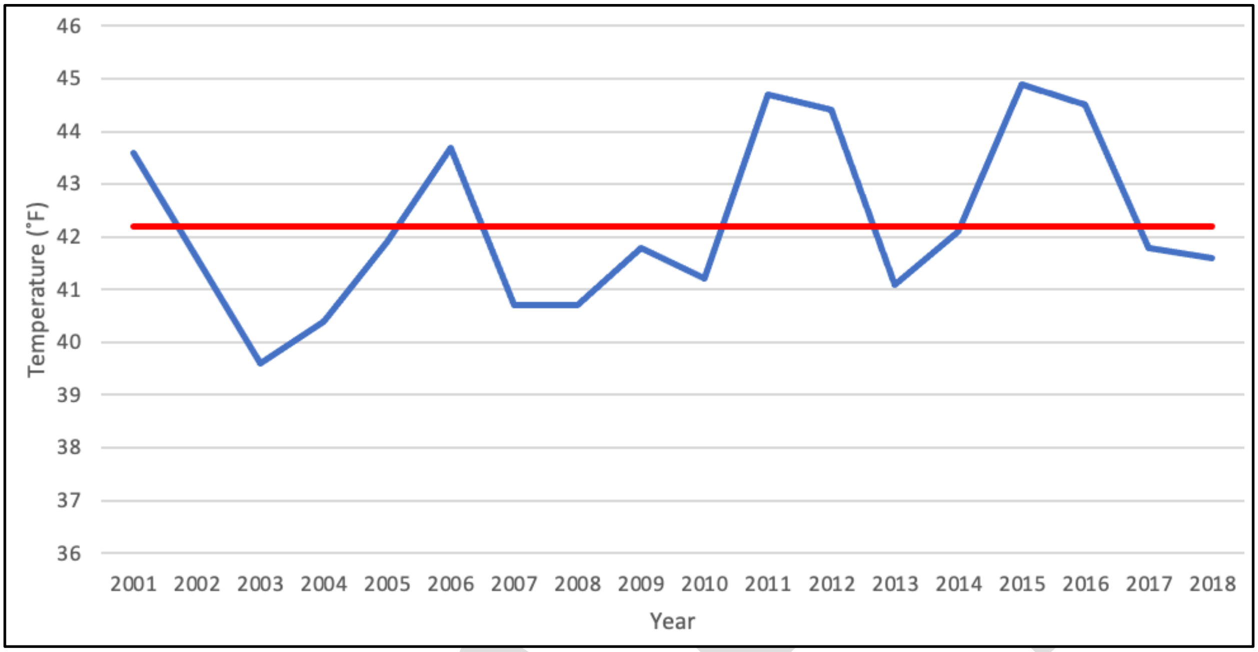

Figure 42. Average annual winter (December-February) sea surface temperature (˚F) at the Massachusetts A01 buoy (2001-2018).[111] The red line is the mean (42.2˚F).

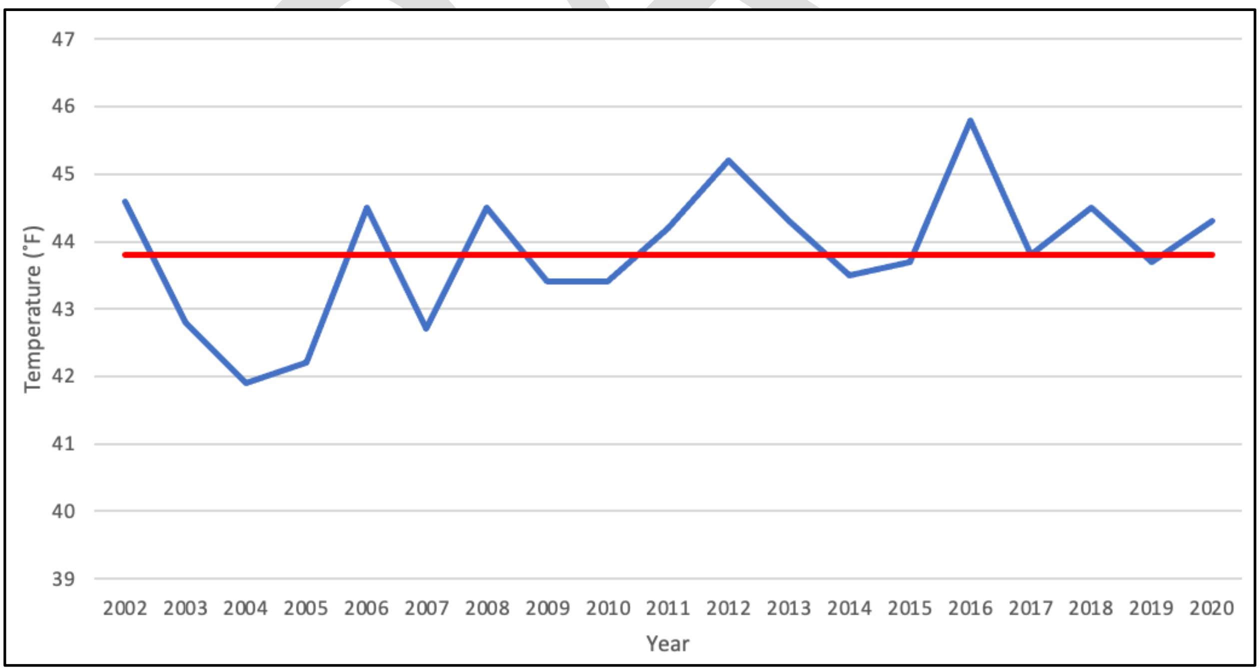

Figure 43. Average annual sea bottom (50 m) temperature (˚F) at the Massachusetts A01 buoy (2002-2020).[112] The red line is the mean (43.8˚F).

