Northeast Ocean Planning Baseline Assessment: Marine Resources, Infrastructure, and Economics

Primary Authors:

Hauke Kite-Powell, Woods Hole Oceanographic Institution

Charles Colgan, Middlebury Institute for International Studies

Porter Hoagland, Woods Hole Oceanographic Institution

Di Jin, Woods Hole Oceanographic Institution

Vinton Valentine, University of Southern Maine

Brooke Wikgren, New England Aquarium

Northeast Regional Planning Body Project Managers:

John Weber, Northeast Ocean Planning Staff

Katie Lund, Northeast Ocean Planning Staff

Project Work Group

Jeff Adkins, National Oceanic and Atmospheric Administration

Todd Callaghan, Massachusetts Office of Coastal Zone Management

Bruce Carlisle, Massachusetts Office of Coastal Zone Management

Michele DesAutels, United States Coast Guard

Bob LaBelle, Bureau of Ocean Energy Management

Kathleen Leyden, Maine Coastal Program

Chris Tompsett, U.S. Navy

This project is supported by a grant from the National Oceanic and Atmospheric Administration (NOAA). The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA.

Abstract

This document summarizes the status of coastal and marine resources in the Northeast region of the United States, and how these resources generate economic and ecological value. The Northeast region, for ocean planning purposes, includes the coastal counties of Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut, and the New York counties (bordering Long Island Sound) of Queens, Bronx, Suffolk, Nassau, and Westchester. The coastal and marine natural resources and coastal infrastructure of the Northeast, and the economic activities and cultural/recreational services that rely them, directly and indirectly support more than 500,000 jobs and $40 billion in economic value (GDP) per year (2013 data) in the region. This represents about 2% of the region's overall economy. In addition, US Navy and Coast Guard activities in the region support more than 10,000 jobs and account for billions of dollars per year in federal expenditures in the region. The region's coastal and ocean resources also generate significant ecosystem service value in the region and beyond, though these values are not well quantified. Coastal and marine recreation and tourism account for about half of the region's ocean economy GDP and for more than 70% of ocean economy employment. The maritime transportation sector account for 16% of ocean economy employment and 29% of ocean economy GDP in the region; ship and boat building accounts for 11% of employment and 13% of GDP; and commercial fisheries and seafood processing account for 6% of employment and 8% of GDP. Information about the spatial distribution and status of coastal and marine resources and the economic activities that make use of them inform and support the Northeast ocean planning process.

Table of Contents

List of Figures

List of Tables

Abbreviations

AIS	automatic independent surveillance
EPA	Environmental Protection Agency
ES	ecosystem service
FTE	full-time equivalent (measure of jobs)
GDP	gross domestic product
IPCC	Intergovernmental Panel on Climate Change
LNG	liquefied natural gas (methane)
MCZM	Massachusetts Coastal Zone Management
NASCA	North American Submarine Cable Association
NEP	National Estuary Program
NERACOOS	Northeast Regional Association of Coastal Ocean Observing Systems
NOAA	National Oceanographic and Atmospheric Administration
RICRMC	Rhode Island Coastal Resources Management Council
RI [O]SAMP	Rhode Island Ocean Special Area Management Plan
RPB	Regional Planning Body
SST	Sea Surface Temperature
TEU	twenty-foot equivalent unit (measure of shipping container capacity)
USACE	US Army Corps of Engineers
USGS	US Geological Survey

1. Executive Summary

The Northeast region, for ocean planning purposes, includes the coastal counties of Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut, and the New York counties (bordering Long Island Sound) of Queens, Bronx, Suffolk, Nassau, and Westchester. The coastal and marine natural resources and coastal infrastructure of the Northeast region, and the economic activities and cultural/recreational services that rely them, directly support more than 320,000 jobs and more than $20 billion in economic value (GDP) per year (2013 data) in the ocean economy. This represents about 2% of the region's overall economy.

The major segments of the region's ocean economy are living resources (commercial fisheries, aquaculture, and seafood processing), coastal and marine tourism and recreation (including beach recreation, boating, fishing, whale watching, and SCUBA diving), maritime transportation of goods and passengers, ship and boat building, coastal and marine construction, and marine minerals (mainly sand and gravel).

Northeast Region Ocean Economy GDP ($million/year, 2013)

	ME	NH	MA	RI	CT	NY	Northeast Region
Living Resources	574.2	67.4	874.9	137.0	69.9	90.6	**1,813.9**
Tourism & Recreation	1,242.3	291.7	3,237.7	1,450.2	1,726.8	2,356.9	**10,305.5**
Transportation	195.7	1,058.4	2,195.3	273.6	817.1	889.2	**5,429.3**
Ship & Boat Building	677.3	--	30.7	309.8	1,679.8	2.1	**2,699.6**
Construction	30.2	6.9	127.9	24.1	49.7	86.8	**325.6**
Minerals	97.3	7.3	25.4	20.6	97.4	17.0	**265.5**
Ocean Economy	**2,817.4**	**1,431.7**	**6,491.7**	**2,215.3**	**4,440.7**	**3,442.6**	**20,839.5**

Northeast Region Ocean Economy Employment (2013)

	ME	NH	MA	RI	CT	NY	Northeast Region
Living Resources	7,744	566	7,436	1,385	818	2,473	**20,421**
Tourism & Recreation	30,694	7,328	68,063	34,439	36,875	64,188	**241,586**
Transportation	3,378	6,039	11,261	2,792	4,172	9,956	**37,599**
Ship & Boat Building	11,080	--	463	3,715	9,203	123	**24,584**
Construction	342	85	1,591	173	355	909	**3,455**
Minerals	328	43	151	176	306	328	**1,332**
Ocean Economy	**53,566**	**14,062**	**88,963**	**42,679**	**51,729**	**77,978**	**328,976**

Coastal and marine national security activities in the region, including US Navy and US Coast Guard bases, support more than 10,000 additional jobs and account for billions of dollars per year in federal expenditures. Including indirect and induced GDP contributions and employment – economic activity in other industries, supported by the ocean economy – the ocean economy, generates more than 500,000 jobs and $40 billion/year in GDP in the Northeast.

This economic activity extends to varying degrees on an interrelated set of natural resources and coastal infrastructure. Infrastructure includes ports, marinas, residential and commercial waterfront real estate, recreational areas, and waterfront access ways. Natural resources include beaches, coastal wetlands, nearshore and open ocean habitats, and complex ecosystems encompassing marine plants, finfish, shellfish, seabirds, and marine mammals. The health and integrity of these ecosystems affects the value they can generate for people. In addition to ocean economy values such as those in the tables above, the region's coastal and ocean resources generate significant ecosystem service value (water filtration, waste assimilation, storm surge protection, and carbon sequestration); and they support a range of historical, cultural, and spiritual values for Native tribes and more recent immigrants and their descendants. Many of these values are not readily observed in markets, and are not well quantified or understood.

The interrelationship between economic activities, resources, and infrastructure that supports the region's ocean economy sometimes gives rise to conflicts between competing users. Some resource uses are compatible with each other in a specific location, implying that the values they can generate in those use sectors are additive; some are incompatible, implying that some values may be diminished or obviated when resource uses overlap. Planning decisions may affect the quantity and/or quality of a resource or infrastructure category, or how it is distributed geographically (an historic example is the decision to improve water quality in Boston Harbor). Planning decisions may also affect access to resources and infrastructure, and the extent to which they are available as inputs to different economic sectors (for example, allocation of coastal ocean space to aquaculture could, in some cases, reduce access to that space by recreational boaters). By affecting the quantity, quality, and availability of resources for different uses, planning decisions affect the future generation of market and non-market (ecosystem) value.

Where use conflicts arise and resource uses are not compatible, legal systems, resource management policies, and planning decisions will affect how those conflicts are resolved and which use(s) have priority over others in each location. Including information about the economic consequences of different resource allocation and planning options can help inform marine resource management decisions.

This Baseline Assessment, the data available through the Northeast Ocean Data Portal, and the many other sources referenced in the pages that follow, are intended to inform and support the Northeast's ocean planning process.

2. Introduction

New England's marine resources are an important source of economic and ecosystem value. Together with the region's coastal infrastructure and human use, these resources are inputs to industrial, recreational, and service sector activities that support jobs and income. They also provide ecosystem services that contribute to the well-being of residents and visitors.

The Northeast Regional Planning Body (RPB) recognized the need to collect information on the region's coastal and marine resources, infrastructure and economy to support ocean planning in the Northeast. This baseline assessment compiles existing information and new analysis to characterize the region and provides guidance on how a Northeast Ocean Plan can address pressures on resources and resource use conflicts while supporting sustainable economic activity. The product is intended to provide a high level overview of current resources, conditions, and recent trends – not a historical look back in time.

To conduct this assessment, the RPB partnered with a team of researchers from the Woods Hole Oceanographic Institution's Marine Policy Center, the University of Southern Maine, the University of Massachusetts Boston, and the New England Aquarium. The assessment was directed by an RPB work group consisting of the following individuals:

- Jeff Adkins, National Oceanic and Atmospheric Administration
- Todd Callaghan, Massachusetts Office of Coastal Zone Management
- Bruce Carlisle, Massachusetts Office of Coastal Zone Management
- Michele DesAutels, United States Coast Guard
- Bob LaBelle, Bureau of Ocean Energy Management
- Kathleen Leyden, Maine Department of Agriculture, Conservation, and Forestry
- Chris Tompsett, United States Navy

2.1. Purpose and scope of baseline assessment

The goals of the baseline assessment are to: 1) describe the connections between natural resources, infrastructure, and economic value (broadly defined) in the region at present and in the future; and 2) provide tools and considerations to the RPB members as they develop a regional ocean plan. The assessment also identifies key gaps in data and information to consider in future planning.

Data on the region's marine resources and economic activity are illustrated in this document with appropriate maps, figures, and tables, as well as text summaries. The Baseline Assessment also contains references and links to more detailed versions of these datasets on the Northeast Ocean Data Portal, and to source documents and other datasets from which the Baseline Assessment data are drawn.

2.2. Resources and economic value generation

The natural coastal and marine resources of the Northeastern United States are an important source of economic and ecosystem service value. Together with the region's coastal infrastructure and human resources, these resources are inputs to industrial, recreational, and service sector activities that support jobs and income in the region. They also have intrinsic value and are a source of ecosystem services that contribute to the well-being of residents and visitors.

With rising population in the region's coastal areas, a growing range and intensity of human uses of coastal and marine resources, and evidence of climate change effects, pressures on natural marine resources and conflicts over their use have increased and are likely to continue to increase. In response to this, the NE RPB has adopted supporting healthy ocean and coastal ecosystems, effective decision making, and compatibility of past, current, and future ocean uses as the three overarching goals for ocean planning in the Northeast. The purpose of this baseline assessment is to support the RPB in the pursuit of these goals, by characterizing the region's ecosystem, economy, and cultural resources, highlighting the important connections between natural resources and the economy, and suggesting how a regional ocean plan can address pressures on resources, manage resource use conflicts, and support sustainable economic activity in the Northeast.

Ocean planning decisions can influence the health and availability of marine natural resources to market- and non-market value generation in the future. Ocean planning decisions will therefore influence the future path of development of the region's marine economy and the provision of ecosystem services. By understanding the connections between natural resources and economic value (broadly defined) in the Region at present and in the future, the baseline assessment seeks to inform and support the development of a regional ocean plan.

2.3. Geography of the Northeast Region

The Northeast region comprises the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, and the adjacent coastal waters, including parts of the Gulf of Maine, Georges Bank, the shelf waters from Cape Cod to the New York Bight, and Long Island Sound. The two major marine areas of the Northeast are the Gulf of Maine north of Cape Cod, and the New York Bight and Long Island Sound south and west of Cape Cod (Figure 1). For purposes of this baseline assessment, to provide information relevant to planning for Northeast ocean waters, we include data from all coastal counties in the Northeast states, plus five coastal counties in New York state that border on Long Island Sound.

NOTE: The map images shown in this document are intended to give a large-scale view of resources, infrastructure, and economic activity in the Northeast as a whole. Of necessity, many of them cannot show the detail needed to identify features at the local scale. The information on which these map images are based, and much other information useful to regional ocean planning, is available at smaller-scale resolution via the Northeast Ocean Data Portal. Readers who wish to explore data at higher resolution are encouraged to use the Data Portal.

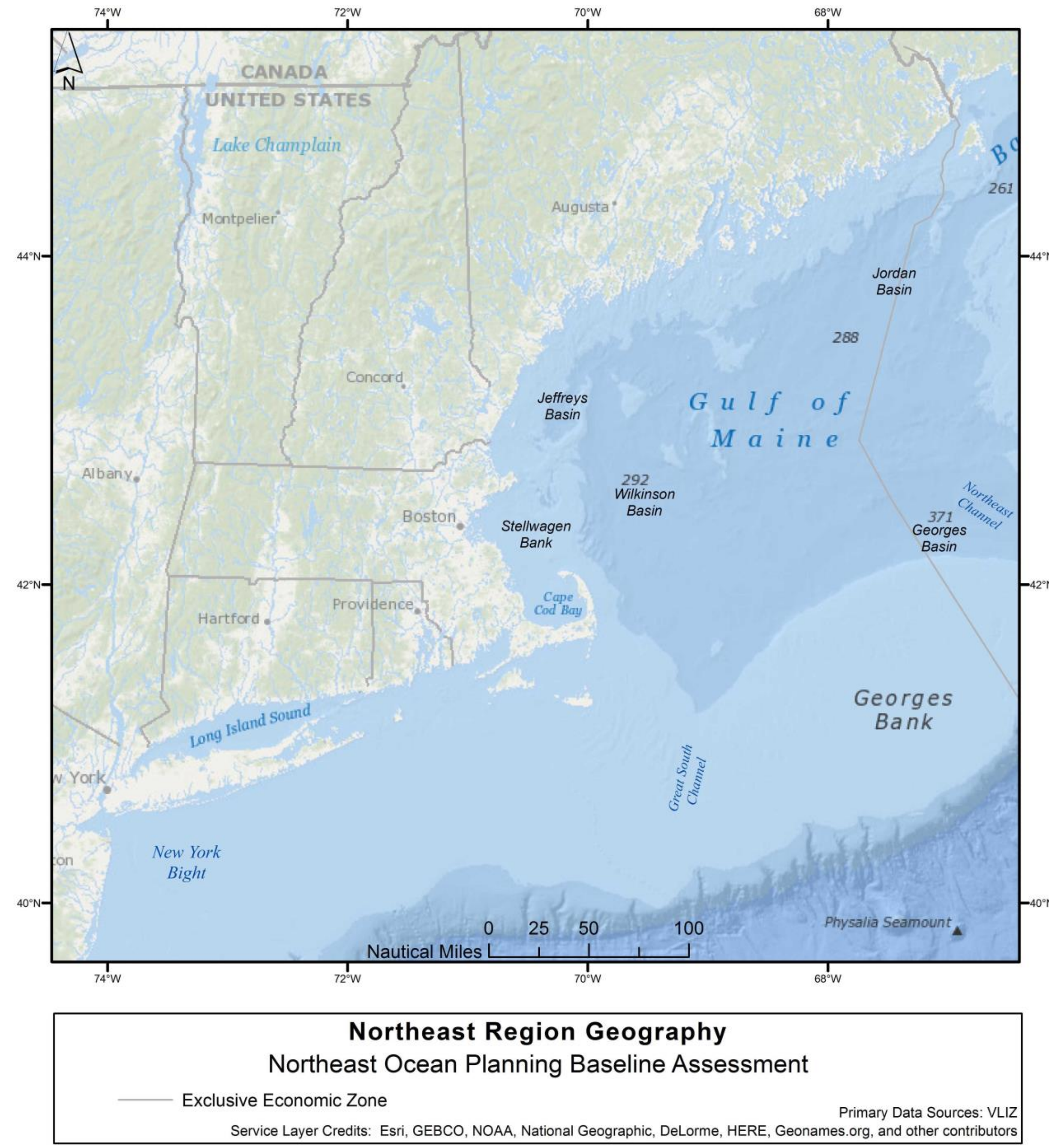


Figure 1 Northeast region geography

3. Resources and Infrastructure

3.1. Marine and coastal natural resources

3.1.1. Ocean waters

The ocean waters of the Northeast region consist of two distinct areas, separated by the Cape Cod peninsula: the Gulf of Maine to the north and east, and Rhode Island Sound, Block Island Sound, Long Island Sound, and parts of the New York Bight to the south and west. Exact numbers depend on boundary specifications, but the total surface area of ocean waters in the Northeast planning area is approximately 1 million km^2 (400,000 square miles, or 100 million hectares). The coastline from the Canadian border to New York City is about 1,000 km (670 miles) in length, which means that the region contains about 10,000 km^2 (4,500 square miles, or 1 million hectares) of bays and nearshore waters within 10 km of the coast.

The Gulf of Maine comprises Massachusetts Bay and the Bay of Fundy, and is home to the highest tidal variations on the planet. The coastline of the Gulf of Maine is predominantly rocky and scenic; the major areas of coastal development are located in the Boston, Portsmouth, Portland, and Saint John metropolitan areas. Glaciation during the last ice age stripped sedimentary soil away from the coastline; and the Gulf of Maine consequently has fewer sandy beaches than regions south and west of Cape Cod. The seabed sculptured during the lower sea levels of the ice ages makes the Gulf a semi-enclosed sea bounded to the south and east by underwater banks. Georges Bank in particular, on its southern end, separates the Gulf of Maine waters from the Gulf Stream. Gulf of Maine waters are strongly influenced by the Labrador Current, which makes Gulf of Maine waters significantly colder and more nutrient-rich than those found to the south. Undersea valleys in the central basin can reach depths of 1,500 feet (500 m) while undersea mountains rise up 800 feet (266 m) from the sea floor, almost reaching the surface in some locations, and in others forming islands.

There are three major basins contained within the Gulf of Maine: Wilkinson Basin to the west, Jordan Basin in the northeast, and Georges Basin in the south, all isolated from each other beneath the 650 foot (200 m) isobath. Georges Basin, just north of Georges Bank, is the deepest of the three at just over 1,200 feet (370 m) and generates a pocket at the end of the Northeast Channel, a deep fissure between Georges Bank and Browns Bank, the southwestern edge of the Nova Scotian Shelf. The Northeast Channel is the major channel between the Gulf and the rest of the Northwest Atlantic. A secondary, shallower connection to the Atlantic is the Great South Channel, located between Georges Bank and the Nantucket Shoals. See Northeast Ocean Data Portal for additional detail on bathymetry.

The New York Bight is a slight indentation along the US Atlantic coast centered on the mouth of the Hudson River, and extending northeasterly from Cape May Inlet in New Jersey to Montauk Point on the eastern tip of Long Island. The sea floor of the Bight consists largely of continental shelf and includes the Hudson Canyon, an undersea Pleistocene submarine canyon formed by the Hudson River during the ice ages. The continental shelf waters of the Northeast region south and west of Cape Cod are generally shallower than the Gulf of Maine (Figure 2).

Long Island Sound is a tidal estuary located between the eastern shore of Bronx County, New York City, the southern shores of Westchester County and Connecticut, and the northern shore of Long Island. The sound stretches 110 miles (177 km) from the East River in New York City eastward along the north shore of Long Island to Block Island Sound. A mix of freshwater from tributaries and saltwater from the ocean, Long Island Sound is 21 miles (34 km) at its widest point and varies in depth from 65 to 230 feet (20 to 70 m).

Block Island Sound, Buzzards Bay, and Nantucket Sound are coastal water bodies shaped by the advance and retreat of the Pleistocene glacial ice sheet in the Late Wisconsinan period (17-18,000 years ago). The maximum advance of the ice during that time produced a discontinuous terminal moraine that extends from Nantucket across Block Island to Long Island. The sounds and bays south of Cape Cod are low bedrock regions bounded by the higher bedrock that underlies Long Island, Block Island, Martha's Vineyard, Nantucket, and Cape Cod (Davis 1994). Nantucket Shoals is an area of shifting sands and shallow water (less than 1m deep in places) that extends from Nantucket Island eastward for 23 miles (37 km) and southeastward for 40 miles (64 km). The Great South Channel is an area of deeper water that runs north-south between Nantucket Shoals and Georges Bank. It is a major shipping channel connecting the Port of New York and New Jersey, and other US east coast ports to the south, with Boston and other ports in the Gulf of Maine.

The watershed of the Gulf of Maine encompasses an area of 69,115 square miles (179,008 km^2), including all of Maine, 70% of New Hampshire, 56% of New Brunswick, 41% of Massachusetts, and 36% of Nova Scotia. The watershed also includes a small southern portion (less than 1%) of the Canadian province of Quebec. Significant rivers that drain into the Gulf include, from east to west, the Annapolis, Shubenacadie, Salmon, Petitcodiac, Saint John, Magaguadavic, St. Croix, Penobscot, Kennebec, Saco, Piscataqua, Merrimack and Charles rivers; the Saint John and Penobscot provide the largest freshwater inflows to the region's coastal waters.

The Atlantic Ocean/Long Island Sound Watershed drains most of the New York City Metropolitan Area and all of Long Island, as well as much of Connecticut and Rhode Island. The watershed encompasses all marine waters in New York Harbor, Long Island Sound, Block Island Sound, and along the South Shore of Long Island, and the fresh waters that drain into them.

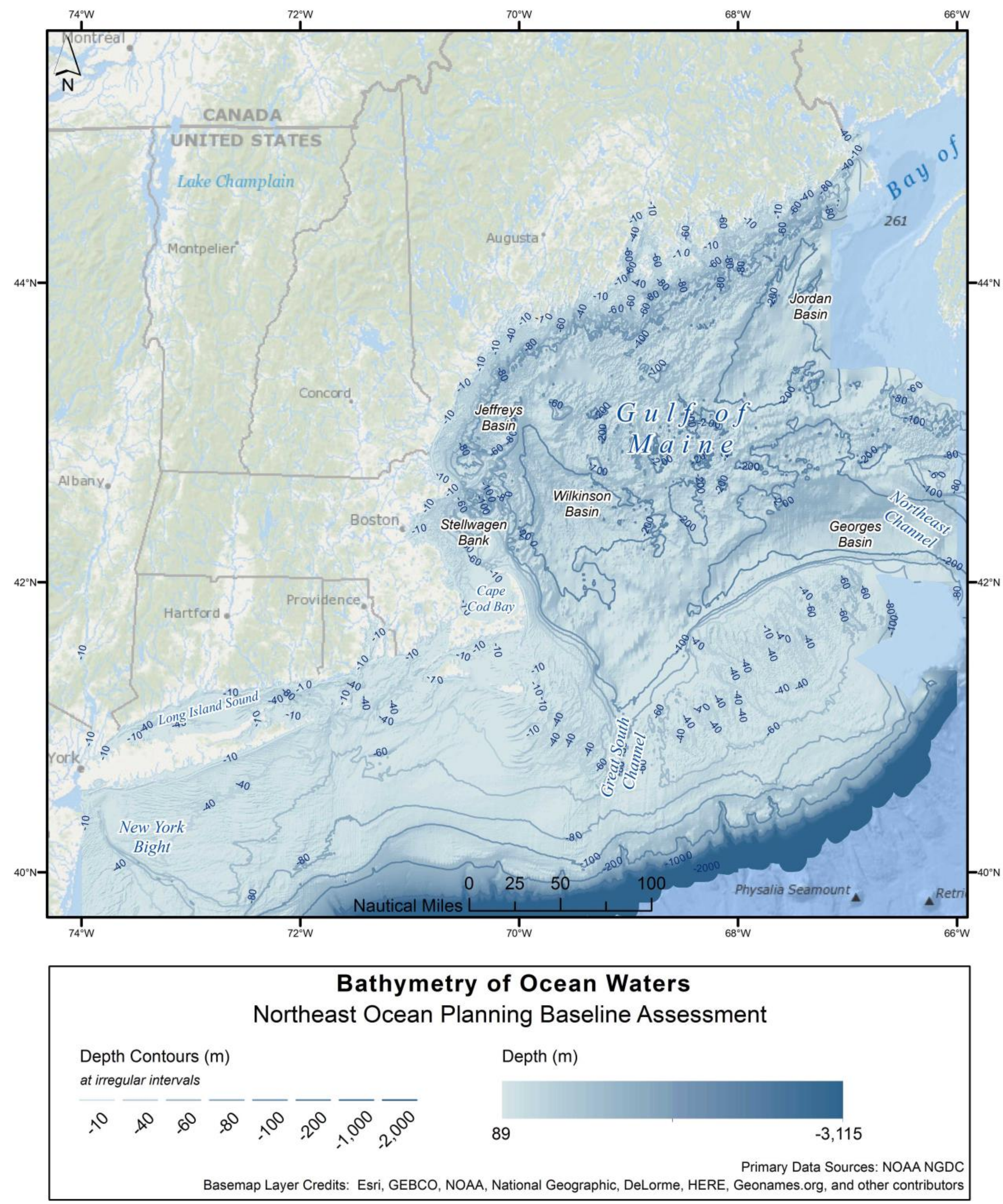


Figure 2 Ocean bathymetry

3.1.2. Coastal water quality

The open ocean waters of the Northeast region are, for the most part, clean and free from pollution that is likely to cause direct harm to marine organisms or people. Some coastal water bodies and sediments around the Region, however, are compromised by anthropogenic pollution.

Information about degraded coastal waters can be found in each state's Impaired Waters List, which is assembled by states pursuant to the federal Clean Water Act. Links to these lists can be found at: https://www.epa.gov/tmdl/impaired-waters-and-tmdls-new-england (Figure 3). States are required to update their list every two years, and include every water body (including coastal waters and estuaries) that is impaired or threatened by one or more pollutants. The most common pollution problems in Northeast coastal waters are the introduction of bacteria and other pathogens to coastal waters from runoff during rain events, and the overloading of coastal waters with nutrients (nitrogen, phosphorus) via groundwater, surface runoff, and atmospheric deposition. States establish Total Maximum Daily Loads (TMDLs) for pollutants for specific water bodies to mitigate impaired water quality. Information about TMDLs can be found at: https://www.epa.gov/tmdl. Many Northeast beaches and shellfish beds are monitored regularly for bacteria concentrations in water, to safeguard human health. When bacteria levels in water samples exceed the EPA's threshold level, this leads to beach closures. Information about beach water quality and closures can be found at: https://www2.epa.gov/beaches/find-information-about-your-beach

Sediments polluted with heavy metals, hydrocarbons, and other hazardous materials have been identified in a number of locations throughout the Northeast, including parts of the Lower Connecticut, Charles, Quinnipiac, Housatonic, Saugatouk, and Hudson Rivers, and Massachusetts Bay and Long Island Sound. Specific National Priorities List sites judged to be heavily impaired and in need of remediation include the New London Naval Submarine Base on the Thames River in Connecticut, New Bedford Harbor in Massachusetts, and the Portsmouth Naval Shipyard in Kittery, Maine. Information about designated hazardous waste contaminated sites in the region can be found at: https://www.epa.gov/cleanups/cleanups-my-community

Additional information related to water quality can be found on the Northeast Ocean Data Portal. More details on sub-regions is also available, see for example the Long Island Sound Report Card – Grading the water quality and ecosystem health of the Urban Sea. Information about current and past marine conditions in the Gulf of Maine can be obtained from the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS).

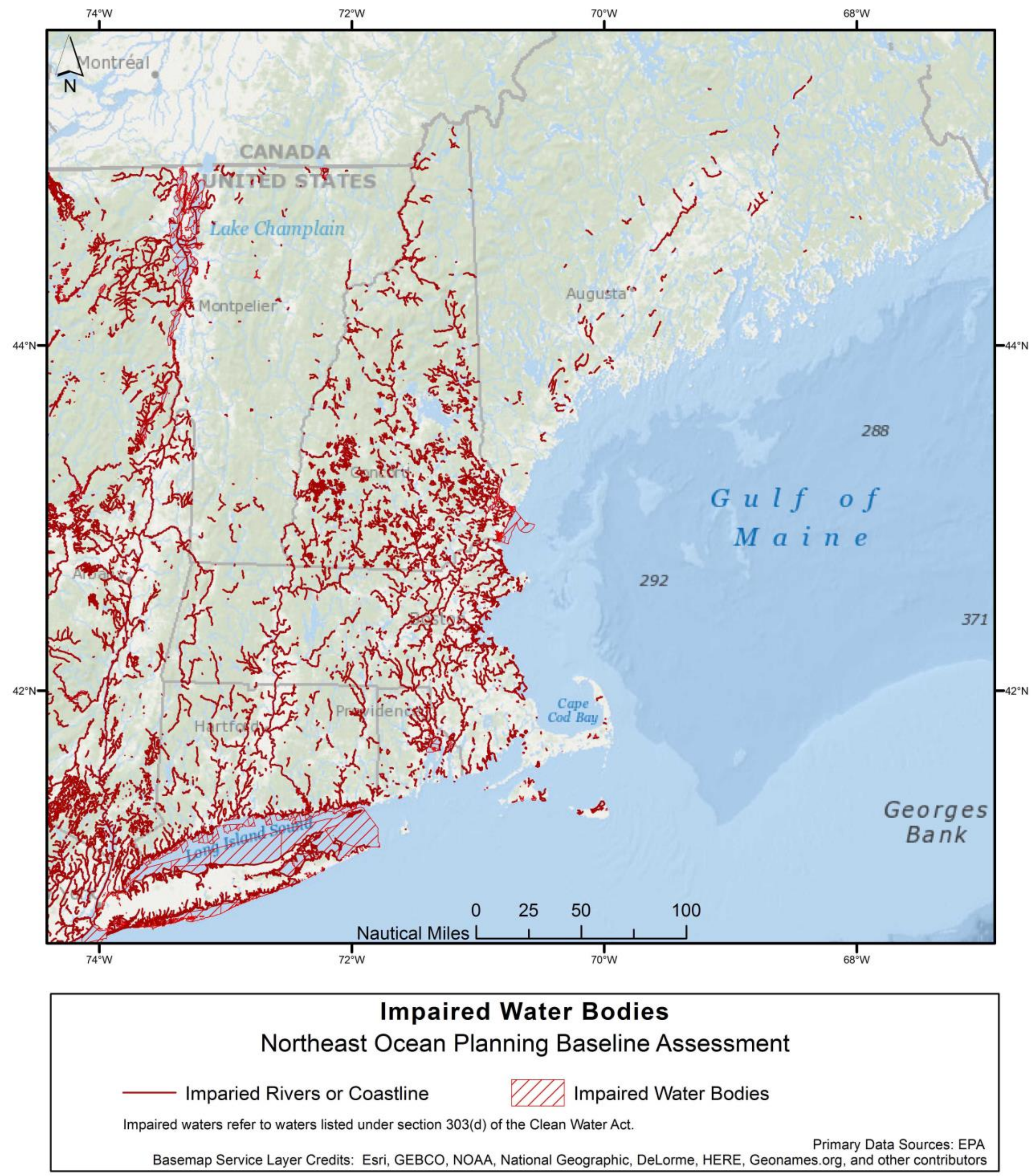


Figure 3 Impaired water bodies

3.1.3. Seabed and habitat

The Gulf of Maine was formed by glaciers pushing debris down from the Appalachian Mountains. When the glaciers retreated some 11,500 years ago, they left behind scoured bedrock and large moraines. These are now the basins and banks that give the Gulf of Maine its distinctive shape.

Because of its relative youth, the Gulf of Maine has a tremendous variety of bottom habitats, from the soft, flocculent muds that are beginning to accumulate in the deep basins, to the unsorted coarse gravel of the banks to areas of scoured bedrock. Combined with nutrient-rich waters, this range of habitats supports a large variety of benthic organisms and provides living space and protection to the developing stages of numerous pelagic and demersal species, making the Region one of the most productive marine ecosystems on the planet. South and west of Cape Cod, the seafloor is more commonly covered in some combination of sand and gravel (pebbles). Figure 4 illustrates the variety and distribution of different seabed and habitat types in the region, and highlights the difference between the deeper waters of the Gulf of Maine and the relatively shallower shelf waters south and west of Cape Cod.

The Gulf of Maine Habitat Primer (Tyrrell 2005) recognizes twenty different habitat types differentiated by the nature the substrate, the water depth, and the biogenic structure. Substrate types include sand dunes, tidal and subtidal mud flats, sand beaches, subtidal sand, intertidal and subtidal gravel and cobble, intertidal and subtidal boulders, and intertidal and subtidal rock outcroppings. Biogenic habitat types include salt marshes and *Phragmites*, shellfish beds, *Codium* beds, seagrass beds, kelp beds, and cold-water coral assemblages.

Seagrass is a general term for flowering plants that live in low intertidal and subtidal marine environments (Tyrrell 2005). Roots anchor seagrass to the sediment, but unlike terrestrial plants, seagrass also absorbs nutrients from the water along the entire length of its blades, which can reach ten feet. Similar to horizontal stems, rhizomes connect the upright shoots. Two species of seagrass are found along the coast of the Northeast. Eelgrass (*Zostera marina*) is the dominant seagrass throughout the region, while widgeon grass (*Ruppia maritima*) is limited to low-salinity waters. Eelgrass tolerates a wide range of temperature (0–30°C) and salinity regimes (10–30 parts per thousand) and takes root on substrates from coarse sand to mud. It even thrives among cobbles and boulders, in small patches of soft sediment. Eelgrass can live everywhere from tide pools along the shoreline to subtidal areas of up to 12 meters depth, as long as the water is relatively clear and allows sufficient light for growth. The most important factor in eelgrass survival and growth is light limitation. Eelgrass beds are a critical habitat in the Gulf of Maine. Their connection to fisheries is especially valuable. Eelgrass also provides vital services to improve water quality by filtering suspended sediment and excess nutrients. Additional information on habitats can be found on the Northeast Ocean Data Portal.

The Northeast Regional Ocean Council (NROC) recently sponsored a project to review marine habitat classification, characterization, and modeling activities in the Northeast region. This project resulted in an overview and comparison of existing marine habitat efforts in the Region being conducted by state and federal agencies, nongovernmental organizations, and academia. This report has been prepared to support NE ocean planning-related efforts and includes the results of a marine habitat classification and modeling workshop that the NE RPB and the Northeast Sea Grant Consortium convened in September 2013. More information is available in Review of Marine Habitat Classification, Characterization, and Modeling Activities in the Northeast United States and in Shumchenia *et al.* (2014).

Supplemental information is available from:

- Gulf of Maine Mapping Initiative
- Long Island Sound Mapping Initiative
- USGS seafloor mapping
  - CZM Cooperative Seafloor-Mapping Project (Massachusetts) provides high-resolution geologic data and products in support of the Massachusetts Ocean Management Plan
- HabCam survey work done in SBNMS (2007-2010) as component of the Northeastern Bentho-pelagic Observatory (NEBO). HabCam is an optical habitat mapping system for characterizing benthic community structure, sediment characteristics and water column properties

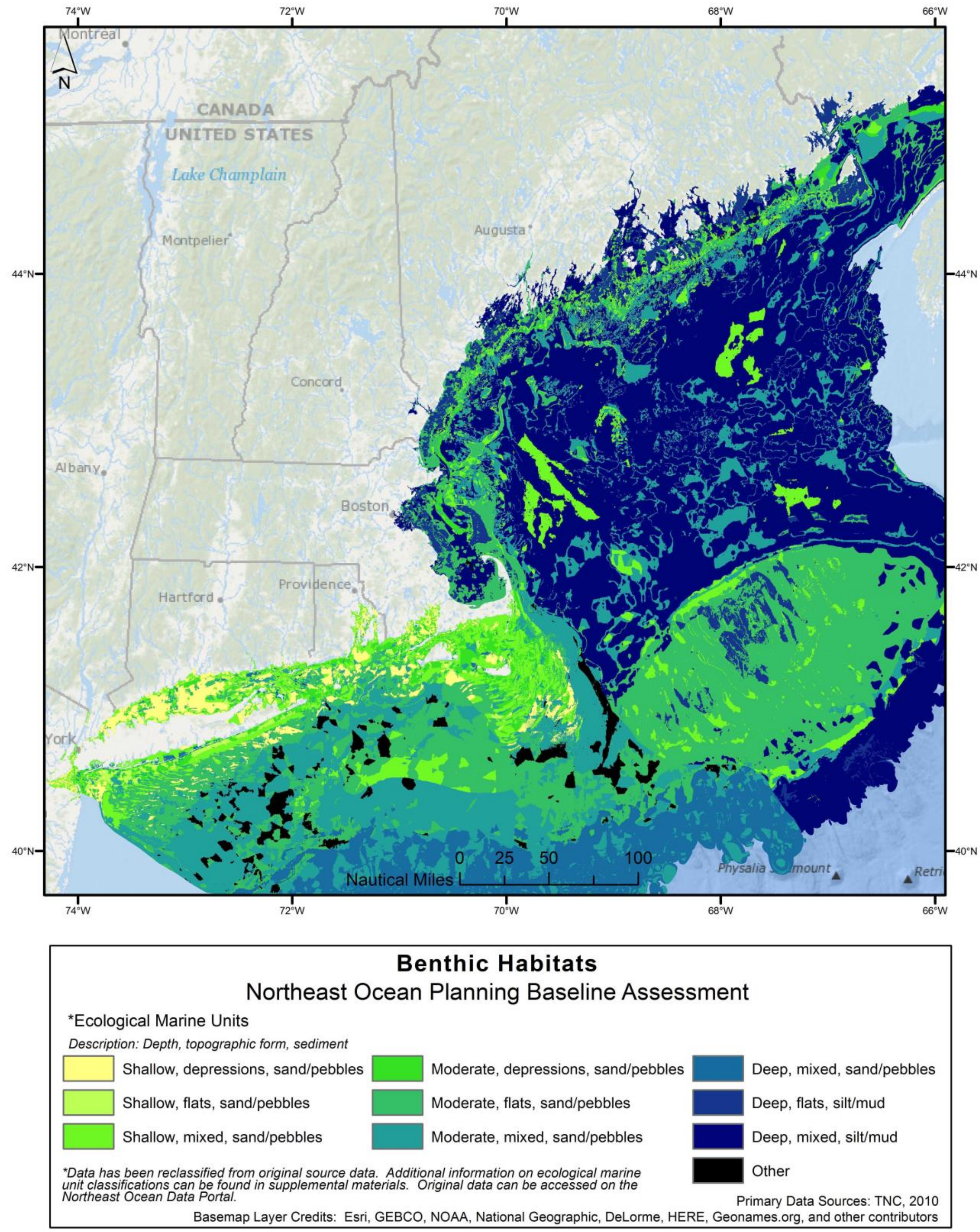


Figure 4 Benthic habitats

The information in Figure 4 is based on benthic habitat classifications from the 'Seafloor Habitats' layer downloaded from the Northeast Ocean Data Portal. Those data were assembled by The Nature Conservancy (TNC) in 2010 as part of the Northwest Atlantic Marine Ecoregional Assessment (NAM ERA). The benthic classifications were created using information on benthic fauna, bathymetry, sediment, and seabed forms. TNC's NAM ERA spatial data page provides updates and describes the synthesis of this diverse spatial data, which can also be downloaded. A complete discussion of the methodology is described in Chapter 3 of NAM ERA.

To simplify the map presentation of habitat types for purposes of this report, we have aggregated the 65 different benthic classifications NAM ERA uses for the Gulf of Maine and Southern New England Regions into 10 habitat categories (Figure 4). These are based on three depth designations (shallow, moderate, deep), three substrate designations (sand and pebbles, silt and mud, any), and four seabed forms classifications (depressions, flats, sloped, mixed). For details on the aggregation procedure, please refer to Appendix A.

3.1.4. Sand and gravel; beaches

For beach water quality monitoring purposes, the EPA recognizes more than 6,000 beaches nationally and about 900 distinct ocean beaches along the shorelines of the Northeast region (Figure 5). Sandy beaches are more prevalent in Massachusetts Bay and south and west of Cape Cod than along the coast of the Gulf of Maine. Massachusetts (374 EPA-listed beaches) and Rhode Island (74), and Connecticut (75) account for about half of the regional total. The Bronx, Nassau, Queens, Suffolk, and Westchester counties of New York have about 300 EPA-listed beaches. New Hampshire has 16, and Maine has 62. These beaches form protective barriers along some sections of the coast, are a major attraction for visitors from within and outside the Northeast region, especially in the Cape Cod area, and help generate significant market and non-market value associated with beach recreation (see section 4.4.3 below). Information is available at: http://www2.epa.gov/beaches

Sandy environments tend to have comparatively low biological productivity and species diversity, but they have unique species assemblages (Tyrrell 2005). Few species of algae grow in sandy areas because of a lack of solid substrates for attachment. Some filter- and deposit-feeding invertebrates thrive in sandy habitats, and fish hide among the ripples and ridges of subtidal sandy bottoms. Moon snails consume their bivalve prey while buried beneath the sand surface. Dunes provide nesting habitat for some imperiled birds, such as the roseate tern, northern harrier, piping plover, and least tern, and for the threatened diamondback terrapin. Some commercially valuable species such as the surf clam, quahog, winter flounder, summer flounder, and Atlantic halibut associate closely with sandy habitats. Dunes can protect inland areas from storm waves and wind, but human alterations of the shoreline frequently compromise this natural service. Sand beaches and dunes are prized for human recreation. The price of real estate along sandy shores reflects this value. The Gulf of Maine Habitat Primer provides additional information about physical habitat types.

Extensive sand and gravel deposits lie beneath the waters of the Northeast region (Figure 5), and support a modest minerals mining industry (see section 4.8.2 below). "Gravel" as used in the context of Figure 5 generally refers to sediments with grain size above 2 millimeters.

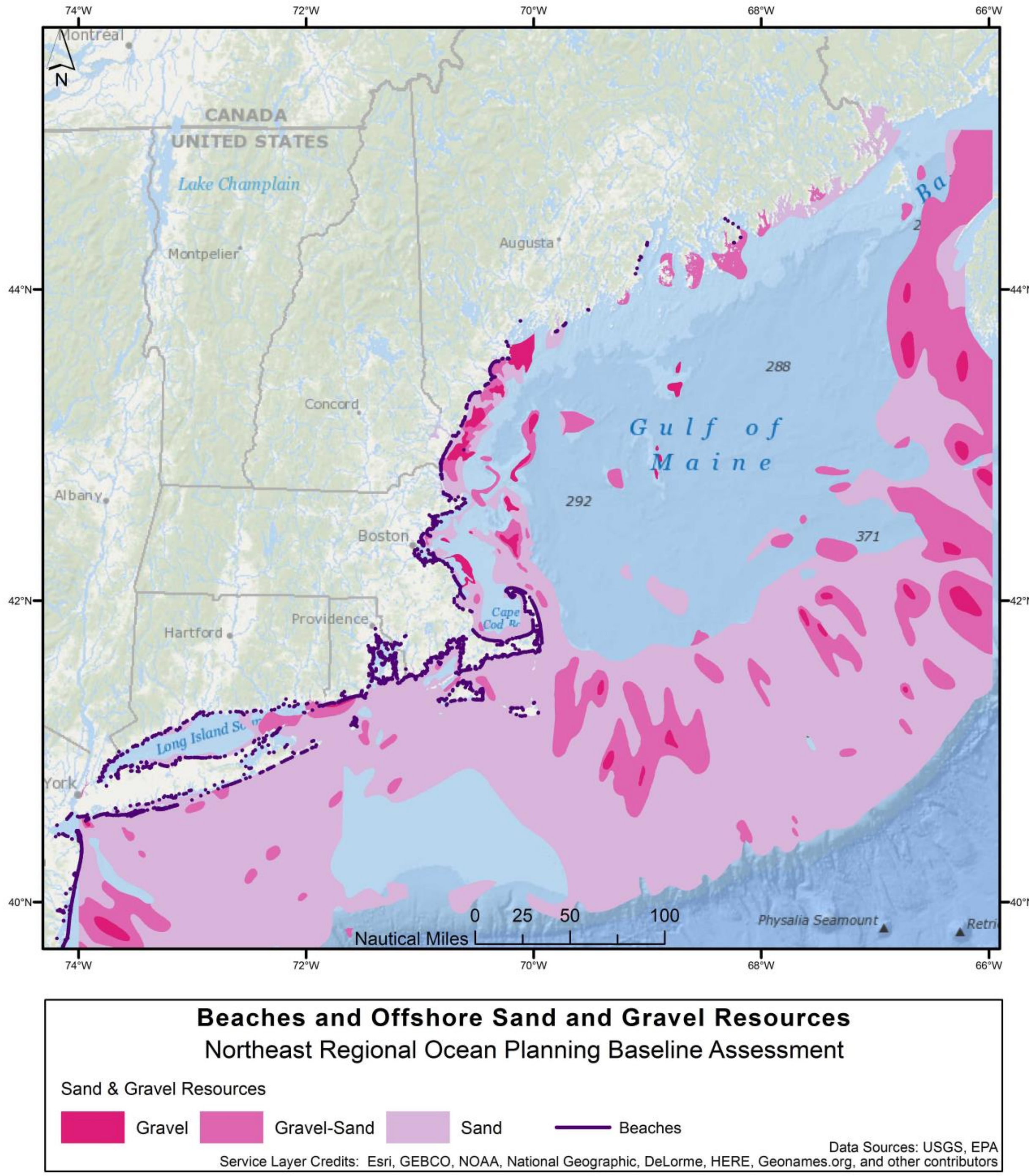


Figure 5 Beaches and offshore sand and gravel resources

3.1.5. Wetlands

Coastal marine wetlands extend along much of the shore of the Northeast region and form important habitats for marine life and birds, provide filtration functions for watershed drainage and coastal runoff, and buffer adjacent near-shore areas against coastal flooding. The Northeast as whole has some 300,000 acres of marine and estuarine wetlands (Table 1; Figure 6), and about 4.5 million acres of fresh water and inland wetlands (palustrine, lacustrine, and riverine). Because wetlands were long seen as "unhealthy" breeding grounds for noxious insects, and unsuitable for construction of residential or commercial buildings, many wetlands were filled or drained in the centuries after European settlement of the Region. It is estimated that the nation's wetland acreage today is about half of what it was before European colonization (Tiner 2005).

Acres of wetlands:	Marine	Estuarine	Fresh water/inland
Maine	69,816	83,175	2,022,141
New Hampshire	886	9,297	282,387
Massachusetts	21,269	61,854	453,356
Rhode Island	930	7,288	62,460
Connecticut	--	18,788	183,091
New York*	4,983	36,161	1,531,609

Table 1 Wetland acreage of the Northeast region states
Source: Tiner (2010). *Figures for New York are based on partial coverage of the entire state, not only the coastal counties included in the Northeast region. See Tiner (2010).

The state of Maine is considered to have the greatest total acreage of wetlands of all the contiguous US states; but most of these are inland freshwater wetlands. Using a measure of coastline length that is based on NOAA's 1975 estimates (CRS 2006), the wetland density along the Northeast's coast ranges from about 200 acres/mile of coast (Connecticut and Rhode Island) to about 700 acres/mile (New Hampshire and Maine). More information is available in Dahl and Stedman (2013), Tiner (2010), and on the Environmental Protection Agency's wetlands pages.

The Gulf of Maine Council on the Marine Environment has provided funding and technical assistance to 120 habitat restoration projects restoring more than 5,000 acres of important habitat in the region since 2002. These projects seek to reverse impacts to impaired coastal wetlands ands streams, and to restore their ecological functions and economic contributions to their full potential. The NE RPB also established a subcommittee to consider how best to recognize and support existing non-regulatory opportunities to work toward conserving, restoring, and maintaining healthy ocean and coastal ecosystems throughout the New England region. The subcommittee includes restoration experts at the non-governmental, tribal, state, and federal level who came together to look at restoration and conservation needs across the region, and strategically prioritize those projects most likely to produce substantial, sustainable benefits. A restoration theme on the NE Data Portal displays the location of priority Northeast US regional ecosystem restoration and conservation projects (including wetlands restoration) that, when implemented, will improve ocean health in the Northeast.

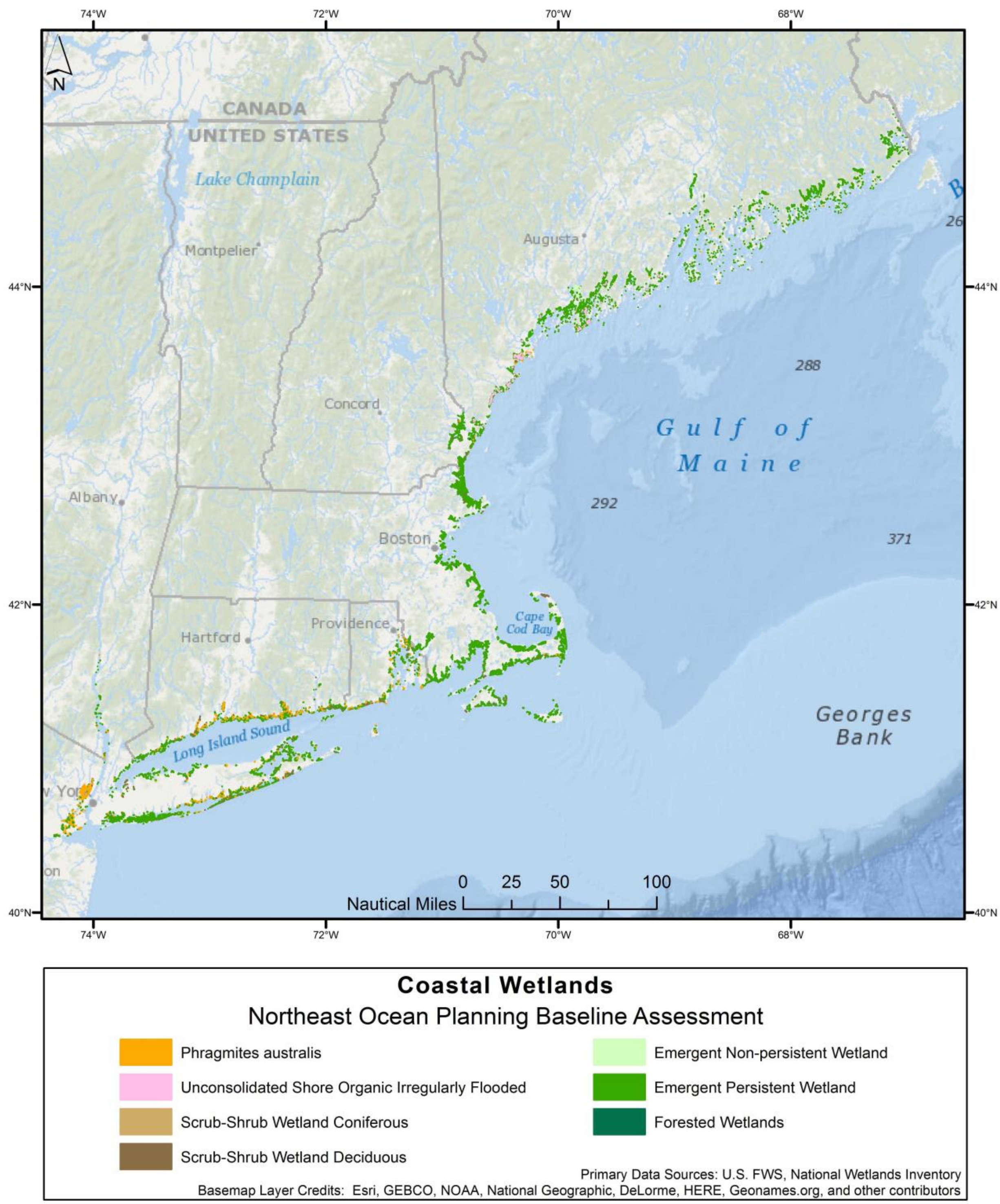


Figure 6 Coastal wetlands

3.1.6. Marine management areas

An extensive patchwork of federal and state marine management areas covers much of the Northeast region's ocean waters. Typically, each management area has a particular conservation focus to protect natural heritage, cultural heritage, or sustainable use of and/or production from marine resources.

Figure 7 illustrates some important federal management areas in the marine and coastal zone including: National Wildlife Refuges, National Park Service management areas, National Marine Sanctuaries, and National Estuarine Research Reserves. More information is available on the NOAA marine protected areas web pages and on the web sites of specific marine management areas (see Appendix B). In addition, the National Marine Fisheries Service has management areas where fishing activity is restricted for conservation or stock protection, areas protecting critical habitat for certain marine species, and areas restricting vessel and other operations to safeguard endangered species.

The Northeast also has six EPA National Estuary Programs (NEPs) established by Section 320 of the federal Clean Water Act. These include: Casco Bay Estuary Partnership, Piscataqua Region Estuaries Partnership, Massachusetts Bays National Estuary Program Buzzards Bay National Estuary Program Narragansett Bay Estuary Program, and Long Island Sound Study. In cooperation with state and local agencies and stakeholders, their work is guided by "comprehensive conservation and management plans" that provide blueprints for the protection and restoration of water quality and living resources in these waters. For more information on NEP study sites see the list of individual NEP homepages.

Examples of state management areas include the Massachusetts Ocean Plan's special, sensitive, or unique habitat designations and the Rhode Island Ocean Special Area Management Plan management areas.

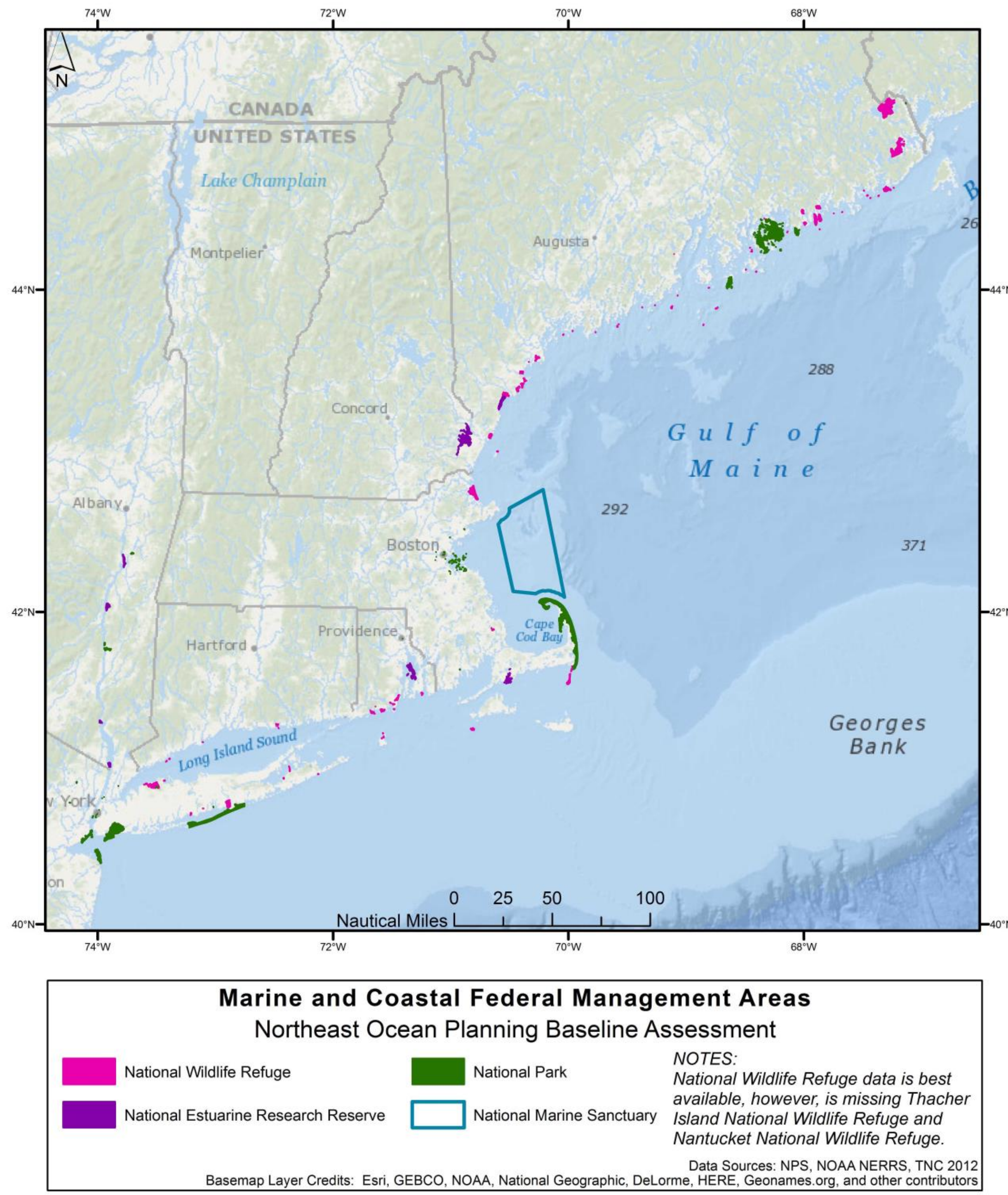


Figure 7 Federal marine management areas

3.1.7. Marine life characterization

The diverse coastal and marine habitat types in the Northeast are home to a variety of marine mammals, birds, fish, invertebrates and other species. The waters of the Gulf of Maine system, particularly at the boundary with the Bay of Fundy, are also home to the summering grounds for many different whale species, most notably the highly endangered North Atlantic right whale (*Eubalaena glacialis*).

Quantitative information about the spatial distribution and abundance of marine life is limited by the extent of human observations, which are concentrated on the coast or at the water surface, during daytime hours, and during good weather. Fish trawls and underwater imagery provide important sources of subsurface information, but are still limited by the types of environments in which they can be employed. Technologies such as satellite sensors, and environmental modeling efforts, supplement direct human observations with additional information. Still, there are geographic areas and a whole host of species—some that play important roles in the ecosystem—for which we have very little quantitative data. Scientific-quality survey data, collected by state and federal agencies, research institutions and other groups, provide information on three major taxonomic groups: marine mammals, birds, and fish. Important gaps for these three taxa remain, and relative to these, there are fewer data available for species such as sea turtles, large-bodied fishes, seals, benthic infauna/epifauna, coastal birds, bats, kelp and macroalage, and others.

Recently, new marine life data products (marine mammals, birds, and fish) were developed through a partnership with the Marine-life Data and Analysis Team (MDAT), which is a collaboration between Duke University, NOAA Northeast Fisheries Science Center, NOAA Centers for Coastal and Ocean Science, and Loyola University. The MDAT team collaborated with the RPB and expert work groups to produce individual species maps characterizing the distribution and abundance or biomass of 150 marine mammal, bird, and fish species, including several measures of uncertainty to supplement each map. Due to agency, work group, and public feedback, the RPB further aggregated these base products into summary maps (e.g., species richness) for whole taxa and certain species groups to provide a very broad snapshot of average annual marine life distribution and abundance. To better understand marine life movement, migration, and other behaviors, other datasets and/or analyses are needed. Some examples of this information are included in the descriptions below.

It is important to note that the MDAT project was conducted concurrent with the development of the Baseline Assessment. Therefore, the MDAT maps and project documentation on the Portal, combined with the Northeast Ocean Plan's Marine Life section of Chapter 3, provide a more complete source of information for marine mammals, birds, and fish. The Portal houses maps for 28 marine mammal species or guilds, 40 bird species, and 82 fish species from four separate trawl datasets. Additionally, these individual species maps have been aggregated into summary products, which represent patterns in groups of species based on existing regulatory frameworks (e.g., Endangered Species Act), species' ecology (e.g., feeding guild), and species' vulnerability to stressors (e.g., sensitivity to sound).

Marine mammals

The MDAT project developed models for 28 marine mammal species or guilds, including seals (all seal species were modeled together as a guild) and the North Atlantic right whale (Figure 8). Marine mammals were modeled at monthly, seasonal, and/or annual scales depending on the number of observations available. The MDAT map of average annual marine mammal species richness for the Atlantic coast (excluding seals; Figure 9) shows the highest number of species near the continental shelf break and slope. At the time of completion of the Phase 1 MDAT marine mammal models, there are plans in Phase 2 to supplement and/or complement the MDAT results with other marine mammals data sources such as observations from the North Atlantic Right Whale Consortium database, the Atlantic Marine Assessment Program for Protected Species database, and the Massachusetts Clean Energy Center monitoring data.

Monthly model outputs for marine mammals can be particularly important for understanding patterns in species that use the Northeast region for breeding and feeding during phases of their annual migrations. Other data sources that provide data and information about the timing and types of marine mammal life histories and behaviors include the passive acoustic monitoring work by the NOAA Protected Species Branch, and the delineation of Biologically Important Areas by the NOAA CetMap project.

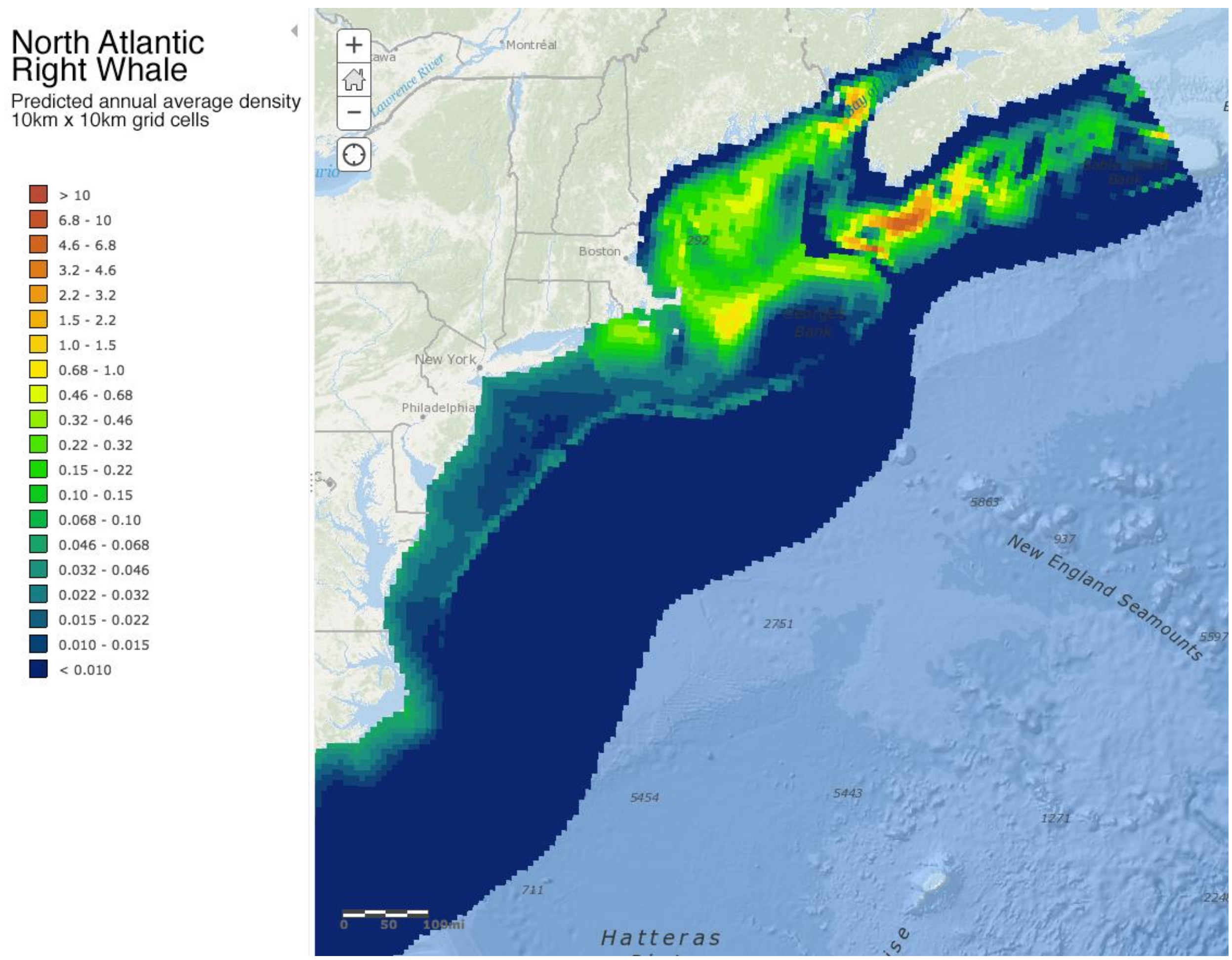


Figure 8 Modeled annual North Atlantic right whale abundance (predicted number of animals per 10km x 10km grid cell) from the Marine-life Data and Analysis team.

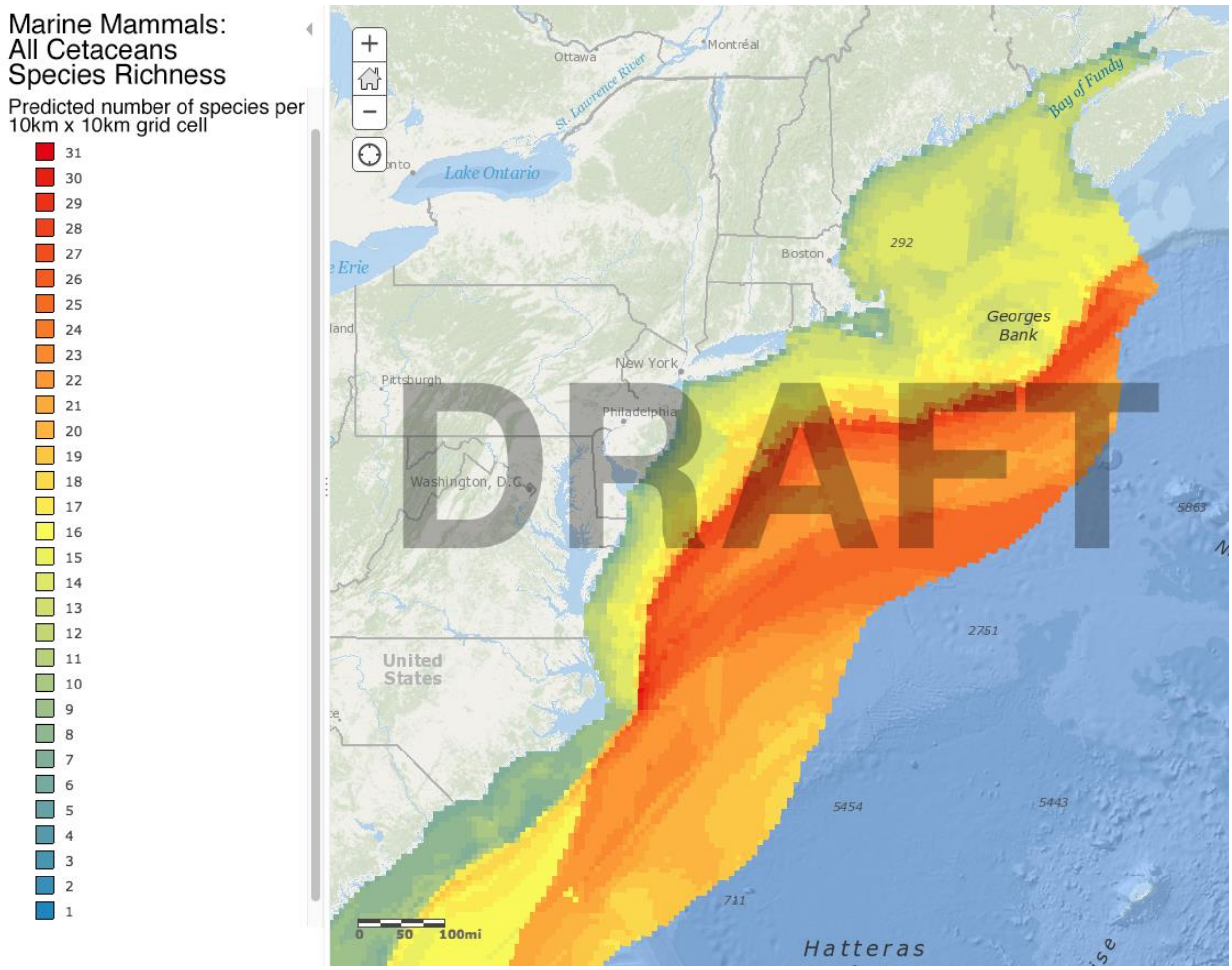


Figure 9 Marine mammals species richness (count of the total number of species present in each 10km x 10km grid cell using the annual individual species model results), excluding seals, from the Marine-life Data and Analysis Team. (Note: the marine life species group products initially were reviewed by the expert work groups and will continue to be reviewed by experts and stakeholders during the review of the draft NE Ocean Plan. Therefore, the species group products are labeled "Draft". The RPB will revise these products accordingly).

Birds

Birds are a diverse taxonomic group for which movement and migration data are also important. Seabirds, shorebirds, ducks, and even some songbirds utilize the Northeast marine environment. The MDAT project modeled the relative abundance and occurrence of 40 species—mostly "seabirds"—at seasonal and annual scales using at-sea observation data. For example, the MDAT avian model shows the relative abundance of long-tailed ducks in the region (Figure 10). The MDAT average annual species richness map for birds shows generally high richness offshore, in areas near Georges Bank, and near the continent shelf break and slope (Figure 11).

The Compendium of Avian Occurrence, from which the MDAT models were developed, is also an important source of information for nearshore and coastal bird observations.

These nearshore and coastal observations weren't included in the MDAT products because the modeling framework relied on oceanographic variables that were only available 1-2km offshore to the EEZ. Other data sources that supplement MDAT products include the US Fish & Wildlife Service Mid-winter Waterfowl Survey, the Atlantic and Great Lakes Seaduck Migration Study, and the Saltmarsh Habitat and Avian Research Program's database. Environmental Sensitivity Index maps also provide valuable supplementary information. There are other numerous ongoing avian tracking and telemetry studies in the region that can be consulted for information about avian movement patterns:

- Northeast Regional Migration Monitoring Network: http://rkozlo51-25.umesci.maine.edu/SBE/avian/MigrationMonitoring.html
- MOTUS Wildlife Tracking System: http://sandbox.motus-wts.org/data/viewtracks.jsp
- Mid-Atlantic Diving Bird Study: http://www.briloon.org/mabs/reports
- Common Eider Wellfleet Bay Virus Tracking Study: http://www.briloon.org/boston-harbor-common-eider-satellite-tracking-study
- Tracking Offshore Occurrence of Terns and Shorebirds in the Northwest Atlantic: http://www.boem.gov/AT-13-01/
- University of Rhode Island avian tracking studies: for example, see http://seagrant.gso.uri.edu/oceansamp/pdf/appendix/11a-PatonAvianRept.pdf

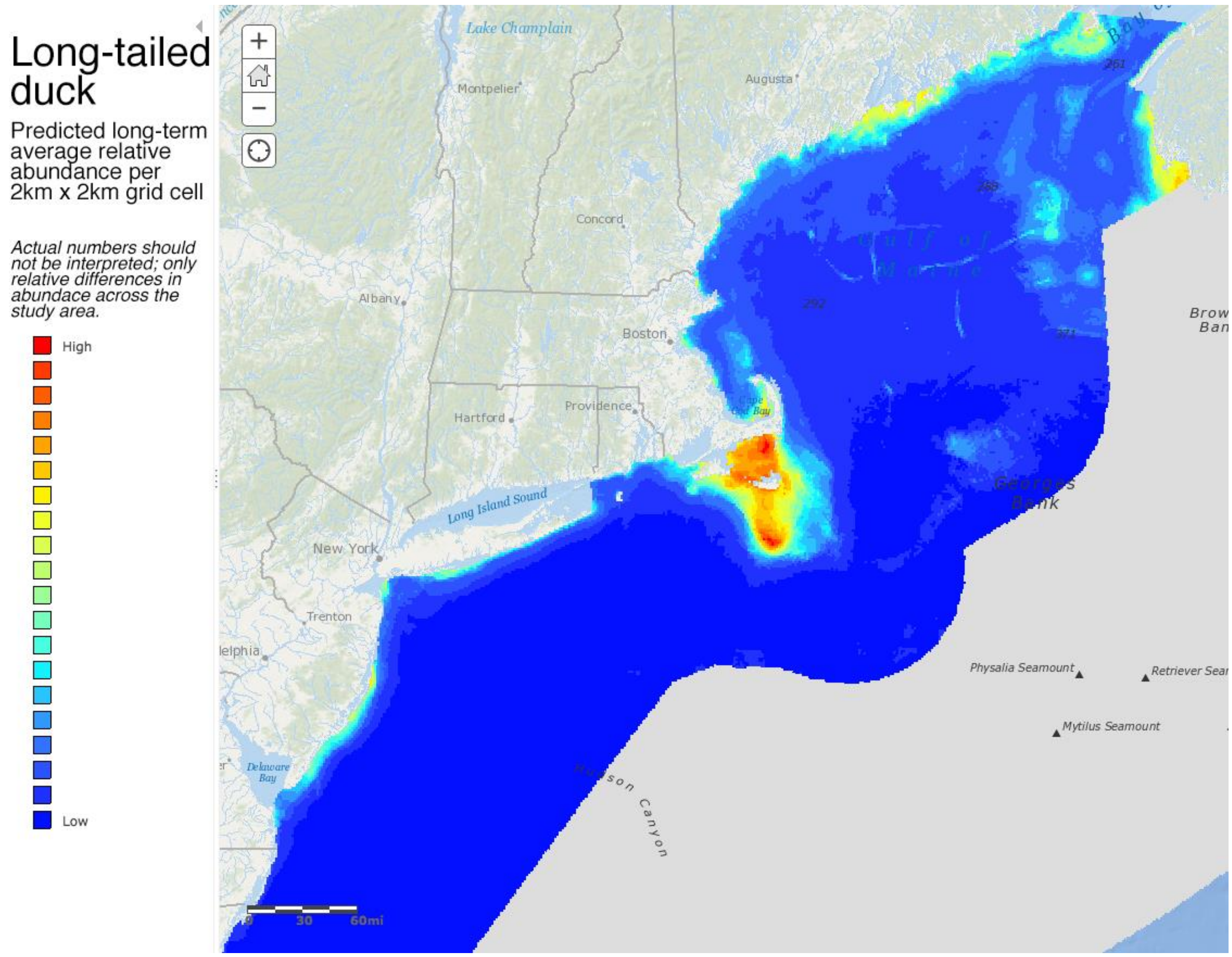


Figure 10 Long-term average annual relative abundance for long-tailed duck from the Marine-life Data and Analysis Team. The grey area masks model results further than 100km from a minimum distance path connecting the raw sighting location data.

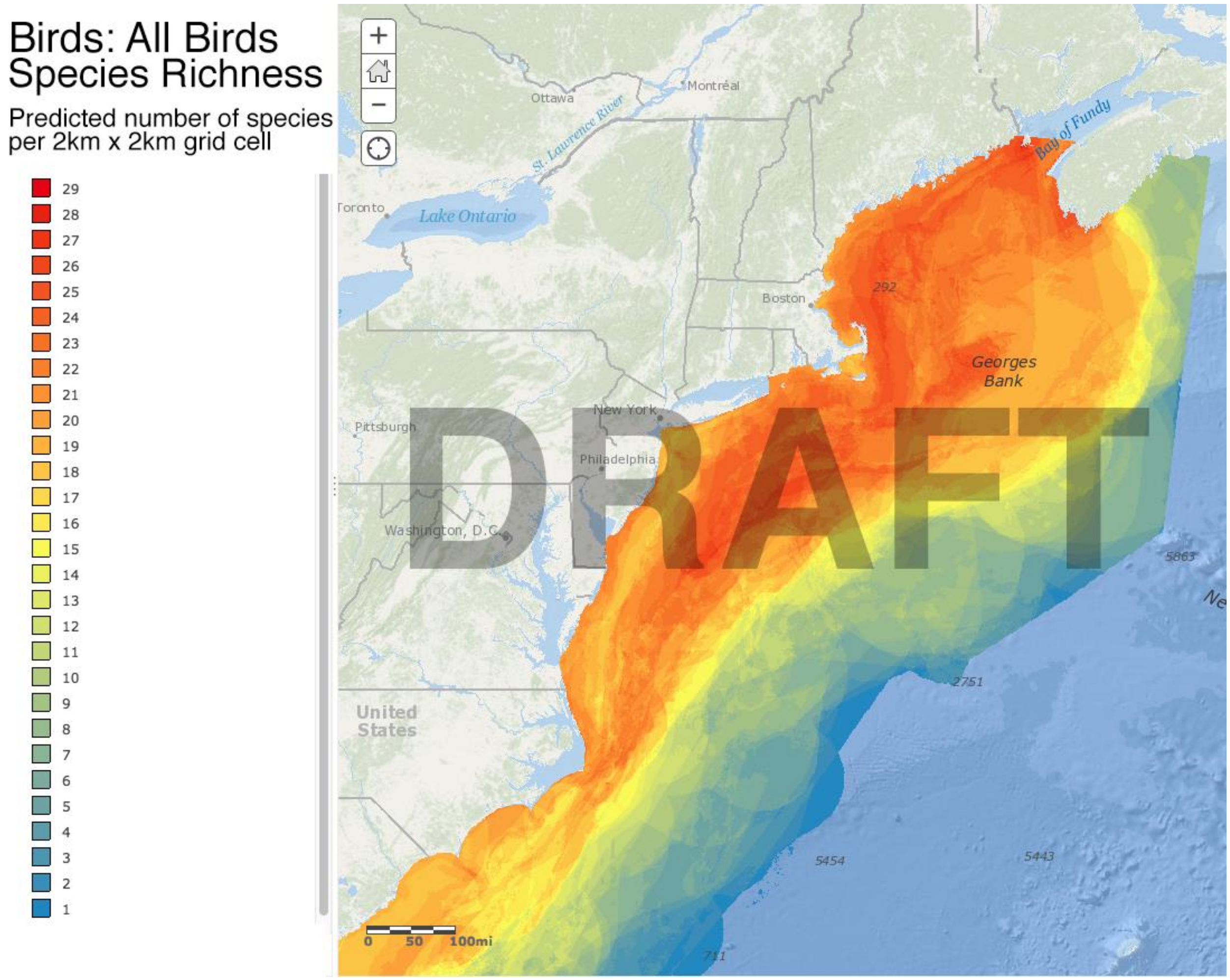


Figure 11 Avian species richness (count of the total number of species present in each 2km x 2km grid cell using the annual individual species model results) from the Marine-life Data and Analysis Team. (Note: the marine life species group products initially were reviewed by the expert work groups and will continue to be reviewed by experts and stakeholders during the review of the draft NE Ocean Plan. Therefore, the species group products are labeled "Draft". The RPB will revise these products accordingly).

Fish

MDAT map products for fish species relied on trawl survey data from several principal sources in the region: the NOAA Northeast Fisheries Science Center (NEFSC) (1970-2014), the North East Area Monitoring and Assessment Program (2007-2014), the Massachusetts Division of Marine Fisheries (1978-2014), and the Maine-New Hampshire state datasets (2000-2014). The states of Rhode Island and Connecticut also conduct nearshore fish trawls that were not part of the MDAT project (these data are planned to be integrated into the Portal separately). Unlike marine mammals and birds, fish distribution data are mapped as total fall season biomass for 82 individual species. Maps were produced for two time periods: the full time series for each trawl survey and the most recent decade, as available. An example MDAT fish map product using NEFSC data shows the interpolated log biomass of red hake in the region for all tows between 1970-2014, mapped onto 10km x 10km grid cells (Figure 12). The MDAT map of fish species richness (considering only the NEFSC trawl data) shows generally high richness near Massachusetts Bay, Cape Cod Bay, and the northern edge of Georges Bank (Figure 13).

The distribution, abundance, and biomass of sea scallops are characterized by three regular surveys on the Atlantic coast – a NOAA NEFSC scallop dredge survey, the University of Massachusetts School of Marine Science and Technology (SMAST) camera surveys, and the Virginia Institute of Marine Science dredge survey. Scallop maps were not developed as part of the MDAT project, but map products from the NEFSC and SMAST surveys are displayed on the Portal (Figure 14).

Commercial fishing effort maps, fishery observer data, anadromous species monitoring, and scientific ship-board or aerial surveys also represent important sources of information for characterizing fish distribution and abundance, especially for species that may not be well represented in the principal trawl surveys. For example, occurrences of large fish such as basking shark, blue shark and ocean sunfish were mapped from aerial photos by the Massachusetts Clean Energy Center (Taylor et al. 2014).

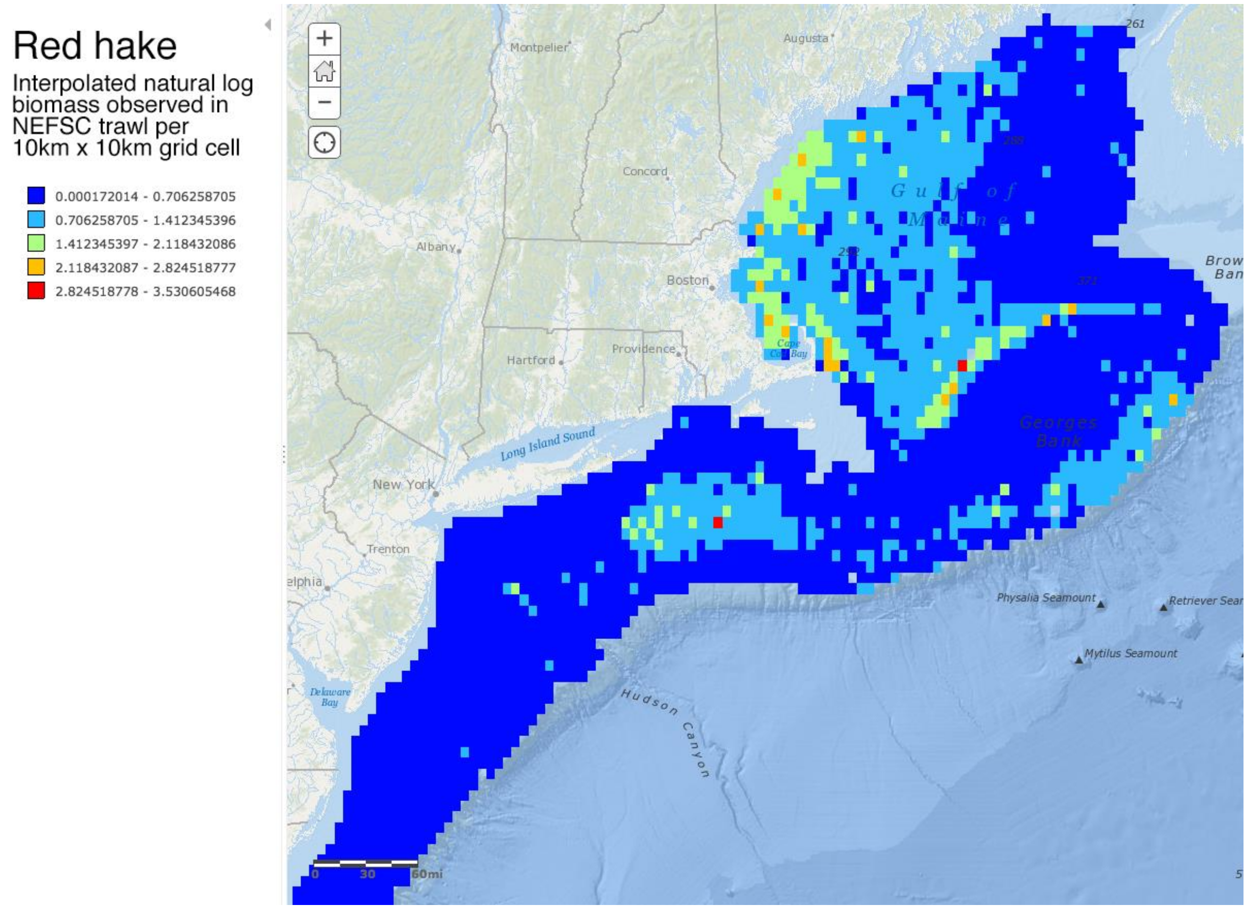


Figure 12 Interpolated natural log biomass of red hake for all NEFSC tows between 1970-2014. Grid cells are 10km by 10km.

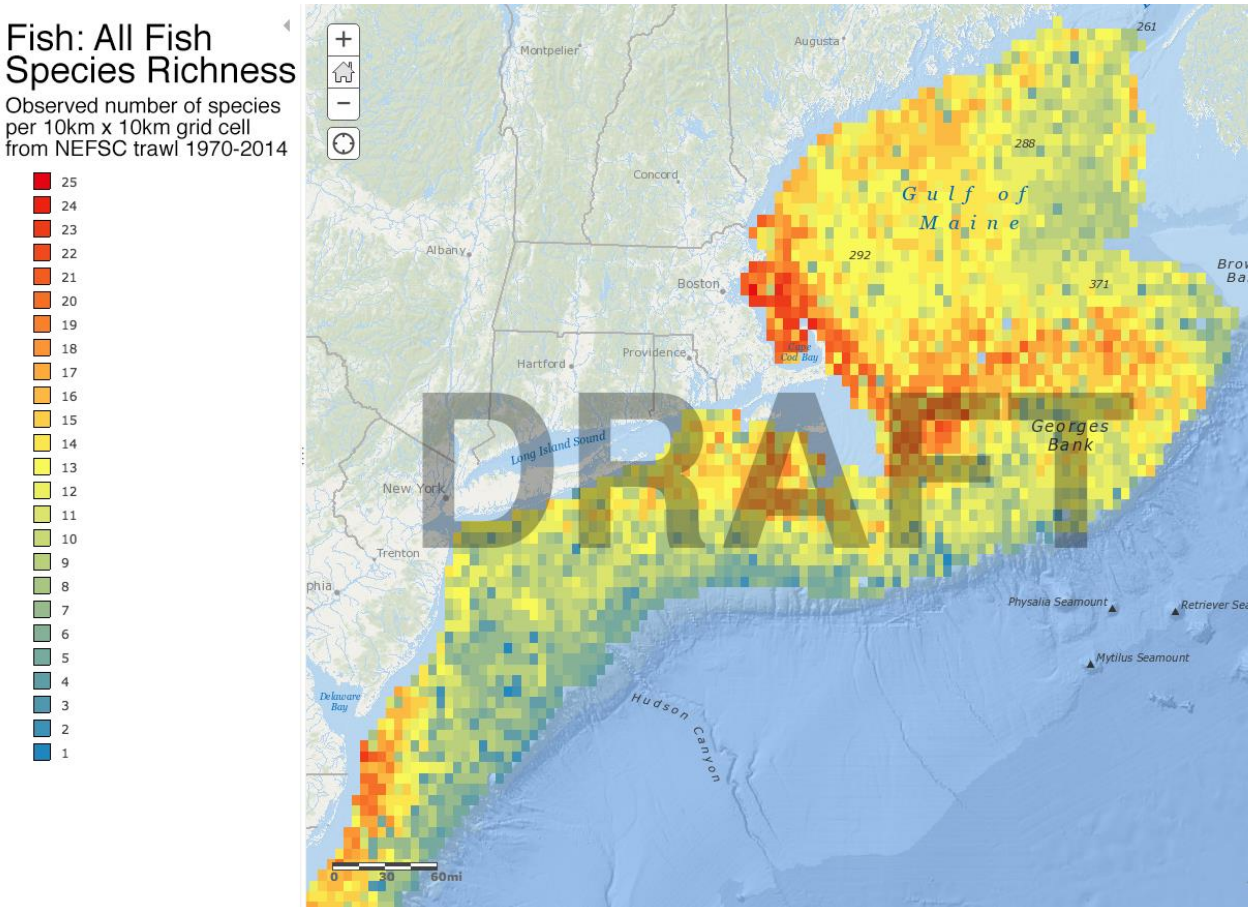


Figure 13 Fish species richness (count of the total number of species present in each 10km x 10km grid cell using interpolated biomass for each species in the NEFSC trawl data), from the Marine-life Data and Analysis Team. (Note: the marine life species group products initially were reviewed by the expert work groups and will continue to be reviewed by experts and stakeholders during the review of the draft NE Ocean Plan. Therefore, the species group products are labeled "Draft". The RPB will revise these products accordingly).

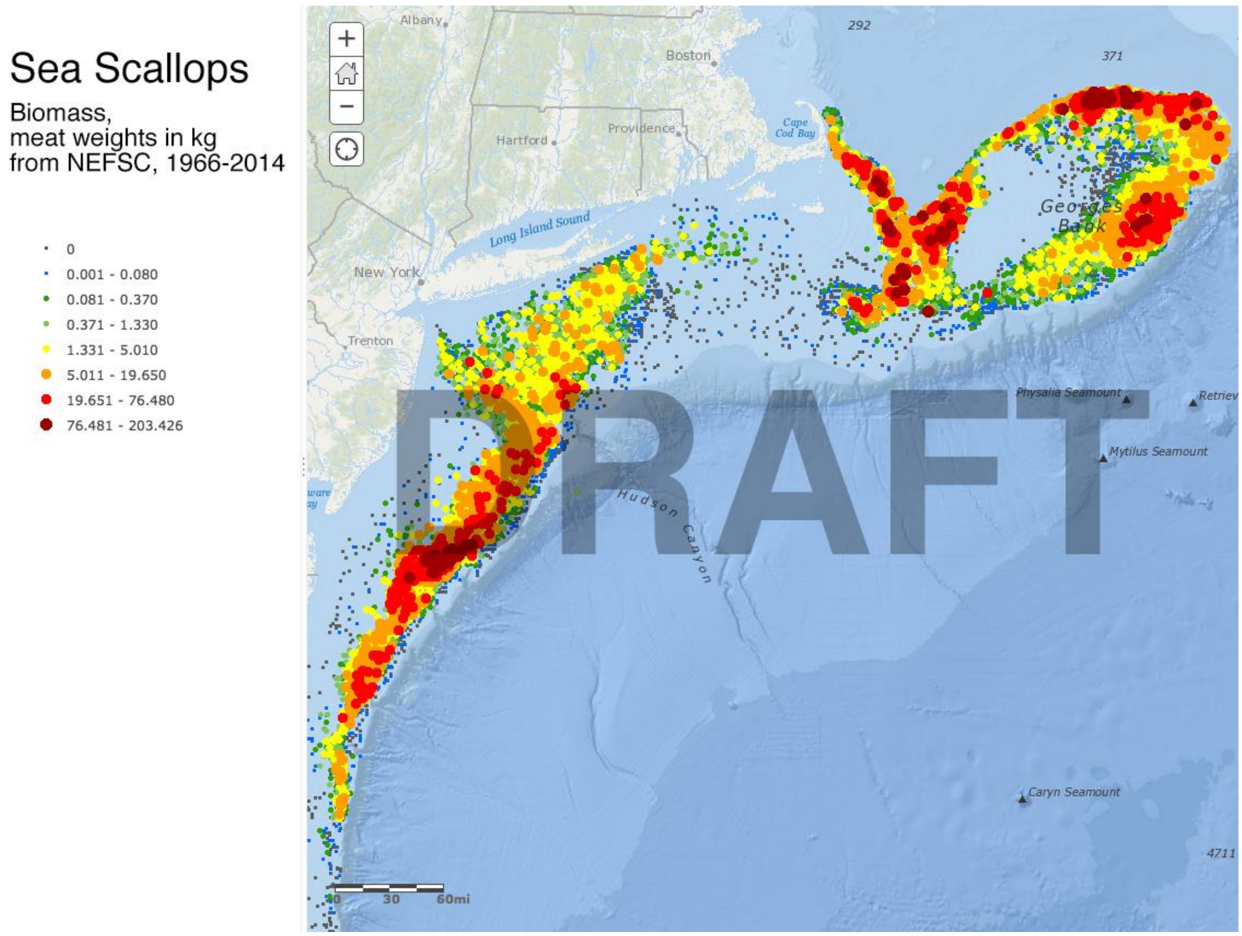


Figure 14 Scallop biomass (meat weights in kilograms) from the NEFSC Scallop trawl database, showing all trawl data from 1966-2014. (Note: these products will continue to be reviewed by experts and stakeholders during the review of the draft NE Ocean Plan. Therefore, these products are labeled "Draft". The RPB will revise these products accordingly).

Through the end of 2016, MDAT will conduct Phase 2 of their mapping efforts, which will include updating models, model outputs, and uncertainty products with additional data (e.g., developing a sea turtle model, adding new observations for marine mammals, adding Long Island Sound fish trawl and RI coastal trawl data), and updating the total abundance, richness, diversity and other summary products as necessary. This work will increase the usefulness of MDAT products for ocean planning purposes by incorporating the newest available marine life data.

3.2. Marine and coastal cultural resources

3.2.1. Tribal culture

Tribes of indigenous (native) people have lived along the coasts of the Northeast region for at least 12,000 years before the arrival of European settlers. Dozens of historical tribes have been identified; and ten have been federally recognized as of 2015 (Figure 15).

Native tribes' traditional culture included close connections with the land and coastal waters, which supported a variety of hunting, gathering, farming, harvesting, fishing, and foraging activities to obtain resources for sustenance, medicinal, spiritual, material or technological purposes, as well as travel, trade, recreation, and ceremonial activities (pers. comm., David Weeden, Mashpee Wampanoag Tribe and Elizabeth J. Perry, Wampanoag Tribe of Gay Head-Aquinnah, 2015; see also Appendix C). In their traditions, the tribes see themselves as caretakers of the land, which they regard as their spiritual mother, and the waters of the region; if the land and waters are kept healthy, they will provide for the people (pers. comm., David Weeden, Mashpee Wampanoag Tribe, July 2015).

Spring and fall anadromous and catadromous fish runs were important parts of tribes' annual harvest from the sea and rivers, including Atlantic eel, Atlantic salmon, shad, herring, Atlantic sturgeon, and whitefish. According to Mohegan Tribe archives, the Thames River (previously known as the Pequot Mohegan River) was widely known for its abundance of fish, including shad, alewives, bass, mackerel, eels, oysters, and lobster (pers. comm., Melissa Zobel and Faith Davidson, Mohegan Indian Tribe of Connecticut). Fish roe was an important part of some tribes' diet, and whales and dolphins were harvested on beaches where they would commonly strand, particularly on the Cape and Islands. Sharks were also caught and cooked. The Wampanoag Tribe of Gay Head-Aquinnah historically fished for swordfish and flatfish, hunted for whales, spearfished lobster, set crab traps in shallow water, and gathered edible seaweed (pers. comm., Elizabeth J. Perry, Aquinnah Wampanoag Tribe, 2015; see also Appendix C). The Wampanoag tribe continue to make their living off the sea in commercial fishing and shellfishing, in charter boat fishing, as tug boat Captains and in related industries such as hatchery work, ownership of seafood restaurants, as marine scientists, scientific illustrators, and marine mammal rehabilitators (pers. comm., Elizabeth J. Perry, Aquinnah Wampanoag Tribe, 2015; see also Appendix C).