[111] http://neracoos.org/datatools/climatologies_display
[112] http://neracoos.org/datatools/climatologies_display

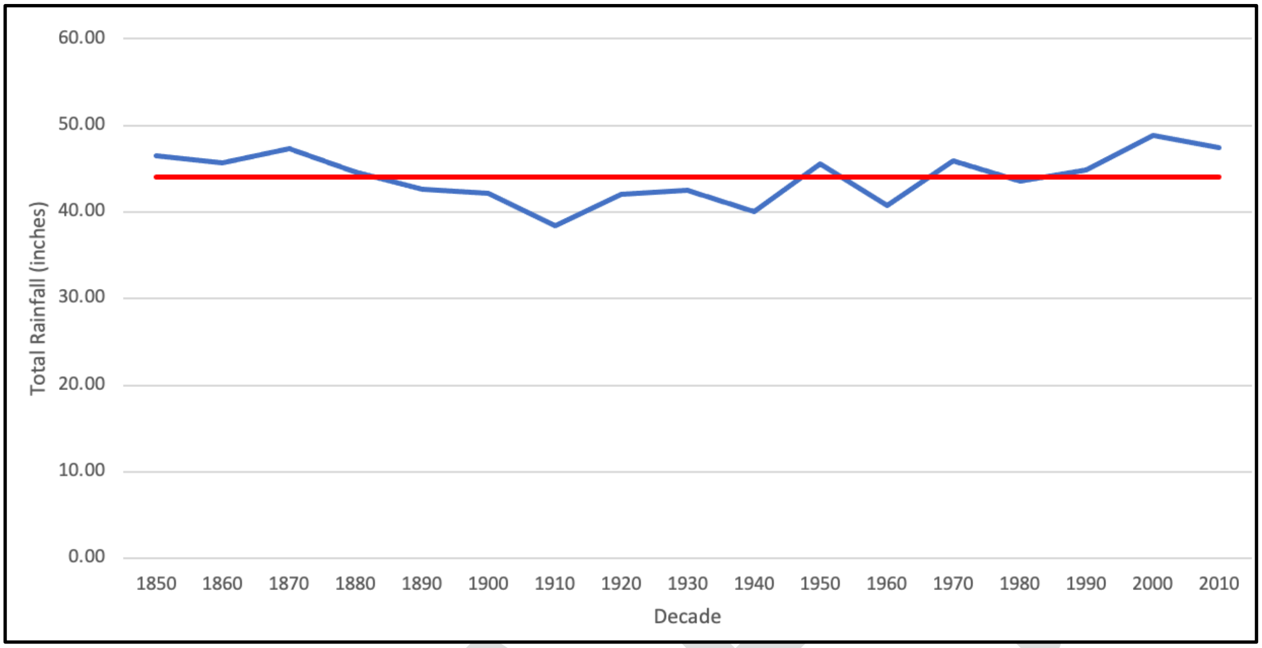

Figure 44. Average decadal rainfall totals (inches) in coastal Massachusetts watersheds from the 1850s to 2010s.[113] The red line is the long-term average of 44 inches.

[113] https://www.mass.gov/info-details/water-data-tracking; https://w2.weather.gov/climate/xmacis.php?wfo=box

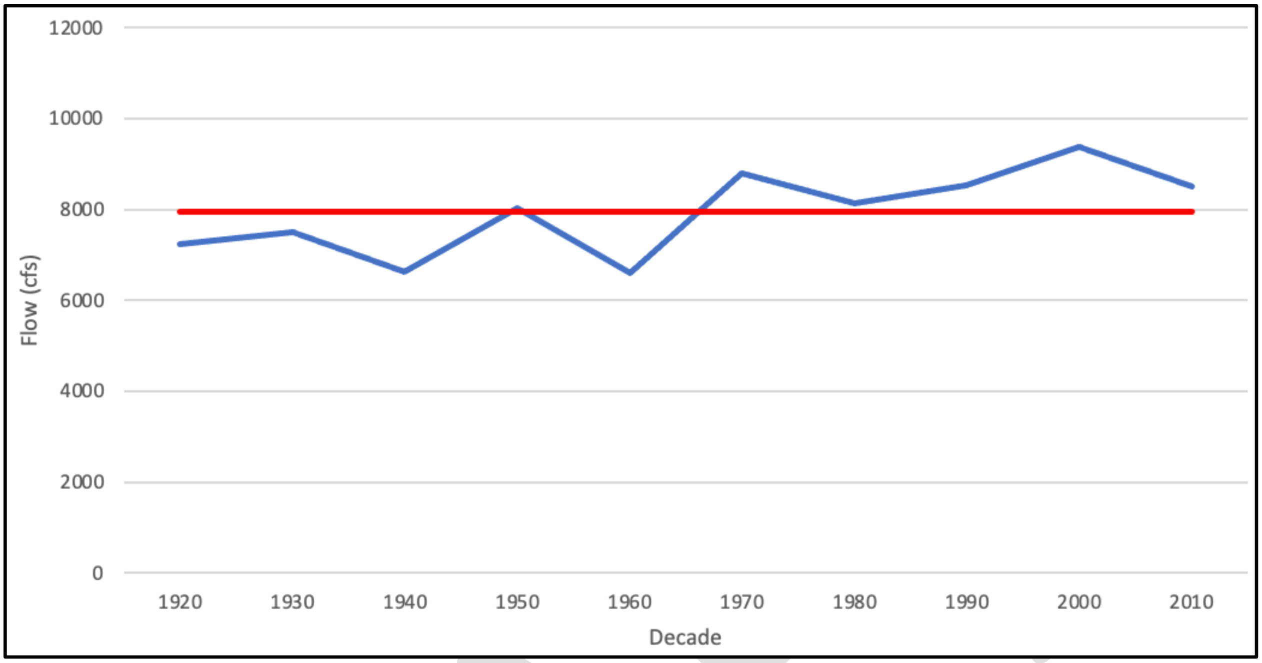

Figure 45. Average decadal flow in cubic feet per second (cfs) of the Merrimack River at USGS gauge 01100000 (1920s to 2010s).[114] The red line is the long-term average of 7,963 cfs.