Certain locations along the Northeast coast and in fresh and brackish rivers are known (or have been rediscovered through archaeology) to have been places where Native people built and maintained elaborate fish weirs for concentrating and trapping fish; Boston Common is one such place, now covered in fill. Mohegan tribal archives document weirs being used to catch eels, bass, shad, smelt and other fish, with some remains of weirs dating back beyond 2500 B.C. (pers. comm., Melissa Zobel and Faith Davidson, Mohegan Indian Tribe of Connecticut). As another important part of tribal sustenance, men and women also gathered shellfish of various species including razor clams, soft shell clams, quahogs and mussels; some of this harvest was also dried for winter use, while the shells of quahog, whelk and oyster were used to manufacture white and purple shell beads for ornament, trade and diplomacy termed wampum in the native language (pers. comm., Elizabeth J. Perry, Wampanoag Tribe of Gay Head-Aquinnah). Archeological records from the Mohegan Tribe indicate shellfish sites containing whelk, bay scallop, blue mussel, moon shell, boat shell, oyster, and soft shell clam – shell middens were the byproduct of large-scale preservation of shellfish for winter consumption (pers. comm., Melissa Zobel and Faith Davidson, Mohegan Indian Tribe of Connecticut).

Rapid development of the region since the arrival of European settlers has diminished or compromised some coastal lands and waters and the once abundant resources they support. Development and privatization of coastal property has also compromised access to waterways, intertidal areas, historic paths and ways, and woodland areas traditionally used for hunting, gathering, and harvesting. Tribes advocate for the restoration of these lands, waters, and resources, and for restoration of access, wherever possible. For example, Wampanoag tribes have been involved with seeding shellfish, growing oyster spat and eelgrass restoration, as well as piping-plover monitoring (pers. comm., Elizabeth J. Perry, Wampanoag Tribe of Gay Head-Aquinnah and Chuckie Green, Mashpee Wampanoag Tribe). Tribes are also concerned about the restoration of anadromous fish populations and prioritize the restoration of water quality and fish habitat for Atlantic Salmon and other species including American shad, river herring, and eel (pers. comm., Sharri Venno, Environmental Planner, Houlton Band of Maliseet Indians). In 2009, five federally recognized Tribal Nations in Maine and the US EPA worked cooperatively to produce the Wabanaki Traditional Cultural Lifeways Exposure Scenario (Harper and Ranco 2009), which documents past environmental contact, diet, and exposure pathways for tribal cultural traditions in Maine and is used to better understand potential impacts to tribal resources (pers. comm., Sharri Venno).

In some locations, sea level changes over thousands of years have led to submergence of settlement and ceremonial sites identified in tribal traditions. For example, Mashpee Wampanoag tribal activities are said to have occurred 200 miles off the present coast of Massachusetts, making some of these offshore areas archaeologically sensitive (pers. comm., David Weeden, Mashpee Wampanoag Tribe, July 2015). Nantucket Sound and Narragansett Bay are examples of areas where submerged sites remain important to tribal culture, history, and way of life. Data collected by USGS from Buzzards Bay, Vineyard Sound, and along the southern coast of Martha's Vineyard indicate that it is possible to detect and re-create now submerged and buried ancient postglacial landscapes. Creating a paleo-landscape map would require additional sediment cores and data mining and analyses to supplement existing USGS data. An accurate paleo-landscape model and map would require specific data analyses performed by experts in the field; and development of a reliable model will require active collaboration with Native American peoples (see p. SF-24 of the Massachusetts Ocean Management Plan (COM 2015).

Some detailed history of the Narragansett Tribe's traditions and pre- and post-colonial activities in southern New England is provided in Section 410.2, Chapter 4 of the Rhode Island Ocean Special Area Management Plan (RICRMC 2010). In Section 420.4, Chapter 4, the Rhode Island Special Area Management Plan also addresses paleocultural landscape reconstruction. Efforts are underway on the part of the Bureau of Ocean Energy Management, the Narragansett Tribe, and University of Rhode Island to develop science-based "best practices" for identifying submerged Native American archaeological sites in the region. These new methods will assist resource planners, managers, and tribal communities in evaluating proposed offshore and continental shelf development projects (pers. comm., Doug Harris, Narragansett Indian Tribe of Rhode Island)

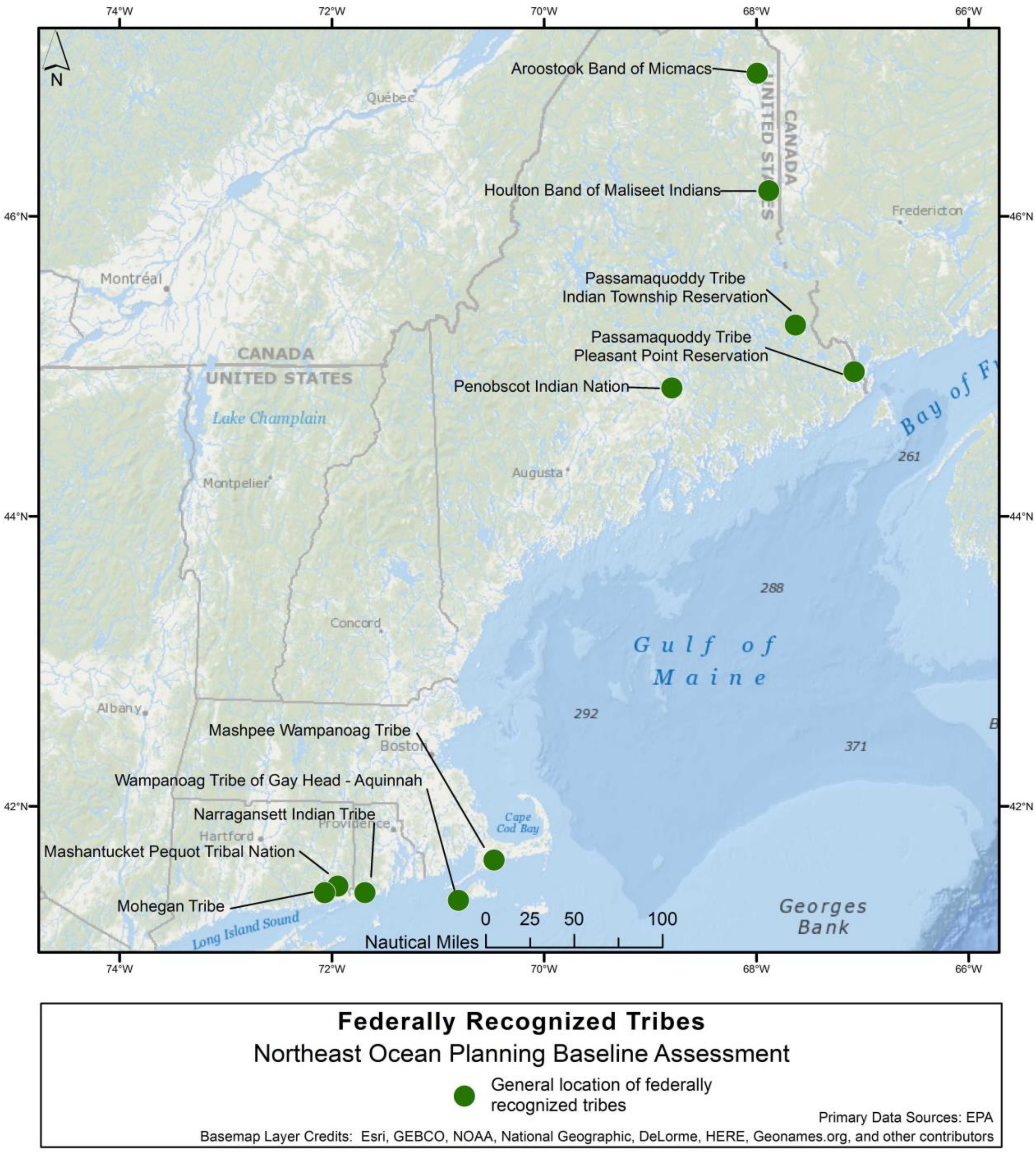


Figure 15 Federally recognized tribes

3.2.2. Coastal Communities

Reflecting the region's maritime tradition, working waterfronts and island communities rely on a healthy ecosystem and continue to have strong economic and cultural ties to the ocean. The existence of many fishing communities is tied to their ability to fish in a particular area - determined in part by the size of their boats, the species being sought, fishing pressure from other communities, and government regulations. The loss of the ability to fish can mean the decline or disappearance of an entire community (Battista 2015).

For example, Maine's coastal economy is reported to be heavily dependent on fisheries – particularly lobster. According to the Island Indicators 2015 report and Maine Department of Marine Resources, in 2014 lobster accounted for 78.1% ($457 million) of the total value of Maine's fisheries ($585 million). While the state of Maine's economy as a whole depends heavily on the lobster industry, for some small island and coastal communities, lobster is the only economy. Even in other communities with significant income from recreation, tourism, and construction, lobstering provides a significant percentage of family income that would not be easily replaced.

There are many working waterfront programs in the Northeast that seek to enhance the capacity of coastal communities and stakeholders to make informed decisions, balance diverse uses, ensure access, and plan for the future of working waterfronts and waterways. In some cases, there are state-level resources such as funding and technical assistance available to help ensure that communities consider long- and short-term needs for working waterfronts. Many of these efforts are intended to help communities maintain access for traditional, economically and culturally important uses, including commercial fishing and recreation.

3.2.3. Historic and Archeological Resources

The National Register of Historic Places is maintained by the US National Park Service as the official list of the nation's historic places worthy of preservation. Authorized by the National Historic Preservation Act of 1966, the National Register of Historic Places is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect America's historic and archeological resources. The Register includes about 1,300 historic places in Maine, 800 in New Hampshire, 4,300 in Massachusetts, 800 in Rhode Island, and 1,600 in Connecticut. Data on these are available on the National Register of Historic Places research pages. The National Park Service is in the process of digitizing the National Register information, and online records are not yet complete.

At least 150 shipwrecks have been located and identified in the waters of the Northeast. Some of these are of historical and archaeological interest; and some are an attraction for recreational divers (see section 4.4.5).

During the past 300 years, there have been at least 1,200 maritime accidents and disasters in the waters of Rhode Island and Rhode Island Sound, many of them in the vicinity of Block Island, Point Judith, Watch Hill, and Beavertail. The Rhode Island Ocean Special Area Management Plan (Section 420.2, Chapter 4, RICRMC 2010) identifies likely locations of about 50 shipwrecks in Rhode Island waters.

The Massachusetts Ocean Management Plan (p. BA-27, COM 2015) describes a list of about 40 shipwreck sites in Massachusetts waters designated for preservation and for activities such as recreational diving, and a "sensitivity map" that captures the approximate location of thousands of other potential wreck sites.

More information is available on the Wreckhunter.net web pages and from NOAA's Automated Wreck and Obstruction Information System (AWOIS). While the locations of some shipwrecks are well know to the navigation community as obstructions to vessel traffic, or to the archaeological and recreational diving communities, the locations of other historic shipwrecks are not known precisely, or not published to protect the site from damage caused by recreational divers or treasure seekers. As a result, there is no single comprehensive list or map of shipwreck locations. For ocean planning purposes, "sensitivity maps" such as that described above can be used to identify areas with potential wreck site that may warrant detailed surveys before carrying out activities that could damage historical resources.

3.3. Marine and coastal infrastructure

3.3.1. Commercial ports

Commercial ports and harbors provide dockage for cargo and passenger vessels, transfer facilities for petroleum, dry bulk, and containerized cargo, vehicles, and ferry and cruise ship passengers, landing facilities and support for commercial fishing vessels, and dockage and anchorages for recreational boats. Major commercial ports of the Northeast are shown in Figure 16, and include:

- Eastport, ME: http://me.usharbors.com/harbor-guide/eastport
- Searsport, ME: http://me.usharbors.com/harbor-guide/searsport
- Portland, ME: http://www.portlandharbor.org/
- Portsmouth, NH: http://nh.usharbors.com/harbor-guide/portsmouth-harbor
- Gloucester, MA: http://www.gloucesterma.com/Boating.cfm?c=84
- Salem, MA: http://ma.usharbors.com/harbor-guide/salem
- Boston, MA: https://www.massport.com/port-of-boston
- New Bedford and Fairhaven, MA: http://www.portofnewbedford.org/
- Fall River, MA: http://ri.usharbors.com/harbor-guide/fall-river-ma
- Providence, RI: http://www.provport.com/
- Quonset/Davisville, RI: http://www.quonset.com/sea/
- New London, CT: http://ct.usharbors.com/harbor-guide/new-london
- New Haven, CT: http://www.cityofnewhaven.com/PortAuthority/Terminal/
- Bridgeport, CT: http://ct.usharbors.com/harbor-guide/bridgeport
- Stamford, CT: http://www.stamfordct.gov/harbor-management

Many of these ports are connected by regional maritime transit routes to the Port of New York and New Jersey: http://www.panynj.gov/port/ .

See section 4.5.1 and Figure 45 below for more details.

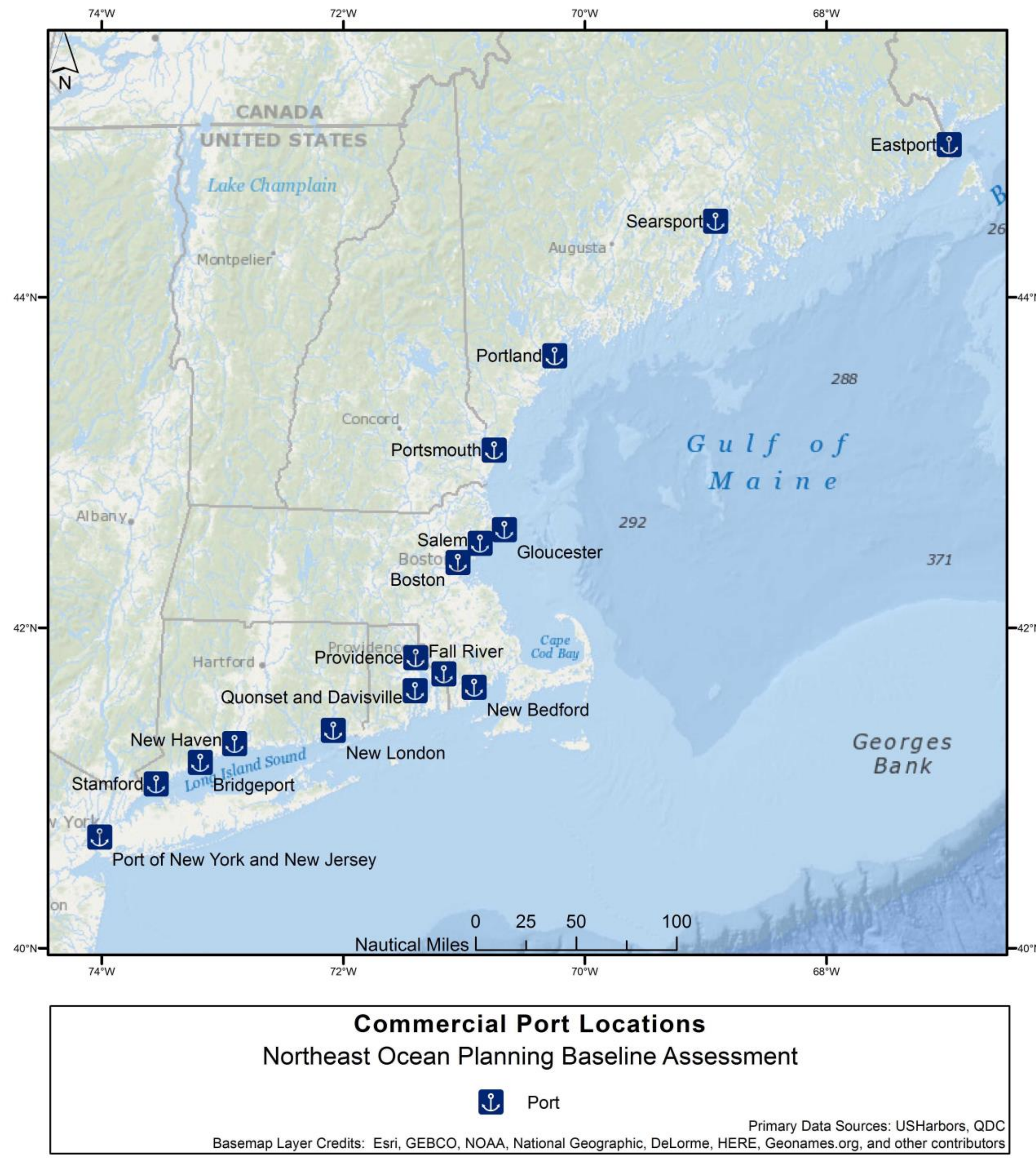


Figure 16 Commercial port locations

3.3.2. Naval/military/national security facilities

Three major naval military facilities are located in the Northeast region:

- Portsmouth Naval Shipyard, Kittery, Maine: focused on overhaul, repair and modernization of the US Navy's Los Angeles-class submarines; http://www.navsea.navy.mil/Home/Shipyards/Portsmouth.aspx

- Naval Station Newport, Rhode Island: a US Navy research, development, training, and education center; http://www.cnic.navy.mil/regions/cnrma/installations/ns_newport.html
- Naval Submarine Base, New London, Connecticut: the US Navy's primary submarine base on the east coast; http://www.cnic.navy.mil/regions/cnrma/installations/navsubbase_new_london.html

In addition, several commercial shipyards in the Northeast support naval ship procurement:

- Bath Iron Works (General Dynamics), Bath, Maine: focused on design, construction, and support of surface combatant ships; https://www.gdbiw.com/
- Electric Boat (General Dynamics), Groton, Connecticut: design, construction, and support of submarines for the US Navy; http://www.gdeb.com/
- Electric Boat (General Dynamics), Quonset Point, North Kingston, RI; http://www.gdeb.com/about/locations/quonset/

There is also a Naval Computer and Telecommunications Master Station in Cutler, ME, that provides communications services to naval surface ships and submarines.

In the Northeast, the US Coast Guard is represented by the First District staff and operates a number of facilities, including 55 onshore units (among them Air Station Cape Cod and International Ice Patrol), 28 "afloat" units, and seven cutters (http://www.uscg.mil/d1/units.asp). More information on USCG resources can be found at: http://www.uscg.mil/datasheet/.

The First District area of responsibility includes Northern New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, and Maine. The district is divested into five sectors: Sector Northern New England (Maine, New Hampshire), Boston (NH border south to Manomet Point, MA), Sector Southeastern New England (Manomet Point, MA to Watch Hill Point, RI), Long Island Sound (South shore of Long Island and along coastal CT), and New York (Long Branch New Jersey to New York City (all boroughs), and up the Hudson River). More information about the First District can be found at: http://www.uscg.mil/d1/units.asp and http://www.uscg.mil/top/missions/

3.3.3. Marinas

Some 600 marinas serve the recreational power boating and sailing community (see sections 4.4.1 and 4.4.2) in the Northeast. From ENOW data, the highest concentration of marinas is in New York, Massachusetts, and Connecticut (Figure 17).

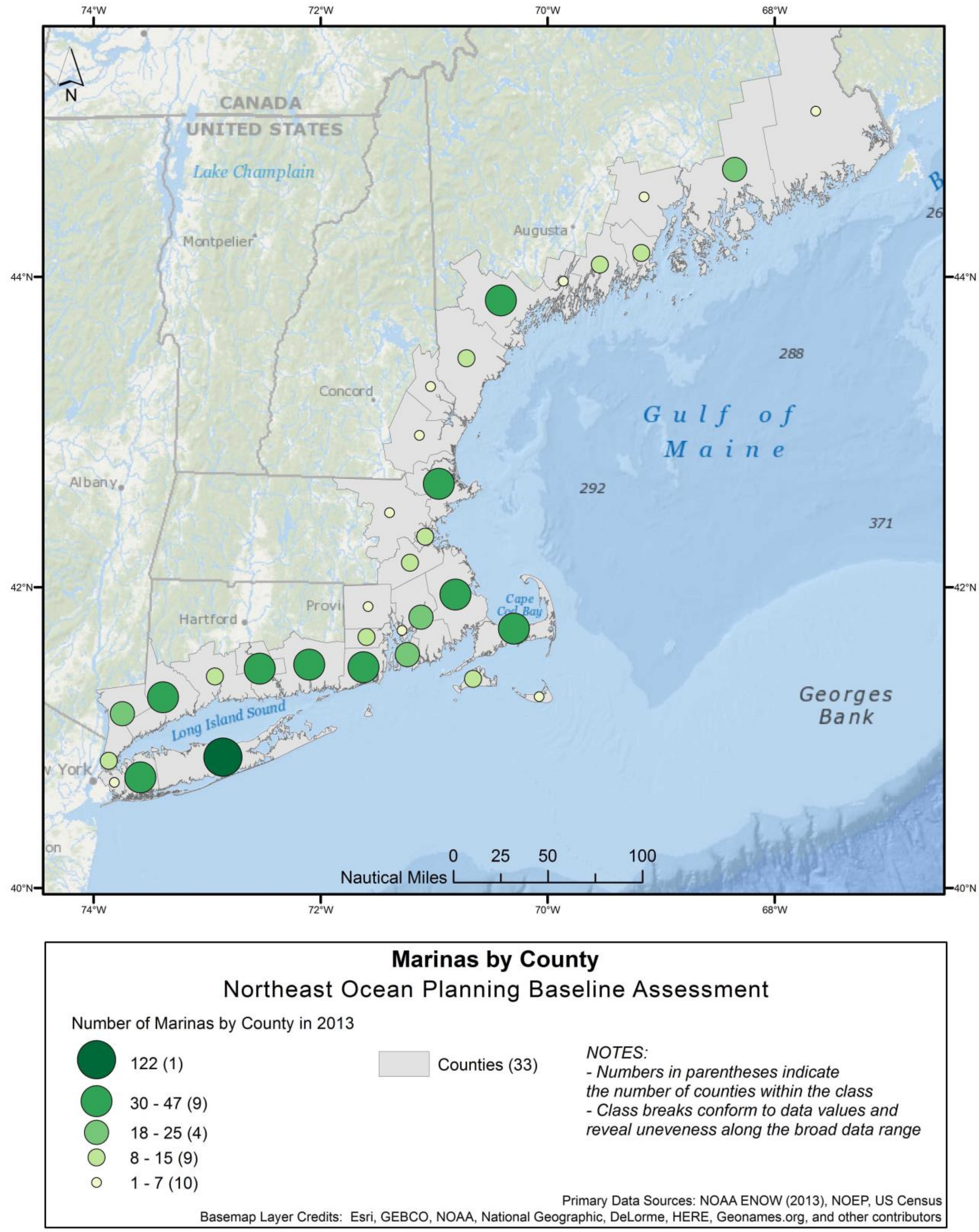


Figure 17 Marinas by county, 2013

3.3.4. Shoreline structures

Much of the shoreline of the Northeast region is extensively developed or settled, even outside urban centers. Where this shoreline is vulnerable to flooding or erosion (e.g. sandy cliffs or beaches), due to exposure to tides and waves, property owners and municipalities or states have taken steps to "armor" the shore to prevent erosion and/or flooding. For example, according to data assembled by the Massachusetts Office of Coastal Zone Management, some 27% of the Massachusetts coastline is armored in some fashion by means of public or private seawalls, bulkheads, revetments, groins, and jetties; and 5% of Maine's shoreline is similarly armored.

3.3.5. Pipelines and cables

Submarine pipelines are used to transport fuel oil and natural gas along short stretches of the Northeast region's coast; and submarine cables are used to transmit power or provide data and communications links. Submarine cables either transmit energy or telecommunication signals across stretches of water. Importantly, this includes 95 percent of the intercontinental internet traffic and essential electricity service to island communities. In New England, transatlantic telecommunication cables run through Long Island Sound and out of Charlestown, RI and Lynn, MA. A number of transatlantic cables are also just to the south of New England, originating in Long Island, New York City, and New Jersey. Electricity cables can be found along the shoreline, making critical grid connections from the mainland to islands offshore each state, and occasionally transiting longer distances with higher transmission capacity, such as in Long Island Sound.

The North American Submarine Cable Association (NASCA) serves as a forum for the exchange of information on submarine cables. Three NASCA cables are known to not have accessible spatial data, and as a result are not shown in Figure 18. These are:

- GlobeNet Segment 5 from GlobeNet
- MAC 1 and MAC 3 from Level 3
- PTAT Segment E2 from Sprint (out of service)

Locations of pipeline and cable areas are shown in Figure 18. Trans-Atlantic cable routing reflects a preference for keeping cables off the shallow shelf and banks as much as possible, since cables must be buried in those regions to protect them from damage by bottom trawling and fishing gear.

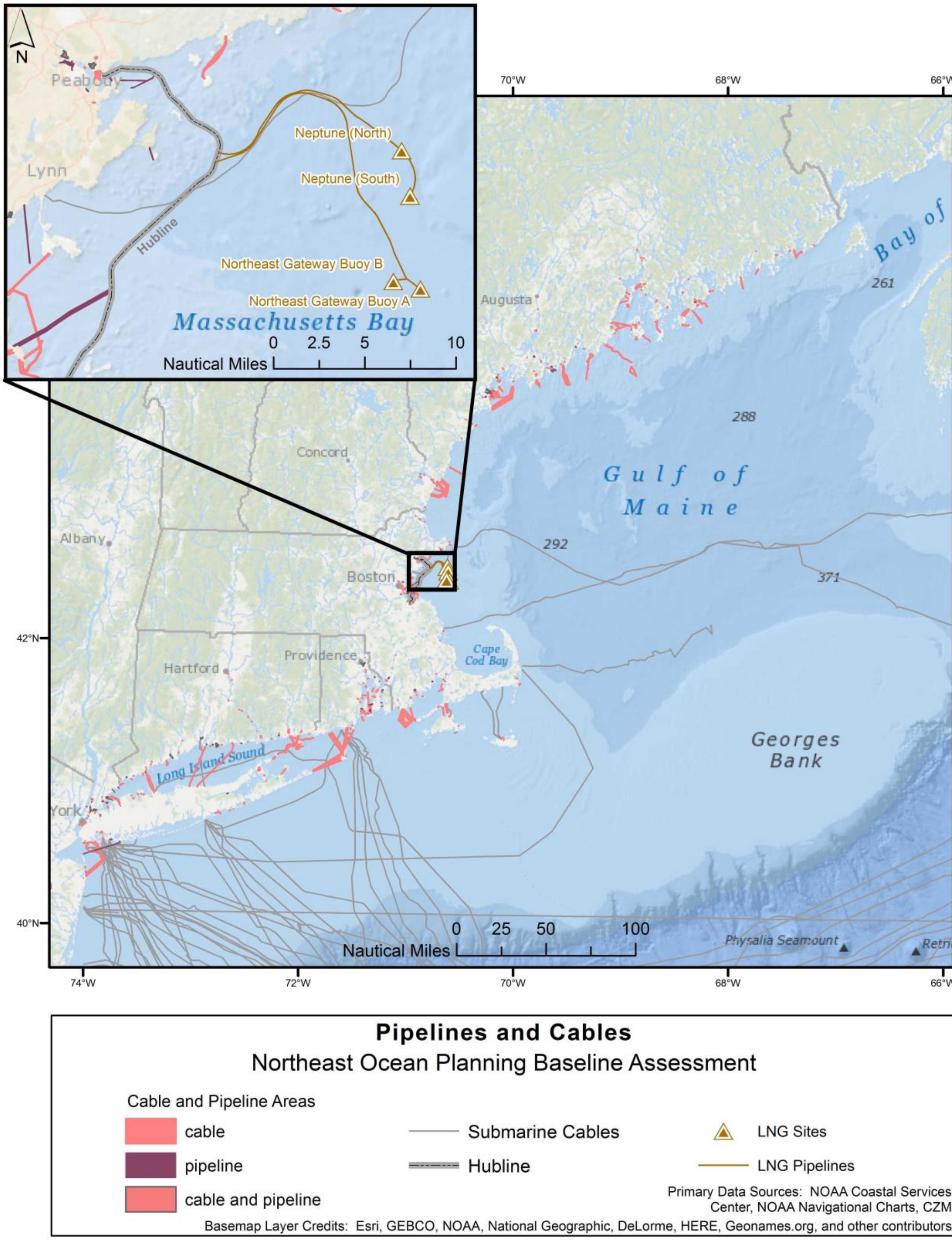


Figure 18 Pipelines and cables

3.4. Human population and residential real estate

All data used in Section 3.4 of this document are based on information from the US Bureau of the Census and on work carried out at the Center for Blue Economy, unless otherwise cited.

The coastal population of the Northeast (Figure 19) is concentrated in major urban centers and adjacent heavily populated coastal suburbs, with less densely populated coastal communities along much of the remainder of the shore. The major urban centers are the New York City area (including Nassau County) and Boston with populations over 600,000. Heavily populated suburbs are located in Suffolk County (New York), Connecticut, Rhode Island, and the South Shore of Massachusetts (the area between Boston and Cape Cod). Slightly lower population density extends up the North Shore of Massachusetts (north of Boston) through coastal New Hampshire and into Cumberland County, Maine. Smaller communities with populations generally less than 10,000 make up much of Maine east of Cumberland County, Martha's Vineyard, and the outer reaches of Cape Cod (but note that these areas have particularly strong seasonal growth in the summer months).

Recent population growth trends vary greatly across the Northeast region (Figure 20). After decades of steady growth in coastal population, some coastal areas of the Northeast saw significant population decline in the past decade. At least one town in each state of the Northeast region, and more than 80 coastal towns in total, have experienced a recent decline in population. Population losses have been particularly pronounced in Downeast Maine (locations east of Acadia National Park), and some Cape Cod towns. In other parts of the region, population growth over the past decade has been generally positive but modest, in most towns well below 2%/year. Strongest growth has been concentrated in eastern Long Island and in a stretch from Connecticut through Rhode Island, the non-Cape communities of Massachusetts, and coastal New Hampshire/Southern Maine.

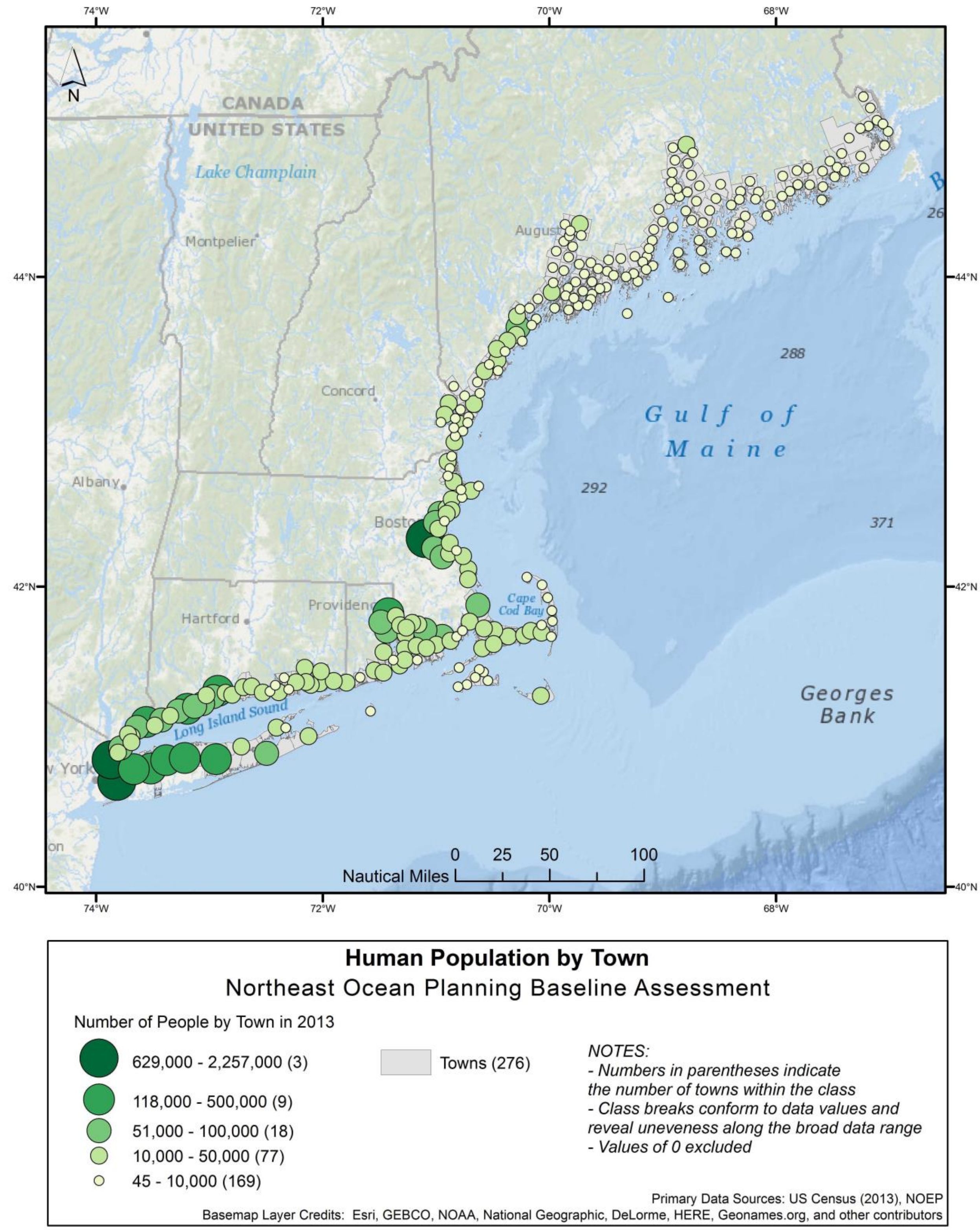


Figure 19 Human population by town, 2013

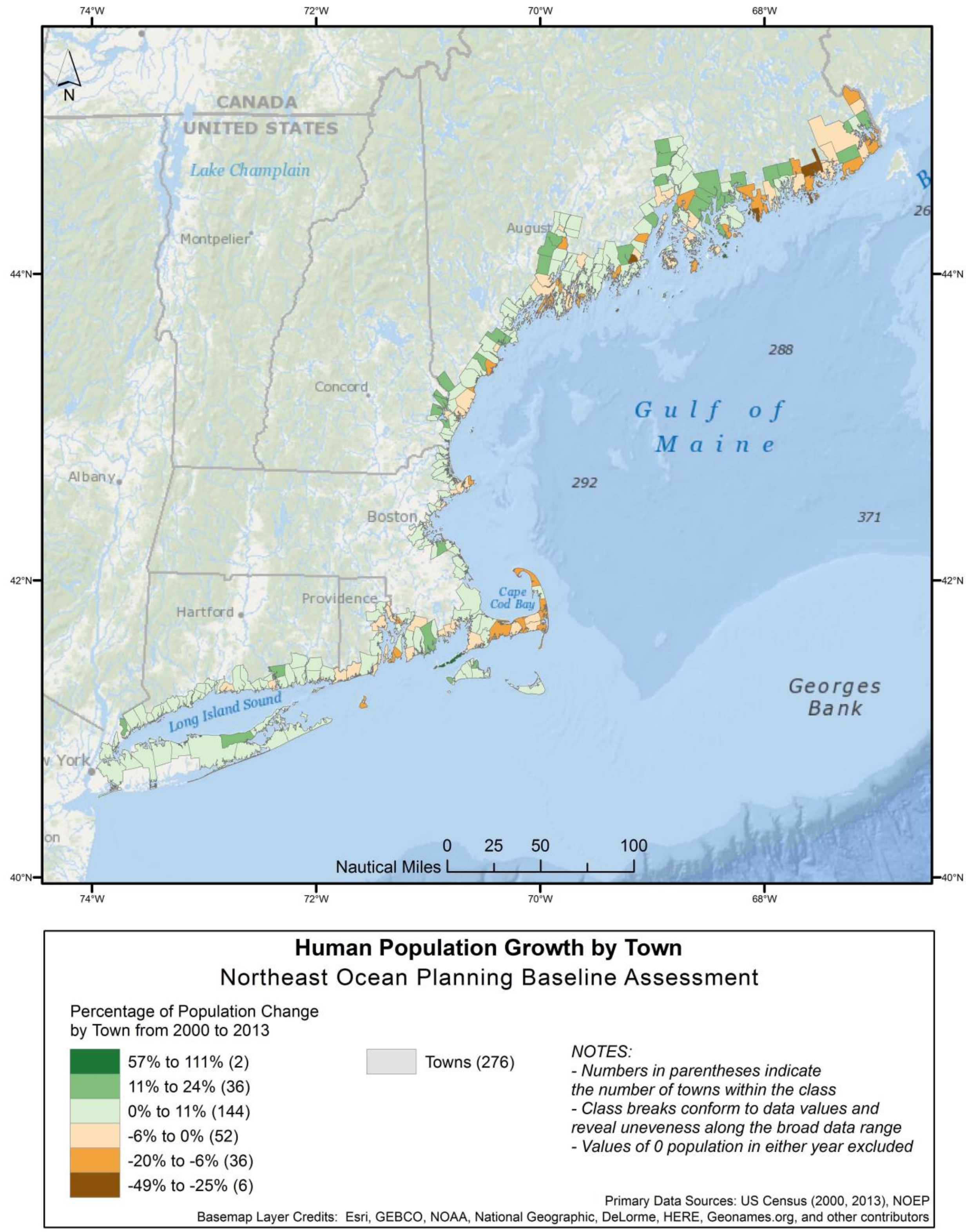


Figure 20 Human population growth by town, 2000 to 2013

The urban concentration of the regional population is mirrored in the distribution of residential housing (Figure 21) in the Northeast region's coastal counties. Housing data also illustrate the strong seasonal changes in coastal population during the summer in the Northeast, when visitors from within the Region and tourists from other parts of the US and the world swell the population of some coastal communities by a factor of five or more. Seasonal housing is concentrated on the eastern end of Long Island, on Cape Cod and the Islands, and in York County and New Hampshire coastal towns (Figure 22).
As a proportion of the total housing stock, seasonal housing is particularly important in eastern Long Island, the Cape and Islands, Southern Maine, Midcoast Maine (Waldo, Knox, Lincoln, Sagadahoc counties), and Hancock and Washington counties of Maine.

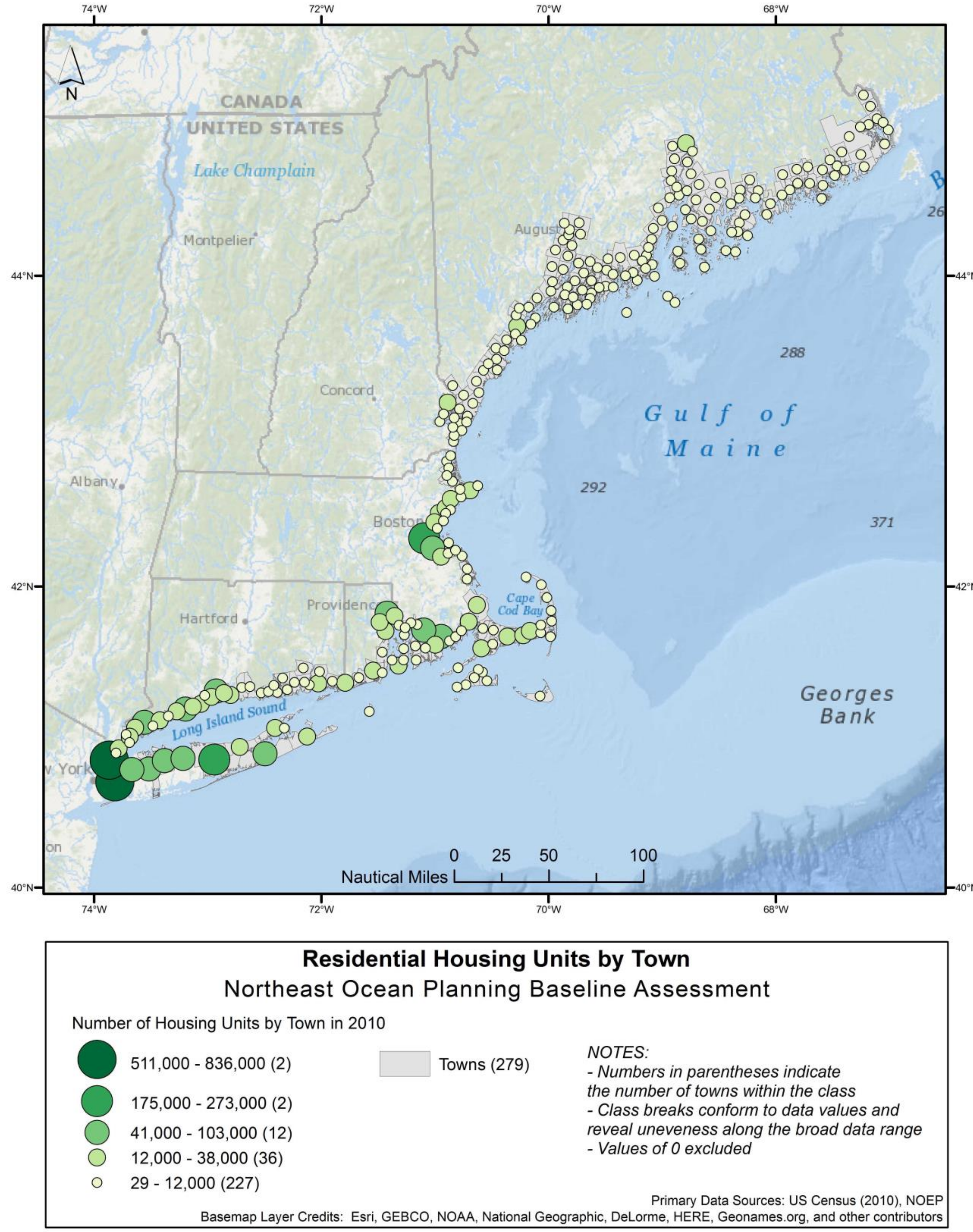


Figure 21 Residential housing units by town, 2010

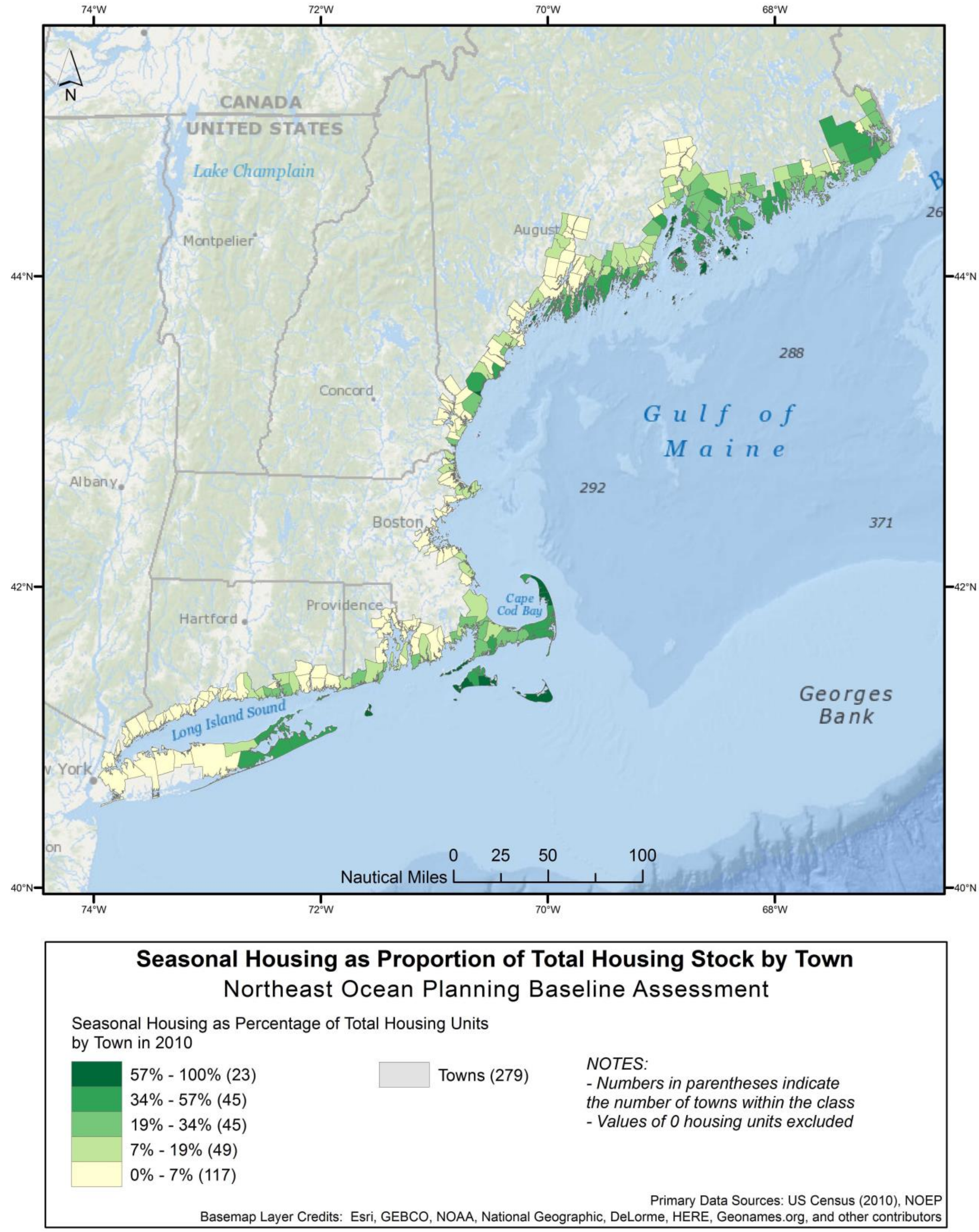


Figure 22 Seasonal housing as proportion of total housing stock by town, 2010

4. Coastal and Marine Economy

Data presented in this section on the coastal and marine economy of the Northeast region draws on information assembled for NOAA's ENOW database and on work carried out at the Center for Blue Economy (see below). ENOW (Economics: National Ocean Watch) is a repository of data on the US coastal and marine economy within the Digital Coastal data repository of NOAA's Office for Coastal Management. ENOW data describe six sectors of the United States economy that depend crucially on the oceans and Great Lakes, with annual time series data (from 2005 to 2013, as of 2016) derived from the national accounts of US Bureau of Labor Statistics and Bureau of Economic Analysis, at a resolution of 400 coastal counties, 30 coastal states, and eight regions. ENOW's four economic indicators are the number of business establishments, number of people employed, wages paid to employees, and contribution to gross domestic product (GDP).

Economic value is a human construct, and exists only in the context of human societies that make use of the market goods and services produced by people and the ecosystem services supplied by environmental resources. Because it derives at least in part from people's preferences, which in turn are a function of their circumstances and understanding of the world, economic values are by definition more ephemeral and changeable than, for example, physical or chemical properties of resources. Some economic values can be estimated directly by observing the prices at which goods and services are traded in markets (e.g. the value of a pound of fresh cod fish). Other "non-market" goods and services (e.g. the value derived by a visitor to the Northeast from a day spent at the beach) are not explicitly traded in markets; their economic value must be estimated by techniques such as travel cost and random utility models, hedonic methods, or contingent valuation.

All data used in Section 4 of this document are based on information assembled for NOAA's ENOW database and on work carried out at the Center for Blue Economy, unless otherwise cited. Data on market and non-market ocean economy values and indicators are also available from the National Ocean Economics Program hosted by the Center for the Blue Economy at the Middlebury Institute of International Studies at Monterey, CA.

Section 4.1 provides an overview of the Northeast's ocean economy, as defined by NOAA's ENOW data, in terms of direct employment and value-added (GDP) contribution. Section 4.2 discusses broader impacts or "multiplier effects" of the Region's ocean economy. Sections 4.3 through 4.10 provide additional detail on each major ocean economy sector and the Region's ocean-related national security and research and education activities.