[114] https://waterdata.usgs.gov/ma/nwis/current/?type=flow&group_key=huc_cd&site_no_name_select=siteno

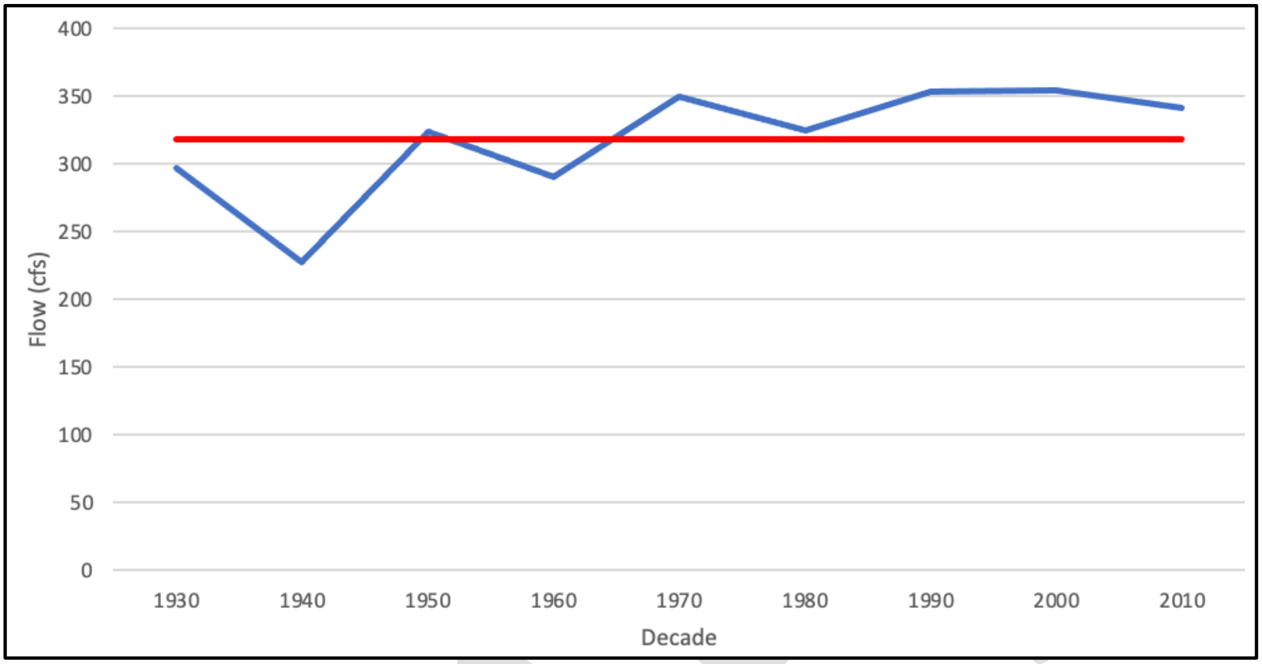

Figure 46. Average decadal flow (cfs) of the Charles River at USGS gauge 01104500, 1930s to 2000s.[115] The red line is the long-term average of 318 cfs.

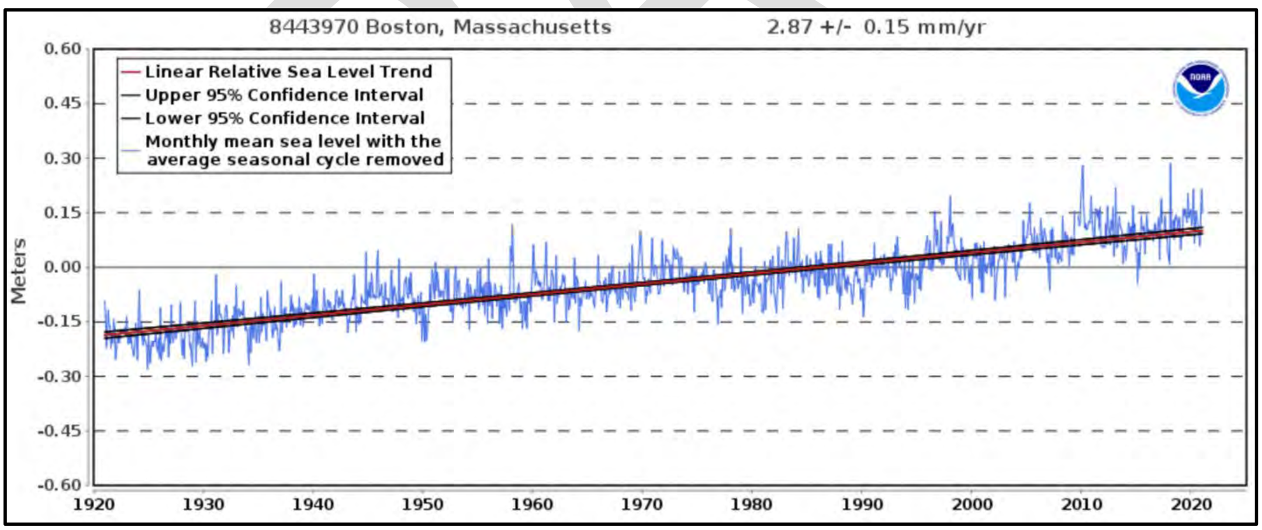

Figure 47. Long-term mean sea level data from the NOAA tide gauge in Boston Harbor, MA with linear trend (red line) and 95% confidence interval (black lines).[116]

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[115] https://waterdata.usgs.gov/ma/nwis/current/?type=flow&group_key=huc_cd&site_no_name_select=siteno

[116] https://tidesandcurrents.noaa.gov/map/index.html

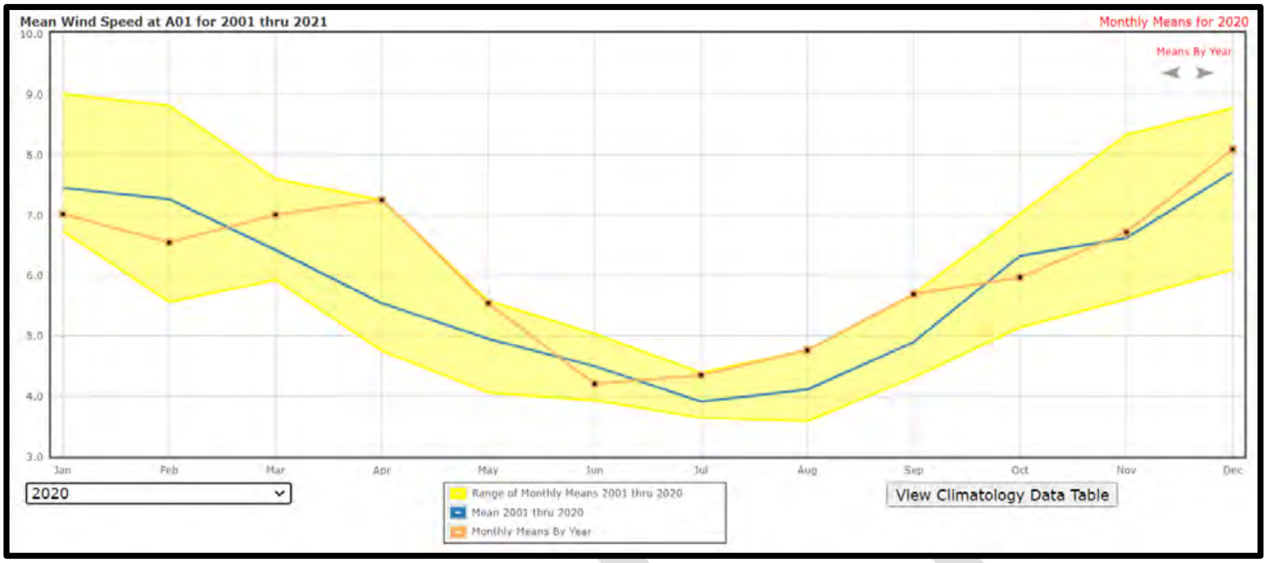

Figure 48. Monthly mean wind speed for 2020 (m/s) at the A01 buoy in Massachusetts Bay, MA. The blue line is the long-term mean and the yellow band represents the range of wind speeds from 2001-2020.[117]

[117] http://www.neracoos.org/datatools/climatologies_display

Science Framework

Introduction

As directed by the Oceans Act of 2008, the Massachusetts Ocean Management Plan (ocean plan) was developed according to the principle that it should reflect an ever-evolving understanding of the ocean environment. To help achieve this goal, the Act specifically requires a review of the ocean plan at least once every five years and a realignment of its priorities, as necessary, after consultation with the Ocean Advisory Commission (OAC), Ocean Science Advisory Council (SAC), and the public.[118] One outcome of this extensive review is a list of scientific and geospatial data recommendations collectively called the Science Framework.

The advancement of these recommendations depends on resources, including the availability of funding, expertise, data, and project management. Consequently, the inclusion of these priorities in the ocean plan should be considered a prioritization rather than a commitment to implementation. Including the Science Framework in the ocean plan, however, has proven to be effective in bringing visibility to these recommendations and developing partnerships to address them. By defining the essential surveys, research, and geospatial data development and analysis needs of the Commonwealth, resources have been focused and leveraged to make meaningful progress on the science priorities through collaborations with partners. The Executive Office of Energy and Environmental Affairs (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.

The first section below describes the progress made on the science priorities included in the 2015 ocean plan and discusses the partners that worked with EEA's Office of Coastal Zone Management (CZM) to achieve these results. The second section outlines the new science priorities that will help further the management goals of the 2021 ocean plan. These priorities derive from recommendations made by the six Technical Work Groups that were convened to review the ocean plan and make recommendations on science and management actions to keep the ocean plan current and relevant, as well as from public comments during the ocean plan review process. The proposed science priorities were presented to and approved by the OAC and the SAC during the development of the 2021 version of the ocean plan.

[118] https://www.mass.gov/service-details/review-and-update-of-the-2015-massachusetts-ocean-management-plan

Progress on the 2015 Science Priorities

The 2015 ocean plan identified 11 science and geospatial information priorities to continue to advance ocean management goals. Significant progress was made on the priorities since 2015, resulting in new information that directly and indirectly supports implementation of the management framework of the ocean plan. Below is a brief description of the progress made since 2015 on the identified science priorities.

2015 Priority 1 - Further characterize marine sand deposits and support development of regional sand budgets

CZM used deposits to the Ocean Resources and Waterways Trust to address this science priority. In 2017, CZM contracted with APTIM (with some services provided by CR Environmental, Inc.) to conduct a preliminary characterization of offshore sand resources in five study areas located offshore of the Massachusetts coastline. The project consisted of an historical data review; collection of vibracores (a sediment sampling method for retrieving underwater cores), surface grab samples, and towed video footage; and sediment analysis. The five study areas included offshore areas adjacent to the Merrimack River, Nantasket Beach, Duxbury Bay, Sandwich, and Cuttyhunk. The study concluded that there are likely more than 400 million cubic yards of sand potentially available within state waters at these five locations. The preliminary volumes of potential sand resources are based on widely spaced reconnaissance-level geotechnical data and varying levels of geophysical data coverage. Design-level geotechnical and geophysical data collection would be required to accurately and fully characterize these sand deposits. Additional information is required to understand the presence of environmental and cultural resources, including fisheries and habitat, and to determine compatibility and dredgeability of the potential sand resource. In a related effort, CZM worked with the U.S. Geological Survey (USGS) to apply a coupled ocean-wave sediment transport model along Cape Cod Bay from Plymouth to Dennis to evaluate how storm events affect shoreline change and the sediment flux to/from shore.

2015 Priority 2 - Characterize potential wind energy transmission corridors

CZM used an optimization and screening analysis to identify several preliminary areas for siting offshore wind transmission cables in state waters. This work was completed in time to be incorporated into the 2015 ocean plan (Volume 1, Chapter 2, Appendix 5). The analysis used information characterizing the geology, benthic fauna, and fisheries resources in state waters south of Cape Cod to assist in advancing offshore transmission planning for offshore wind development in the Southern New England wind energy areas.

The purpose of mapping these areas was to identify routes from the offshore wind energy lease areas to potential land-based transmission connections that had the least number of conflicts with protected areas and existing water-dependent uses. Although to date offshore wind developers have not used these exact routes, the maps in the 2015 ocean plan are highly informative, and the Vineyard Wind 1's proposed offshore export cable routes approximate the potential wind transmission corridor identified through Muskeget Channel. Since 2015, CZM has worked with offshore wind developers as they consider potential cable corridors from the Southern New England wind energy areas to the onshore transmission grid. These discussions have and will continue to inform the planning and permitting of current and future offshore transmission corridors in areas south of New England, in the New York Bight, and in other areas under consideration for BOEM leasing such as the Gulf of Maine. Additionally, data collected by offshore wind developers and provided to CZM will further enhance the already extensive catalogue of the Commonwealth's seafloor habitats.