4.1. Direct employment and GDP contribution

The ocean economy (defined as marine construction, living resources (fisheries and aquaculture), ship and boat building, marine transportation and related services, ocean tourism and recreation, and a small minerals sector) directly generated $20.8 billion in GDP and directly supported more than 300,000 jobs in the Northeast in 2013. This represents about 1% of regional GDP and 2% of overall employment for Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut. This proportion is highest for

Maine and Rhode Island, where approximately 4% of GDP and 7-8% of employment are generated by the ocean sector. Tourism and recreation is the largest ocean economy sector in the region, accounting for 50% of ocean economy value added and 75% of employment. Tables 2 and 3 show the breakdown by ocean economy sector and state.

Note that this definition of the ocean economy does not include either national security (US Navy, US Coast Guard) activities associated with the ocean, or marine-related research and education activities, such as oceanography departments of the Region's colleges and universities. As a result, the aggregate ocean economy employment and GDP numbers presented in sections 4.1 and 4.2 do not include contributions from national security or from research and education. Although ENOW-compatible data on employment and GDP contribution for these activities are not available, information on their broader impacts is included in section 4.9 and 4.10 below.

			$ millions (2013)				
	ME	**NH**	**MA**	**RI**	**CT**	**NY**	**Northeast Region**
Living Resources	574.2	67.4	874.9	137.0	69.9	90.6	**1,813.9**
Tourism & Recreation	1,242.3	291.7	3,237.7	1,450.2	1,726.8	2,356.9	**10,305.5**
Transportation	195.7	1,058.4	2,195.3	273.6	817.1	889.2	**5,429.3**
Ship & Boat Building	677.3	--	30.7	309.8	1,679.8	2.1	**2,699.6**
Construction	30.2	6.9	127.9	24.1	49.7	86.8	**325.6**
Minerals	97.3	7.3	25.4	20.6	97.4	17.0	**265.5**
Ocean Economy	**2,817.4**	**1,431.7**	**6,491.7**	**2,215.3**	**4,440.7**	**3,442.6**	**20,839.5**

Table 2 Ocean economy GDP by sector and state, 2013

			jobs	(2013)			
	ME	**NH**	**MA**	**RI**	**CT**	**NY**	**Northeast Region**
Living Resources	7,744	566	7,436	1,385	818	2,473	**20,421**
Tourism & Recreation	30,694	7,328	68,063	34,439	36,875	64,188	**241,586**
Transportation	3,378	6,039	11,261	2,792	4,172	9,956	**37,599**
Ship & Boat Building	11,080	--	463	3,715	9,203	123	**24,584**
Construction	342	85	1,591	173	355	909	**3,455**
Minerals	328	43	151	176	306	328	**1,332**
Ocean Economy	**53,566**	**14,062**	**88,963**	**42,679**	**51,729**	**77,978**	**328,976**

Table 3 Ocean economy direct employment by sector and state, 2013

The data in Table 2 and Table 3 capture GDP and employment information from Northeast coastal counties, which comprise the 33 counties from Maine to New York included in the NOAA ENOW data set (Table 4). (Among other things, NOAA uses the population data for these and other coastal counties to calculate funding under section 306 of the Coastal Zone Management Act.) Because of their location in the coastal zone and their proximity to ocean resources and amenities, data from coastal counties result in a better estimate of ocean-related economic activity than data from coastal states.

Geographically, much of the Northeast region's ocean economy is concentrated in urban areas like Suffolk County (Boston, MA) and the New York City region (Figures 23 and 24). But Barnstable County (Cape Cod, MA), Suffolk County in New York, and Cumberland County in Maine have significant ocean economy employment, largely from tourism and recreation.

State	Counties
Maine*	Cumberland
	Hancock
	Knox
	Lincoln
	Sagadahoc
	Waldo
	Washington
	York
New Hampshire	Rockingham
	Strafford
Massachusetts	Barnstable
	Bristol
	Dukes
	Essex
	Middlesex
	Nantucket
	Norfolk
	Plymouth
	Suffolk
Rhode Island	Bristol
	Kent
	Newport
	Providence
	Washington
Connecticut	Fairfield
	Middlesex
	New Haven
	New London
New York	Bronx
	Nassau
	Queens
	Suffolk
	Westchester

Table 4 Northeast region coastal counties

*NOAA includes Kennebec and Penobscot counties in the list of Maine's coastal zone counties for the purpose of calculating coastal population and other statistics, because they contain tidal waters within their boundaries. These counties are not included in the ENOW data because most economic activity in those counties is not closely linked to the ocean.

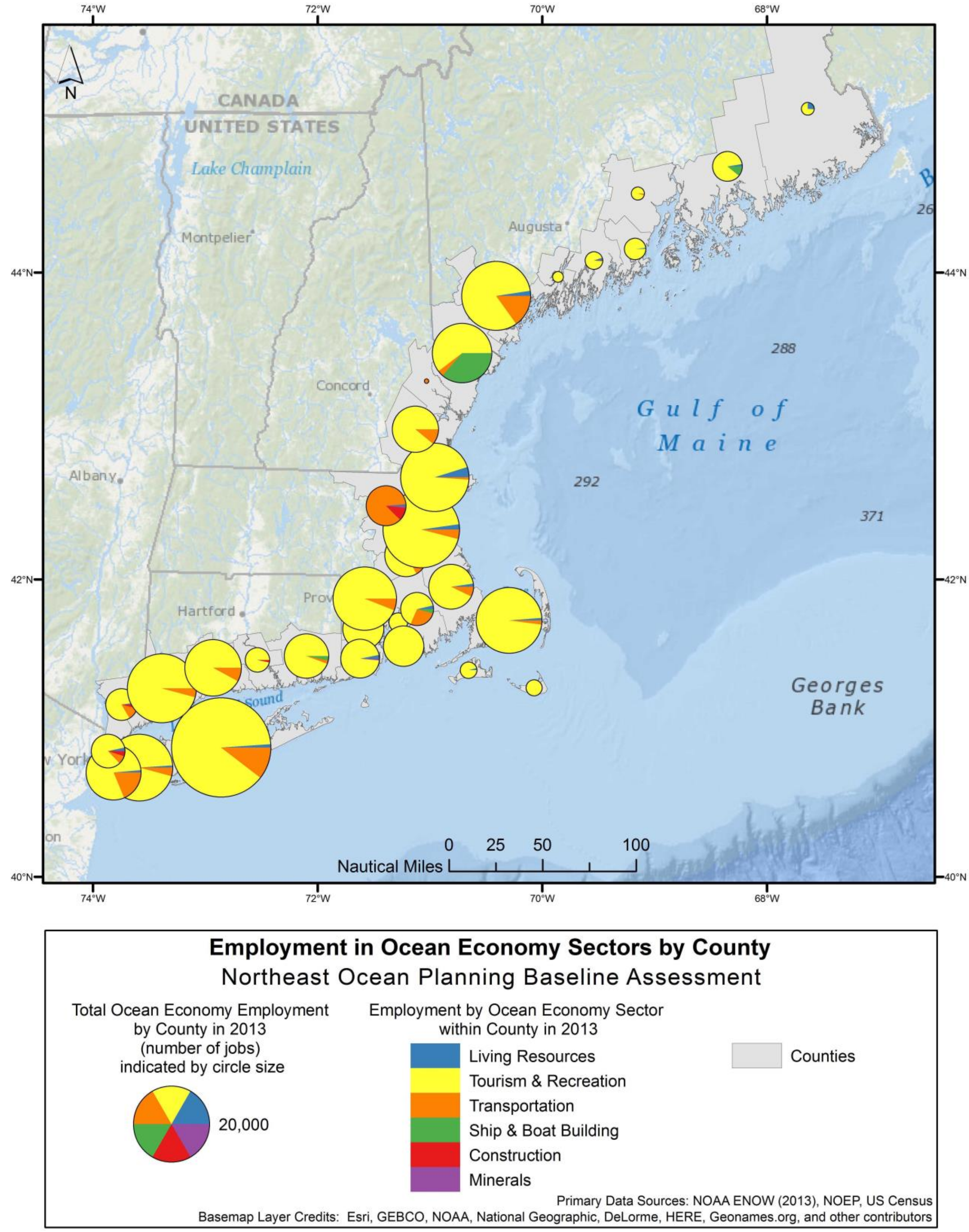


Figure 23 Employment in ocean economy sectors by county, 2013

The contribution of the ocean economy to each county's GDP (Figure 24) shows similar patterns as ocean economy employment. Essex County in Massachusetts and Fairfield County in Connecticut have among the largest ocean economies measured by absolute GDP or value added.

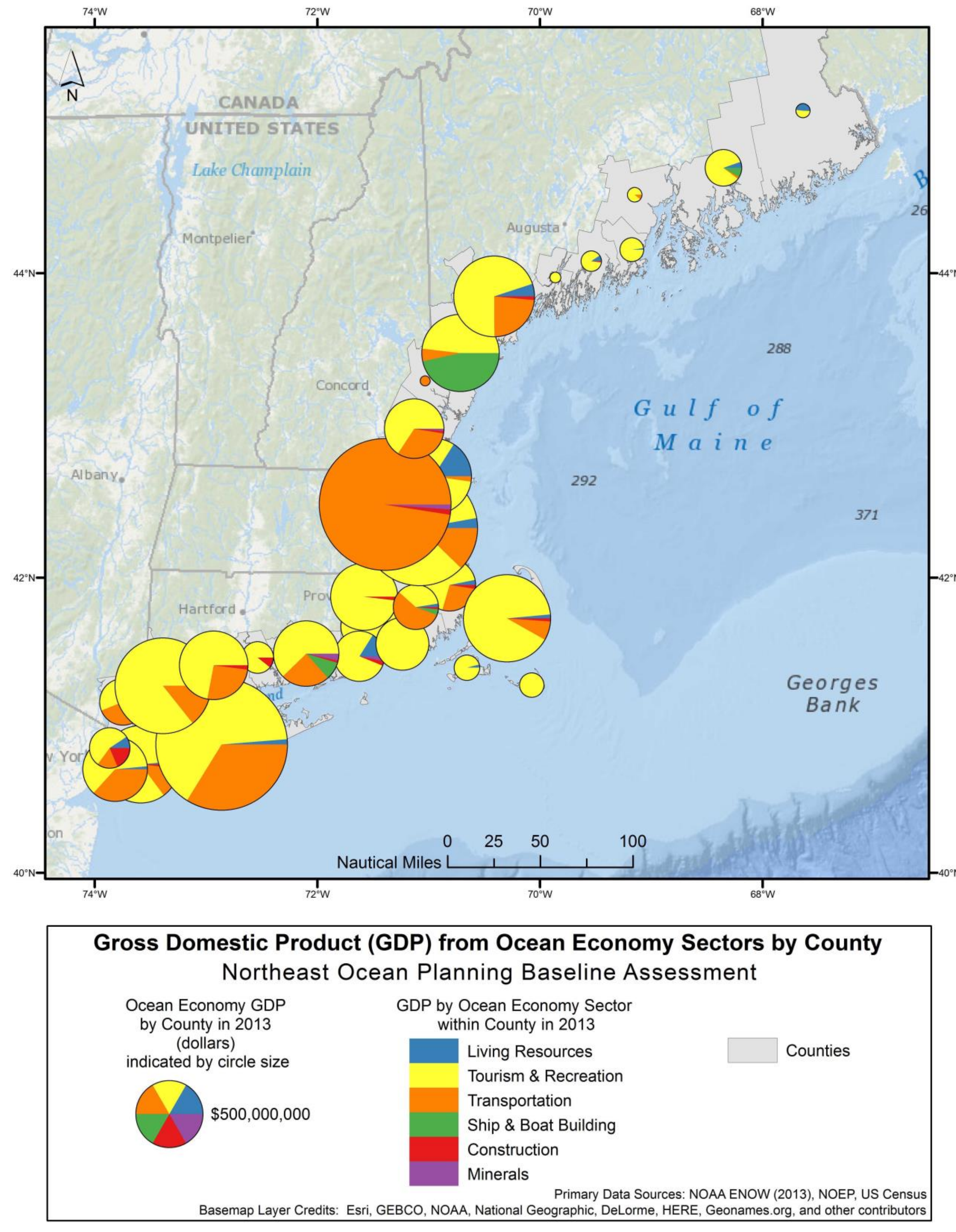


Figure 24 GDP from ocean economy sectors by county, 2013

While the ocean economy is largest, as measured by GDP contribution, in the more urban areas of southern New England, it is most important in relative terms, as a proportion of overall economic activity, in coastal Maine, Cape Cod and the Islands (Massachusetts), and Washington County (Rhode Island). Figure 25 illustrates this stronger relative dependence of some coastal communities on the ocean economy, using employment measures. This highlights the fact that non-urban coastal communities tend to be much more dependent on ocean resources and the ocean economy than larger urban center with significant non-ocean-dependent industries.

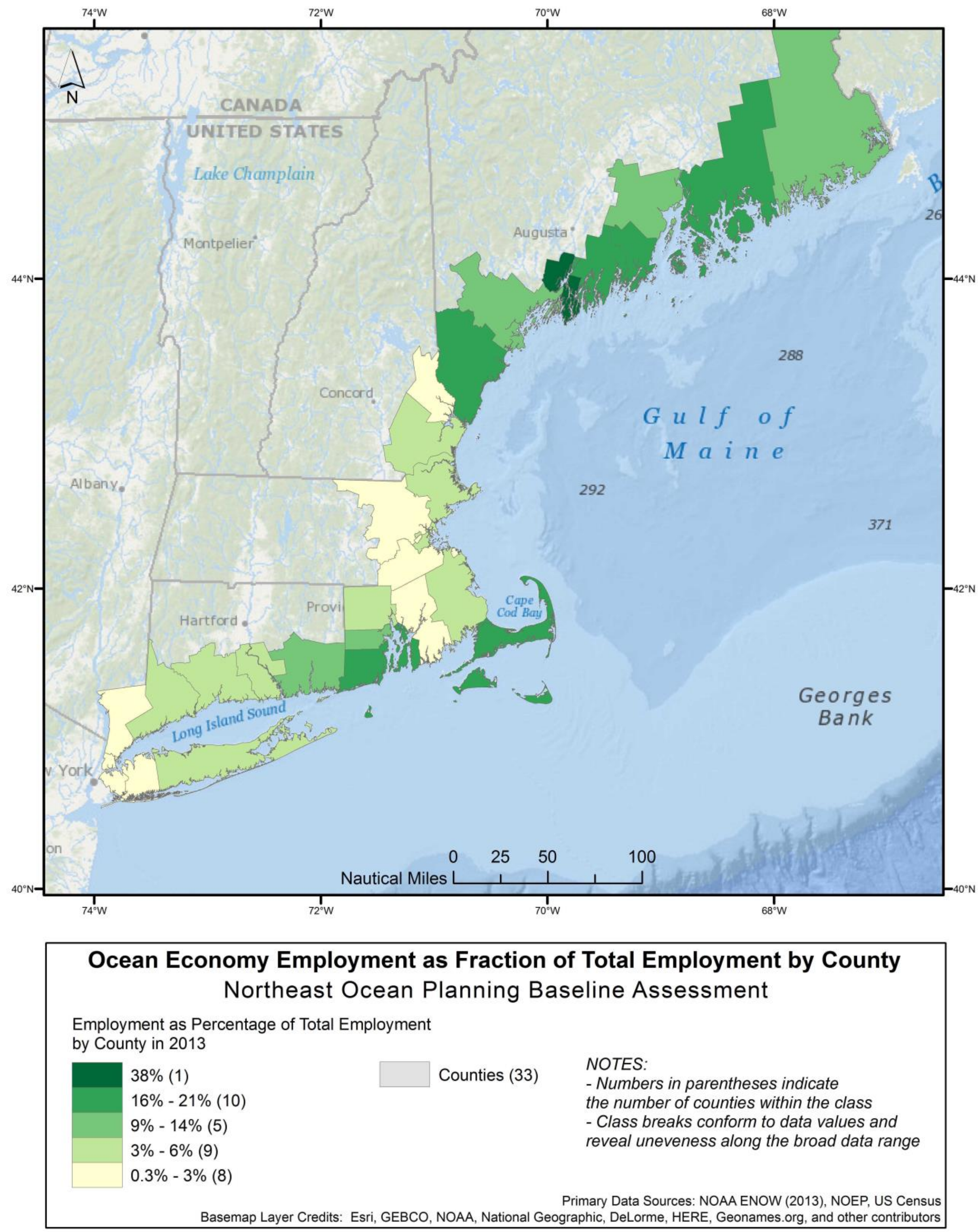


Figure 25 Ocean economy employment as fraction of total employment by county, 2013

4.2. Broader regional impacts of the ocean economy

The Northeast region's ocean economy is a subsector of the overall regional economy. Industries in the ocean sectors are closely connected with industries in non-ocean sectors, and thus exert broader economic impacts on the regional economy. Understanding these broader impacts is important to understanding the total regional economic effects of changes in ocean resource use and activity. This section describes estimates of these linkages and the broader regional economic impacts of the Northeast ocean economy.

The broader impacts of an economic sector are sometimes described as "multiplier effects" or, more specifically, indirect and induced employment and GDP effects. For example, when a new seaside hotel is built in a coastal community, the resulting additional jobs in the hotel and income earned by the hotel's employees are measured as "direct" effects in the ocean economy; these would be reflected in increases in the "tourism and recreation" sector numbers in Tables 2 and 3 above. Changes in related industries, such as additional jobs and income in the industrial laundry and food service supply industries, are considered "indirect" effects of the new hotel. And finally, the increase in household incomes of the hotel, laundry, and food service employees lead to "induced" effects, which include higher regional spending on groceries, housing, automobiles, services, etc. Similarly, using a fisheries example, if a fishing vessel is taken out of service, the resulting lost fishing jobs and income are measured as "direct" effects in the economy. Changes in related industries, such as lost jobs and income in boat repairing, are "indirect" effects; and lower household incomes for employees in the affected industry and in the industries to which it is connected lead to "induced" effects. A standard tool for estimating these multiplier effects is an input-output (IO) model (Miller and Blair 1985; Hoagland *et al.* 2005), which measures the "connectedness" between different sectors of a region's economy.

Tables 5 and 6 show the direct, indirect, and induced GDP and employment effects of the Northeast's ocean economy sectors, based on estimates from a modified IMPLAN input-output model (MIG 2000). The six ocean sectors directly generated $20.8 billion in GDP (see Table 2 above) and employed 329,000 people (Table 3 above) in 2013 in the Northeast. Accounting for the indirect and induced effects of about $19.8 billion, the total GDP impact of the six ocean sectors was $40.6 billion in 2013 (Table 5) – or about 2% of total regional GDP. With about 173,000 indirect and induced jobs attributed to ocean economy sector, total employment impacts for 2013 come to 502,000 jobs (Table 6).

	$ millions (2013)			
	Direct	Indirect	Induced	Total
Living Resources	1,813.9	751.7	868.9	**3,434.5**
Tourism & Recreation	10,305.5	3,595.7	4,727.8	**18,629.0**
Transportation	5,429.3	3,382.1	3,094.7	**11,906.1**
Ship & Boat Building	2,699.6	1,315.4	1,487.7	**5,502.8**
Construction	325.6	127.4	172.0	**625.0**
Minerals	265.5	85.8	142.5	**493.7**
Ocean Economy	**20,839.5**	**9,258.1**	**10,493.6**	**40,591.1**

Table 5 Direct, indirect, and induced ocean economy GDP by sector, 2013

	jobs (2013)			
	Direct	Indirect	Induced	Total
Living Resources	20,421	3,428	4,510	**28,358**
Tourism & Recreation	241,586	33,186	53,723	**328,495**
Transportation	37,599	20,756	21,251	**79,606**
Ship & Boat Building	24,584	13,910	17,934	**56,428**
Construction	3,455	1,279	1,904	**6,637**
Minerals	1,332	435	815	**2,582**
Ocean Economy	**328,976**	**72,994**	**100,136**	**502,105**

Table 6 Direct, indirect, and induced ocean economy employment by sector, 2013

As mentioned above, tourism and recreation is the largest sector within the Northeast's ocean economy, accounting for 73% of its direct employment and 49% of its direct GDP contribution. Transportation, ship and boat building, and living resources are in the second tier set of ocean economy sectors. Overall, indirect and induced employment in the ocean economy is 22% and 30%, respectively, of direct employment; and indirect and induced GDP is 44% and 50%, respectively. This means that, averaging across all ocean economy sectors, an increase in 10 direct ocean economy jobs results in five additional jobs outside the ocean economy; and every additional dollar of ocean economy GDP results in just under one additional dollar of GDP through multiplier effects.

However, the ocean economy sectors differ greatly in the size of their multiplier effects. Tourism and recreation, and living resources, have relatively modest indirect and induced employment effects: indirect and induced employment amounts to 14-17% and 22% of direct employment, respectively, in these sectors. In contrast, the ratios are 55% and 57% for transportation, and 57% and 73% for ship and boat building. That means that for 10 additional jobs in living resources or tourism and recreation, the region should expect about four other new jobs to be supported, whereas ten additional jobs in transportation or ship and boat building might support 13 new jobs in other sectors. These multiplier ratios are important to consider in estimating the total regional economic impact of future changes in the ocean economy sectors. It is also important to consider site specific vs. regional characteristics of categories such as living resources and tourism sectors. For example on the coast of Maine, seafood transportation, packaging, gear shops, and shore side support facilities all rely on the living resource sector in part if not in whole, which the ENOW data may not adequately capture.

4.3. Seafood

Based on NOAA's ENOW data (see introduction to Section 4 above), the living marine resources sector (commercial fishing, aquaculture, and seafood processing) encompassed about 1,200 establishments and supported more than 20,000 direct jobs in the Northeast in 2013, with a contribution to regional GDP of about $1.8 billion.

The economic contribution of fisheries can be measured a variety of ways. For example, ENOW data focus on measures such as GDP, the net value added by an economic sector. Other documents, such as the Fisheries Economics of the United States (NOAA 2014), estimate measures such as "sales impact," the total sales revenue generated by the sector. Each measure has its purpose, but it is important to keep in mind that a measure such as "sales impact" can include sales revenue from a single fish at the dockside, wholesale, and retail level – a form of double counting, if the goal is to estimate the value of the fish. GDP, in contrast, measures the net value added at each stage in the value chain. As a result, "sales impact" and "economic impact" numbers often are significantly larger than "GDP" numbers.

To illustrate, NOAA's *Fisheries Economics of the U.S. 2012* (NOAA 2014) estimates that the total sales impact of the New England Region's seafood industry for 2012 was close to $13 billion – nearly 10 times the contribution to GDP estimated by ENOW. Total sales revenue for fishermen, processors, dealers, wholesalers, distributors, importers, and retailers were $603 million in Connecticut, $1.9 billion in Maine, $8.5 billion in Massachusetts, $609 million in New Hampshire, and $1.2 billion in Rhode Island. Massachusetts generated the largest impacts in the region, with 107,000 jobs, $2.2 billion in income, and $3.4 billion in value added impacts. The smallest income impacts were generated in Connecticut, with 3,900 jobs and $128 million in income.

4.3.1. Commercial fishing

The cultural and economic importance of commercial fishing in New England spans hundreds of years. There is no single commercial fishery in New England; fishing operations vary from harbor to harbor depending on a myriad of factors, which vary throughout the region and over time: targeted species, vessel sizes, proximity to fishing grounds (current and historic), changes in environmental conditions, economic and market-driven forces, shore-side supporting infrastructure, and many more. Commercial fishing in Maine currently looks quite different than in southern New England. Ports such as New Bedford and Gloucester, Massachusetts (scallops and groundfish) and Stonington, Maine (lobster) have consistently ranked among the top US ports in terms of landings value in recent years (Fisheries Economics of the US 2012).

In 2012, commercial fishermen in New England landed 664 million pounds of finfish and shellfish worth about $1.2 billion in landings revenue (Fisheries Economics of the US 2012). This was a 72% increase (a 24% increase in real terms) from 2003 levels ($691 million) and an 8.1% increase (a 8.5% increase in real terms) relative to 2011 ($1.1 billion). While the 2012 report summarizes economic information related to commercial and recreational fishing activities and fishing related industries in regions of the US, it is important to note that fishing activity is heavily influenced by regulatory factors such as closed areas and that the ability to effectively map fishing activity (Figures 27-33) is limited by the monitoring requirements of a particular fishery and on specific components of that fishery. Figure 26 illustrates the scale and composition of commercial fisheries landings by port. Ports with the largest landings (by weight) are New Bedford MA (mainly scallops and finfish), Gloucester MA (finfish), and Stonington ME (mainly lobster). In general, Massachusetts landings are dominated by finfish and scallops, while Maine landings are dominated by lobster.

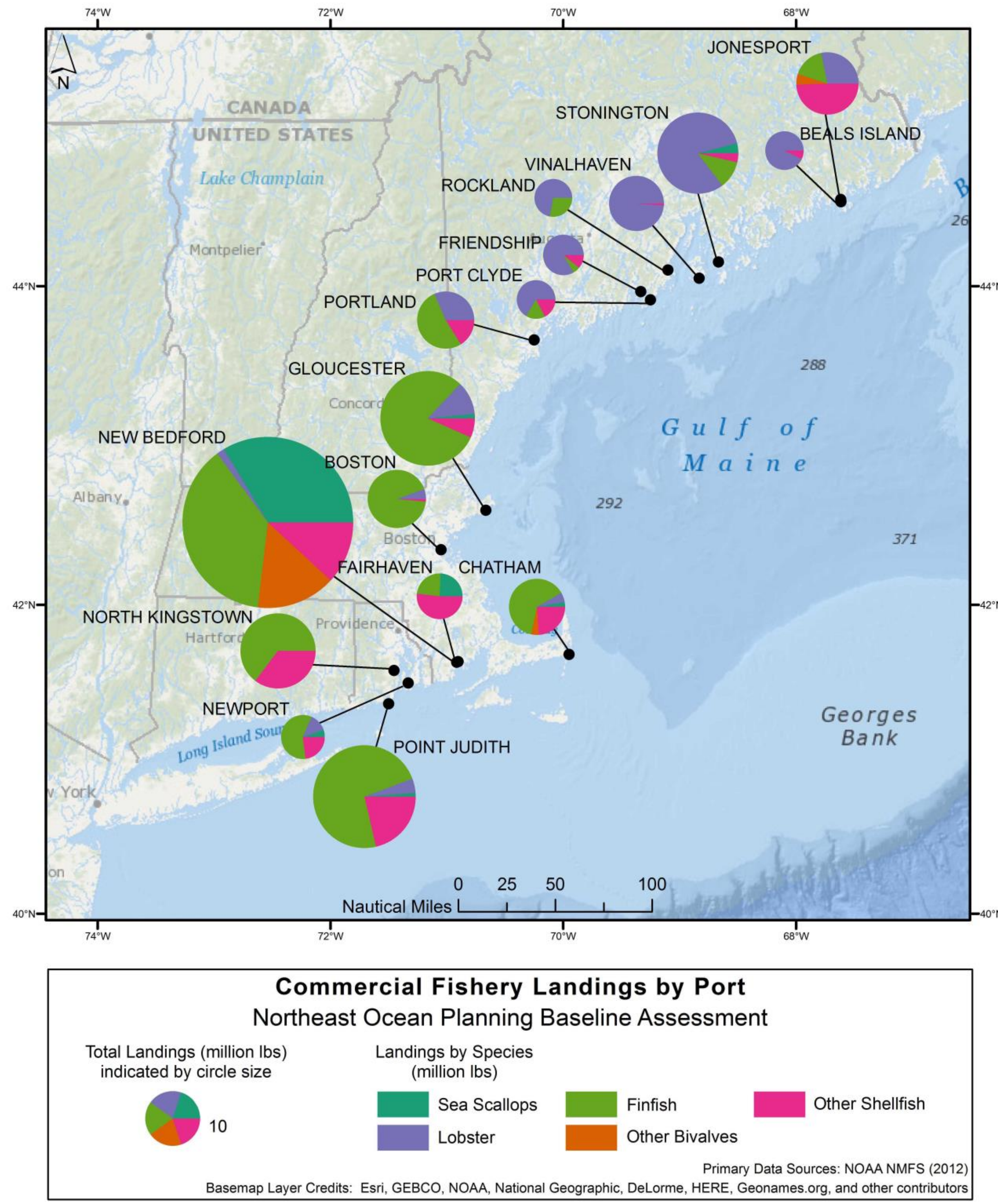


Figure 26 Commercial fishery landings by port, 2012

The NE RPB has supported two phases of work on characterizing the on-water vessel activity associated with the Region's commercial fishing industry:

- Commercial Fishing Phase 1: This project began in 2012 to map federally managed commercial fisheries in the Northeast using data through 2010. Starting with existing data available for certain fisheries, map products were developed and discussed with the fishing industry, scientists, and managers. A 2013 Commercial Fisheries Spatial Characterization Report and a 2014 Fishing Fact Sheet summarize the results of this initial phase.

- Commercial Fishing Phase 2: This project focused on spatial distribution of federally managed species, with additional mapping based on Vessel Monitoring System data through 2013, Vessel Trip Report analysis (using vessel speed to differentiate fishing from other vessel activities, using 2011-2013 data). Results are summarized below and additional detail can be found on the NE Ocean Planning website with a new the Commercial Fishing Spatial Characterization, Phase 2 report.

Results of this work are illustrated in Figures 27 to 33 below. These figures show fishing vessel activity density, based on data collected under NOAA's Vessel Monitoring System (VMS) Program. The figures show an index of vessel activity density over the specified calendar years, for vessels permitted to fish for various species, illustrating both the ports from which the vessels operate, their routes to/from the fishing grounds, and the fishing grounds themselves. Similar data for earlier years (2006-2010) can be found in Appendix D, as can maps illustrating estimated density of fishing activity without the transit routes to/from fishing grounds.

Figure 34 illustrates the geographic extent of the Northeast's lobster fisheries, using data from the Industrial Economics (2014) Vertical Line Model, which was developed to support efforts to protect marine mammals from entanglement in fishing gear. The data in Figure 34 represent the density of vertical or end lines from lobster trap strings, which in turn is representative of the intensity of lobster fishing effort. For the waters off Maine, where most of the region's lobster fishing and landings are concentrated, other data on lobster fishing are available from the Maine Department of Marine Resources and Brehme *et al.* (2015).

Additional information about commercial fisheries is available from the Northeast Ocean Data Portal.