2015 Priority 3 - Advance marine habitat mapping

For more than 15 years, CZM has worked with Division of Marine Fisheries (DMF), USGS, and the National Oceanic and Atmospheric Administration (NOAA) to map the seafloor of Massachusetts. In 2018, CZM and USGS signed a cooperative agreement to produce a high-resolution geophysical map of southern Cape Cod Bay. By 2022, USGS will have conducted a geophysical survey (swath bathymetry, backscatter, and seismic reflection profile data); collected sediment samples, underwater videos, and seafloor photos to groundtruth the acoustic information; and published interpretive maps for this area of the Commonwealth's seafloor. These mapping and survey efforts continue to be critical partnerships that gather robust and detailed information about the ocean planning area and that inform the sustainable siting and planning of projects and activities within nearshore waters.

CZM is in the process of building a spatial bibliography tool that depicts the geographic extent for publicly available seafloor mapping data in and adjacent to Massachusetts waters. The tool provides full citation information for a variety of data types, including sediment samples, photos, videos, bathymetry, side scan sonar, and subbottom profiling, and allows users to find and download data relevant to a specific area of interest. CZM has also been working with NOAA and the coastal programs in New Hampshire and Maine on a project to map the unique geoforms, or habitats, of the seafloor according to the Coastal and Marine Ecological Standard (CMECS) classification system from Nantucket Shoals to the Canadian border out to 24 nautical miles (NM). Future related efforts will add biotic data and habitat descriptions to the geoform mapping project.

2015 Priority 4 - Monitor climate change across Massachusetts ocean waters

Since 2015, CZM has continued to be actively involved in regional efforts to monitor and report on long-term temperature changes and secondary physical effects, such as changes in ocean pH, salinity, and sea level. Additionally, CZM tracks changes in the distribution and abundance of coastal resources through updates to the mapping of sensitive coastal habitats that may be influenced by the physical changes to ocean waters relating to climate change (e.g., core whale habitat). CZM is a board member of the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS), co-chair of the Northeast Regional Ocean Council (NROC), and contributor to the Integrated Sentinel Monitoring Network for Ecosystem Change and the Gulf of Maine Council's Ecosystem Indicator Partnership. CZM is also actively involved in efforts to address coastal and ocean acidification, contributing to the Northeast Ocean Acidification Network (NECAN) and serving as a member of the legislatively convened Massachusetts Ocean Acidification Commission. The Commission released a final report in February 2021[119] that documents the potential drivers and impacts of ocean and coastal acidification as well as recommendations which provide a pathway for the Commonwealth to mitigate rapidly acidifying coastal waters.

2015 Priority 5 - Identify ecologically important areas

Identifying ecologically important areas is a key component of ecosystem-based management and a primary goal of ocean planning. Since 2015, CZM and its partners have been collecting new information to update the 12 important areas of special, sensitive, or unique (SSU) marine life and habitats that are the foundation of the ocean plan. CZM continues to partner with Massachusetts Department of Environmental Protection (MassDEP) and DMF to understand changes in the extent of eelgrass. Partnerships with the New England Aquarium and the Massachusetts Clean Energy Center (MassCEC) support annual surveys for cetaceans, such as the endangered North Atlantic right whale, humpback whale, and fin whale. In addition, CZM served as an advisor to an NROC-funded project to model and produce probability maps for hundreds of species that inhabit the northwestern Atlantic Ocean. These data layers are made available through the Northeast Ocean Data Portal and can be viewed for individual species, by classes of species, by total abundance or biomass, and by species richness.

2015 Priority 6 - Develop data tools and products to improve interpretation and refinement of the important fish resources SSU area map

The ocean plan's important fish resources SSU area map is generated from the biomass or counts of 20 species and two life stages (juvenile Atlantic cod and black sea bass young-of-

[119] https://drive.google.com/file/d/1Pcx8r-rSu8T4mf-FBHLRQH48KdGXP1uj/view

year) collected in the DMF spring and fall stock assessment surveys from 1978 to the most recently available survey. The goal of the map is to produce a statewide distribution identifying areas of relatively high biomass that are consistent over time for commercially and recreationally important species. To address potential weighting of high species biomass from previous decades that may no longer be representative DMF assessed the implications of using a truncated time series with data from the most recent 10 years. Additionally, CZM began working with DMF to use an analysis tool that depicts upward or downward trends in biomass or counts in specific regions where repeated trawls have been made. DMF has also developed maps of classes of key species and life stages based on their vulnerability to specific types of ocean development activities (e.g., sand extraction, cable and pipeline installation). These efforts to better characterize the important fish resources SSU area map will increase the characterization of these areas for inclusion in future iterations of the ocean plan.

2015 Priority 7 - Advance work on an effort-corrected sea turtle database and improve resolution of marine bird spatial data

Filling the data gap for sea turtles and marine birds continues to be a priority for CZM, but one that has proven difficult to achieve as comprehensive data from directed surveys are limited. As stated above, the Northeast Ocean Data Portal contains probability maps for hundreds of species in the Northeast, including sea turtles and marine birds. While these data are useful for some planning exercises, they cannot be classified in the manner used by CZM to identify SSU areas for ocean planning. Organizations such as MassCEC, NOAA, U.S. Fish and Wildlife Service, New England Aquarium, and Mass Audubon Wellfleet Bay Wildlife Sanctuary have collected data on sea turtle observations however, because they are off-survey and opportunistic, they cannot not be used to develop spatial maps for ocean planning purposes. CZM also acquired tracks of tagged sea turtles from Kara Dodge of the New England Aquarium, but the majority of those data place turtles well outside of the Massachusetts Ocean Management Planning Area.

2015 Priority 8 - Develop higher resolution maps and characterization of recreational and commercial fishing

The Northeast Ocean Data Portal used Vessel Monitoring System (VMS) data to characterize multispecies (groundfish) commercial fishing hotspots based on vessel speed in state and federal waters from 2006 through 2016. Although the portal includes data extending to the outer continental shelf, the resulting maps show vessel activity at less than four knots (a speed threshold determined with industry input to highlight fishing areas) in parts of the planning area. In the case of recreational fishing, data in the 2015 ocean plan were based on a survey of 25 recreational fishermen within areas that were considered hotspots for this recreational fishing activity. Recognizing the limitations of these data, DMF explored the possibility of integrating questions on spatial data of recreational fishing in the NOAA recreational fishing survey. However, this effort was placed on hold until an alternative method could be developed and funding for the survey becomes available.

2015 Priority 9 - Revise and update the state inventory of submerged wrecks

The Massachusetts Board of Underwater Archaeological Resources (BUAR) maintains files documenting shipwrecks, aircraft, and other submerged archaeological resources and historic properties. This inventory includes more than 3,500 archivally documented shipwreck sites in Massachusetts waters and serves as a resource for managing these important cultural resources. Up until recently, these files were only available in paper format. Since the 2015 ocean plan, BUAR has collaborated with the Geography Department at Salem State University and with CZM's GIS specialists to convert these site files into searchable geo-referenced databases. When complete, the state inventory of submerged shipwrecks database will provide an inventory of reliable site locations with associated attribute information that will inform BUAR's project review, permitting, and protection of these sensitive and unique resources.

2015 Priority 10 - Develop a paleolandscape and predictive model of ancient Native American land use

The development of a paleolandscape model and subsequent archaeological sensitivity maps of the seabed is an initial step for determining the potential presence and preservation of ancient Indigenous archaeological sites on these now submerged lands. Early paleolandscape and predictive models relied heavily on applying sea level rise data to bottom contours to estimate where and when areas of the seafloor had been exposed land available for human occupation with potential for containing archaeological sites. These models, however, failed to account for the effects that coastal processes, sea level rise, and local erosion/accretion have on determining where and what parts of the paleolandscape are preserved. The collection and analysis of sub-bottom profiling data and geo-technical sediment cores are required to assess the paleolandscape and the potential for archaeological site presence and preservation. Recent research by the Bureau of Ocean Energy Management (BOEM) and the University of Rhode Island (URI) has led to the refinement of archaeological survey standards, elements of which were incorporated into BUAR's current survey guidelines. Development of a paleolandscape model and a predictive model of archaeological sensitivity remain a research priority.

2015 Priority 11 - Refine and implement the monitoring and evaluation framework to improve the review and updating of the ocean plan

The Oceans Act requires the ocean plan to be based on an adaptive management approach. To address this aspect, CZM worked with SeaPlan to develop a survey to gather information on progress toward plan goals. The first survey, targeted to members of the OAC and the SAC, was developed in 2014 to gather information as part of the review of the 2009 ocean plan. In keeping with the framework used for the 2015 ocean plan, CZM developed and released a second survey in early 2019 to seek for public feedback on the 2015 ocean plan implementation planning process. The survey was also sent to the OAC and SAC. CZM received 86 responses (a 10% response rate) providing suggestions for new or enhanced management actions for the ocean plan including: new maps, additional scientific research, and increased coordination and collaboration. This critical public input from the survey was used to inform the adaptive management framework and implementation of the ocean plan.

Science and Data Priorities for the 2021 Ocean Plan

As part of the ocean plan process, six Technical Work Groups consisting of over 100 technical and scientific experts met to discuss and review the 2015 ocean plan. These work groups include Habitat, Fisheries, Transportation and Navigation, Sediment and Geology, Cultural Heritage and Recreational Resources, and Energy and Infrastructure. Work group members were tasked with reviewing the management framework, mapped resources, and science and data priorities associated with their work group's expertise. Specifically, the scope of the work group reviews was to: 1) identify changes since 2015 to the special, sensitive, or unique (SSU) areas and water-dependent uses (WDUs) mapped in the ocean plan; 2) identify trends in resources or uses addressed by the ocean plan or that may be addressed in the future; 3) propose new science or data sources that would inform the ocean plan; and 4) review the science and data priorities in the 2015 ocean plan and make recommendations for updated science and data priorities. Recommendations from each of the Technical Work Groups included the development of new or additional data, revisions to existing analysis methods, revisions of mapping approaches, or a combination of these.

The work groups developed reports of their findings that are summarized in the Review and Update of the 2015 Massachusetts Ocean Management Plan.[120] The findings were also presented to the SAC and OAC. The following list of science and geospatial information priorities were developed based on the guidance of work group specialists, the OAC, and the SAC, and influenced by recent experience of EEA agencies with ocean use issues. The science priorities for the 2021 ocean plan are discussed below.

Addressing these priorities is integrally linked to available resources. Consequently, the ocean plan's science priorities serve as a recommendation for prioritization rather than a commitment to implementation. CZM collaborates with multiple institutions and organizations to address these shared goals.

2021 Priority 1 – Advance data and information to support the sustainable use of shared ocean resources with existing and emerging uses in the development of offshore wind

This priority reflects EEA's ongoing commitment to the sustainable and balanced siting of offshore wind to support renewable energy goals in Massachusetts and New England. The development of offshore wind will continue through the review and permitting of projects in existing lease areas located in southern New England waters and the potential planning,

[120] https://www.mass.gov/service-details/review-and-update-of-the-2015-massachusetts-ocean-management-plan

siting, and leasing of new wind energy areas in other regions off New England. Through BOEM's Gulf of Maine Intergovernmental Renewable Energy Task Force, areas may be identified for commercial floating offshore wind and the state of Maine has begun a BOEM process to site a 12-turbine research array in 16 square miles in the Gulf of Maine. This priority will support and inform these efforts by Maine, New Hampshire, and Massachusetts by mapping existing uses and resources in the Gulf of Maine and using advanced Geographic Information System (GIS) techniques to identify areas of least conflict for siting offshore wind. Under this priority, CZM will also identify data gaps and collaborate with other states to fill data gaps to inform these siting processes. A second means to advance this priority, in response to comments received by the energy transmission industry, will be to use existing spatial data on uses and resources to develop "presumably permittable" corridors for offshore wind export cables to onshore connection points north of Cape Cod. A similar effort was done for the 2015 ocean plan to identify potential cable corridors south of Cape Cod.

2021 Priority 2 - Further characterize offshore sand resources

Climate change—via higher sea levels and increased frequency and intensity of storm events—is resulting in greater erosion and flooding impacts in coastal Massachusetts. Under accelerated rates of sea level rise, low-lying coastal areas will be particularly vulnerable to increased erosion, flooding, and inundation. One method of protecting coastal structures and resources is through the active nourishment of beaches from offshore sand donor sites.