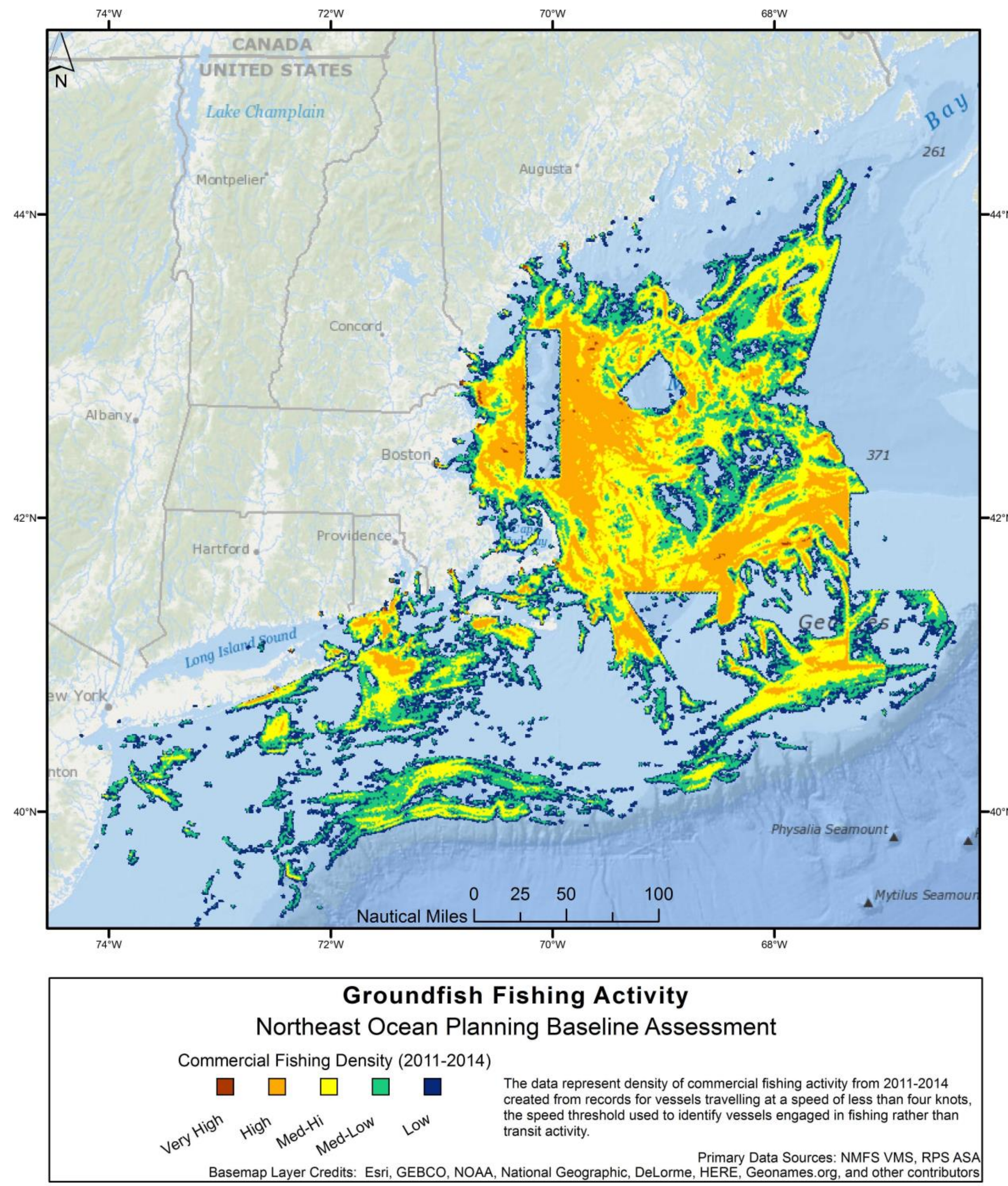


Figure 27 Groundfish fishing activity, 2011-2014

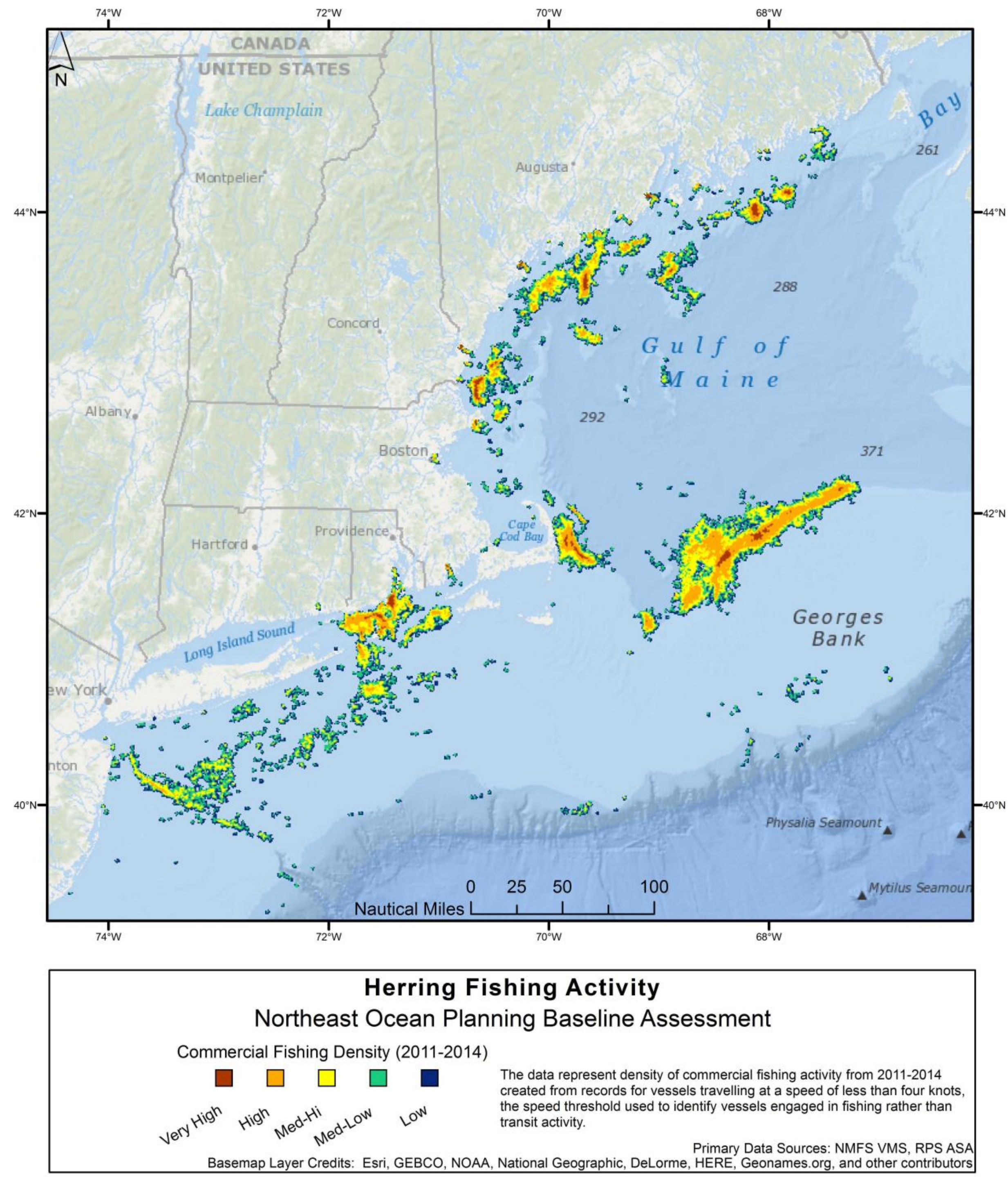


Figure 28 Herring fishing activity, 2011-2014

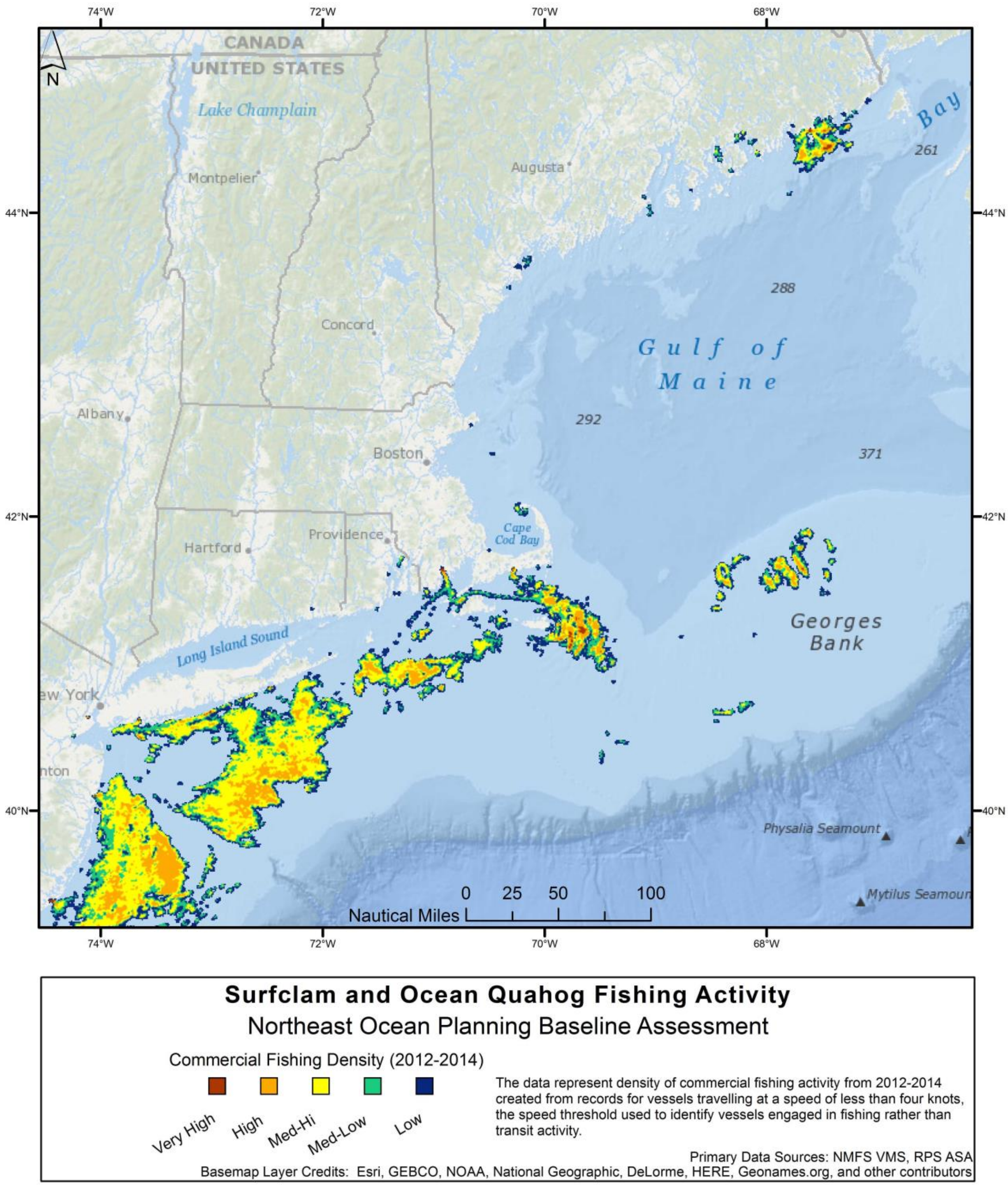


Figure 29 Surf clam and ocean quahog fishing activity, 2012-2014

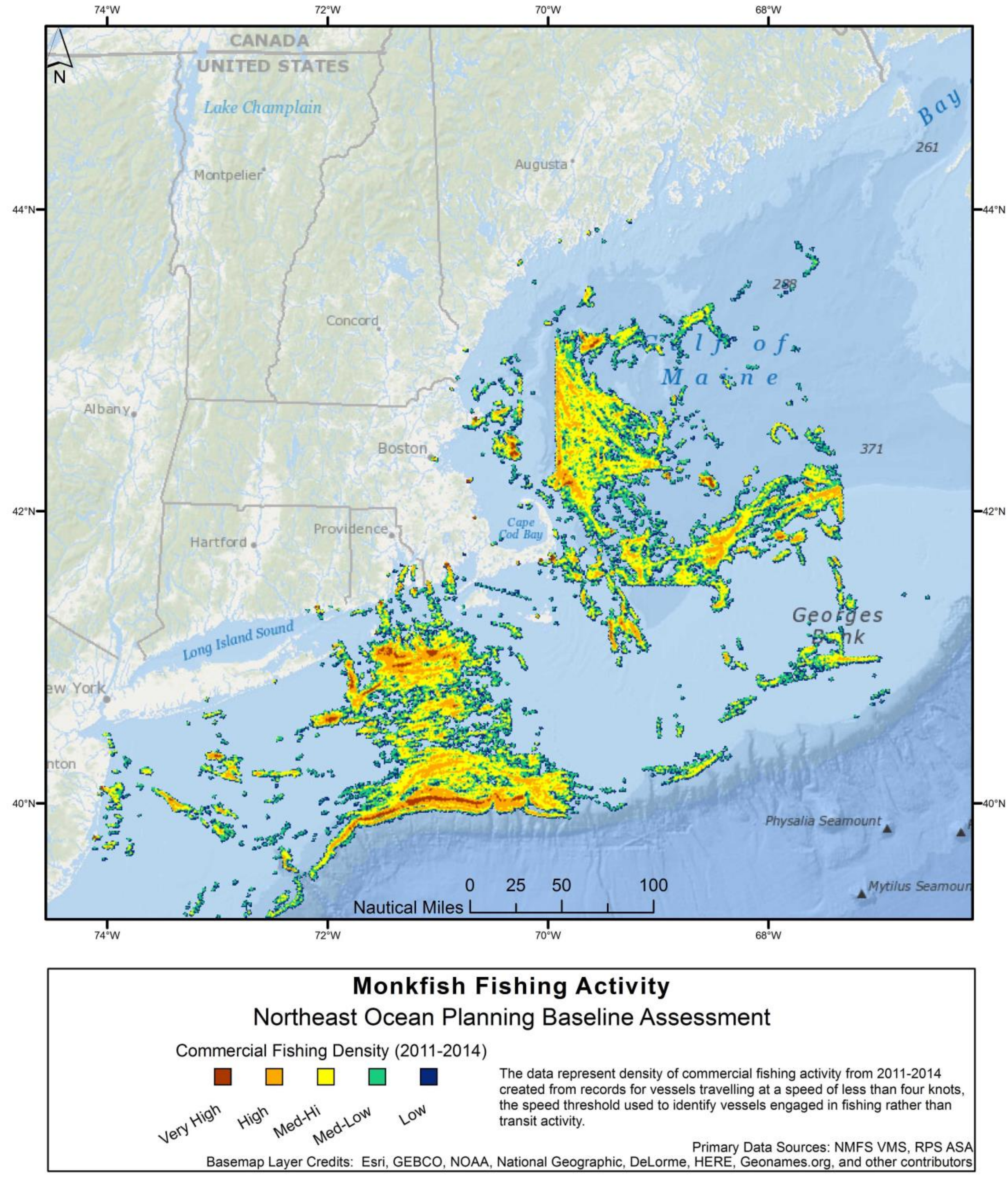


Figure 30 Monkfish fishing activity, 2011-2014

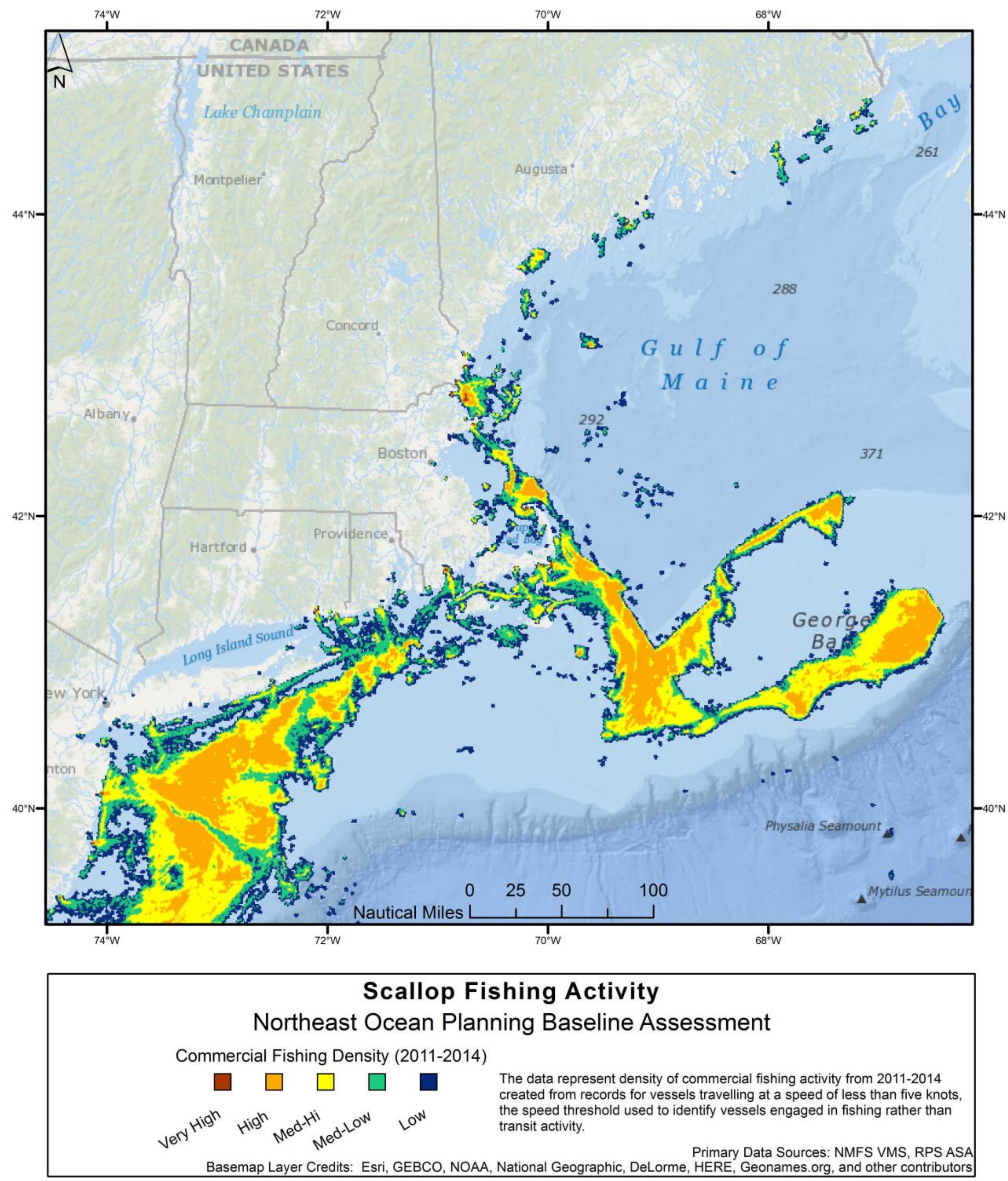


Figure 31 Scallop fishing activity, 2011-2014

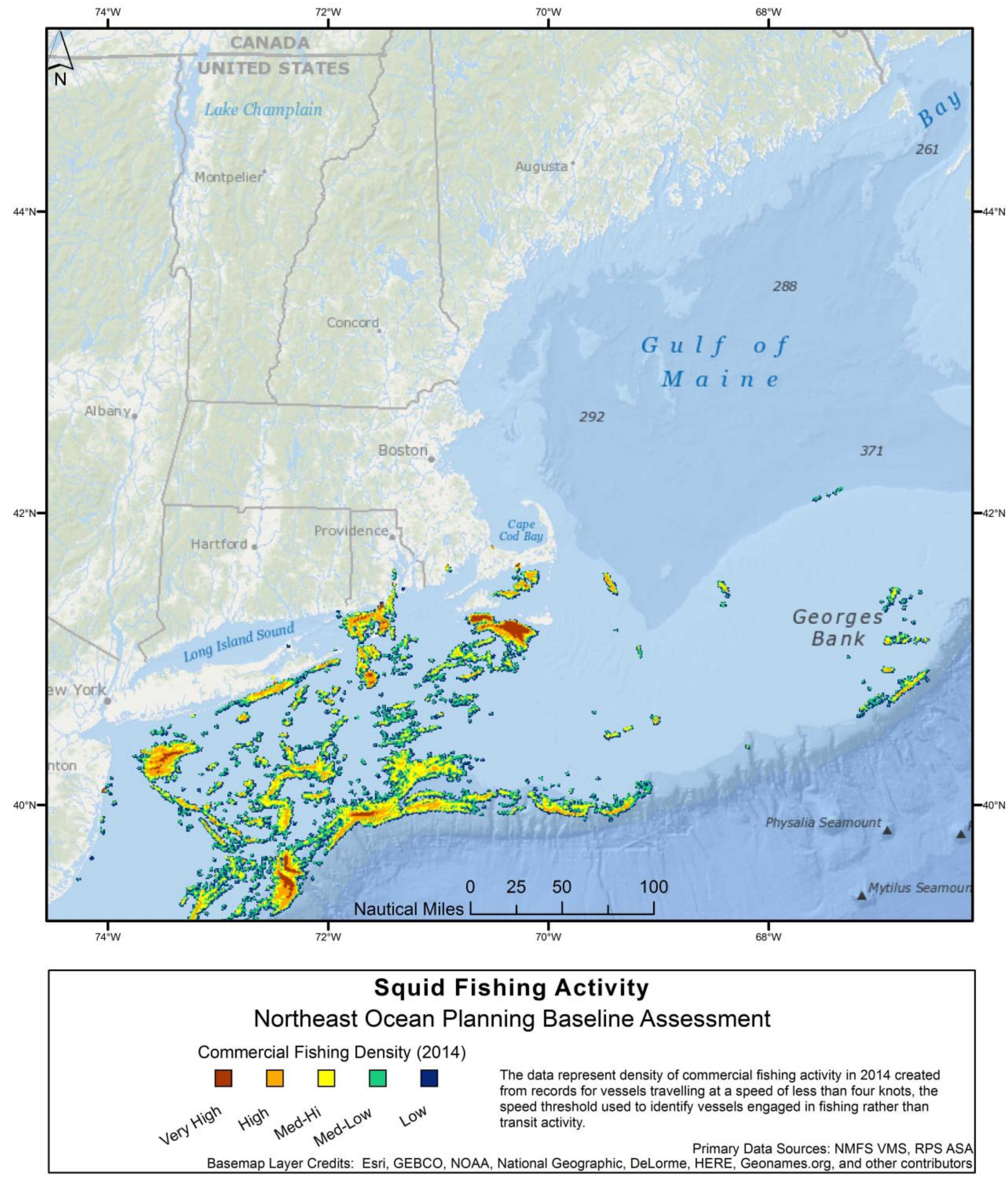


Figure 32 Squid fishing activity, 2014

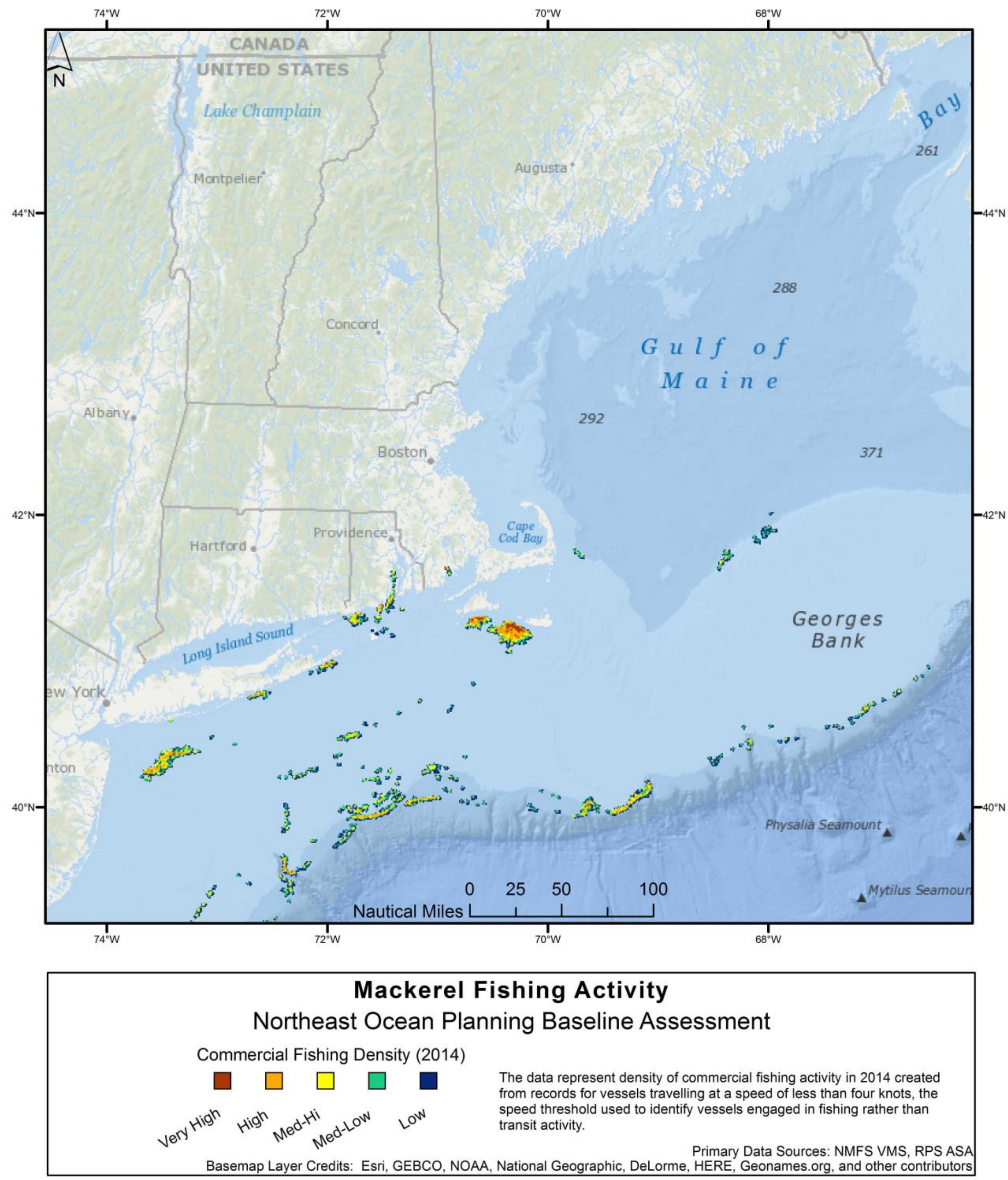
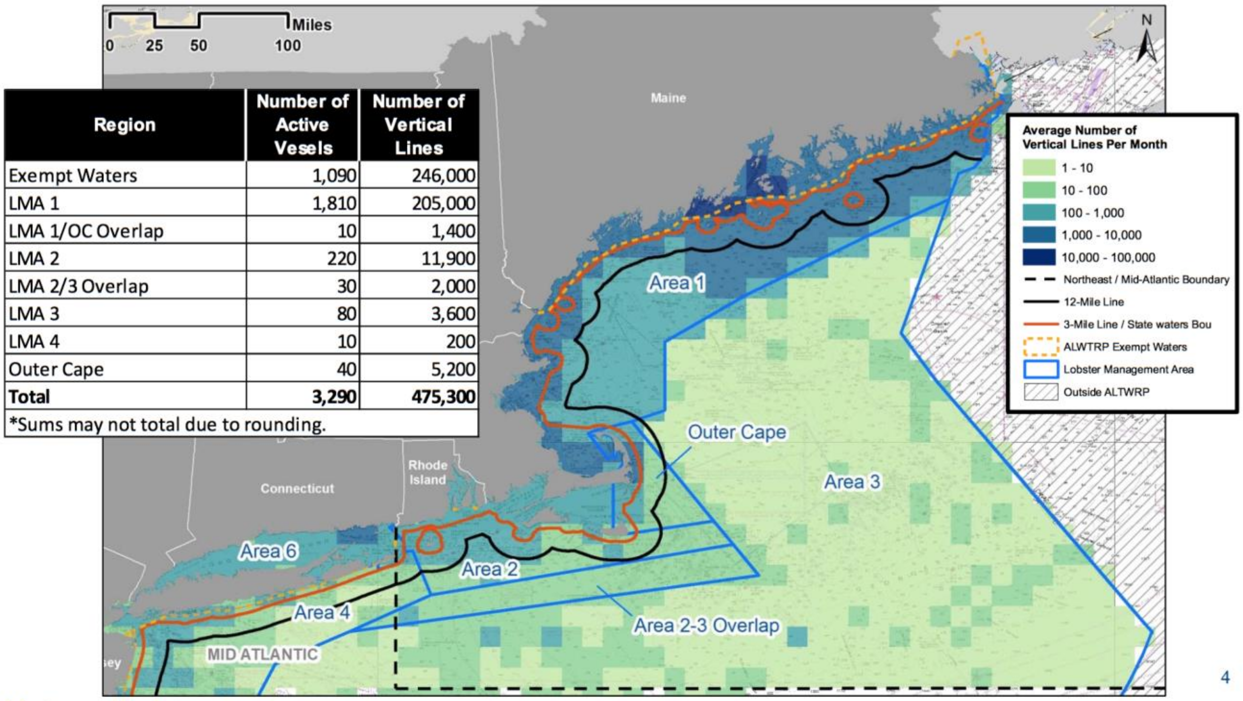


Figure 33 Mackerel fishing activity, 2014



Region	Number of Active Vesels	Number of Vertical Lines
Exempt Waters	1,090	246,000
LMA 1	1,810	205,000
LMA 1/OC Overlap	10	1,400
LMA 2	220	11,900
LMA 2/3 Overlap	30	2,000
LMA 3	80	3,600
LMA 4	10	200
Outer Cape	40	5,200
Total	**3,290**	**475,300**

*Sums may not total due to rounding.

Figure 34 Lobster fishing activity
(source: Industrial Economics 2014)

4.3.2. Aquaculture

Commercial aquaculture production in the Northeast consists primarily of oysters, clams, and salmon. Commercial finfish aquaculture in the region almost entirely consists of Atlantic salmon rearing in Maine, which had a market value of over $73 million in 2010. The majority of this production comes from one New Brunswick based company, with a few other smaller, family owned operations (LaPointe 2013).

Shellfish aquaculture is more widespread than finfish aquaculture in New England, with over 1500 leases from Maine to Connecticut (Figure 35) producing $45-50 million per year of dockside value (point of first sale) with oysters representing the largest portion of that total. The leading producer is Connecticut, where oyster and clam farming generated output of more than $30 million (2010) and supported some 300 jobs. Massachusetts is second with $10.8 million in oysters and $10 million in quahog production in 2013. Maine and Rhode Island each have about $3 million/year in shellfish aquaculture production. Shellfish aquaculture operations in New England include small, family owned companies often with roots in fishing families or from communities looking for economic diversification from wild harvest fisheries as well as large corporations. (LaPointe 2013).

There is future growth potential for aquaculture in New England. NOAA's Marine Aquaculture Strategic Plan (FY 2016-2020) indicates that national production of farm-raised seafood increased 8% per year from 2007-2012, with local shellfish production recently reaching all-time highs in several states. There is also increased interest in the production of new species, such as certain seaweed varieties, and establishing polyculture facilities that combine multiple species at one site. Combining finfish, shellfish and kelp in a single site can help buffer the effects of changing market and environmental conditions and mitigate waste and nitrogen inputs from finfish culture. In addition, while shellfish aquaculture has traditionally been located in intertidal or nearshore waters, there has been recent interest in locating operations further offshore.

There are many potential advantages to siting aquaculture offshore. Offshore areas often have better water quality and fewer existing activities that may conflict with the development of new facilities. Therefore, offshore areas may be better suited for larger operations. Alternatively, the challenges include a complex permitting process, variable ocean conditions, and increased distance to portside support and infrastructure. In 2014 and early 2015, two long-line blue mussel operations were permitted in federal waters – one 8.5 miles off Cape Ann and the other in Nantucket Sound representing the first two locations permitted for aquaculture in federal waters offshore New England.

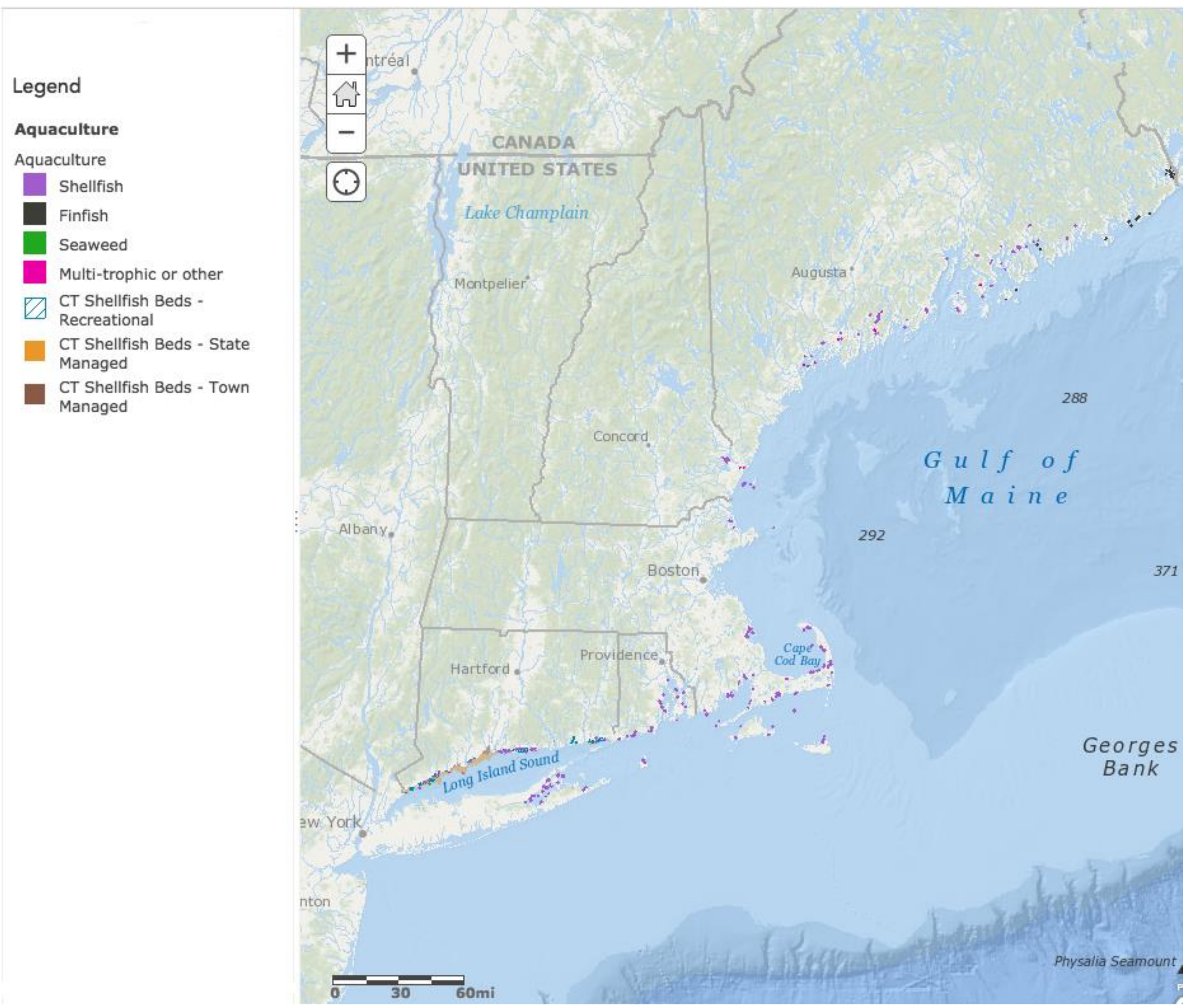


Figure 35 Aquaculture

Three working sessions with aquaculture industry representatives were held in 2012 and focused on topics of: permitting and leasing, current and future space needs, compatibility of aquaculture with other ocean uses, and data about existing aquaculture sites and leases. The Northeast Region Aquaculture White Paper (LaPointe 2013) summarizes these discussions and data on leases and harvest levels by state. Additional information on leases, permits, and harvest levels is available from the relevant state agencies:

Maine Department of Marine Resources
New Hampshire Fish and Game Department
Massachusetts Division of Marine Fisheries
Rhode Island Coastal Resources Management Council
Connecticut Bureau of Aquaculture
New York State Department of Environmental Conservation

4.3.3. Seafood processing

Seafood processing includes activities that convert seafood landed by fishing vessel in Northeast region ports (or imported from elsewhere) into fresh, canned, cured, and frozen seafood products. The Region's seafood processing industry is located primarily in or near the major traditional fishing ports such as New Bedford and Gloucester in Massachusetts, and Portland in Maine. With the declines in regional catch and landings over recent decades, the processing industry has also seen declines; but the US imports some 80% of the seafood consumed in the country, and Northeast processors have maintained output by increasing reliance on imported fish. Essex County in Massachusetts and Knox and Waldo counties in Maine have the largest numbers of seafood processing establishments (Figure 36).

Traditionally, New England's shellfish, particularly lobsters, have received relatively little processing; most of the product is sold in fresh markets. This is beginning to change with the growth of lobster processing, first in Canada, and now in locations like Portland. These changes in the seafood processing industry are not yet reflected in the data presented in this report.

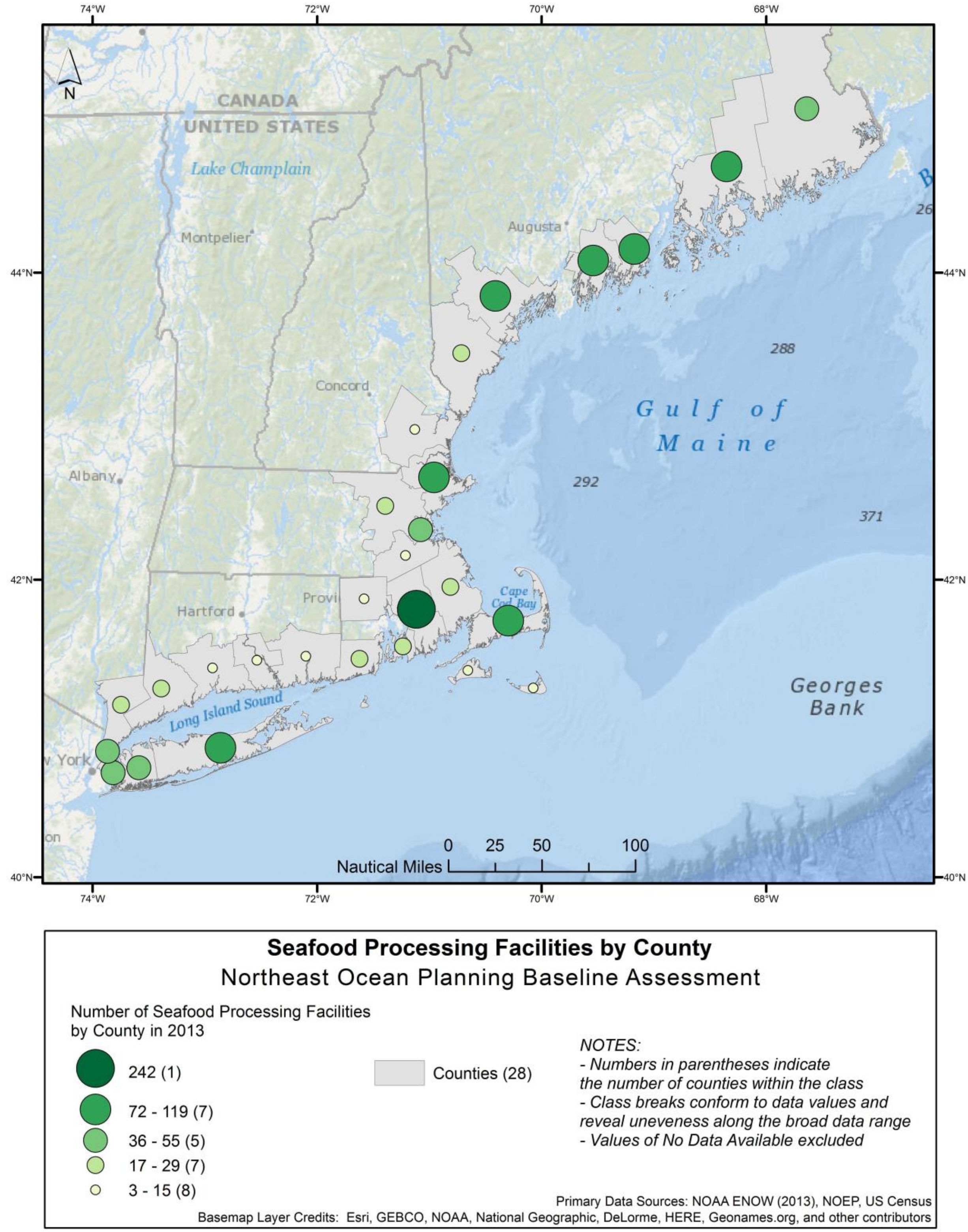


Figure 36 Seafood processing facilities by county, 2013

4.4. Recreation and Tourism

Recreation and tourism account for about half of the economic value generated in the Northeast region's ocean sector. More than the other sectors of the ocean economy, marine recreation and tourism in the Northeast is highly seasonal, concentrated during the summer months, creating seasonal employment patterns. Often, non-urban counties with higher dependency on the ocean economy have, as a consequence of the large role of tourism and recreation employment, much higher employment levels in the summer. Tourists flock to the coast, increasing employment in the tourism and recreation sector by close to 90% in some counties. Nantucket (Dukes County), Martha's Vineyard, and the Maine counties of Lincoln and Hancock show the largest difference between summer and annual average employment (Figure 37).

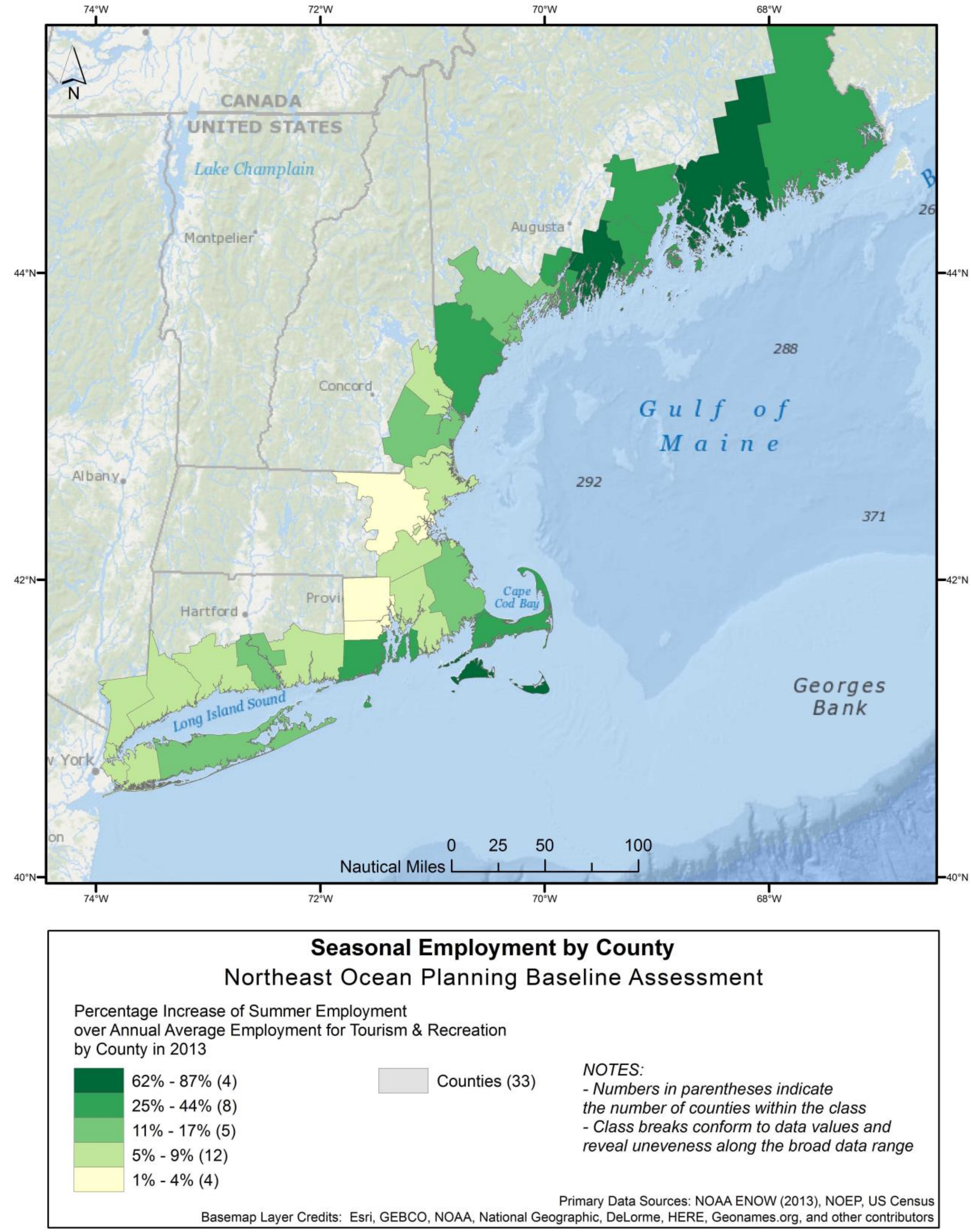


Figure 37 Seasonal employment by county, 2013

Data on economic indicators and values associated with ocean tourism and recreation in the Northeast are available from the Center for the Blue Economy's National Ocean Economics Program, including a summary of published information on non-market values. A 2015 Northeast RPB report on Coastal and Marine Recreational Activity in the Northeast United States (Point 97 *et al*. 2015) describes the results of a study by Point97, the Surfrider Foundation, and SeaPlan to characterize coastal and marine recreational activities in the Northeast. The study focuses on commercial whale watching, SCUBA diving, sailing races and regattas, sportfish tournaments, competitive board and paddle events, and individual activities such as beach going, wildlife viewing, surfing, and non-motorized boating (e.g. kayaking).

4.4.1. Recreational boating and fishing

The 2012 Northeast Recreational Boater Survey (SeaPlan 2013) identified nearly 374,000 marine boaters with boats registered between Maine and New York. Surveys of these boaters suggest that they collectively undertake more than 900,000 boating trips on the ocean each year, and that this activity contributes approximately $3.5 billion/year and the equivalent of nearly 27,000 year-round jobs to the Northeast region's economy. Of these, about 7,700 jobs are in leisure and hospitality; 6,700 in trade, transportation, and utilities; and 5,600 in boat repair and other services. Economic impacts and employment from recreational boating are highest in New York ($1.4 billion/year; 10,800 jobs) and Massachusetts ($840 million/year; 6,500 jobs), followed by Connecticut ($554 million/year; 4,300 jobs), Rhode Island ($227 million/year; 2,000 jobs), Maine ($205 million/year; 1,900 jobs), and New Hampshire ($69 million/year; 500 jobs) (SeaPlan 2013). Note, as with the seafood industry data in section 4.3, that these "economic impact" figures are not compatible with the GDP and employment measures used in the ENOW data.

Recreational boating and fishing activity is particularly intense in the coastal waters south and west of Cape Cod (Figure 38), moderately intense on the coast of Massachusetts from Cape Cod north to New Hampshire, and still significant but moderate along the coast of Maine, with low levels of activity north and east of Acadia National Park. Most recreational boating takes place within 20 nautical miles of the coast, though some fishing trips go further offshore, particularly off the coast of Massachusetts.

Recreational boating includes both power boating and sailing in nearshore and offshore waters, and rowing and paddling in the proximity of the coast. Some 200 sailing clubs organize several hundred races and regattas in the Northeast each year, and about 50 fishing clubs organize on the order of 100 fishing tournaments in the region each year. The 2015 Northeast RPB report on Coastal and Marine Recreational Activity in the Northeast United States (Point 97 *et al*. 2015) documents the coastal areas and routes most frequently used for distance sailing races (Figure 39). It also maps coastal areas used for standup paddle board (SUP) and other paddle events, surf contests, and triathlons. SUP contests are the most common of these, representing 62% of all competitive board and paddle events identified in the report (Figure 40). For additional information, see the Point 97 *et al.* (2015) report on Northeast US coastal and marine recreational activity, and the Rhode Island Ocean Special Area Management Plan (RICRMC 2010).

Angling for recreational purposes is widespread and targets many different species. Striped bass, summer flounder, groundfish, and countless other species are targeted by shoreside anglers, surf-casters, boaters, charter and party boats, and fishing tournaments throughout New England all summer long, drawing residents and visitors by the hundreds of thousands. In 2013, an estimated 5 million trips were taken (Fisheries Economics of the US 2012). The NE RPB is supporting an ongoing pilot project, due to be completed in 2016, to explore methodologies for mapping charter boat activity in New York and Rhode Island waters. Intended to produce better information for fisheries management purposes, the project is deploying apps on the smart phones of approximately 20 charter boat captains to capture spatial data on charter boat location, differentiating between transit and fishing activity.

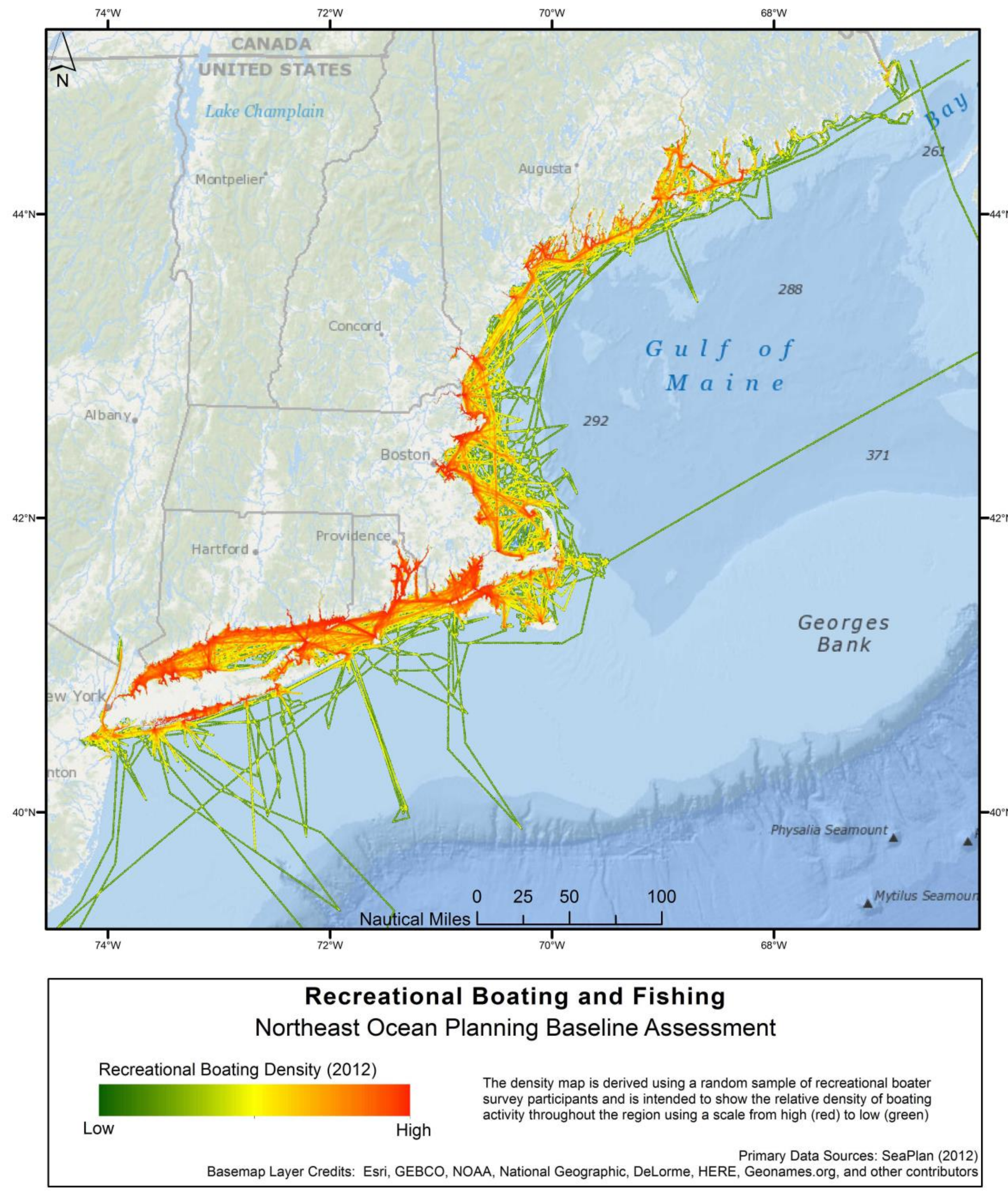


Figure 38 Recreational boating and fishing

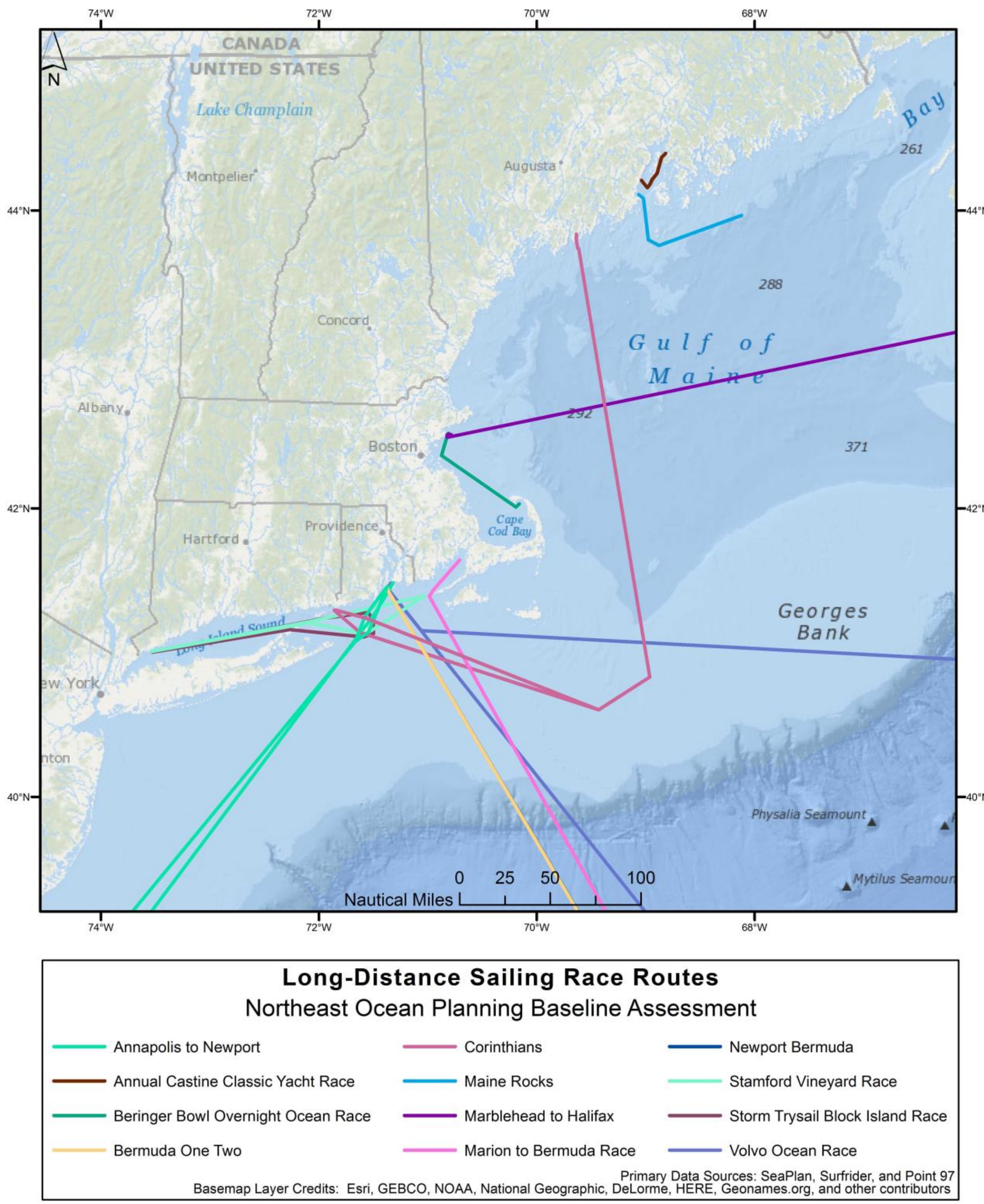


Figure 39 Long-distance sailing race routes

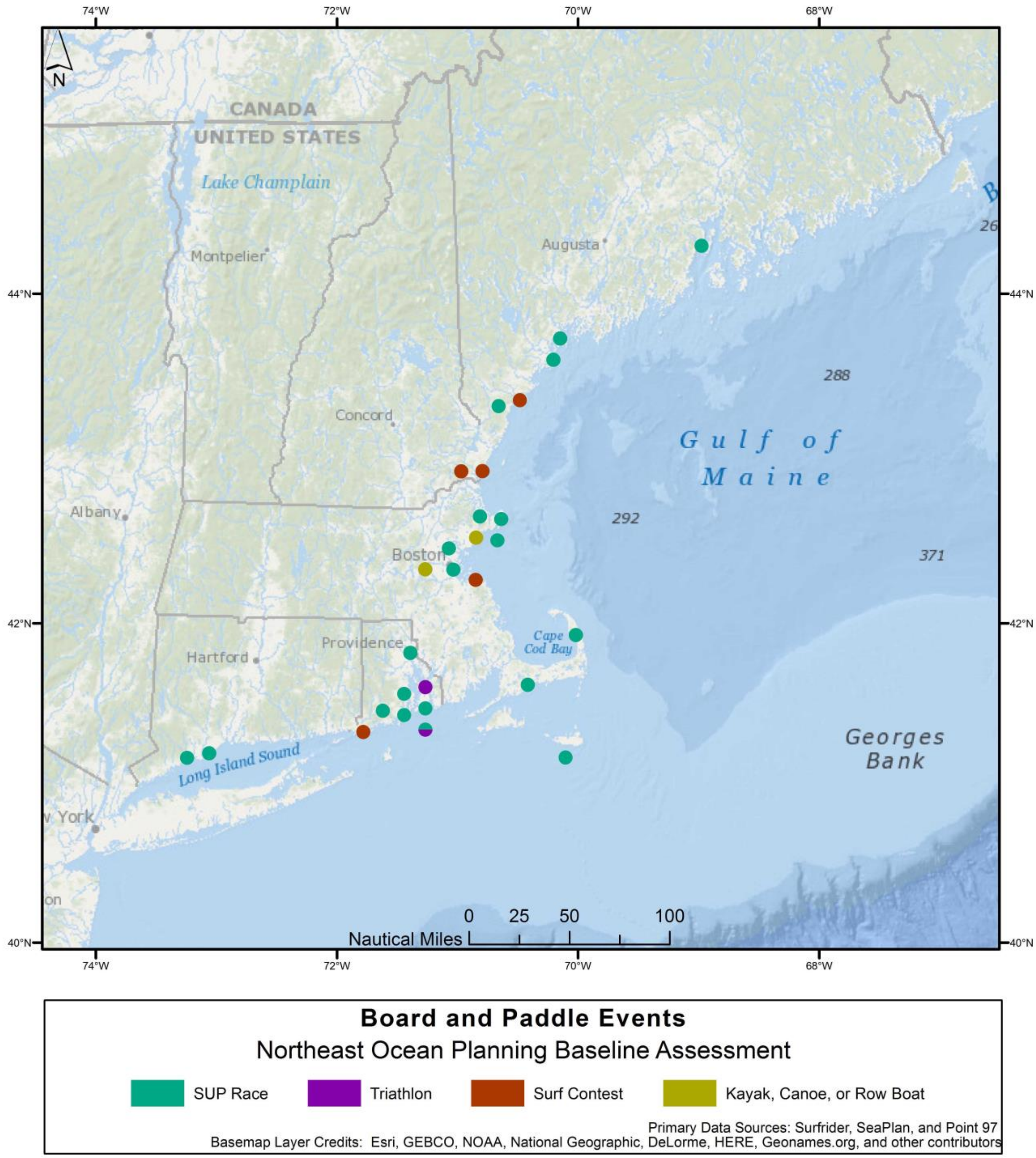


Figure 40 Board and paddle event locations

4.4.2. Marinas

Some 600 marinas in the Northeast region (see Figure 17 above) employ more than 5,000 people and generate about $400 million/year in regional GDP. The highest concentration of marinas is found in New York, Massachusetts, and Connecticut (ENOW data).

Marinas in New England are primarily privately owned and operated and primarily serve recreational boating, including recreational deep-sea fishing. Other activities such as commercial fishing, water taxis, and water tours also operate out of marinas. Marinas are located throughout the coastal area; their dependence on recreational boating makes them one of the most seasonally variable industries in the ocean economy. Suffolk County in New York is the location of the largest number of marinas, followed by Fairfield County in Connecticut and Barnstable and Essex Counties in Massachusetts (see Figure 17 above).

4.4.3. Boat dealers

About 300 boat dealers throughout the Northeast region employ about 2,000 people and generate between $100 and $200 million/year in GDP (ENOW data). Boat dealerships are evenly represented in all Northeast states except New Hampshire, which has relatively few.

4.4.4. Beach recreation

Residents of and visitors to the Northeast region spend approximately 100 million person-days at the regions 1,000+ ocean beaches (see Figure 5 above). This represents about 10% of total beach visits for the United States. Massachusetts and New York provide the largest contribution to the region's total, with an estimated 30 million person-days each. These numbers are estimates based on limited survey work; no detailed visitor numbers are collected for most beaches in the region.

Most of this beach activity (see Figure 41) is concentrated in the summer months, and more than half of beach visits include swimming. Among respondents to a (non-random) survey of waterfront and marine recreation participants conducted by Point 97, the Surfrider Foundation and collaborators, the top five activities individual user participated in were beach going, scenic enjoyment, swimming/body surfing, biking/hiking, and wildlife viewing. On average, respondents to this individual user coastal recreation survey spent $263.29 in trip expenditures during their last trip with approximately 40% of those expenditures spent on food and beverages and approximately 20% spent on lodging (Point 97 et al. 2015). Figure 41 shows the geographic extent of various individual coastal recreational activities (other than boating) in the Northeast.

Using estimates of the non-market value of beach recreation from $5 to $20/day, beach visits in the Northeast generate an estimated $500 million to $2 billion in non-market recreational value each year (see section 5 and Appendix E below for a more detailed discussion of beach recreation opportunity as an ecosystem service).

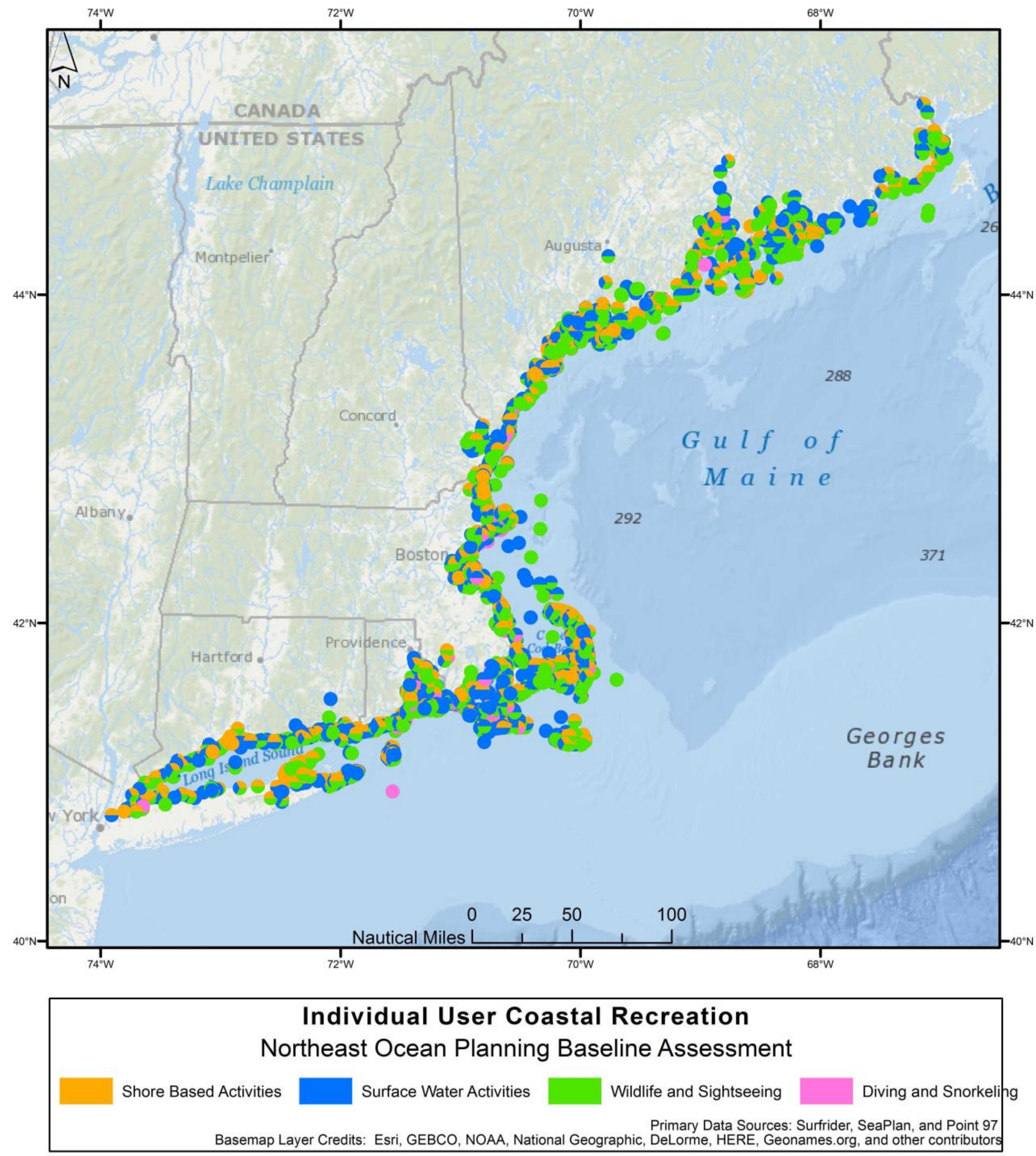


Figure 41 Individual user coastal recreation

4.4.5. SCUBA diving

Shore- and boat-based recreational SCUBA diving is a popular activity occurring at various sites throughout the Northeast, primarily focusing around historical shipwrecks, interesting benthic communities, and popular wildlife viewing areas. Despite the relatively cool water temperatures, diving activity in the Northeast occurs year-round but is concentrated in the months of May through October, and is clustered around regions with attractive underwater topography such as Cape Ann, MA. Much diving activity occurs from private boats or from the shore, while groups may also charter diving excursions through professional dive boats. Divers engage in a number of activities while diving, including wildlife viewing, photography, and fishing or hunting. The average value per day of SCUBA diving in the Northeast has been valued at $14.93, based on individual diver consumer surplus. Some 100 SCUBA diving clubs are active in the Northeast. In Rhode Island alone, the net economic value of SCUBA diving and snorkeling together was valued at $25.8 million (RICRMC 2010, Kaval and Loomis 2003).