As discussed in 2015 Priority 1, CZM conducted a preliminary characterization of offshore sand resources in five study areas located offshore of Massachusetts in 2017. The preliminary volumes of potential sand resources identified through this project were based on widely spaced reconnaissance-level geotechnical data and varying levels of geophysical data coverage. Design-level geotechnical and geophysical data collection would be required to accurately and fully characterize these five sand deposits for potential sand nourishment projects.

Future characterization of the five offshore sand resources and efforts to better understand the capacity to supply compatible sediment to beaches in need of nourishment may proceed on three parallel tracks:

1. Benthic fauna characterization,
2. Matching potential donor sand resources and recipient beaches, and
3. Modeling to determine the potential effects of removing sand and to determine how quickly it may replenish.

To advance benthic fauna characterizations of offshore sand resources, CZM will work with DMF, the National Marine Fisheries Service (NMFS), and the fishing industry to implement surveys of benthic fauna (crustaceans, fish, molluscs). Various methods may be used including ventless traps, trawls, camera/video, and other assessment tools. The specific objective will be to determine the distribution and abundance of species vulnerable to sand extraction technologies and to determine if there are more appropriate locations and/or times for sand extraction in each of the sand resource areas. To match potential donor sand resources and recipient beaches, CZM will work with partners to gather data on the sediment grain size across each of the sand resources and identify appropriate recipient beaches. Recipient beaches may be chosen from lists of those that are known to have long-term erosional losses, are public or protect public property, and have adequate grain size characterizations. Sediment budgets and transport analysis models may be developed to quantify sources and sinks of sediment along sections of the Massachusetts coast and to better predict and assess the effects of sand removal from potential offshore sand sites. To assist managers in deciding if an offshore sand resource is an appropriate donor—and if so, how much sand can be extracted—a sediment transport model may be created and validated. As a near-term priority, the dynamics of one offshore sand site will be modeled as a test case.

Potential partners for the tasks in this priority action include: CZM, USGS, BOEM, the University of Massachusetts and its Massachusetts Geological Survey Office, DMF, Massachusetts Department of Conservation and Recreation (DCR), MassDEP, Center for Coastal Studies, Woods Hole Sea Grant and Cape Cod Cooperative Extension, and municipalities.

2021 Priority 3 – Further characterize sensitive cultural and recreational areas

This priority includes five potential areas of investigation associated with it, each described below.

- **Identify Indigenous coastal access sites** - There is a lack of information on historical coastal rights-of-way (ROWs) used by the Indigenous community to access the waters off the Massachusetts coast for reasons of ceremony and sustenance. Some of these pathways are currently used, while others have been lost over time, due to inundation by sea level rise, or have been blocked by private landowners. These ROWs are important for their cultural and historical values, as well as for their practical value to today's Indigenous community for fishing, fowling, and navigation. CZM and BUAR will work with federal- and state-recognized Tribes in Massachusetts, and with the Massachusetts Commission on Indian Affairs (MCIA), to identify current and historical Indigenous coastal ROWs as the initial step in developing coastal community ethnographies. Over the next five years, a regional approach will be applied to collect data and information, starting with coastal areas around Nantucket Sound where the Mashpee Wampanoag Tribe, Wampanoag Tribe of Gay Head (Aquinnah), and Chappaquiddick Wampanoag Tribe's homelands are all concentrated, and where projected offshore wind energy infrastructure development may be sited. Geospatial databases will be developed and made available to Tribal, federal, and state managers and developers to be considered during future coastal and ocean spatial planning.

- **Update the archaeological site database** - This project will update data sets compiled from previous relevant research and will include information from the Massachusetts Historical Commission's Massachusetts Cultural Resource Information System (MACRIS), BUAR's updated shipwreck database, and new seafloor mapping/coring data collected for benthic mapping and offshore sand locations.

- **Map recreational diving hotspots** - A comprehensive database on recreational diving hotspots in Massachusetts does not currently exist. Recreational diving (mainly SCUBA) often takes place in areas that offer opportunities for shipwreck viewing. Based on this premise, the 2015 ocean plan included a map of 40 shipwrecks drawn from a list of Marine Protected Areas compiled by NOAA for U.S. waters (2015 ocean plan, Volume 2 Figure 27). Identified as "exempted sites," these are underwater archaeological resource sites that BUAR has exempted from their permit process due to their well-known locations, condition, history, and resource value, which are intended for the continued enjoyment of recreational diving as a WDU. The map in the 2015 ocean plan was used as a proxy for popular recreational diving sites and provided a spatial representation of this activity in the planning area. In addition to its importance as a recreational activity, the recreational diving community has been instrumental in providing information on shipwrecks and other types of underwater archaeological sites, in conducting fish censuses, and in monitoring invasive species. Recreational diving also serves as an important contributor to the marine economic sector. For these reasons, a science priority over the next five years is to conduct a comprehensive inventory of recreational dive sites based on information gathered with the help of diving clubs in Massachusetts. The data gathered will provide spatial information on hotspots for this WDU. Additional data on frequency of visits as well as number of visitors will be collected. Spatial data may then be used to develop a WDU map for recreational diving. In addition, CZM will coordinate closely with the diving community to verify and obtain better locational information on inventoried shipwreck sites. The data will be used to improve the accuracy and precision of the geospatial information needed for the development of an SSU map for shipwrecks that can be used by Tribal, federal, and state agency managers and developers to avoid archaeologically sensitive areas during offshore development.

- **Compile USGS data to map priority research areas for future sediment coring to assist in identifying paleolandscapes** - The development of a paleolandscape model and subsequent archaeological sensitivity maps of the seabed remains a research priority for the 2021 ocean plan. This effort will assist in determining the potential presence and preservation of ancient Indigenous archaeological sites on these now submerged lands. Archaeological sensitivity maps will be created that illustrate the potential presence of archaeological deposits. To advance the development of paleolandscape and archaeological sensitivity models for the Massachusetts Ocean Management Planning Area, CZM and BUAR will compile USGS legacy data to create a map of priority research areas. These data will be used in conjunction with CZM sand resource and habitat mapping data to identify future sediment coring locations that could assist in identifying preserved paleolandscapes and inform the regional stratigraphic and paleolandscape models and archaeological sensitivity mapping.