Figure 42 illustrates recreational dive site locations in the Northeast. More information is available in the 2015 report Coastal and Marine Recreational Activity in the Northeast United States (Point 97 *et al.* 2015), which summarizes information about ocean dive sites assembled by state agencies and diving experts around the region, and includes a map of commonly used Northeast ocean diving locations.

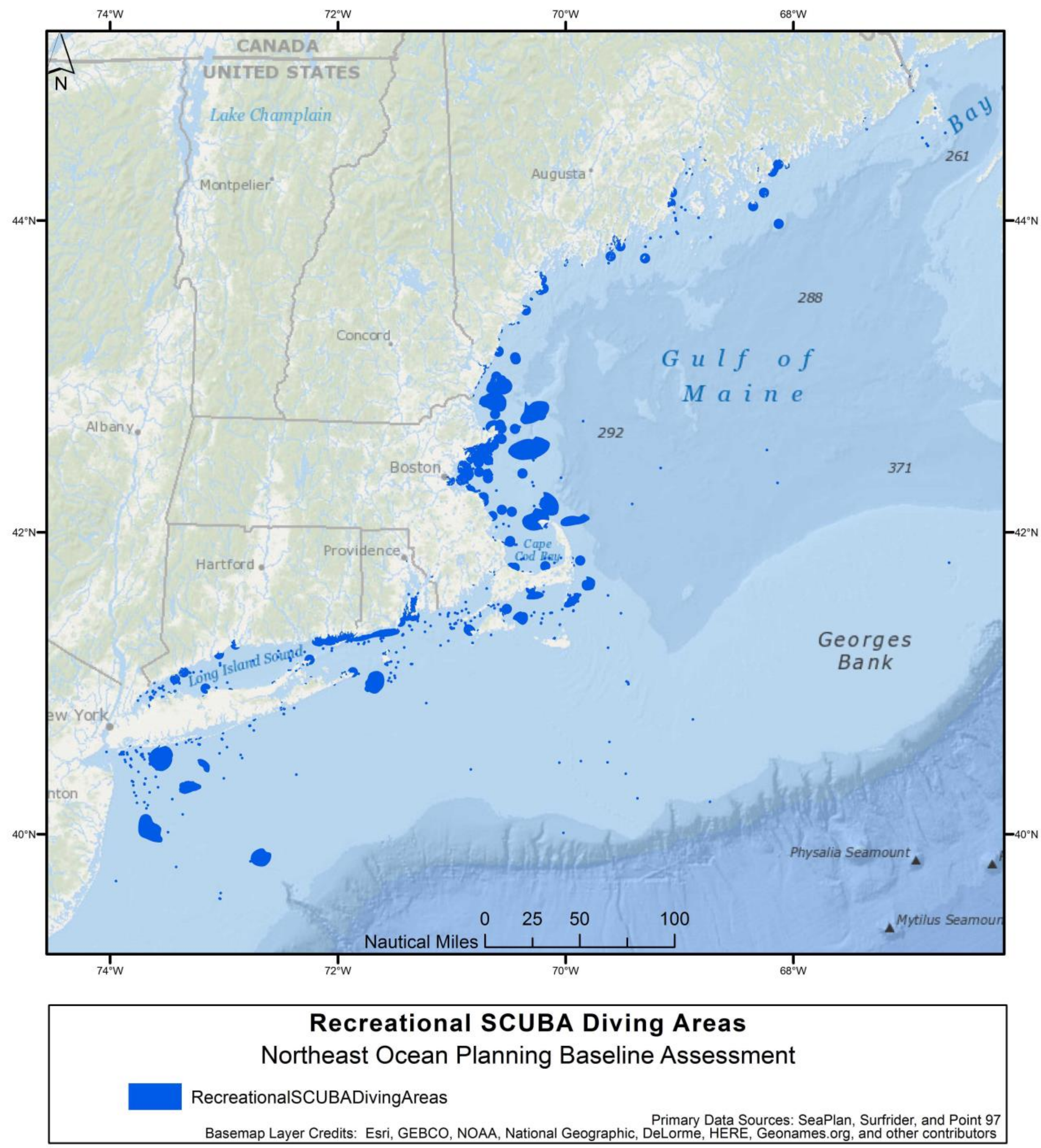


Figure 42 Recreational SCUBA diving areas

4.4.6. Whale watching

Whale watching in the Northeast began in the 1970s and has grown to rank among the region's signature recreational industries, generating total direct and indirect expenditures of $126 million. More than 30 commercial whale watch companies operate from a number of ports from New York to Maine, with Stellwagen Bank National Marine Sanctuary (SBNMS), 25 miles to the east of Boston, the most popular whale watching destination and accounting for around 80% of whale watching in the region (Figure 43; O'Connor et al. 2009; Hoagland and Meeks 2000; RICRMC 2010). Whale watching occurs primarily during July and August when the demand is highest and the whales are active within the area; however, whale watch operations may extend from the spring through the fall. Companies operate vessels that range from small, semi-private charters that may conduct single daily trips for 6 passengers, to large charters out of hubs like Boston and Bar Harbor (Maine) that may accommodate up to 400 passengers on 3 to 5 trips and serve thousands of patrons daily. The whale species observed most frequently during whale watch trips in the Northeast are humpback (*Megaptera noveangliae*), fin (*Balaenoptera physalus*), and minke whales (*Balaenoptera acutorostrata*). For more information is available in the coastal and marine recreational activity survey report (Point 97 *et al.* 2015).

The commercial whale watching areas shown in Figure 43 are based on information provided by whale watch industry experts in the Northeast Coastal and Marine Recreational Use Characterization Study (Point97 *et al.* 2015). Whale watch vessel owners, operators, naturalists, and data managers attended participatory mapping workshops to map areas where whale watching takes place in the region, and assemble information about seasonality, species, and overall industry trends. The data are classified by the following categories:

- **General use areas** reflect the full footprint of whale watch activity in the last 3 – 5 years (2010 – 2014) regardless of frequency or intensity.
- **Dominant use areas** include all areas routinely used by most users most of the time, according to seasonal patterns.
- **Transit routes** include areas used for transit to and from general or dominant use areas.
- **Supplemental areas** depict areas used for closely related activities and infrequent specialty trips.
- **RI Ocean Special Area Management Plan areas** were mapped as part of the Rhode Island Ocean Special Area Management plan and are symbolized separately to reflect different data collection methodologies.

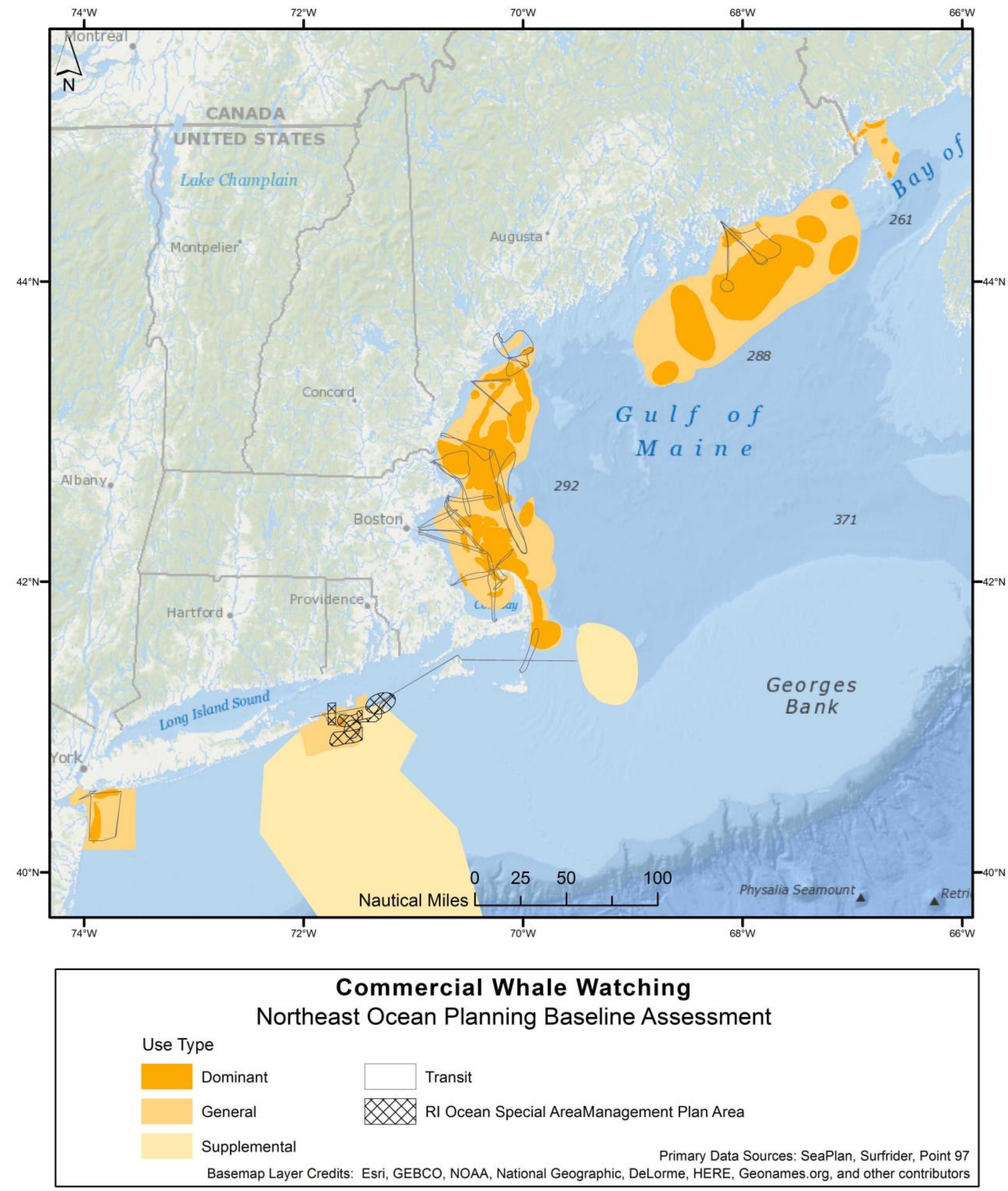


Figure 43 Commercial whale watching

See text above for source information and description of "use types."

4.4.7. Eating and drinking establishments

About 10,000 eating and drinking establishments (restaurants and bars) in the Northeast region's coastal counties employ more than 150,000 people and generate more than $5 billion/year in GDP, making up more than half of the tourism and recreation segment of the region's ocean economy (ENOW data). Higher numbers of eating and drinking establishments are found along the shores of Long Island Sound, Cape Cod, Massachusetts, New Hampshire, and southern Maine (Figure 44).

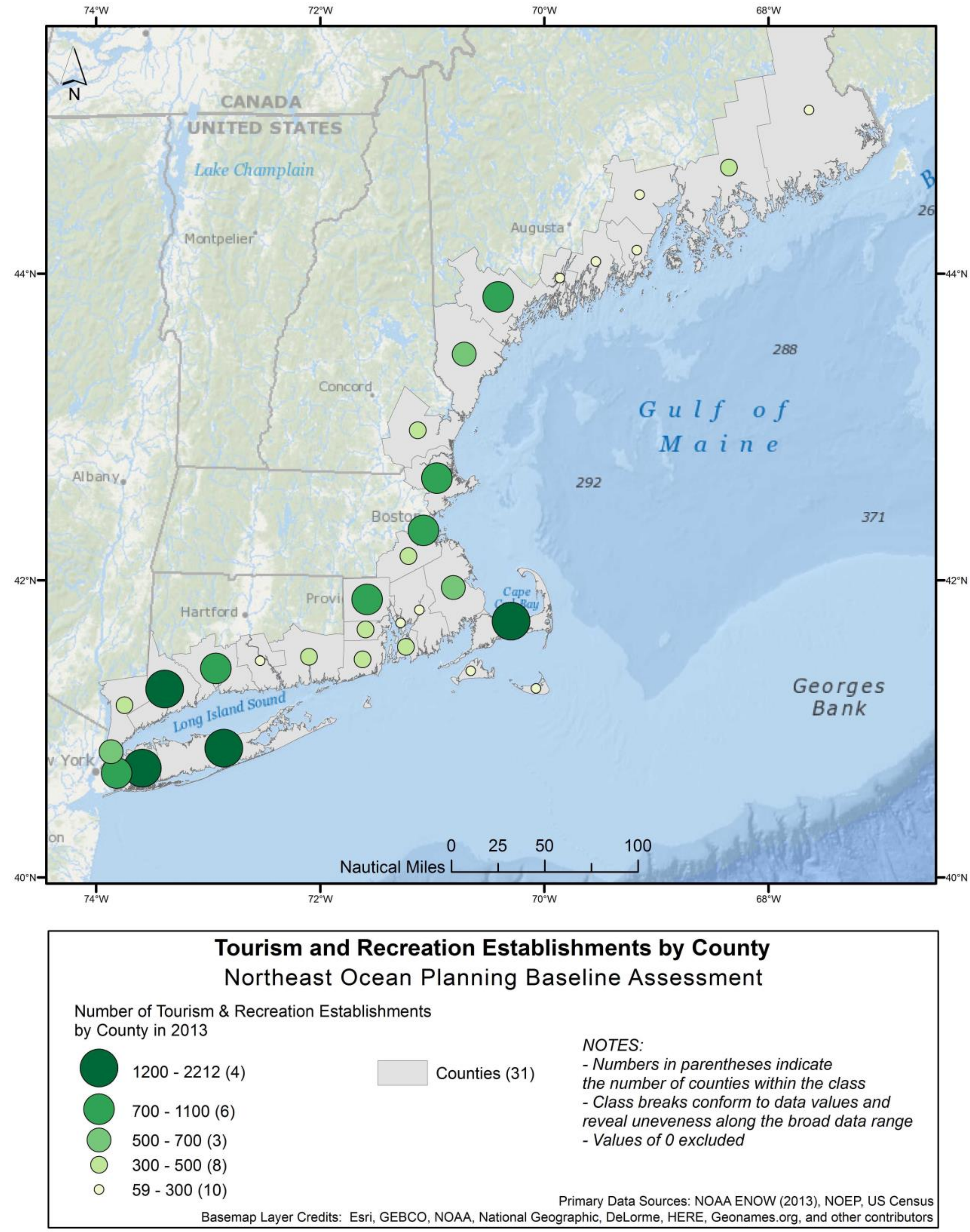


Figure 44 Tourism and recreation establishments by county, 2013

4.4.8. Hotels and lodging places

About 1,500 hotels and lodging places in the coastal counties of the Northeast region employ more than 30,000 workers and generate more than $2 billion/year in GDP (ENOW data). They are included in the tourism establishments shown in Figure 44 above, and are concentrated along the shore of Long Island Sound, Cape Cod, and the coast of Massachusetts. Close to 500 such establishments also exist along the coast of Maine.

4.5. Marine Transportation

The Marine Transportation System is an interconnected system of waterways and ports that moves people (e.g., ferries, cruises, sightseeing) and goods (e.g., agriculture, oil and gas, cars, clothing, appliances). Marine transportation is also crucial to national security by enabling the rapid movement of military resources and logistical support. This system is economically critical to the region as it provides for jobs -- such as pilots, port operators, vessel staff -- as well as taxes to local, state and federal entities. As such, it has broad reaching impacts to the Northeast region, nationally, and internationally.

4.5.1. Deep sea and coastal freight transportation

The commercial ports in the Northeast region of the United States handled about 102 million short tons of cargo in 2013 (Table 7 and Figure 45), or 6% of the nation's waterborne trade (US Army Corps of Engineers 2015). The Port of New York and New Jersey is the busiest port on the United States east coast, and accounts for half of the Northeast's total tonnage. Portland and Boston together account for another 25% (in weight terms). Not including the Port of New York and New Jersey, commercial ports in the Northeast handled about 54 million short tons of cargo in 2013, or 3% of the nation's waterborne trade. Portland and Boston together account for more than half of the cargo moved through the region's ports (in weight terms), and for nearly 70% of foreign imports to these ports.

Foreign imports account for about 60% of all cargo moving through the Northeast region's ports; foreign export cargo is minimal in comparison. About two thirds of all cargo (by weight) moved through northeastern ports is inbound crude oil (only to Portland, ME and New York and New Jersey) and refined petroleum products (gasoline, diesel fuel, heating oil) (Figure 45).

Container traffic on the US east coast is dominated by the Port of New York and New Jersey, which handled more than 4.2 million TEU (twenty-foot equivalent unit[1]) movements in 2013 – about 12% of container traffic for all Unites States ports. Container traffic in the Northeast is concentrated almost entirely in Boston, which transshipped about 226,000 TEUs in FY2015. The Port of New York and New Jersey handled imports of more than 394,000 cars and the Port of Boston handled imports of more than 60,000 cars in 2014 (source: Port Authority of NYNJ; MassPort). Boston also processed more than 317,000 cruise passengers (113 cruise ship port calls) in 2014 (source: MassPort). Included in the foreign import trade for Boston is liquefied natural gas (LNG), accounting for about 1

[1] [The most common commercial cargo shipping container today is 40 feet in length; one such container is equivalent to 2 TEUs.]

million tons of imports or 20 port calls in 2014. New York/New Jersey ranks 3rd and Boston ranks approximately 30th among US ports in total tonnage handled per year (American Association of Port Authorities).

Unlike bulk cargoes such as crude oil and petroleum products, containers and cars are also commonly moved on roads (via trucks) or on railroads. As a result, Northeast regional ports compete for container traffic with ports including Halifax (Nova Scotia) and Montreal (Quebec). Unlike bulk carriers, container ships (and cruise ships) often operate on tight schedules and are sensitive to potential delays imposed by factors such as tides and channel depths, and areas closed to navigation because of marine mammals.

	foreign trade, 1,000s short tons		domestic coastal trade, 1,000s short tons	
	imports	**exports**	**inbound**	**outbound**
Eastport, ME	--	--	--	314
Searsport, ME	1,235	--	198	24
Portland, ME	11,040	70	831	1
Portsmouth, NH	2,004	158	499	12
Salem, MA	219	--	19	--
Boston, MA	9,983	1,442	5,365	105
New Bedford & Fairhaven, MA	35	144	21	--
Fall River, MA	260	--	1,105	2
Providence, RI	4,236	681	2,450	285
New London, CT	102	--	136	4
New Haven, CT	2,232	341	5,608	130
Bridgeport, CT	83	--	1,709	10
Stamford, CT	--	--	490	56
New York and New Jersey, NY	27,989	4,670	5,128	10,161

Table 7 *Commercial cargo volumes by port, 2013*
Source: US Army Corps of Engineers (2015)

Table 8 shows the number of vessel transits for each Northeast commercial port. Large commercial ship traffic in the region is concentrated in Portland (tankers) and Boston (tankers, container ships, and cruise ships). Transit numbers for the Port of New York and New Jersey are shown for context. Most of the "dry cargo" transits in the Northeast are Handymax and Panamax dry bulk ships; in Boston, these also include about 180 container ship and 110 cruise ship port calls. The cruise ship segment is seen as a potential future growth area by several ports in the region, including Boston and Portland. The "tankers" are mainly product tankers; they also include crude oil carriers in New York/New Jersey and Portland, and about 30 liquefied natural gas (LNG) tankers in Boston. There is significant barge traffic in New York/New Jersey, Portland, Boston, New Bedford/Fairhaven, Providence, New Haven, Bridgeport, and Stamford.

Since each port call involves two transits (one into and one out of the port), the commercial vessel traffic described in Table 8 represents about 4,000 transits of commercial ships and

8,000 transits of barges with tug/tow boats through Northeast regional waters each year. Commercial fishing vessels account for perhaps an additional 10,000 transits per year. These numbers can fluctuate substantially with seasonal conditions (e.g. a cold winter increases heating fuel demand and associated vessel transits) and general economic conditions in the region. Figure 45 illustrates the major routes used by commercial shipping into and out of the Northeast, and the cargo volume handled by the Region's major ports.

	Dry cargo ships	Tankers	Dry cargo barges	Tank barges
Eastport, ME	77	--	3	--
Searsport, ME	24	60	--	39
Portland, ME	98	198	1	230
Portsmouth, NH	41	60	2	60
Salem, MA	4	--	4	11
Boston, MA	398	251	57	773
New Bedford & Fairhaven, MA	7	--	58	457
Fall River, MA	40	4	9	24
Providence, RI	59	133	20	309
New London, CT	23	--	28	42
New Haven, CT	26	83	56	705
Bridgeport, CT	2	1	332	189
Stamford, CT	--	--	346	22
totals	**797**	**788**	**916**	**2,861**
New York and New Jersey	4,106	1,814	1,184	903

Table 8 *Commercial vessel calls by port, 2013*
Excludes fishing vessels and local and regional ferry traffic.
Source: US Army Corps of Engineers (2015)

New England is the region most heavily dependent on oil for its energy supplies, primarily because of high dependence on heating oil in the winter. Most of New England's petroleum arrives by water, with large volumes of petroleum product (gasoline, diesel, heating oil, etc.) coming to terminals in Boston and Portland. Product brought to New England comes either from the refineries in New Jersey and near Philadelphia (and thus passes through the southern waters of the region) or comes from the Irving Oil refinery in Saint John, New Brunswick, and thus crosses the Gulf of Maine.

Smaller terminals serve regional markets such as New Haven, Providence and Searsport. A number of smaller terminals such as in Salem, MA bring oil to power plants. Long Island Sound oil ports serve Connecticut; the port of New York and New Jersey serves Long Island oil needs. Historically, Portland has been the leading oil port northeast of New York/New Jersey, because of the crude oil brought to South Portland for transport through the 240-mile pipeline to Montreal refinery. Crude oil imported by ship has been declining in the Canadian market because of increasing production from western Canada.

More information is available in the [Northeast Region Maritime Commerce White Paper]() (Kite-Powell 2013).

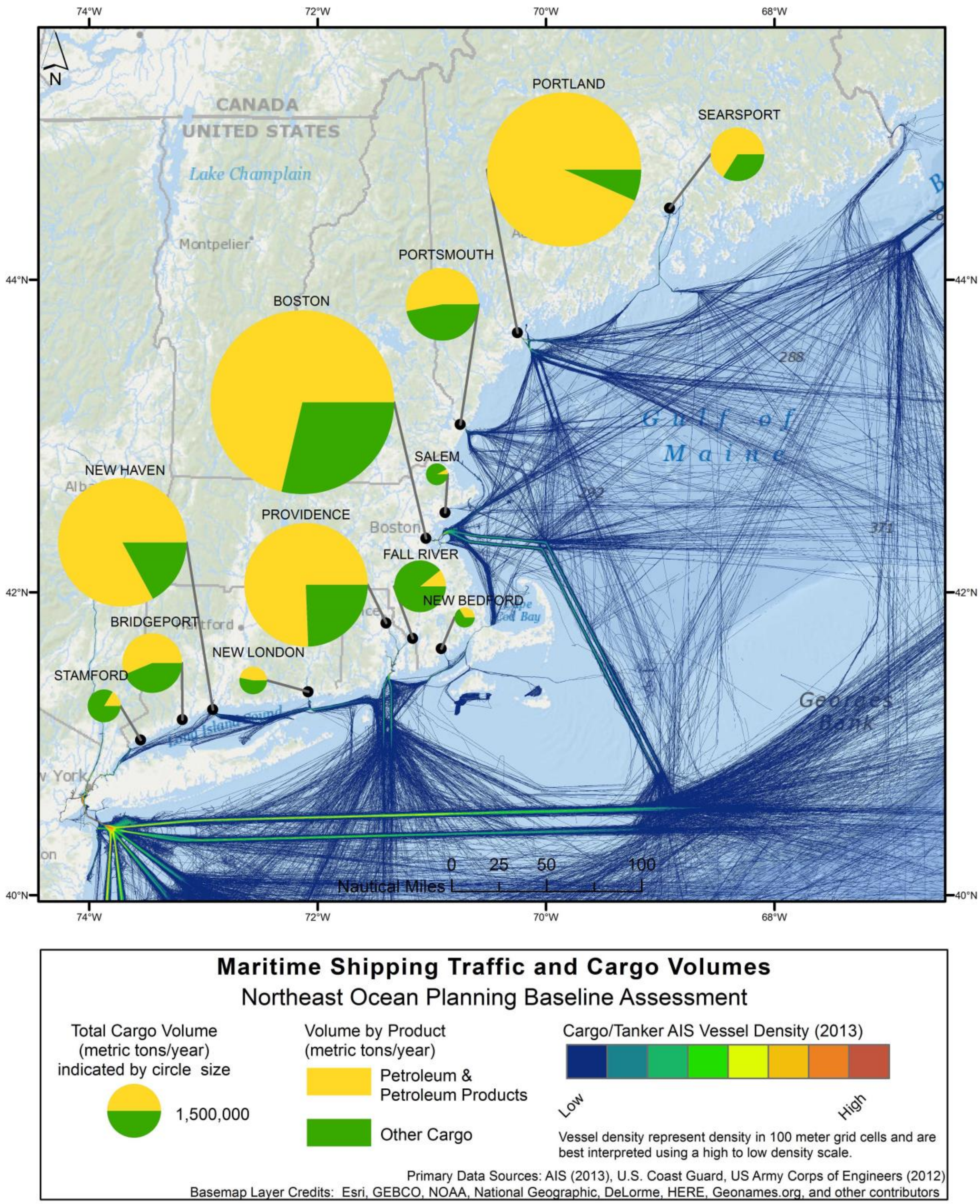


Figure 45 Maritime shipping traffic and cargo volumes

4.5.2. Marine passenger transportation

Marine passenger transportation in the Northeast region is concentrated in Massachusetts and Cape Cod Bay, the coastal waters from Long Island Sound to Buzzards Bay, and the waters between Cape Cod and the islands of Martha's Vineyard and Nantucket (Figure 46). There is seasonal passenger ferry traffic throughout the region. In addition, there are year-round ferry operations to and from Block Island, Martha's Vineyard, Nantucket, and islands along the coast of Maine, as well as cruise ship traffic in and out of the Ports of New York and New Jersey, and Boston. Some of the cruise ship traffic is coastal; other cruise routes connect the Northeast region with Atlantic Canada and Bermuda.

Marine transportation offers an alternative way to commute in some heavily congested areas and may be the only method to get to work in certain Northeast island and coastal communities. Northeast ferries carried 26.6 million passengers and 5.4 million vehicles in 2010, and are expected to carry more in the coming decade. The cruise industry reports a predicted increase in usage with a 16% increase in expenditures over the last four years.

Figure 46 illustrates the combination of all of these types of passenger vessel traffic. The higher concentrations indicated with warmer colors in nearshore/coastal areas are due to ferry service routes. Note that this figure is based only on 2013 data; and while areas that show higher density (such as routes to Long Island and Martha's Vineyard/Nantucket) generally reflect patterns that will persist in future years, passenger traffic routes are subject to change.

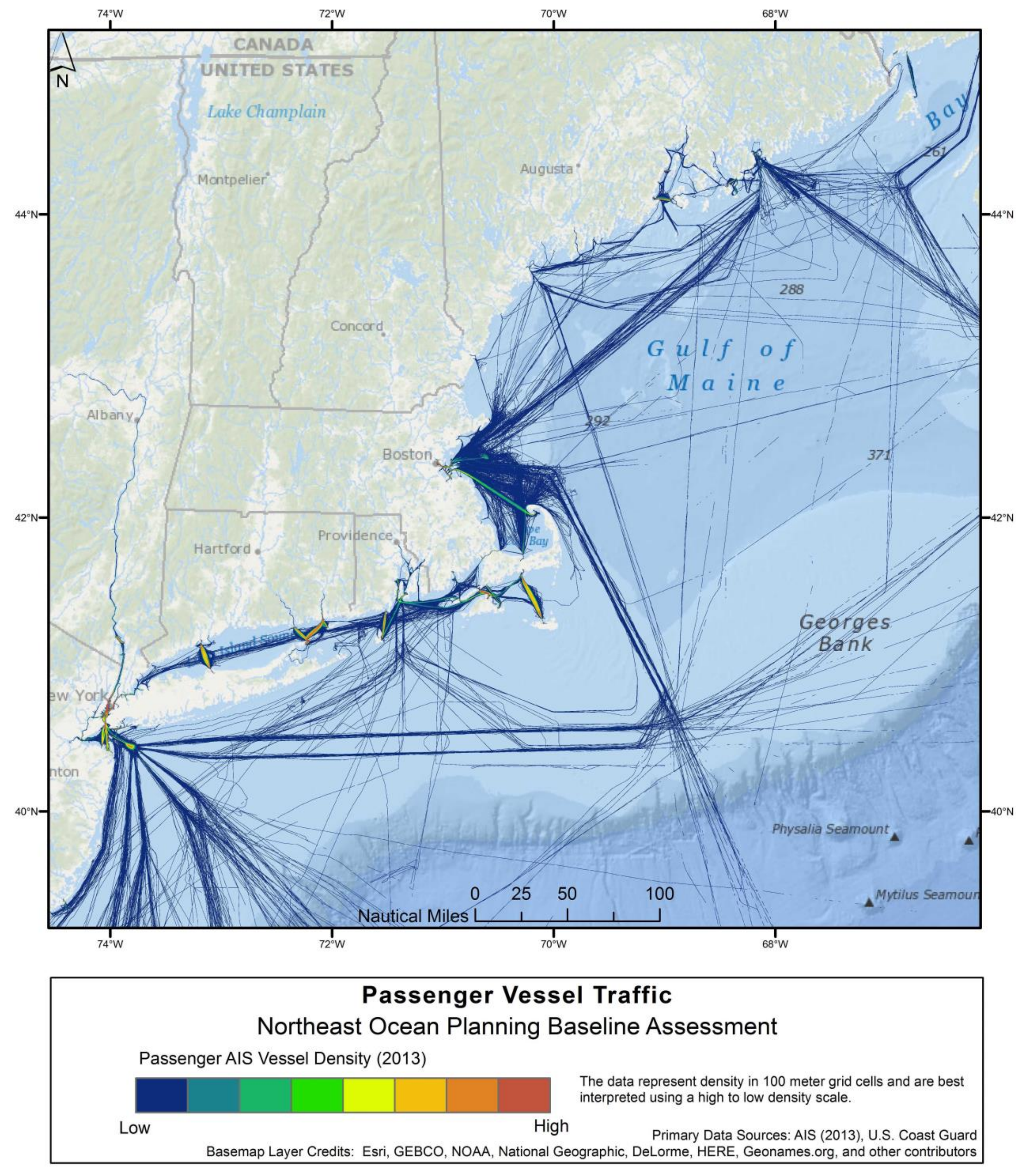


Figure 46 Passenger vessel traffic

4.6. Ship- and boat building and repair

Ship- and boat building and repair is the third largest major segment of the Northeast region's ocean economy, with $2.8 billion in annual GDP and more than 23,000 jobs (NOAA ENOW data). This work is heavily concentrated in Connecticut and Maine, where naval shipbuilding and repair facilities and ancillary businesses are located (see section 3.3.2). Connecticut accounts for 60% and Maine accounts for 30% of this sector, with minor levels of activity in Massachusetts and Rhode Island.

4.7. Manufacturing and construction

Marine manufacturing and construction is one of the smaller sectors of the Northeast region's ocean economy, accounting for 2,360 jobs and $248 million in GDP in 2012 (just over 1% of the region's ocean economy) (NOAA ENOW data).

4.7.1. Marine technology and instrumentation

A small but vibrant "marine high technology" industrial sector exists in the coastal counties of Massachusetts and other parts of the region, supported and nurtured in part by the marine and oceanographic research laboratories of the region. In 2005, some 481 companies employing 55,000 people and generating $7.7 billion in annual sales were involved in providing marine science and technology products and services in the Northeast (Barrow *et al.* 2005). Some of this is due to small companies that specialize in marine technology. However, most of it is due to large corporations that have marine technology divisions but generate most of their revenue and employment from other lines of business. As a result, the marine technology business is difficult to identify in national economic data and is not well characterized in the NOAA ENOW data.

4.7.2. Marine construction

About 200 marine-related construction companies in the Northeast region employ about 2,000 people and generate roughly $200 million/year in GDP.

4.8. Energy and minerals

In 2012, three working sessions were held for members of the Northeast's offshore wind, marine hydrokinetic, and gas and infrastructure energy sectors. Key issues facing these energy sectors, anticipated changes in coming years, and the potential role of Northeast ocean planning to address issues and opportunities were discussed. The working sessions focused on several key topics: permitting and governmental coordination, data needs, and other sector-specific challenges. A White Paper on the Northeast Region energy sector (ESS Group 2012) summarizes key features of the sector and discussions at these sessions.

4.8.1. Renewable energy

Wind resources offshore New England are abundant and provide an opportunity for offshore renewable energy development in the near term due to available technology. Beginning in November 2010 with the Cape Wind project, nearly one-quarter of a million hectares (222,004 ha) have been leased on the US outer Continental Shelf (OCS) for potential offshore wind power development in the Northeast. More than $4 million in bonus bids were accepted for these leases. Projects have been moving forward slowly, and none is expected to be fully implemented before 2020. Estimated resource rents per hectare range from zero for Cape Wind (which did not involve a lease sale) to $1.73 for the North Lease and South Lease Wind Energy Areas located in the "area of mutual interest" proposed for federal renewable energy leasing by Rhode Island and Massachusetts. Only one small-scale nearshore project (five turbines), known as the Block Island Wind Farm, has begun construction – but not operation – on Rhode Island submerged lands.

Tidal current and, to a lesser extent, wave resources offshore New England have also generated interest as potential energy sources though are still mainly in the research and development stage. In recent years, several small scale tidal projects have either been installed or are at different stages of permitting. These ocean current or tidal power projects are located in river mouths (the ORPC Maine Tidal Energy Project in the Bay of Fundy, Eastport, Maine) or nearshore (the UMass Muskegat Tidal Energy Project, Edgartown, Massachusetts).

Future development of all of these projects will depend upon the negotiation of favorable generation charges though power purchase agreements with regional electricity distributors and the maintenance or expansion of federal subsidies, including tax incentives and production tax credits, and binding state renewable portfolio standards. The current sharp decline in prices for fossil fuels makes it unlikely that projects can be economically justified in the near future. The economic potential of these projects could change with increased regulation of hydraulic fracturing, the removal of subsidies on the production of fossil fuels, the establishment of a carbon price on fossil fuel production, or the ratcheting down of renewable portfolios. Further establishment and growth of offshore wind energy development in particular will be influenced by continued efforts to reduce capital costs (which differ substantially from land-based wind) variations in energy market prices, evolving financing options, and government policy.

Figure 47 illustrates renewable energy leasing areas in the Northeast.

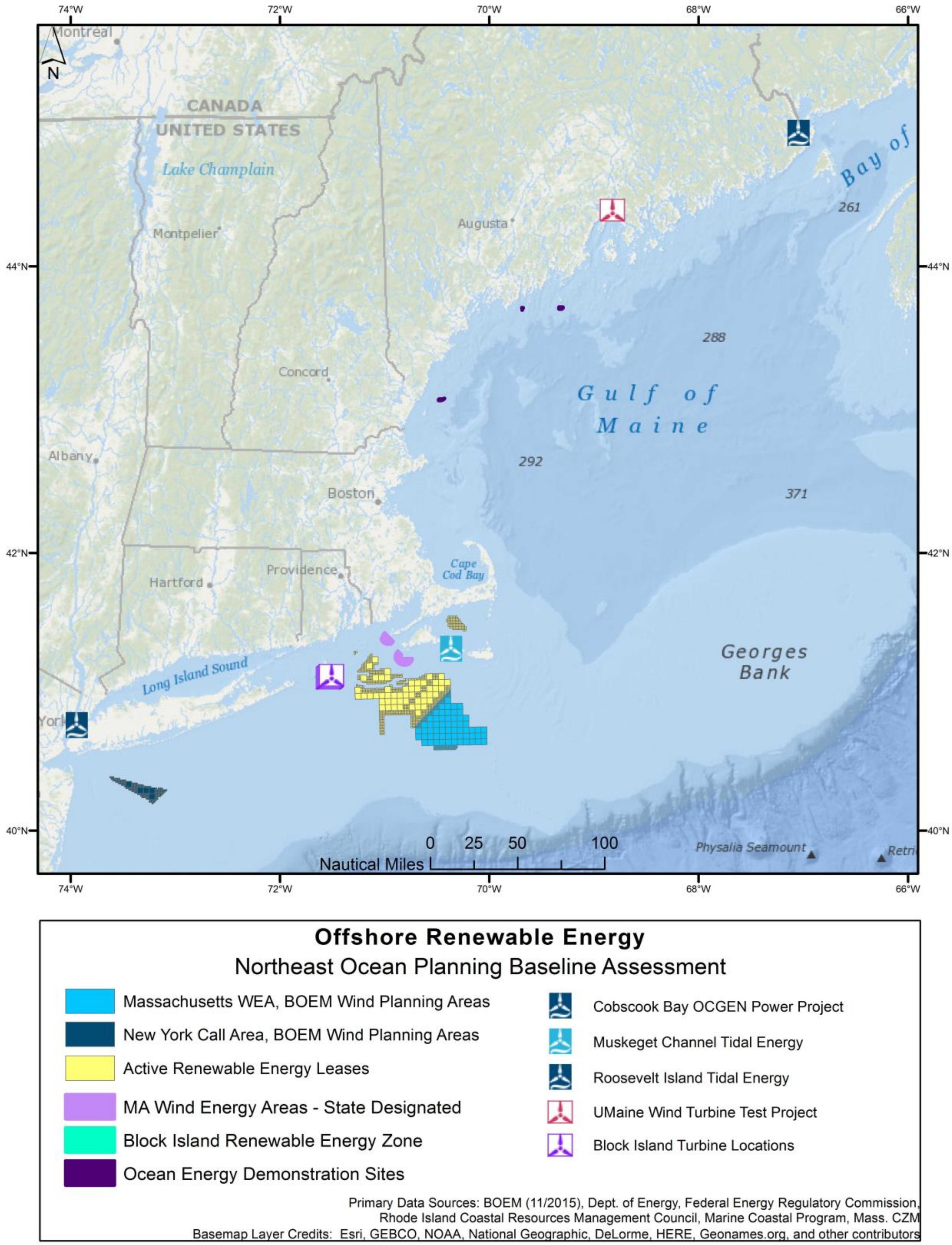


Figure 47 Renewable energy lease areas

More information about ocean-related energy issues in the Northeast is available in the White Paper on the Northeast Region energy sector (ESS Group 2012). The US Bureau of Ocean Energy Management (BOEM) develops and maintains data related to the gross and technical potential for various ocean energy resources, including offshore wind, wave, tidal, ocean current, and ocean thermal. BOEM's Environmental Studies Program gathers and synthesizes environmental, social, and economic science information to support decision-making concerning the offshore renewable energy and oil and gas programs. Relevant BOEM reports include:

- Environmental Risks, Fate and Effects of Chemicals Associated with Wind Turbines on the Atlantic Outer Continental Shelf - final report and technical summary
- Underwater Cultural Heritage Law Study - final report and technical summary
- Inventory and Analysis of Coastal and Submerged Archaeological Site Occurrence - final report and technical summary
- Critical Technical Review and Evaluation of Site-Specific Studies Techniques for the MMS Marine Minerals Program - final report and technical summary
- Compendium of Avian Occurrence Information (Database Section-Seabirds) for the Continental Shelf Waters Along the Atlantic Coast of the United States
- Effects of Electromagnetic Fields from Undersea Power Cables on Elasmobranchs and other Marine Species

4.8.2. Offshore oil and gas

As directed by the Outer Continental Shelf (OCS) Lands Act, the US Bureau of Ocean Energy Management periodically conducts assessments of undiscovered oil and gas resources in the OCS. The 2011 assessment for the Atlantic OCS included the Northeast region and was updated in a 2014 assessment of oil and natural gas resources off the US Atlantic Coast (as a result of additional, geologically analogous new discoveries offshore Africa and accounting for technological advances). The 2014 assessment includes estimates for the North, Mid, and South Atlantic Planning Areas as well as across the entire Atlantic OCS for the amount of "undiscovered, technically recoverable" oil and gas resources. The BOEM assessment does not report resource estimates for subsets of areas within OCS planning areas. Therefore, estimates specific to the New England portion of the Atlantic coastline are not available. Total Atlantic OCS oil resource estimates range from 1 to 9 billion barrels of oil with a mean estimate of nearly 5 billion barrels. Natural gas estimates range from nearly 12 to 68 trillion standard cubic feet of gas with a mean estimate of 38 trillion cubic feet. The 2011 assessment also provides information on "economically recoverable" gas resources, providing price-supply curves which show the relationship of price to economically recoverable resource in various OCS Regions. There are other reports from BOEM and outside of government that attempt to assess national or coast-wide economic benefits of increased oil and gas and fair market value of tracts offered for lease.

There are currently no areas in the North Atlantic Program Area (which includes federal waters off of the New England states) under lease for oil and gas development. In the Draft Proposed Program for the 2017-2022 oil and gas leasing program, there are no locations identified as potential lease sales in the North Atlantic Program Area. In the early 1980s, several exploratory wells drilled on Georges Bank did not encounter "significant concentrations" of oil or gas. In late 2015, Canadian authorities grant approval for an exploratory lease for an area approximately 225 miles southeast of Bar Harbor, Maine, east of Georges Bank in Canadian waters.

Thus to date, New England has not had oil and gas production off its coast, relying instead on the distribution of oil and natural gas by pipeline, truck, and shipping to local ports such as Portland, Boston, and New York. Notably for ocean planning purposes, this includes the HubLine high pressure gas pipeline and two recently established deepwater LNG ports located in Massachusetts Bay. Each LNG port includes large buoys that receive gas from shipping tankers and distribute the gas to the HubLine through a system of underwater pipelines. The use of these offshore LNG ports and the frequency of associated ship traffic are subject to the dynamics of the natural gas market.

4.8.3. Sand and gravel

The marine minerals industry in the Northeast is focused on sand and gravel resources (Figure 5 above). As shown in Tables 2 and 3 above, the minerals industry generally accounts for $265 million/year in GDP and over 1,300 jobs, with the highest values for both in Maine and Connecticut. A significant portion of these values reported through ENOW minerals sector data can be attributed to sand and gravel resources with a small amount of activity related to oil and gas exploration and production (NOAA 2013 ENOW data).

Many Northeast coastal communities are facing the reality of more frequent flooding and coastal erosion that adversely affect residential and commercial areas, critical infrastructure and important habitat. As a result, several New England states and municipalities are now considering using offshore sand resources to help protect public infrastructure, nourish beaches, and enhance coastal habitat. The Northeast Regional Ocean Council established a Sand and Gravel Work Group that is pursuing pilot projects to study areas in need of sand resources to manage coastal erosion, characterize offshore borrow areas, and consider potential ecological impacts associated with sand extraction, and how sand and gravel mining should be integrated in regional ocean planning.

There are many potential public benefits of nearshore and coastal sand nourishment. Beach and dune systems provide and protect coastal habitat and can be used as an alternative to seawalls and other hardened structures, which can negatively affect habitat and local sediment dynamics. Sand nourishment restores and widens public beaches, improving access and providing safer recreational opportunities. Nourished beaches and stabilized shorelines protect structures, including residential areas, businesses, cultural resources, and critical public infrastructure. However, sediment extraction from offshore sources may also impact benthic and fish habitat and conflict with existing human activities. While offshore shoals and ridges provide good sources of sand, they may also represent valuable habitat for fish and other species.

Additional information related to sand and gravel resources and mining can be found in the following:

- Regional sediment management plans (Rhode Island and Massachusetts, and potentially Connecticut) are considering coastal storm damage risk reduction and associated sand/gravel needs for large sections of New England coastline.
- BOEM's Marine Minerals webpage and related fact sheets:
    - Marine Minerals Program fact sheet
    - BOEM response to Hurricane Sandy, update on recovery assistance and resilience planning fact sheet

4.9. National Security

Multiple branches of the U.S. Department of Defense (DOD) (i.e. U.S. Navy, Army, Marine Corps, and Air Force) and the Department of Homeland Security (USCG) are responsible for our nation's security. Employment and income/wages associated with national security personnel in the Northeast are not captured by the ocean economy data sets described above so are summarized in sections that follow.

4.9.1. US Navy

In terms of national security, the US Navy is the primary branch within the DOD that carries out training and testing activities and therefore is the primary focus for military activities related to ocean and coastal planning programs. The Navy historically uses areas along the eastern coast of the United States and in the Gulf of Mexico for training and testing. These areas were designated by the Navy into geographic regions, and named "range complexes" as illustrated in Figure 48. A range complex is a set of adjacent areas of sea space, undersea space, land ranges, and overlying airspace delineated for military training and testing activities. Range complexes provide controlled and safe environments where military ship, submarine, and aircraft crews can train in realistic conditions. The Boston, Narragansett, Atlantic City, and Virginia Capes range complexes are located along the Mid-Atlantic and Northeastern Seaboard of the United States. Combined, these areas are the principal locations for portions of the United States Navy's major training and testing events and infrastructure, including activities originating out of nearby Navy installations.

Three separate range complexes (the Boston Range Complex, the Narragansett Bay Range Complex, and the Atlantic City Range Complex) are collectively referred to as the Northeast Range Complex. The Northeast Range Complex spans 761 miles along the coast of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey. The Northeast Range Complex also includes operating areas (OPAREAs) and associated special use airspace for Navy training and testing activities. The Naval Undersea Warfare Center Division Newport Testing Range consists of waters within Narragansett Bay, nearshore waters of Rhode Island Sound and Block Island Sound, and coastal waters of New York, Connecticut, and Massachusetts.