- **Conduct an updated recreational fishing survey** - Every year, NOAA conducts a comprehensive survey (Marine Recreational Information Program) to gather catch and effort data for recreational fishing in the United States. However, spatial information on recreational fishing activity is lacking. Data on recreational fishing hotspots for the 2009 and 2015 ocean plan were gathered from a targeted survey of recreational fishermen. Responses from a relatively small subset of fishermen in 2009 and 2015 were used to develop WDU maps of concentrated recreational fishing effort. However, for effective ocean planning, spatial data at higher resolution are required. DMF's Recreational Fishing Advisory Committee recommended that a comprehensive and methodical survey be conducted to gather statistically robust data on this activity. A science priority over the next five years is to conduct a comprehensive survey to identify and delineate recreational fishing hotspots based on information gathered with the help of the recreational fishing community in Massachusetts. For this effort, CZM will coordinate closely with DMF to reach out to the recreational fishing community to develop the survey, ensure the privacy of the data and information gathered, and use the data to accurately map concentrations of recreational fishing in the Massachusetts Ocean Management Planning Area.

2021 Priority 4 - Continue seafloor and habitat mapping

Efforts to characterize and classify marine habitats have been underway for more than 15 years through programs and projects by CZM, DMF, USGS, 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 high-resolution bathymetry data, 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 groundtruth the surficial sediment map through opportunistic sources, such as ocean development proponents, and through directed surveys, like the offshore sand resource characterizations and the ongoing CZM/USGS mapping collaborative. CZM will continue to acquire acoustic data, perform groundtruthing, and create maps in areas where these data are limited (e.g., Nantucket Sound, southern Cape Cod Bay, shallow coastal areas). CZM will continue to work with NOAA and regional partners to map geoforms (bottom habitats) throughout the Gulf of Maine, from Nantucket Shoals to the border with Canada, out 24 NM. CZM is hopeful that this effort will be a step toward improved, regionally consistent habitat maps.

Both the Habitat and Fisheries Work Groups identified the need for mapping various biological resources. In particular, there is a need to better understand the spatial distribution of biogenic habitats such as mussels, kelp, and worm reefs. These areas provide shelter for juvenile fish and crustaceans, provide foraging areas for adults, and affect sediment dynamics. Another area of needed research is to determine which plankton species are associated with the presence of North Atlantic right whales in and adjacent to Massachusetts waters. Knowing this association might help managers predict where whales may forage. More research is needed regarding how seabirds utilize offshore areas. Knowing when these birds migrate, where their migratory pathways are, and at what heights they fly may inform the siting and operations of offshore development, including offshore wind. Lastly, a need to better understand the distribution and abundance of important forage fish such as sand lance is important to the management and preservation of many species including seabirds, whales, and finfish. By incorporating these objectives as science priorities, CZM hopes to leverage other research programs to further habitat mapping.

2021 Priority 5 - Adapt the management framework in response to the most recent science and geospatial data, including climate change

As directed by the Oceans Act, a founding principle of the ocean plan is that it be a living document that responds to new science and geospatial data. While certain management areas (e.g., whale, bird, and eelgrass SSU areas) have been updated over time in response to new data, the management framework has remained the same. After more than a decade of implementing the ocean plan, knowledge of new maritime uses, as well as understanding of how species and habitats may be vulnerable to new and existing uses, has evolved. With this in mind, there are opportunities to adapt the following management elements in response to new science and data. In particular, one driver in the evolving distribution and abundance of marine organisms is the long-term increase in ocean temperature associated with climate change.

- **Evaluate the Fisheries Technical Work Group proposal for changes to the management of important fish resources SSU areas** - The important fish resources SSU area map was based upon the biomass of 22 species caught via the DMF spring/fall stock assessment trawl between 1978 and 2012. As part of the review of the 2015 ocean plan, the Fisheries Technical Work Group recommended that this map be updated to use the biomass of the same 22 species caught via the DMF trawl with the more recent data from 2008 and 2018 because of species distribution shifts associated with long-term, climate change-related increases in sea water temperature. Additionally, the Fisheries Technical Work Group recommended that the map incorporate the extent of the Massachusetts Bay Cod Spawning Areas. A review of the inclusion of the cod spawning areas in the important fish resources SSU area map will be a science priority for the next five years. The ocean plan process will also evaluate the list of uses that conflict with the fish resources SSU area map.

- **Use existing and emerging research to determine species or groups of species that are vulnerable to cable or pipeline construction, or sand extraction** - The Fisheries Technical Work Group report proposed a vulnerability matrix for several classes of organisms relative to the types of expected permitted activities in the planning area, including cable and pipeline laying and sand extraction. These vulnerabilities will be reviewed as an adaptation of the existing siting and performance standards in the ocean plan. In addition, similar to the fisheries vulnerability matrices, the Fisheries Technical Work Group proposed the use of matrices for additional benthic taxa including stony corals (*Astrangia),* soft corals (*Alcyonium, Gersemia*), high densities of Cerianthid anemones, stalked sponges (*Haliclona, Microciona, Isodictya, Phakellia*), rock-like sponges (*Cliona*), the stalked ascidian (*Boltenia*), and Asabellides worm reefs. While comprehensive maps of these taxa do not currently exist, a management framework could be proposed to be prepared for the time when these benthic resources are better mapped.

- **Collect new data to refine the existing concentrated recreational fishing WDU map** - The existing concentrated recreational fishing WDU maps are based on the responses of a relatively small number of recreational fishermen. The objective of this priority would be to survey a minimum of 2,000 fishermen about offshore recreational fishing activity, locations and other data associated with this activity.

- **Use existing and emerging research to update the performance standards and potential resource conflicts for allowed uses in the planning area** - The existing performance standards and matrices of potential conflicts between allowed uses and resources were developed with the original ocean plan. Since that time, understanding of the distribution and vulnerability of various species has improved, while at the same time, understanding of the potential impacts from the uses allowed in the planning area has also matured. This priority would evaluate each of the allowed uses against each SSU area and WDU to see if changes to the siting and performance standards are warranted based on current understanding and data available.