The Northeast Range Complexes also support training and testing by other branches of the military, primarily the USCG and the U.S. Air Force from nearby bases, as well as visiting operators with home bases located farther away. Overall, minimal surface training occurs within the Northeast OPAREAs due to the time and distance from the operators' homeports and home bases. The primary activities in the Northeast OPAREAs consist of submarine and submersible training and testing. Submarine and submersible testing and training is conducted out of NSB New London and the Naval Undersea Warfare Center Division Newport, while Bath Iron Works builds and tests surface ships in the area. In addition to these users, non-DOD users are likely to use the offshore range complexes for research, including various government agencies such as various branches of the NOAA, research institutions such as Woods Hole Oceanographic Institution, universities such as the University of Rhode Island, the University of Connecticut, and Rutgers University (among others), and various state agencies.

Several military installations including the Portsmouth Naval Shipyard, Naval Station Newport, Naval Submarine Base New London, Naval Weapons Station Earl, and Joint Base McGuire-Dix-Lakehurst, are located on land adjacent to the offshore Northeast Range Complexes. These installations use the waters and airspace of the range complexes for training or testing activities. Work is underway to identify regulated marine areas where the US Navy carries out testing, bombing, and other operations.

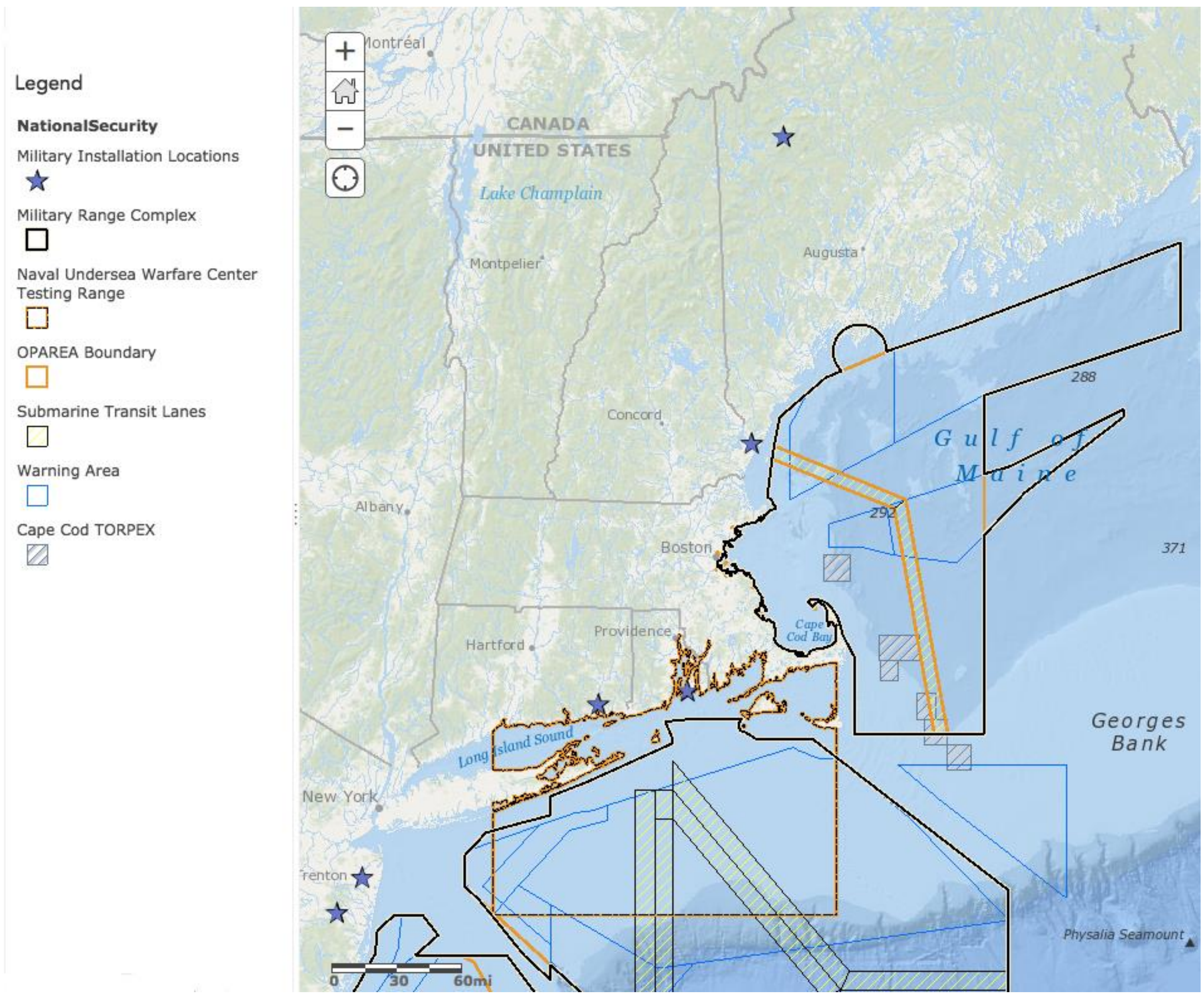


Figure 48 National security range complexes

The Naval Station Newport and the Naval Undersea Warfare Center Division Newport had a total military payroll of about $336 million in FY2013 (about 5,000 military personnel) and a total civilian payroll of about $693 million (9,900 employees). The combined operations also issued some $641 million in contracts and procurements in FY2013 (Naval Undersea Warfare Center Division Newport, RI: Summary of NUWC Division Newport's 2014 Economic Impact on Southern New England).

The Naval Submarine Base, New London, Connecticut, reported a total military payroll of $467 million (about 11,400 military personnel) and a total civilian payroll of $180 million (about 2,900 civilian employees) in FY2014. Procurement of goods and services accounted for about $7 billion (Navy Region Mid-Atlantic FY 2014 Economic Impact Report).

The Portsmouth Naval Shipyard in Kittery, Maine, reported a total military payroll of $42.2 million for 2014. The shipyard purchased goods and services worth about $53.1 million and issued contracts for maintenance, support, and utilities in the amount of $157 million. Civilian employment associated with the shipyard accounted for about 5,900 jobs and $432 million in wages in 2014 (Portsmouth Naval Shipyard Economic Impact Statement – CY2014).

Additional information on US Navy activity and engagement in Northeast ocean resource management can be found in the following:

- Atlantic Fleet Training and Testing (AFTT) Final Environmental Impact Statement (covers Navy activities in the NE for 5 years)
- Wide range of Environmental Assessments (EA) and Environmental Impact Statements (EIS). (e.g. Overseas Environmental Impact Statement (EIS/OEIS))
- The Navy has an overall at-sea Environmental Compliance page that includes the AFTT EIS/OEIS and other comprehensive planning documents.
- Marine Resource Assessment for the Northeast Operating Areas (Prepared for Dept. of Navy, 2005). This MRA documents and describes the marine resources in the vicinity of the Northeast Operating Areas (NE OPAREAs), which include the Atlantic City, Narragansett Bay, and Boston OPAREAs.

4.9.2. US Coast Guard

The U.S. Coast Guard is one of the five armed forces of the United States and the only military organization within the Department of Homeland Security. Since 1790 the Coast Guard has safeguarded our Nation's local, national, and international maritime interests. By law, the US Coast Guard has 11 missions:

- Ports, waterways, and coastal security
- Drug interdiction
- Aids to navigation
- Search and rescue
- Living marine resources

- Marine safety
- Defense readiness
- Migrant interdiction
- Marine environmental protection
- Ice operations
- Other law enforcement

The Coast Guard's First District Headquarters is responsible for Coast Guard activities in Northern New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, and Maine. This region includes both ashore and afloat units all described in more detail here: http://www.uscg.mil/d1/units.asp. The US Coast Guard employs about 3,400 active duty military, 800 civilians, and 1,100 reservists in the First District whose headquarters is located in Boston, Massachusetts.

4.10. Research and education

Coastal marine and oceanographic research and education institutions are an important part of the Northeast region's higher education and research sector, and include some of the most prominent marine science institutions in the world. These institutions employ several thousand people and collectively account for more than $500 million/year in research and education work (Barrow *et al.* 2005). They also provide education and training for hundreds of undergraduate and graduate students in marine and geosciences. Technologies developed at these institutions help support the Region's marine technology industry (see section 4.7.1).

Marine research and education institutions in the Northeast include (this list is not exhaustive):

- Mt. Desert Island Biological Lab, Maine
- Bigelow Laboratory for Ocean Sciences, Maine
- Darling Marine Center, University of Maine
- School of Marine Sciences, University of Maine
- University of New England, Maine
- Gulf of Maine Research Institute, Maine
- Bowdoin College, Maine
- Seacoast Science Center, New Hampshire
- University of New Hampshire Center for Coastal and Ocean Mapping
- Northeastern University Marine Science Center, Massachusetts
- University of Massachusetts Boston School for the Environment
- University of Massachusetts Dartmouth School for Marine Science and Technology
- New England Aquarium, Boston, Massachusetts
- Stellwagen Bank National Marine Sanctuary, Massachusetts
- US Geological Survey Woods Hole Coastal and Marine Science Center, Massachusetts
- Center for Coastal Studies, Provincetown, Massachusetts
- Five Colleges Coastal and Marine Science Program, Amherst region, Massachusetts

- Massachusetts Maritime Academy, Buzzards Bay, Massachusetts
- Marine Biological Laboratory, Woods Hole, Massachusetts
- Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Sea Education Association, Woods Hole, Massachusetts
- Graduate School of Oceanography, University of Rhode Island
- Roger Williams University, Rhode Island
- Marine Sciences Program at Avery Point, University of Connecticut
- Mystic Aquarium, Mystic, Connecticut
- US Coast Guard Academy, New London, Connecticut

5. Mapping Resources to Economic Value Generation

The resources and infrastructure described in section 3 can be thought of as inputs to ecological processes and economic activities that generate the value (wealth) described in section 4. Understanding how resources and infrastructure contribute to economic value is important because one aspect of ocean planning is to ensure that ocean resources are managed and used in a way that benefits the people of the region and the nation. A common way to measure that benefit is to quantify the economic value generated from the resources. This section describes what is known about the links between Northeast region marine resources and value generation, and how that information can be used in the planning process.

As discussed in the introduction to section 4 above, economic value exists only in the context of human populations and societies. One important determinant of economic value, therefore, is the people who participate in and receive benefits from the economic activity. The market and non-market value generated from marine resources in this region is, in part, a function of how many people live, work, and play in Northeast coastal and ocean areas, and how many visitors and tourists come to the region. There are some exceptions to this, especially in the more basic categories of ecosystem service values. For example, the value of carbon dioxide (CO_2) uptake by the coastal and ocean waters of the Northeast is largely independent of the region's population. But most categories of value will rise and fall with the number of participants; and that number can change because of population trends, changes in tourism, changes in recreational preferences, changes in wealth distribution, and other socioeconomic factors. Of particular interest to ocean planning, an increase in the number of participants in an economic or recreational activity, such as shellfish farming or recreational boating, often increases the demand for marine resources (e.g. coastal waters) and infrastructure (e.g. boat ramps, docks, marinas). That increase in demand can contribute to conflicts that ocean planning seeks in part to address.

5.1. Economic activity and ecosystem services

The economic values reflected in the NOAA ENOW data and used in much of section 4 to describe the Northeast region's ocean economy are "market" values measured or estimated from prices and quantifies of goods and services traded in markets. As mentioned in section 4, marine resources and activities can also generate values that affect human wellbeing but are not measurable in market transactions. These include the non-market or intrinsic values derived from walking on a beach, for example, and a range of other values sometimes referred to as "ecosystem service" values. There is some overlap between ecosystem service values and market values: for example, the primary production that supports biological populations of food fish is an ecosystem service, and its value is (partially) reflected in the commercial fisheries landings data.

The Millennium Ecosystem Assessment (MEAB 2003) framework suggests the following classification of ecosystem services derived from coastal and marine resources:

- Provisioning Services
  - Food (fisheries, aquaculture)

  - Sea water
  - Biochemical and genetic resources
  - Minerals and other physical resources
- Regulating and Supporting Services
  - Climate regulation (CO_2 uptake, heat exchange)
  - Water purification (filtration, dilution)
  - Flood/storm protection
  - Erosion control
  - Waste assimilation
  - Nutrient cycling
  - Primary production
- Cultural Services
  - Beach recreation and coastal access
  - Recreational boating, fishing, diving
  - Aesthetic, spiritual, and cultural uses of the coast and ocean
  - Existence/bequest value of local species (value attributed by people to knowing that species exist, and will survive for future generations)

Table 9 illustrates how different subsets of the Northeast region's marine resources and infrastructure (section 3) contribute to economic value generated in different segments of the Region' marine economy (section 4) and to three other major ecosystem service functions (climate regulation, water purification, and storm surge regulation) that are not captured by market data. The table is not exhaustive, but illustrates two important points. First, each natural resource and infrastructure component typically supports value generation in a variety of economic sectors and ecological functions. And second, different ocean economy sectors depend on different combinations of resources and infrastructure.

	Natural Resources/Habitats						Infrastructure					
	Ocean waters	Coastal waters/bays	Beaches	Wetlands/estuaries	Living resources	Cultural/archaeological resources	Shoreline structures	Commercial ports	Commercial real estate	Naval and Coast Guard facilities	Marinas	Residential real estate
Commercial fishing	X	X		X	X			X				
Aquaculture		X			X			X				
Seafood processing								X	X			
Seafood markets									X			
Recreational boating & fishing	X	X	X	X	X	X					X	
Beach recreation			X									
Tourism	X	X	X	X				X	X		X	X
Maritime transportation	X	X						X	X			
Ship- & boat building/repair	X							X	X	X		
Marine construction & manufacturing							X	X	X	X	X	X
Ocean energy	X	X						X				
Research and education	X	X	X	X	X	X		X	X			
National security	X	X						X		X		
Climate regulation	X	X		X	X							
Water purification		X		X								
Storm surge regulation		X	X	X			X					

Table 9 Mapping resources to economic sectors

5.2. Ecosystem service values and production functions

Although we know in principle which resources are used as inputs to which categories of ecosystem service and value, as suggested by Table 9, our ability to predict how changes in resources and infrastructure might affect value generation is, in most cases, incomplete at best. That is because the relationship between inputs (natural resources, infrastructure) and outputs (e.g., seafood, or recreation days) and the value of those outputs is often complicated. For some economic activities, the simple existence of access to a category of resources is sufficient: for example, the maritime transport industry needs port infrastructure and access to coastal and ocean waters to generate value; but that value does not increase, as a rule, when coastal water quality is improved. Furthermore, different areas of the open ocean may have different levels of value to the maritime transportation sector, depending on their location relative to preferred shipping routes. On the other hand, the value generated by activities such as commercial fishing, aquaculture, and recreational boating and fishing depends both on the quantity **and quality** of coastal and ocean water resources.

In general, the economic value of a resource or infrastructure component is best estimated at the margin, that is, in the context of a question such as "what is the value of **an additional square kilometer** of coastal wetlands to the Region's seafood or coastal tourism industries," or "what is the value of **an additional kilometer** of beach to Northeast coastal recreation"? The value per unit area of an incremental piece of marine habitat, for example, depends not only on the location and characteristics of that piece, but also on how much of that kind of habitat already exists in the regional ecosystem. For these reasons, estimates of unit value (dollars per square kilometer, or dollars per year per square kilometer) for natural resources should be treated with caution.

Most ecosystem service values cannot be observed from prices in markets, and therefore must be estimated by quantifying the ecological service produced (for example, tons of CO_2 absorbed by the ocean waters of the Gulf of Maine each year) and then applying a unit value (in this case, the cost imposed by adding a ton of CO_2 to the atmosphere – see EPA web pages on social cost of carbon). Published estimates of ecosystem service value from marine environments around the world span a very wide range, from near zero to more than $100 million per year per square kilometer ($1 million per year per hectare), depending on the location and the specific values included and assumptions used in the estimation. Using ecosystem service values in any particular planning context requires careful attention to the ways in which resources are used and valued, and the consequences of incremental management actions (Johnston and Russell 2011). Ecosystem service value estimates are broadly indicative of orders of magnitude for ecosystem services, but, as planning tools, they should be used with care.

Published work on Northeast ecosystem service value has focused largely on value associated with recreation, tourism, and seafood production. The highest value estimates for the Northeast Region come from recent ranges of estimates of total ecosystem service values for the Long Island Sound estuary and its beaches, seagrass beds, and coastal wetlands (Kocian *et al*. 2015). Northeast beach visits give rise to approximately $4 million/year/km^2 ($40,000/year/hectare) in ecosystem service value; and the Long Island Sound work estimates values as high as $10 million/year/ km^2 ($100,000/year/hectare) for seagrass beds and $20 million/year/ km^2 ($200,000/year/hectare) for coastal wetlands. These estimates are at the high end of values reported in the literature for marine resources around the world, particularly those for coastal wetlands, which range from $1,000 to $1 million/year/ km^2 ($10 to $10,000/year/hectare) (deGroot *et al.* 2012). An estimate of ecosystem service value from whale watching on Stellwagen Bank, based on a non-market (travel cost) model, is approximately $15,000/year/ km^2 ($150/year/hectare) (Hoagland and Meeks 2000).

The value of Northeast ocean areas for seafood production from commercial fishing averages about $1,200/year/ km^2 ($12/year/hectare), but ranges widely from near zero to more than \$50,000/year/ km^2 (\$500/year/hectare) for specific locations. Estimates of ecosystem service value associated with (hypothetical) open ocean aquaculture operations range from \$1 million to \$100 million/year/ km^2 (\$10,000 to \$1 million/year/hectare). See Appendix E for more detail on these and other ecosystem service value estimates for the Northeast.

Figure 49 summarize what is known about the major groups of market and ecosystem service value from coastal and ocean resources and infrastructure in the Northeast. The market value (GDP, \$billion/year) numbers in blue are drawn from section 4 of this report. The ecosystem service values in green are estimated from unit values drawn from the published literature (see list of references and Appendix E). The Northeast region encompasses about 1 million km^2 of open ocean water, 10,000 km^2 of coastal waters and bays, 1,000 km^2 of coastal wetlands, and 500 km of beaches. Applying the unit values (see above) to these areas results in estimates of on the order of \$1 billion/year in climate regulation from Northeast ocean waters, \$10 billion/year in supporting services (water purification, storm surge resilience, etc.) from coastal habitats, and \$1 billion/year in non-market recreational value from beaches (Figure 49). It is important to note that the benefits of climate regulation and supporting services such as water purification accrue in part to people outside the Northeast region.

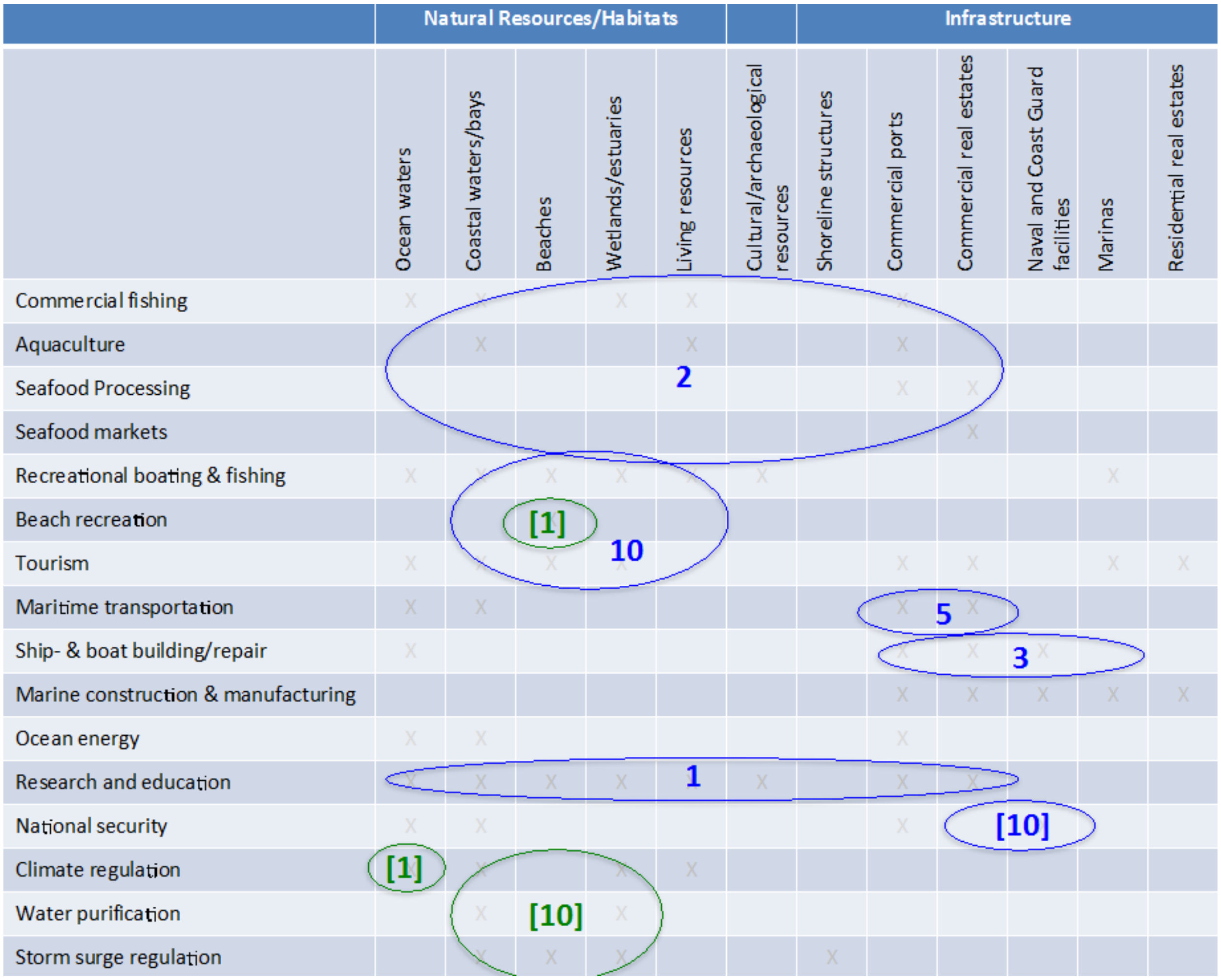


Figure 49 Major categories of market and ecosystem service value generation
Estimates of market economy value added (GDP) in blue and ecosystem service value in green, both in billions of dollars/year. [Brackets] denote an order of magnitude estimate. See text above for details and Table 2 for source information.

5.3. Use of economics in planning processes

It is the interrelationship between uses and resources illustrated in Table 9 that sometimes gives rise to conflicts between competing users of common resources in the coastal ocean. Some resource uses are compatible with each other in a specific location, implying that the values they can generate in those use sectors are additive; some are incompatible, implying that some values may be diminished or obviated when resource uses overlap. For example, shellfish farming on the bottom of a coastal bay may be compatible with recreational boating, allowing both food production and recreational values to be generated, whereas finfish farming with sea surface cages and mooring systems in that same bay might interfere with and largely preclude recreational boating.

Planning decisions can affect resources, infrastructure, and value generation in a variety of ways. Planning decisions may affect the quantity and/or quality of a resource or infrastructure category, or how it is distributed geographically (an historic example is the decision to improve water quality in Boston Harbor). Planning decisions may also affect access to resources and infrastructure, and the extent to which they are available as inputs to different economic sectors (for example, allocation of coastal ocean space to aquaculture could, in some cases, reduce access to that space by recreational boaters). By affecting the quantity, quality, and availability of resources for different uses, planning decisions affect the future generation of market and non-market (ecosystem) values.

Where use conflicts arise and resource uses are not compatible, legal systems, resource management policies, and planning decisions will affect how those conflicts are resolved and which use(s) have priority over others in each location. Including information about the economic consequences of different resource allocation and planning decisions can help ensure that marine resource management in the Northeast results in outcomes that are economically efficient and equitable.

5.4. Gaps in present knowledge

Incorporating economic information into planning decisions is difficult when available knowledge about ecosystem service production and value is incomplete. Details on the calculations for each of the uses reported here and some of the issues that arise can be found in Appendix E, along with a discussion of the significant gaps in present knowledge about ecosystem service values. These gaps include:

- <u>Incomplete coverage</u> – limited number of studies of Northeast ecosystem services and values
- <u>Influential studies</u> – incomplete coverage leads to excessive reliance on the few studies that have been performed
- <u>Emerging future uses</u> – new and emerging uses of coastal and marine resources can give rise to values that are not captured in most published studies
- <u>Spatial and temporal variability</u> – habitat and resource values can vary greatly between locations; this is often not captured well when a single unit value is applied
- <u>Estimating unit values is difficult</u> – reliance on survey methods to estimate non-market unit values requires significant effort to generate credible estimates
- <u>Relationships and threshold effects</u> – the relationships between quality and quantity of natural resources, and the value they generate, is often complex and not easy to model; and in particular, as resources are heavily used or degraded, there may be ecological thresholds at which a small change in economic activity can have large effects on resource values
- <u>Passive uses unstudied</u> – very little work has been done to understand “passive use” values

6. Future Trends

Several long-term trends that are largely outside the control of Northeast ocean planners will affect the region's marine resources and the production of value in the coming decades. Climate change effects will alter the physical and chemical properties of the region's marine waters, and change the ecology of the region's coastal and marine ecosystems (see US Global Change Research Program, National Climate Assessment 2014; NOAA's Climate.gov web pages, and NERACOOS Ocean and Weather Climate pages). Sea level rise associated with climate change will change the Region's coastline and have implications for coastal infrastructure such as commercial and residential waterfront development in coastal towns, port infrastructure, and national security facilities. And demographic changes will bring slow and uneven population growth to the Region's coastal communities, affecting the number of people who participate in the ocean economy.

6.1. Climate change

Global climate change is expected to affect marine resources in the Northeast in at least three major ways: sea levels will continue to rise, inundating coastal areas; ocean waters will continue to warm, and salinity levels will change, modifying the suitability of marine habitats and the geographic range of some marine species; and ocean waters will become more acidic in response to rising CO_2 levels in the atmosphere, potentially affecting the health of marine species that depend on calcification.

Data from the NOAA tide gauge in Boston Harbor describe a rise in sea level of about 2.79 millimeters (mm)/year (0.11 inches/year) since 1921. This translates to a 28 cm (0.92 foot) increase over a 100-year period. Similar increases have been measured at long-term tide stations in Woods Hole and Nantucket. The mean sea level trends from these long-term stations are listed in Table 10. Analysis by NOAA indicates that the recent trend in mean sea level rise is increasing, with the rate from 1921-2006 at 2.63 mm/year (0.10 in/year) and the rate from 1921-2013 at 2.80 mm/year (0.11 in/year).

Station	Mean sea level trend and 95% confidence interval (millimeter/year)	(inch/year)	Period	Century rate (feet/100 years)
Boston, MA	2.79 ± 0.17	0.11 ± 0.007	1921-2012	0.92
Woods Hole, MA	2.81 ± 0.19	0.11 ± 0.007	1932-2012	0.92
Nantucket, MA	3.52 ± 0.42	0.14 ± 0.017	1965-2012	1.15

Table 10 Sea level rise trends, Massachusetts stations.
Source: MCZM 2013

Sea level rise along the Northeast region's coast is expected to accelerate as climate change effects (polar melting and ocean thermal expansion) accumulate over the course of the next 100 years. Most models predict seal level rise in the Region between 2 and 7 feet over the course of the coming century (Figure 50). A rise of 4 feet is expected to threaten $32 billion of real property, and put 84,000 people at risk of extreme flooding in the Northeast (http://thinkprogress.org/climate/2014/04/24/3430234/sea-level-rise-new-england/). Private and public entities across the region and the nation are formulating plans to deal with these changes; see for example the climate change planning pages of the City of

Boston, and US Department of Transportation work on [resilience in marine transportation systems](#).

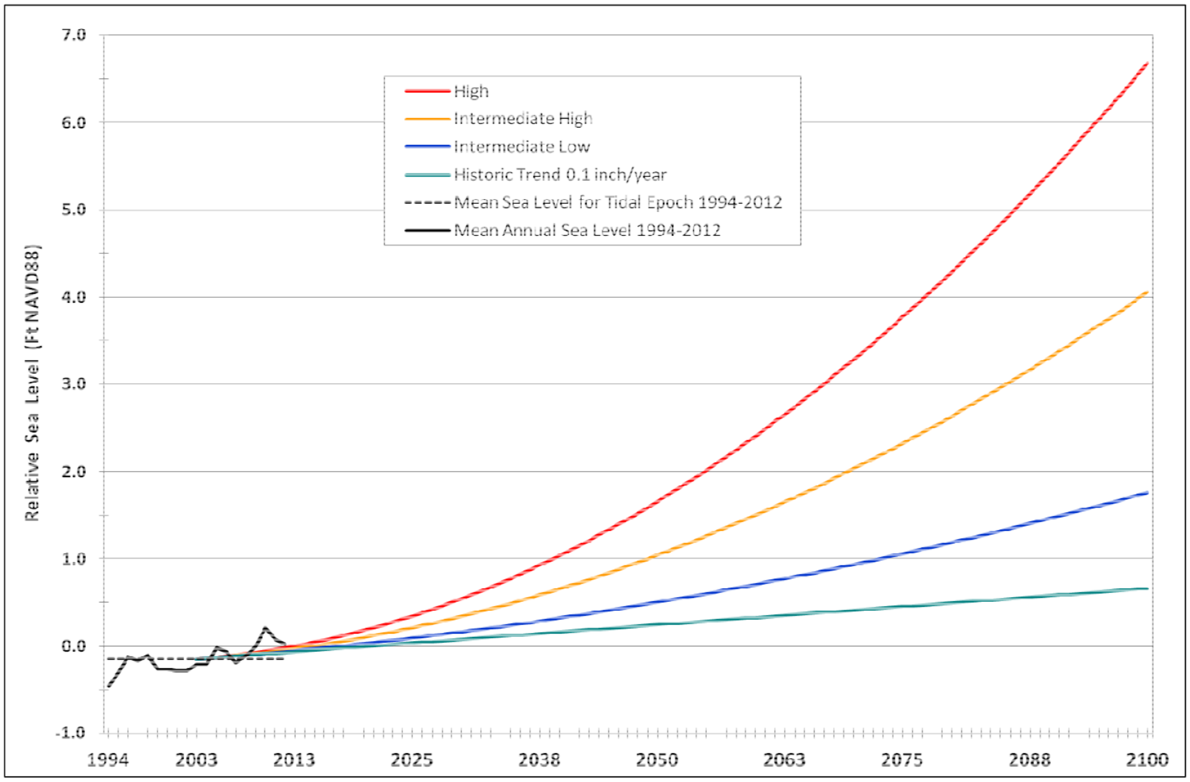


Figure 5. Relative sea level rise scenarios estimates (in feet NAVD88) for Boston, MA. Global scenarios from were adjusted to account for local vertical land movement with 2003 as the beginning year of analysis.

Figure 50 Sea level rise scenarios.
Source: MCZM 2013

Ocean water temperature has been rising more rapidly off the coast of the Northeast region than in most other parts of the global ocean. For example, sea surface temperature in the Gulf of Maine rose by 0.03 degrees Celsius (°C)/year from 1982 to 2004, roughly three times the global rate; and the warming has accelerated significantly since then (Figure 51) (Pershing *et al*. 2015). It is projected to continue to rise as a consequence of global climate change over the course of the next century, possibly by more than 2°C in Gulf of Maine bottom waters (Figure 52) (Hare *et al.* 2012).

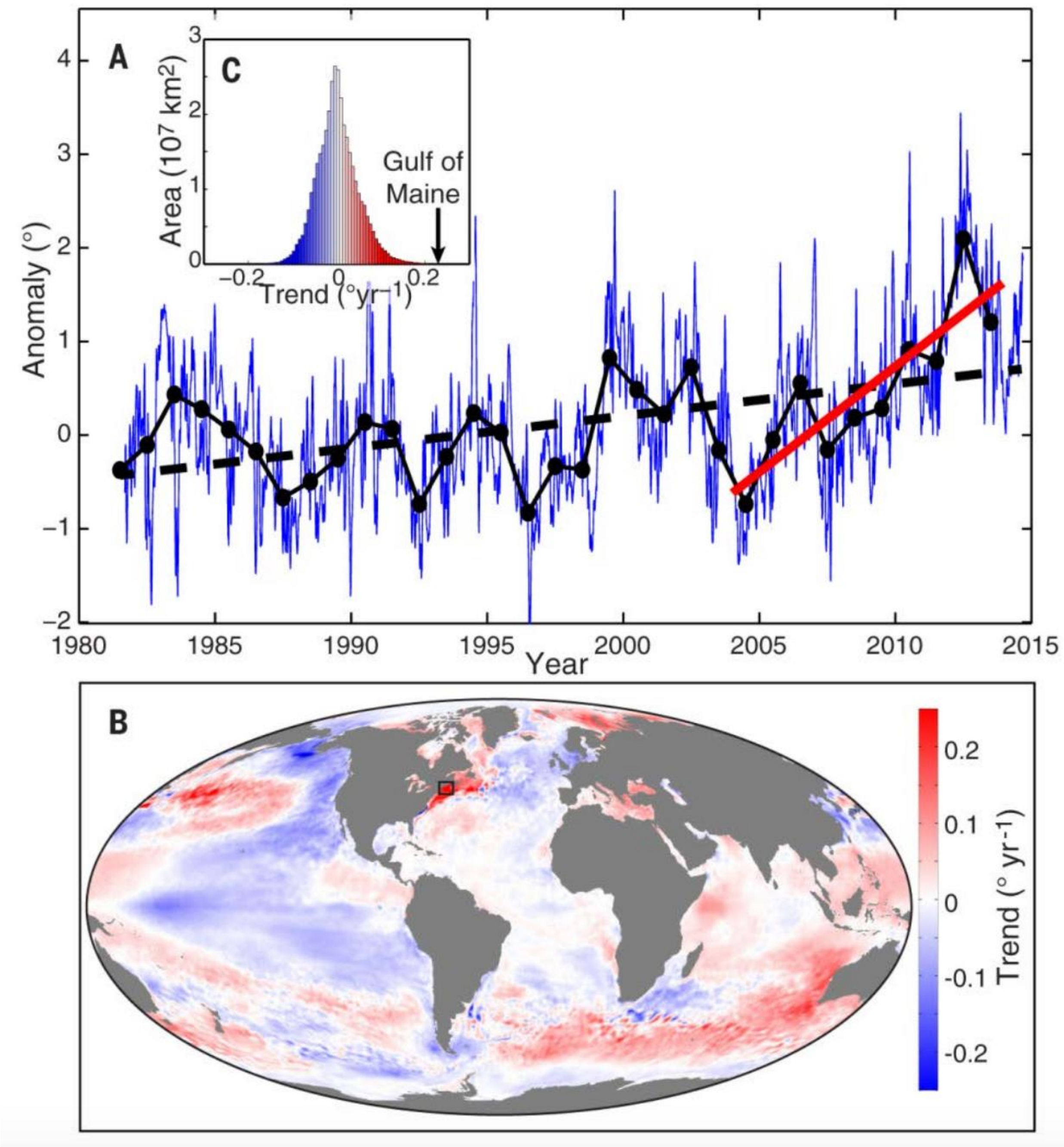


Figure 51 Sea surface temperature for the Gulf of Maine and global ocean. Source: Pershing *et al.* 2015: (A) Daily (blue, 15 days smoothed) and annual (black dots) sea surface temperature (SST) anomalies from 1982-2013 with the long-term trend (black dashed line) and trend over the last decade (2004-2013). (B) Global SST trends (degrees C/year) over the period 2004-2013. The Gulf of Maine is outlined in black. (C) Histogram of global 2004-2013 SST trends with the trend from the Gulf of Maine indicated at the right extreme of the distribution.

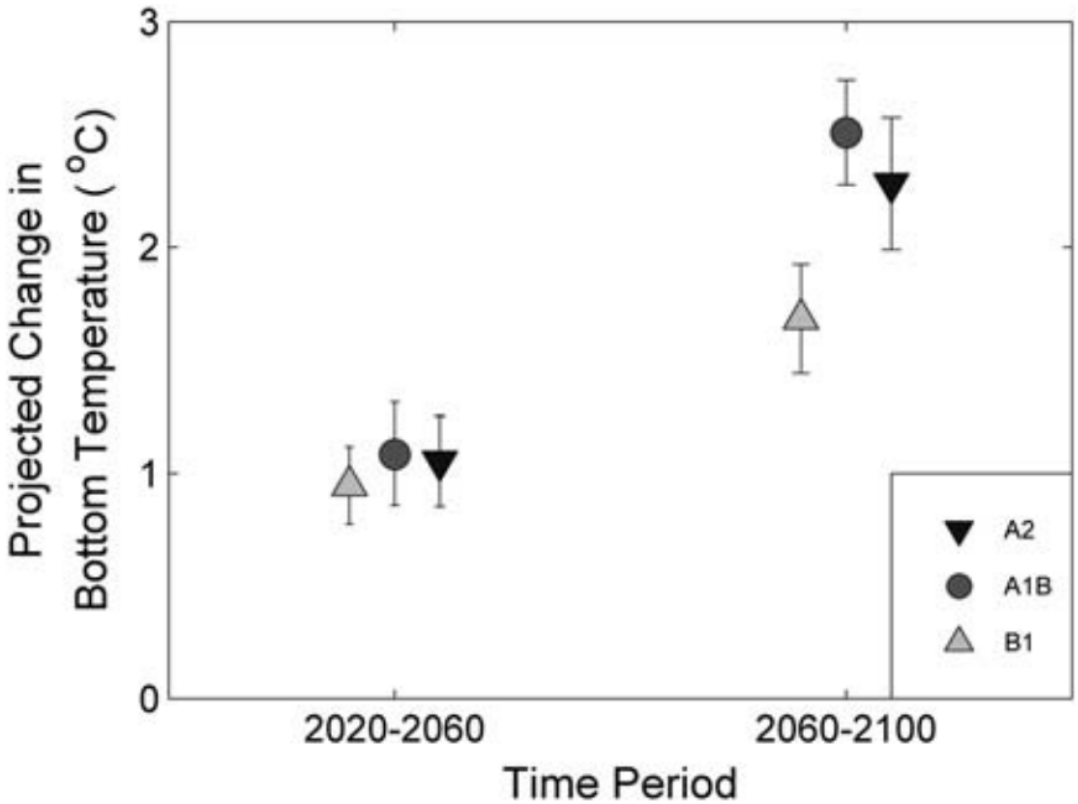


Figure 52 Projections for Gulf of Maine bottom water temperature.
Source: Hare *et al.* 2012: Based on an ensemble of eight Atmosphere-Ocean General Circulation Models for two time periods (2020-2060 and 2060-2100) and three emission scenarios (B1, A1B, and A2). Ensemble means and standard deviations are provided.

These temperature changes have already had measurable effects on marine species, and have been implicated, among other effects, in lobster population decline in southern New England (URI 2013) and failure of cod stock recruitment in the Gulf of Maine (Pershing *et al.* 2015). Further warming expected over the coming decades will likely affect additional biological populations and ecosystems in the Northeast, and lead to further changes in species ranges. For example, Hare *et al.* (2015) have modeled the change in suitable habitat in the Gulf of Maine for cusk under changing climate conditions.

As they become warmer, ocean and coastal waters of the Northeast are likely also to experience changes in salinity; this may exacerbate stresses on marine species (Mills and Pershing 2015). Salinity in the region's ocean waters is largely determined by ocean circulation patterns and precipitation. Strong flow from the Labrador Current brings cooler and relatively fresh water into the region, whereas stronger Gulf Stream flow provides warm, saline continental slope water. Melting and transport of Arctic sea ice caused a marked freshening of the region's waters during the 1990s after two large pulses of low-salinity water entered the region from the Arctic Ocean via the Labrador Sea (Smith *et al.* 2001, Häkkinen 2002, Greene *et al.* 2008, MERCINA 2012).

Precipitation affects salinity most strongly near the coast. For example, Balch *et al.* (2012) observed marked reductions in salinity in the coastal currents of the Gulf of Maine during extreme precipitation years since 2005. Across the Northeast, winter precipitation has been increasing at a rate of 0.15 inches per decade (Wake *et al.* 2006). More of this precipitation is falling as rain instead of snow (Frumhoff *et al.* 2006).

Arctic sea ice extent has been steadily declining since monitoring began in 1979; climate models predict that this trend will continue and that the Arctic Ocean will be nearly ice-free during the summer before mid-century (Wang and Overland 2009, Kirtman et al. 2013). As sea ice melts, increased freshwater from the Arctic will enhance the strength of the Labrador Current, and fresher water will move downstream towards the Northeast US Shelf. Most climate models also suggest that annual precipitation in the region will increase, particularly in the winters (Frumhoff et al. 2006), and that the combined effect of these two influences will result in surface waters in Gulf of Maine becoming fresher in the future, and those in Southern New England becoming saltier (ESRL 2015).

The acidity (pH) and carbonate chemistry (e.g. aragonite saturation state) of ocean and coastal waters influence the ability of calcifying organisms, including bivalve mollusks (oysters, clams, mussels, scallops) and crustaceans (lobster, crabs), to build and maintain their shells. The waters of the Gulf of Maine, in particular, are naturally acidic (low pH and aragonite saturation state) because of the region's strong freshwater inflow, geology, and water temperature (Figure 53). Rising CO_2 concentrations in the atmosphere are driving more CO_2 into ocean surface waters, lowering the pH and reducing aragonite saturation. This results in the acidification of ocean waters.

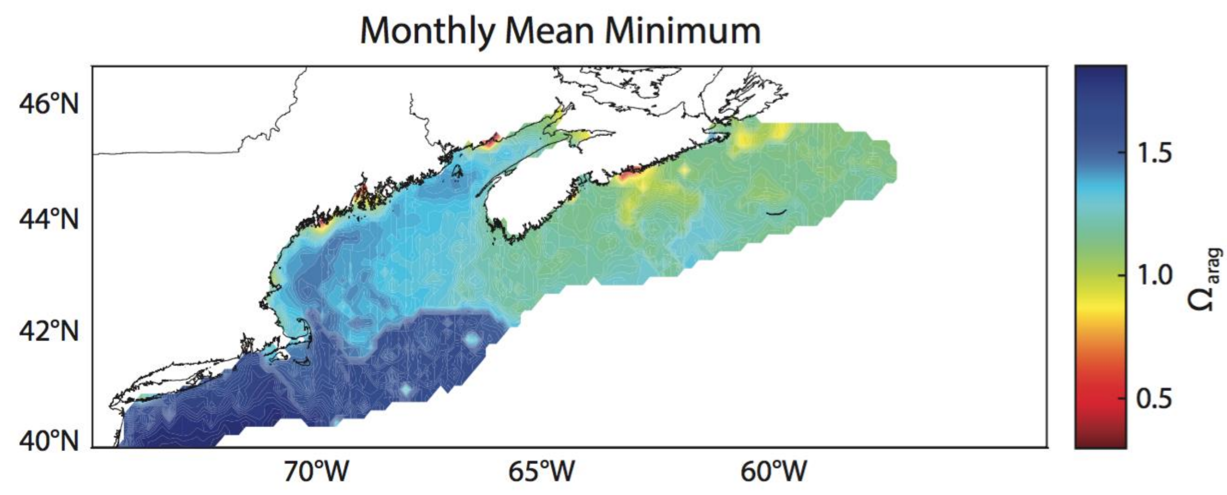


Figure 53 Mean minimum aragonite saturation conditions.
Source: Gledhill *et al.* 2015: Mapped distribution of minimum monthly averaged sea surface aragonite saturation state (Ω_{arag}). Long Island Sound is not mapped due to satellite land masking.

The acidification of ocean waters is expected to continue as atmospheric CO_2 concentrations rise in the coming century (Figure 54). Marine organisms respond to changing ocean chemistry in a variety of ways. Most marine calcifying organisms studied to date show decreased rates of calcification or even dissolution of shells, which is understood to result from decreased aragonite saturation. The increase in CO_2 or decrease in pH can also affect organisms' internal chemical balance, metabolic rate, immune response, organ development, and sense of smell. Gledhill et al. (2015) summarize the present knowledge about ocean acidification effects on marine organisms of commercial importance in the Northeast. Cooley *et al.* (2015) estimate that the Region's scallop industry may experience a 20% decrease in revenue by 2050 as a result of ocean acidification effects on the sea scallop population. Negative effects are likely to arise for other species, especially the early life stages of mollusks. While higher CO_2 has negative implications for many marine animals, it can be a positive change for organisms that rely on photosynthesis (marine plants and algae).

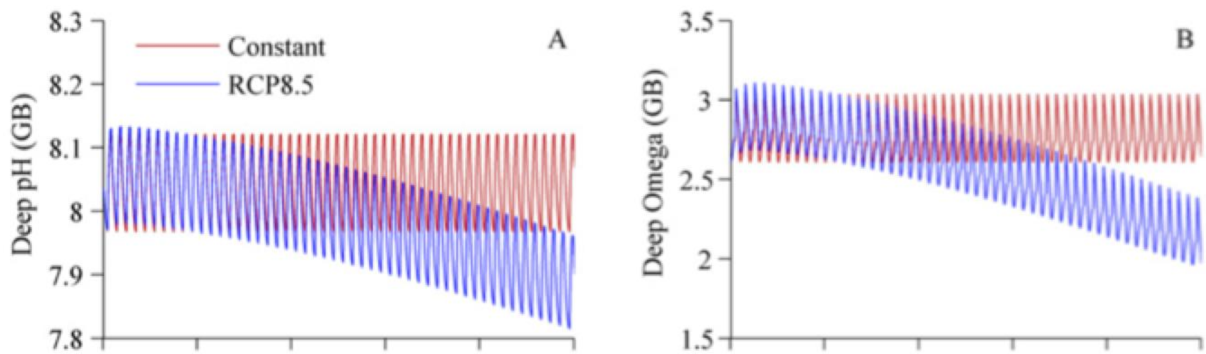


Figure 54 Ocean acidification projections for deep water in Georges Basin, 2000-2050.

Source: Cooley *et al.* 2015: Deep water pH and aragonite saturation (Omega) projections under constant climate (red) and a scenario in which carbon emissions continue to rise (RCP8.5 – the high emissions scenario from the Intergovernmental Panel on Climate Change's (IPCC) fifth Assessment Report, AR5 (2014).

Many near-shore coastal waters in the Northeast region are influenced by nutrient loading and significant freshwater inputs that can occasionally produce local conditions or "plumes" so low in pH as to be corrosive to calcium carbonate – that is, conditions where calcium carbonate shells begin to dissolve. Nutrient loading of coastal waters with nitrogen and phosphorous promotes marine plant growth; when these plants die and decompose, the intense respiration by bacteria and other organisms associated with plant decay can drive up local CO_2 concentrations, leading to what is known as coastal acidification. Coastal acidification generally exhibits higher frequency variability compared to open ocean acidification (Gledhill *et al.* 2015). The pH of water in coastal bays can vary by 1 to 2 pH units over the course of a day. The low pH events in nearshore waters are often accompanied by low dissolved oxygen conditions, exposing marine organisms to combined stresses from multiple sources.

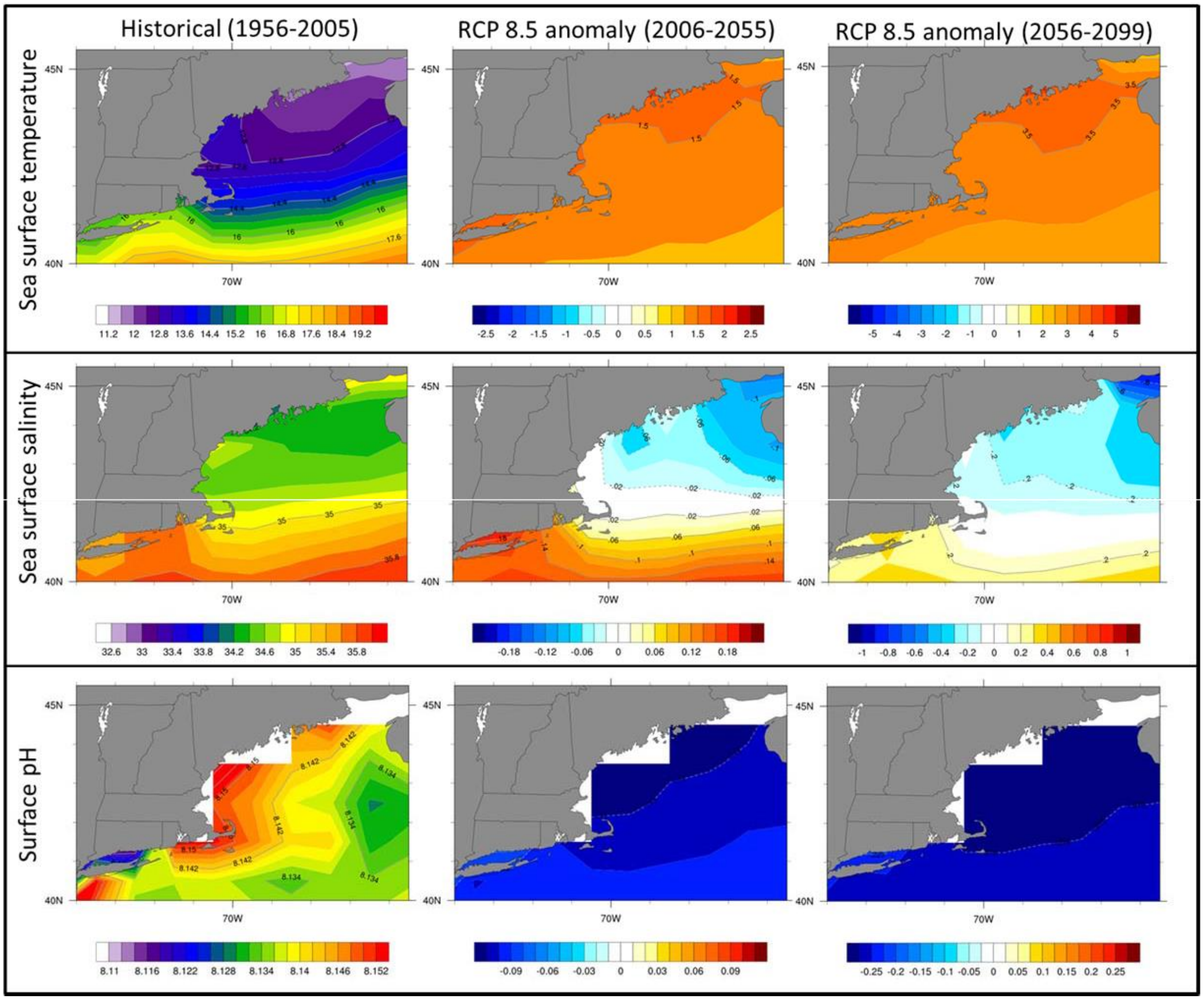


Figure 55 Sea surface temperature, salinity, and pH projections.
Source: ESRL (2015), using an average of all available models and the RCP8.5 climate scenario – the high emissions scenario from the Intergovernmental Panel on Climate Change's (IPCC) fifth Assessment Report, AR5 (2014).

Figure 55 illustrates historical observations (column 1) and future climate model predictions to 2055 (column 2) and 2099 (column 3) for sea surface temperature (row 1), sea surface salinity (row 2), and surface pH (row 3). These and other changes in physical and chemical conditions will affect physiological performance and habitat selection of organisms at different trophic levels in the ecosystem in complex ways. How this will affect a particular species generally depends on its physiological tolerance for environmental change, its life history strategies and needs, predator-prey relationships, and the influence of other stressors. Different species, and sometimes sub-populations within a species, may respond to environmental variability and climate change in different ways or at different rates; and responses are likely to vary based on not just one factor but the whole suite of ecosystem conditions the species encounters (Mills and Pershing 2015; Gledhill *et al.* 2015).

Since many commercially important shellfish species spend part or all of their life in these nearshore waters, coastal acidification, water temperature changes, and the response of marine organisms to changing coastal and ocean water conditions are important considerations for ocean planning to sustain the Northeast's seafood industries and healthy marine ecosystems.

6.2. Demographics

As described in section 3.4 above and Table 11 below, recent population growth in the Northeast region has varied significantly across states and towns, and generally been modest compared to the United States as a whole. The Region's population grew by 3.8% from 2000 to 2010, less than half of the growth for the nation as a whole.

	1970	1980	growth 1970-1980	1990	growth 1980-1990	2000	growth 1990-2000	2010	growth 2000-2010
Maine	992,048	1,124,660	*13.4%*	1,227,928	9.2%	1,274,923	3.8%	1,328,361	4.2%
New Hampshire	737,681	920,610	*24.8%*	1,109,252	20.5%	1,235,786	11.4%	1,316,470	6.5%
Massachusetts	5,689,170	5,737,037	*0.8%*	6,016,425	4.9%	6,349,097	5.5%	6,547,629	3.1%
Rhode Island	946,725	947,154	*0.0%*	1,003,464	5.9%	1,048,319	4.5%	1,052,567	0.4%
Connecticut	3,031,709	3,107,576	*2.5%*	3,287,116	5.8%	3,405,565	3.6%	3,574,097	4.9%
Vermont	444,330	511,456	*15.1%*	562,758	10.0%	608,827	8.2%	625,741	2.8%
New England	10,849,615	11,223,833	*3.4%*	11,979,015	6.7%	12,647,594	5.6%	13,116,504	3.7%
United States	203,211,926	226,545,805	*11.5%*	248,709,873	9.8%	281,421,906	13.2%	308,745,538	9.7%
New England as % of USA	5.3%	5.0%		4.8%		4.5%		4.2%	

Table 11 Population growth trends by state.

Source: NE Journal of Higher Education, 3 May 2012.
http://www.nebhe.org/thejournal/trends-indicators-demography/

Going forward, the Region's population is expected to grow slightly faster in the current decade (to 2020), and then slow its growth again to 2030 and 2040 (Table 12). The Region is expected to add about 1.5 million people by 2040. Like past growth, projected future growth is unevenly distributed: New Hampshire is expected to continue to grow more rapidly than other Northeast states (and faster than the nation as a whole); the other states are likely to grow more slowly than the national average, generally less than 5% per decade. All growth is expected to slow in the coming decades, both in the Region and in the nation as a whole.

population (millions)	2010	2020	2030	2040
Maine	1.33	1.39	1.45	1.50
New Hampshire	1.32	1.45	1.57	1.67
Vermont	0.63	0.66	0.70	0.72
Massachusetts	6.55	6.81	7.04	7.19
Rhode Island	1.05	1.09	1.11	1.13
Connecticut	3.57	3.72	3.86	3.95
NE Region	14.44	15.12	15.73	16.17
United States	308.8	335.6	361.0	382.2

growth, by decade	2010	2020	2030	2040
Maine	4.2%	4.8%	4.3%	3.0%
New Hampshire	6.5%	9.6%	8.5%	6.7%
Vermont	2.8%	5.2%	5.2%	3.8%
Massachusetts	3.1%	3.9%	3.4%	2.2%
Rhode Island	0.4%	3.4%	2.7%	1.5%
Connecticut	4.9%	4.3%	3.6%	2.4%
NE Region	3.8%	4.7%	4.0%	2.8%
United States	9.7%	8.7%	7.6%	5.9%

Table 12 Demographic projections by state.

Source: U. Virginia, Weldon Cooper Center for Public Service, *National Population Projections.*

The proportion of the population 65 and older is projected to peak in 2030, then plateau or decline slightly in most US states; but in several Northeast states, the older population will become and remain a significant proportion of state residents. Nationally, 18.4 percent of individuals are projected to be 65 or older by 2030; the proportion is expected to be higher in Maine (27 percent), Vermont (25 percent), and New Hampshire (24 percent).

Another consistent trend in the Northeast since 1990, and expected to continue in the coming decade, is the growing significance of traditional ethnic “minority” groups within the region’s overall population. As Table 13 shows, this trend has been particularly pronounced in Connecticut, Massachusetts, and Rhode Island. By 2020, it is likely that nearly half of the population aged 25-29 will be minorities in these states (Coelen and Berger 2006).

	1990	2000	2010	2020
Connecticut	17.0	19.9	24.1	27.7
Maine	2.2	2.6	3.2	4.0
Massachusetts	12.5	15.2	19.1	27.7
New Hampshire	2.9	4.0	5.9	7.9
Rhode Island	10.8	14.2	19.8	25.1
Vermont	2.0	2.8	4.5	7.5

Table 13 Trends in minority population (% of total) by state
Source: Coelen and Berger (2006).

These population projections have implications for the recreation and tourism segments of the Northeast region's marine economy. Demand for recreation and visitor numbers are likely to rise roughly in proportion with the regional and national population; and larger numbers of residents in their retirement years may further increase visitor numbers. The implications for marine resource use of growing ethnic minorities in the Northeast are less clear.

7. References

Allen, B.P. and J.B. Loomis. 2008. The decision to use benefit transfer or conduct original valuation research for benefit-cost and policy analysis. *Contemporary Economic Policy* 26:1-12.

Barrow, C., R. Loveland, and D. Terkla. 2005. Sailing into a strong future: the Massachusetts marine science and technology industry. Economics Faculty Publication Series 1-1-2005, University of Massachusetts Boston. http://scholarworks.umb.edu/cgi/viewcontent.cgi?article=1024&context=econ_faculty_pubs

Battista, N. and R. Clark. 2015. Incorporating Community into Regional Ocean Planning. Island Institute.

Boyd, J. and S. Banzhaf. 2007. What are ecosystem services? *Ecological Economics* 63: 616-626.

Brehme, C.E., P. McCarron, and H. Tetreault. 2015. A dasymetric map of Maine lobster trap distribution using local knowledge. *The Professional Geographer* 67(1):98-109.

Brouwer, R., I.H. Langford, I.J. Bateman, and R.K. Turner. 1999. A meta-analysis of wetland contingent valuation studies. *Regional Environmental Change* 1:47-58.

Coelen, S. and J.B. Berger. 2006. New England 2020: A forecast of educational attainment and its implications for the workforce of New England states. Report commissioned by the Nellie Mae Educational Foundation.

Colgan, C.S. 2007. A Guide to the Measurement of the Market Data for the Ocean and Coastal Economy in the National Ocean Economics Program. National Ocean Economics Program (NOEP).

Commonwealth of Massachusetts (COM). 2015. 2015 Massachusetts Ocean Management Plan. http://mass.gov/eea/waste-mgnt-recycling/coasts-and-oceans/mass-ocean-plan/2015-final-ocean-plan.html

Congressional Research Service (CRS). 2006. "U.S. International Borders: Brief Facts"

Cooley, S.R., J.E. Rheuban, D.R. Hart, V. Luu, D.M. Glover, J.A. Hare, and S.C. Doney. 2015. An integrated assessment model for helping the United States sea scallop (*Placopecten magellianicus*) fishery plan ahead for ocean acidification. *PLoS ONE* 10(5): e0124145. doi:10.1371/journal. pone.0124145

Dahl, T.E. and S.M. Stedman. 2013. Status and trends of wetlands in the coastal watersheds of the Conterminous United States 2004 to 2009. U.S. Department of the Interior, Fish and

Wildlife Service and National Oceanic and Atmospheric Administration, National Marine Fisheries Service. (46 p.)

Davis, R.A., ed. 1994. *Geology of Holocene barrier island systems*. Springer Verlag, Berlin.

Earth System Research Laboratory (ESRL). 2015. NOAA Climate Change Web Portal. http://www.esrl.noaa.gov/psd/ipcc/

Edwards, S.F. and S.A. Murawski. 1993. Potential economic benefits from efficient harvest of New England groundfish. *North American Journal of Fisheries Management* 13:437-449.

ENOW. 2015. Economics: National Ocean Watch. ENOW Explorer. <Available at http://www.coast.noaa.gov/enowexplorer/> Accessed on 08-29-2015.

ESS Group, Inc. 2013. Overview of the energy sector in the Northeastern United States. NROC White Paper, http://neoceanplanning.org/wp-content/uploads/2013/12/Energy-White-Paper1.pdf.

Freeman, M.A. 1995. The benefits of water quality improvements for marine recreation: a review of the empirical evidence. *Marine Resource Economics* 10:385-406.

Freeman, M.A. 2010. The wealth of nature: valuing ecosystem services. *Proc. 2010 EEPSEA Impact Conference*. Hanoi: Environmental Economics Program for South East Asia (February 26-27).

Gledhill, D.K., M.M. White, J. Salisbury, H. Thomas, I. Mlsna, M. Liebman, B. Mook, J. Grear, A.C. Candelmo, R.C. Chambers, C.J. Gobler, C.W. Hunt, A.L. King, N.N. Price, S. Signorini, E. Stancio , C. Stymiest, R.A. Wahle, J.D. Waller, N.D. Rebuck, Z.A. Wang, T.L. Capson, J.R. Morrison, S. Cooley, and S. Doney. 2015. Ocean and coastal acidification off New England and Nova Scotia. Oceanography 28(2):182-197.

Hare, J.A., J.P. Manderson, J.A. Nye, M.A. Alexander, P.J. Auster, D.L. Borggaard, A.M. Capotondi, K.B. Damon-Randall, E. Heupel, I. Mateo, L. O'Brien, D.E. Richardson, C.A. Stock, and S.T. Biegel. 2012. Cusk (*Brosme brosme*) and climate change: assessing the threat to a candidate marine fish species under the US Endangered Species Act. *ICES Journal of Marine Science* 69(10):1753–1768. doi:10.1093/icesjms/fss160

Harper, B. and D. Ranco. 2009. *Wabanaki Traditional Cultural Lifeways Exposure Scenario*. Prepared for the US EPA in collaboration with the Maine Tribes. EPA New England, Region One, Boston MA.

Hoagland, P., D. Jin, E. Thunberg, and S. Steinback. 2005. Economic activity associated with the Northeast Shelf Large Marine Ecosystem: application of an input-output approach. In Hennessey, T., Sutinen, J. (Eds.), Sustaining Large Marine Ecosystems: The Human Dimension. Elsevier Science, New York, pp. 157-179.

Hoagland, P. and A. E. Meeks. 2000. *The Demand for Whalewatching at Stellwagen Bank National Marine Sanctuary,* Marine Policy Center, Woods Hole Oceanographic Institution and NOAA. http://hawaiihumpbackwhale.noaa.gov/documents/pdfs_science/whalewatch_benefits.pdf.

Industrial Economics, Inc. 2014. *Technical documentation for the Vertical Line Model.* NMFS Contract #EA133F-14-NC-0682, March 2014.

Jin, D., P. Hoagland, and B. Wikgren. 2013. An empirical analysis of the economic value of ocean space associated with commercial fishing. *Marine Policy* 42:74-84.

Johnston, R.J., T.A. Grigalunas, J.J. Opaluch, M. Mazzotta, and J. Diamantedes. 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System Study. *Coastal Management* 30:47–65.

Johnston, R.J. and M. Russell. 2011. An operational structure for clarity in ecosystem service values. *Ecological Economics* 70:2243–2249.

Kaval, P. and J. Loomis. 2003. *Updated Outdoor Recreation Use Values with Emphasis on National Park Recreation*, Department of Agricultural Resource Economics, Colorado State University.

Kite-Powell, H.L. 2013. Overview of the maritime commerce sector in the Northeastern United States. NROC White Paper, http://neoceanplanning.org/wp-content/uploads/2013/12/Maritime-Commerce-White-Paper.pdf

Kline, J.D. and S.K. Swallow. 1998. The demand for local access to coastal recreation in Southern New England. *Coastal Management* 26:177-191.

Kocian, M., A. Fletcher, G. Schundler, D. Batker, A. Schwartz, and T. Briceno. 2015. *The Trillion Dollar Asset: The Economic Value of the Long Island Sound Basin*. Earth Economics, Tacoma, 84pp.

LaPointe, G. 2013. Overview of the aquaculture sector in New England. NROC White Paper, neoceanplanning.org/projects/aquaculture/.

Lipton D., D.K. Lew, K. Walmo, and A. Dvarskas. 2014. The evolution of non-market valuation of US coastal and marine resources. *Journal of Ocean and Coastal Economics* 1:6.

Massachusetts Office of Coastal Zone Management (MCZM). 2013. Seal level rise: understanding and applying trends and future scenarios for analysis and planning.

Minnesota IMPLAN Group (MIG). 2000. IMPLAN Professional Version 2.0. Minnesota IMPLAN Group, Inc. Stillwater, MN.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-Being: Wetlands and Water Synthesis*. Washington: Island Press.

Miller, R.E. and P.D. Blair, 1985. Input-Output Analysis. Prentice Hall. Englewood, NJ.

Mills, K.E. and A.J. Pershing. 2015. The influence of environmental variability and climate change on marine fisheries in the Northeast United States: a synthesis of scientific knowledge and forward-looking synthesis. White paper prepared for NROC and the NE RPB, July 30, 2015.

National Oceanographic and Atmospheric Administration (NOAA). 2012. Economics Program: Fisheries Economics of the US 2012. http://www.st.nmfs.noaa.gov/economics/publications/feus/fisheries_economics_2012

National Oceanographic and Atmospheric Administration (NOAA). 2014. Status of Stocks 2013: Annual report to Congress on the status of US fisheries. http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/status_of_stocks_2013.html

O'Connor, S., R. Campbell, H. Cortez, and T. Knowles. 2009. *Whale Watching Worldwide: tourism numbers, expenditures and expanding economic benefits*, a special report from the International Fund for Animal Welfare, Yarmouth MA, USA, prepared by Economists at Large. http://www.ifaw.org/sites/default/files/whale_watching_worldwide.pdf.

Pendleton, L., ed. 2008. *The Economic and Market Value of Coasts and Estuaries: What's at Stake?* Ch. 8. Arlington, VA: Restore America's Estuaries, pp. 140-175.

Pershing, A.J., M.A. Alexander, C.M. Hernandez, LA. Kerr, A. LeBris, K.E. Mills, J.A. Nye, N.R. Record, H.A. Scannell, J.D. Scott, G.D. Sherwood, and A.C. Thomas. 2015. Slow adaptation in the face of rapid warming leds to collapse of the Gulf of Maine cod fishery. *Science* 350(6262):809-812. DOI: 10.1126/science.aac9819

Point 97, Surfrider Foundation, and SeaPlan. 2015. Ocean Planning in the Northeast: Characterization of coastal and marine recreational activity in the US Northeast. Report Draft Aug. 2015. http://neoceanplanning.org/wp-content/uploads/2015/10/Recreation-Study_Final-Report.pdf

Rhode Island Coastal Resources Management Council (RICRMC). 2010. *Rhode Island Ocean Special Area Management Plan (Ocean SAMP)*.

SeaPlan. 2013. 2012 Northeast Recreational Boater Survey: a socio-economic and spatial characterization of recreational boating in coastal and ocean waters of the Northeast United States. http://www.seaplan.org/boating/

Shumchenia, E.J., M.L. Guarinello, D.A. Carey, A. Lipsky, J. Greene, L. Mayer, M.E. Nixon, and J. Weber. 2014. Inventory and comparative evaluation of seabed mapping, classification and modeling activities in the Northwest Atlantic, USA to support regional ocean planning. *Journal of Sea Research* 100:133-140.

Taylor, JDK, Kenney RD, LeRoi DJ, Kraus SD. 2014. Automated vertical photography for detecting pelagic species in multitaxon aerial surveys. Marine Technology Society Journal 48: 36-48.

Tiner, R.W. 2005. Assessing cumulative loss of wetland functions in the Nanticoke River watershed using enhanced national wetlands inventory data. *Wetlands* 25(2):405-419.

Tiner, R.W. 2010. Wetlands of the Northeast: Results of the National Wetlands Inventory. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA. 71 pp.

Troy, A. 2012. Valuing Maine's natural capital. Report to Manomet Center for Conservation Sciences. https://www.manomet.org/publications-tools/sustainable-economies/valuing-maine%E2%80%99s-natural-capital-full-report

Tyrrell, M.C. 2005. Gulf of Maine Marine Habitat Primer. Gulf of Maine Council on the Marine Environment, www.gulfofmaine.org/habitatprimer

US Army Corps of Engineers (USACE). 2015. *Waterborne Commerce of the United States, 2013*. www.navigationdatacenter.us/wcsc/wcsc.htm

University of Rhode Island (URI). 2013. Lobster shell disease expanding north: One of several diseases of marine organisms causing worry. *ScienceDaily*, 3 September 2013. www.sciencedaily.com/releases/2013/09/130903101552.htm

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1982. Benefit transfer of outdoor recreation demand studies, 1968-1988. *Water Resources Research* 28:707-713.

Woodward, R.T. and Y.-S. Wui. 2001. The economic value of wetland services: a meta-analysis. *Ecological Economics* 37:257–270.

8. Appendix A: Habitat Classification

Table A1. Original depth descriptive value (left column) and reclassified descriptive value (right column).

Depth (Bathymetry)	
Original Descriptive Value	**Reclassified Descriptive Value**
very shallow water (0 - 23 m)	Shallow
shallow to moderate depths (0 – 44 m)	Shallow
very shallow to shallow water (0 - 23 m)	Shallow
very shallow to moderate depths (0 – 75 m)	Shallow
shallow water (23 - 44 m)	Shallow
shallow water (8-44 m)	Shallow
shallow depths (23 - 44 m)	Shallow
shallow water (8 - 31 m)	Shallow
shallow depths (8.4 to 44 meter)	Shallow
shallow water (23 - 31 m)	Shallow
very shallow to moderate depths (0 – 75 m)	Shallow
very shallow water (0 - 15 m)	Shallow
shallow water (15 and 22 m)	Shallow
shallow water (15 - 22 m)	Shallow
shallow (15 - 22 m)	Shallow
shallow to moderate depth (0 - 45 m)	Shallow
shallow water (25 - 45 m)	Shallow
shallow to moderate depth (0 - 45 m)	Shallow
shallow to moderate depths (22 - 45 m)	Shallow
shallow water (25 - 45 m)	Shallow
very shallow (0 - 22m),	Shallow
moderate depth (42 - 79 m)	Moderate
moderate depths (42 - 101 m)	Moderate
moderate depths (61 - 101 m)	Moderate
moderate depths (42 - 101 m)	Moderate
moderate depths (61 - 70 m)	Moderate
moderate depths (70 - 101 m)	Moderate
moderate depths (42 to 83 m)	Moderate
moderate depth (42 - 101 m)	Moderate
over 69 m	Moderate
moderate depths (70 - 101 m)	Moderate
moderately shallow water (42 - 70 m)	Moderate
moderate depth (70 - 233 m)	Moderate

moderate to deep water (101 - 233 m)	Moderate
moderate to deep depths (over 101 m)	Moderate
moderate depths (23 - 44 m)	Moderate
moderate depths (44 – 75 m)	Moderate
moderate depths (31 - 75 m)	Moderate
moderate depths (44 - 75 m)	Moderate
moderate depths (44 - 79 m)	Moderate
moderately deep water (44 – 139 m)	Moderate
moderately deep water (75 - 139 m)	Moderate
moderate to very deep depths (average 128 m, min 44 m)	Moderate
moderate to deep depths (44 - 139 m)	Moderate
moderate depths (15 - 82 m)	Moderate
moderate depth (45 - 82 m)	Moderate
medium depth (45 - 82 m)	Moderate
moderate depths (45 - 82 m)	Moderate
moderate depths (45 - 82 m)	Moderate
moderate depths (45 - 82)	Moderate
moderate depth (22 - 82 m)	Moderate
moderately deep water (82 - 95 m)	Moderate
moderate depths (45 - 82 m)	Moderate
deep water (143 - 233 m)	Deep
deep depths (143 - 233 m)	Deep
deep water (143 - 233 m)	Deep
deep water (101 - 233 m)	Deep
deep water (over 233 m)	Deep
deep water (75-139 m)	Deep
deep water (60 – 485 m	Deep
deep to very deep water (75 - 200 m)	Deep
very deep water (>139 m)	Deep
shallow to deep depths (22 - 592 m)	Deep
deep water (95 - 592 m)	Deep
deep water (95 - 592 m)	Deep
very deep water (>592 m)	Deep
moderate to deep depths (45 -592)	Deep

Table A2. Original substrate descriptive value (left column) and reclassified descriptive value (right column).

Substrate	
Original Descriptive Value	**Reclassified Descriptive Value**
fine to medium sand	Sand and pebbles
fine sand	Sand and pebbles

very fine sand	Sand and pebbles
fine to medium to coarse sand	Sand and pebbles
on medium to coarse sand but occasionally on silt	Sand and pebbles
very fine to medium sand	Sand and pebbles
fine to coarse sand	Sand and pebbles
medium to coarse sand	Sand and pebbles
very fine to fine sand	Sand and pebbles
coarse to fine sand	Sand and pebbles
fine to coarse sand	Sand and pebbles
silt to fine sand	Sand and pebbles
medium to coarse substrate	Sand and pebbles
medium sand	Sand and pebbles
medium to coarse sand	Sand and pebbles
mostly coarse to occasionally fine sand	Sand and pebbles
coarse to fine sand	Sand and pebbles
fine to coarse sand	Sand and pebbles
very coarse sand or pebbles	Sand and pebbles
silt and mud	Silt and mud
silt to fine sand	Silt and mud
silt and mud	Silt and mud
silt to fine sand	Silt and mud
mostly on silt and fine sand, but substrate is variable	Silt and mud
silt and mud	Silt and mud
silt, fine sand and sand	Silt and mud
any substrate	Any

Table A3. Original seabed form descriptive value (left column) and reclassified descriptive value (right column).

Seabed Form	
Original Descriptive Value	**Reclassified Descriptive Value**
Depressions	Depressions
Flat depressions	Depressions
High flats	Flats
All types of flats	Flats
Mid and low flats	Flats
High and mid-position flats	Flats
Mid and high position flats	Flats
High slopes	Sloped
High slopes	Sloped
Slopes and canyons	Sloped

High flats and depressions	Mixed
Depressions and mid-position flats	Mixed
Mid-position flats and depressions	Mixed
Depressions and high flats	Mixed
Mid position flats and depressions	Mixed
High flats and slopes	Mixed
Flats and slopes	Mixed
High slopes, canyons, flats	Mixed
High slopes and flats	Mixed
High slopes and flats	Mixed
Flats and slopes	Mixed
Flats and side slopes	Mixed
Depressions and high flats	Mixed
Depressions and high flats	Mixed
Steep slopes and flats	Mixed
Various seabed positions	Mixed
Depressions and mid-position flats	Mixed
Depressions and los slopes	Mixed

Habitat categories were then created with the combinations of the physical factors new classification schemes. This resulted in 10 categories covering all the combinations found within the project study area. Those categories with their descriptions are listed below. The original habitat classifications that fall within each category are listed below category headings.

Categories

Category #1 – characterized by shallow depth, sand/pebbles substrate, and depressions seabed forms.

Original classifications that were grouped in this category are:

- Habitat 109 (134 Samples): Depressions in very shallow water (0 - 23 m) mostly on medium to coarse sand but occasionally on silt.
- Habitat 200 (163 Samples): Depressions at very shallow to moderate depths (0 – 44 m) on very fine to medium sand.
- Habitat 390 (117 Samples): Depressions in shallow water (23 - 44 m) in very fine to fine sand.
- Habitat 230 (227 Samples): Depressions in shallow depths (23 - 44 m) on very fine sand.
- Habitat 229 (225 Samples): Depressions in shallow depths (8.4 to 44 meter) on very fine sand.
- Habitat 768 (22 Samples): Depressions in very shallow water (0 - 15 m) on silt to fine sand.
- Habitat 38 (95 Samples): Depressions in water shallow (15 - 22 m) on medium to coarse sand.

- Habitat 2 (58 Samples): Flat depressions at shallow to moderate depth (0 - 45 m) in medium sand.

Category #2 – characterized by shallow depth, sand/pebbles substrate, a flats seabed forms.
Original classifications that were grouped in this category are:

- Habitat 316 (301 Samples): Flats in shallow water (8-44 m) on very fine to medium sand.
- Habitat 32 (52 Samples): Mid-position flats at shallow to moderate depths (22 - 45 m) on medium sand.
- Habitat 4 (128 Samples): Mid-position flats in shallow water (25 - 45 m) on coarse to medium sand.

Category #3 – characterized by shallow depth, sand/pebbles substrate, and mixed seabed forms.
Original classifications that were grouped in this category are:

- Habitat 25 (492 Samples): Flats and side slopes in very shallow to shallow water (0 - 23 m) on fine to coarse sand.
- Habitat 36 (61 Samples): Depressions and high flats in very shallow to moderate depths (0 – 75 m) on medium to coarse sand.
- Habitat 873 (113 Samples): Flats and side slopes in shallow water (8 - 31 m) on very fine to medium sand.
- Habitat 2537 (37 Samples): Depressions and high flats in shallow water (23 - 31 m) on very fine to fine sand.
- Habitat 36 (61 Samples): Depressions and high flats in very shallow to moderate depths (0 – 75 m) on medium to coarse sand.
- Habitat 113 (314 Samples): Depressions and mid-position flats at moderate depths (23 - 44 m) on very fine sand.
- Habitat 64 (62 Samples): Depressions and mid-position flats in shallow water (15 and 22 m) on medium sand.
- Habitat 87 (20 Samples): Depressions and high flats in shallow water (15 - 22 m) on medium sand.
- Habitat 1(109 Samples): Depressions and mid-position flats, shallow to moderate depth (0 - 45 m) on coarse to fine sand.
- Habitat 7 (83 Samples): Mid-position flats and depressions in shallow water (25 - 45 m) on medium to coarse substrate.
- Habitat 44 (82 Samples): Depressions and mid-position flats mostly very shallow (0 - 22m), but occasionally very deep on fine to coarse sand.

Category #4 – characterized by moderate depth, sand/pebbles substrate, and depression seabed forms.
Original classifications that were grouped in this category are:

- Habitat 2367 (40 Samples): Depressions at moderate depths (61 - 70 m) on very fine sand.

- Habitat 25 (46 Samples): Depressions at moderate depths (15 - 82 m) on fine to coarse sand.
- Habitat 218 (96 Samples): Depressions at moderate depths (45 - 82 m) on medium to coarse sand.

Category #5 – characterized by moderate depth, sand/pebbles substrate, and flats seabed forms.
Original classifications that were grouped in this category are:

- Habitat 557 (125 Samples): Mid position flats at shallow to moderate depth (42 - 79 m) on fine to medium sand.
- Habitat 1451 (127 Samples): Mid-position flats at shallow to moderate depths (42 - 101 m) on fine sand.
- Habitat 1078 (305 Samples): Mid-position flats on at moderate depths (61 - 101 m) on fine sand.
- Habitat 1028 (67 Samples): Mid-position flats at moderate depths (61 - 101 m) on fine sand.
- Habitat 183 (136 Samples): Mid-position flats in shallow to moderate depths (42 - 101 m) on fine sand.
- Habitat 133 (61 Samples): Mid-position flats at moderate depths (70 - 101 m) on fine sand.
- Habitat 91 (307 Samples): Mid-position flats at moderate depths (42 to 83 m) on fine to medium sand.
- Habitat 9 (219 Samples): High and mid-postion flats at moderate depth (42 - 101 m) on fine to medium sand.
- Habitat 24 (139 Samples): Mid-position flats at moderate depths (70 - 101 m) on silt to fine sand.
- Habitat 317 (190 Samples): Mid-position flats at moderate depths (31 - 75 m) on fine to medium sand.
- Habitat 381 (99 Samples): Mid and high position flats in moderate depths (44 - 79 m) on fine to very fine sand.
- Habitat 949 (31 Samples): Mid and low flats in deep water (75-139 m) on medium to fine sand.
- Habitat 592 (50 Samples): Mid-position flats at moderate depth (45 - 82 m) on medium sand
- Habitat 306 (29 Samples): All types of flats at medium depth (45 - 82 m) on medium sand.
- Habitat 84 (104 Samples): All types of flats at moderate depth (22 - 82 m) on fine to medium sand.
- Habitat 1223 (35 Samples): High flats in moderately deep water (82 - 95 m) on medium sand.
- Habitat 219 (44 Samples): High flats at moderate depths (45 - 82 m) on coarse to fine sand.

Category #6 – characterized by moderate depth, sand/pebbles substrate, and mixed seabed forms.

Original classifications that were grouped in this category are:

- Habitat 12 (56 Samples): Steep slopes and flats at depths over 69 m, on fine to medium sand.
- Habitat 2 (116 Samples): Flats and slopes at moderate depth (70 - 233 m) on very coarse sand or pebbles.
- Habitat 372 (125 Samples): Depressions and los slopes at moderate depths (44 – 75 m) on very fine sand.
- Habitat 223 (98 Samples): Mid-position flats and depressions at moderate depths (44 - 75 m) on fine to medium sand.
- Habitat 66 (121 Samples): Hihg flats and slopes in moderately deep water (75 - 139 m) on very fine to fine sand.
- Habitat 6 (105 Samples): High slopes and flats at moderate to deep depths (44 - 139 m) on coarse to fine sand.
- Habitat 395 (78 Samples): Depressions and high flats at moderate depths (45 - 82 m) on fine to medium sand.
- 520 (31 Samples): Mid position flats and depressions at moderate depths (45 - 82) on mostly coarse to occsasionaly fine sand.
- *Habitat 3 (78 Samples): Flats and slopes at moderate to very deep depths (average 128 m, min 44 m) on fine to very fine sand.

Category #7 – characterized by deep depth, sand/pebbles substrate, and mixed seabed forms.
Original classifications that were grouped in this category are:

- Habitat 11 (78 Samples): High slopes, canyons, flats in deep water (60 – 485 m) on medium to fine sand.
- Habitat 229 (57 Samples): High flats and depressions at shallow to deep depths (22 - 592 m) on a fine to medium sand.
- Habitat 387 (29 Samples): High slopes and flats in very deep water (>139 m) on fine sand.
- Habitat 437 (34 Samples): High flats and slopes in deep to very deep water (75 - 200 m) on fine sand.

Category #8 – characterized by deep depth, silt/mud substrate, and mixed seabed forms.
Original classifications that were grouped in this category are:

- Habitat 18 (204 Samples): High flats at moderate to deep depths (over 101 m) on silt to fine sand.

Category #9 – characterized by deep depths, silt/mud substrate, and flat seabed forms.
Original classifications that were grouped in this category are:

- Habitat 247 (62 Samples): Depressions and high flats in moderate to deep water (101 - 233 m) on silt and mud.
- Habitat 7: (157 samples) Depressions, and high flats and slopes, in deep water (143 - 233 m) mostly on silt and fine sand, but substrate is variable.

- Habitat 72 (152 Samples): Depressions and high flats at deep depths (143 - 233 m) on silt and mud.
- Habitat 8 (266 Samples): Depressions and side slopes in deep water (143 - 233 m) on silt and mud.
- Habitat 5 (130 Samples): Depressions, high flats and slopes in deep water (101 - 233 m) on silt, fine sand and sand.
- Habitat 103 (42 Samples): High slopes, steep slopes and depressions in deep water (over 233 m) on silt and fine sand.
- Habitat 505 (51 Samples): Slopes and canyons in very deep water (>592 m) on silt and mud.

Category #10 – characterized by any depth, any substrate, and any seabed forms. Original classifications that were grouped in this category are:

- *Habitat 4 (791 Samples): Any seabed form at any depth and any substrate. Not a habitat type, but included in this list for completeness.
- Habitat 82 (92 Samples): All types of flats in moderately deep water (44 – 139 m)

9. Appendix B: Marine Management Areas

Site Name	Management Agency	Primary Conservation Focus
Bluff Point State Park/Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Silver Sands State Park/Charles Island Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Hammonasset Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Barn Island Wildlife Management Area	Connecticut Department of Environmental Protection	Natural Heritage
Bride Brook Wildlife Management Area	Connecticut Department of Environmental Protection	Sustainable Production
Charles E. Wheeler Wildlife Management Area	Connecticut Department of Environmental Protection	Natural Heritage
Duck Island Wildlife Management Area/Natural Area Preserve (Westbrook)	Connecticut Department of Environmental Protection	Natural Heritage
East Haven Marsh Wildlife Management Area	Connecticut Department of Environmental Protection	Sustainable Production
East River Marsh Wildlife Area/ East River Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Ferry Point Marsh Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
Great Harbor Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Great Island Wildlife Area/Roger Tory Peterson Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Hager Creek Marsh Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
Hammock River Marsh Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Lords Cove Wildlife Area/Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Nott Island Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Pattagansett River Marsh Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
Pawcatuck River Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
Pine Orchard Marsh Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production

Plum Bank Marsh Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Popes Island Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Quinnipiac River Marsh Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Ragged Rock Creek Marsh Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Six Penny Island Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
South Cove Wildlife Area	Connecticut Department of Environmental Protection	Natural Heritage
Thatch Bed Marsh Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
Hammonasset Beach State Park	Connecticut Department of Environmental Protection	Natural Heritage
West River Marsh Wildlife Area	Connecticut Department of Environmental Protection	Sustainable Production
Harkness Memorial State Park/William A Niering Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Selden Neck State Park/Natural Area Preserve	Connecticut Department of Environmental Protection	Natural Heritage
Cape Henlopen State Park	Delaware Department of Natural Resources and Environmental Control	Natural Heritage
Ted Harvey Conservation Area (Wildlife Area)	Delaware Department of Natural Resources and Environmental Control	Natural Heritage
Little Creek Wildlife Area	Delaware Department of Natural Resources and Environmental Control	Natural Heritage
Cheesequake State Park	New Jersey Department of Environmental Protection	Natural Heritage
Port Republic Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Swan Bay Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Great Bay Boulevard Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Sedge Islands Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Mad Horse Creek Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production

Nantuxent Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Egg Island Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Heislerville Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Dennis Creek Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Fortescue Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Cape May Wetlands Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Absecon Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Higbee Beach Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Barnegat Lighthouse State Park	New Jersey Department of Environmental Protection	Natural Heritage
Dix Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
New Sweden Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Pork Island Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Malibu Beach Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Tuckahoe Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Cape Island Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Salem River Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Navesink River Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Upper Barnegat Bay Wildlife Management Area	New Jersey Department of Environmental Protection	Sustainable Production
Cohansey River Wildlife Management Area	New Jersey Department of Environmental Protection	Natural Heritage
Island Beach State Park	New Jersey Department of Environmental Protection	Natural Heritage
Liberty State Park	New Jersey Department of Environmental Protection	Cultural Heritage
Swan Point State Natural Area	New Jersey Department of Environmental Protection	Natural Heritage

North Brigantine State Natural Area	New Jersey Department of Environmental Protection	Natural Heritage
Cape May Wetlands State Natural Area	New Jersey Department of Environmental Protection	Natural Heritage
Corson's Inlet State Park	New Jersey Department of Environmental Protection	Natural Heritage
Swimming River Natural Area	New Jersey Department of Environmental Protection	Natural Heritage
Carl N. Shuster, Jr. Horseshoe Crab Reserve	National Marine Fisheries Service	Sustainable Production
Mudhole Closure	National Marine Fisheries Service	Natural Heritage
Waters off New Jersey Closure	National Marine Fisheries Service	Natural Heritage
Seatuck National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Stewart B. McKinney National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Wertheim National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Target Rock National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Bombay Hook National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Cape May National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Conscience Point National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Edwin B. Forsythe National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Oyster Bay National Wildlife Refuge	U.S. Fish and Wildlife Service	Sustainable Production
Prime Hook National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Bayswater Point State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Heckscher State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Hither Hills State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Jones Beach State Park	New York State Office of	Natural Heritage

	Parks, Recreation and Historic Preservation	
Montauk Point State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Napeague State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Nissequogue River State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Orient Beach State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Camp Hero State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Robert Moses State Park - Long Island	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Shadmoor State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Wildwood State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Captree State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Caumsett State Historic Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Gilgo State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Governor Alfred E. Smith/Sunken Meadow State Park	New York State Office of Parks, Recreation and Historic Preservation	Natural Heritage
Neshaminy State Park - Tidal Marsh Natural Area	Pennsylvania Department of Conservation and Natural Resources	Natural Heritage
Little Tinicum Island Natural Area	Pennsylvania Department of Conservation and Natural Resources - Bureau of	Natural Heritage

	Forestry	
Albert Gallatin Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Alice M. Colburn Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Alice M. Lawrence Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Ardandhu Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Barge and Crane Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
California Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Charles S. Haight Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Chester A. Poling Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Chelsea Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
City of Salisbury Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Corvan Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Dixie Sword Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Edward Rich Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Henry Endicott Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Herbert Exempt Site	Massachusetts Board of	Cultural Heritage

	Underwater Archaeological Resources	
Herman Winter Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Hilda Garston Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
James S. Longstreet Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
John Dwight Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Kershaw Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Kiowa Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Lackawana Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Lunet Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Mars Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Pemberton Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Pendleton Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Pinthis Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Port Hunter Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Pottstown Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage

Romance Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Seaconnet Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Trojan Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
U.S.S. Grouse Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
U.S.S. New Hampshire Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
U.S.S. Triana Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
U.S.S. Yankee Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
U.S.S. YSD Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
H.M.C.S. Saint Francis Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
French Van Gilder Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Vineyard Sound Lightship Exempt Site	Massachusetts Board of Underwater Archaeological Resources	Cultural Heritage
Bourne Back River Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Sandy Neck/Barnstable Harbor Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Waquoit Bay Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Weir River Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Wellfleet Harbor Area of	Massachusetts Department of	Natural Heritage

Critical Environmental Concern	Conservation and Recreation	
Weymouth/Hingham Back River Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Cape and Islands Ocean Sanctuary	Massachusetts Department of Conservation and Recreation	Natural Heritage
Cape Cod Bay Ocean Sanctuary	Massachusetts Department of Conservation and Recreation	Natural Heritage
Cape Cod Ocean Sanctuary	Massachusetts Department of Conservation and Recreation	Natural Heritage
North Shore Ocean Sanctuary	Massachusetts Department of Conservation and Recreation	Natural Heritage
South Essex Ocean Sanctuary	Massachusetts Department of Conservation and Recreation	Natural Heritage
Ellisville Harbor Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Egg Rock (Henry Cabot Lodge) State Wildlife Sanctuary	Massachusetts Division of Fisheries and Wildlife	Natural Heritage
Horseneck Beach State Reservation	Massachusetts Department of Conservation and Recreation	Natural Heritage
Herring River Watershed Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Milk Island (Knight) State Wildlife Sanctuary	Massachusetts Division of Fisheries and Wildlife	Natural Heritage
Inner Cape Cod Bay Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Ram Island State Wildlife Sanctuary - Salisbury	Massachusetts Division of Fisheries and Wildlife	Natural Heritage
William Forward Wildlife Management Area	Massachusetts Division of Fisheries and Wildlife	Natural Heritage
Neponset River Estuary Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Winter Flounder Spawning Closure Area	Massachusetts Division of Marine Fisheries	Sustainable Production
North Shore Groundfish Closure Area	Massachusetts Division of Marine Fisheries	Sustainable Production
Demarest Lloyd State Park	Massachusetts Department of Conservation and Recreation	Natural Heritage
Right Whale Critical Habitat	Massachusetts Division of	Natural Heritage

and Adjacent Waters Restricted Gear Area	Marine Fisheries	
Cape Cod Bay Year-Round Fish Pot Trawl Floating Ground Line Prohibition Area	Massachusetts Division of Marine Fisheries	Natural Heritage
Parker River/Essex Bay Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Pleasant Bay Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Pocasset River Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Rumney Marshes Area of Critical Environmental Concern	Massachusetts Department of Conservation and Recreation	Natural Heritage
Jenness State Beach	New Hampshire Division of Parks and Recreation	Natural Heritage
Wallis Sands State Beach	New Hampshire Division of Parks and Recreation	Natural Heritage
North Hampton State Beach	New Hampshire Division of Parks and Recreation	Natural Heritage
Hampton Beach State Park	New Hampshire Division of Parks and Recreation	Natural Heritage
Odiorne Point State Park	New Hampshire Division of Parks and Recreation	Natural Heritage
Rye Harbor State Park (Ragged Neck)	New Hampshire Division of Parks and Recreation	Natural Heritage
Closed Area I Habitat Closure Areas	National Marine Fisheries Service	Sustainable Production
Closed Area I	National Marine Fisheries Service	Sustainable Production
Closed Area II Habitat Closure Area	National Marine Fisheries Service	Sustainable Production
Georges Bank Seasonal Closure Area	National Marine Fisheries Service	Sustainable Production
Nantucket Lightship Habitat Closure Area	National Marine Fisheries Service	Sustainable Production
Western Gulf of Maine Habitat Closure Area	National Marine Fisheries Service	Sustainable Production
Closed Area II	National Marine Fisheries Service	Sustainable Production
Cashes Ledge Habitat Closure	National Marine Fisheries Service	Sustainable Production
Jeffrey's Bank Habitat Closure	National Marine Fisheries	Sustainable Production

Area	Service	
Cashes Ledge Closure Area (Multispecies)	National Marine Fisheries Service	Sustainable Production
Nantucket Lightship Closed Area	National Marine Fisheries Service	Sustainable Production
Oceanographer Canyon Closed Area	National Marine Fisheries Service	Sustainable Production
Lydonia Canyon Closed Area	National Marine Fisheries Service	Sustainable Production
Cape Cod Bay Restricted Area	National Marine Fisheries Service	Natural Heritage
Oceanographer Canyon Gear Restricted Area	National Marine Fisheries Service	Sustainable Production
Lydonia Canyon Gear Restricted Area	National Marine Fisheries Service	Sustainable Production
Veatch Canyon Gear Restricted Area	National Marine Fisheries Service	Sustainable Production
Great South Channel Restricted Trap/Pot Area	National Marine Fisheries Service	Natural Heritage
Western Gulf of Maine Closure Area	National Marine Fisheries Service	Sustainable Production
Great South Channel Sliver Restricted Area	National Marine Fisheries Service	Natural Heritage
Great South Channel Restricted Gillnet Area	National Marine Fisheries Service	Natural Heritage
Cashes Ledge Closure Area	National Marine Fisheries Service	Natural Heritage
SAM West	National Marine Fisheries Service	Natural Heritage
Massachusetts Bay Management Area	National Marine Fisheries Service	Natural Heritage
Offshore Closure Area	National Marine Fisheries Service	Natural Heritage
SAM East	National Marine Fisheries Service	Natural Heritage
Stellwagen Bank/Jeffreys Ledge Restricted Area	National Marine Fisheries Service	Natural Heritage
Gerry E. Studds/Stellwagen Bank National Marine Sanctuary	National Marine Sanctuaries	Natural Heritage
Block Island National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Mashpee National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage

Great Bay National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Monomoy National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Ninigret National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Nomans Land Island National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Parker River National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
John H. Chafee National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Pond Island National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Rachel Carson National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Sachuest Point National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Narrow River	Rhode Island Department of Environmental Management	Natural Heritage
Salt Ponds Region	Rhode Island Department of Environmental Management	Natural Heritage
Bissel Cove/Fox Island Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Greenwich Bay Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Mill Gut, Colt Park Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Sakonnet River Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Kickemuit River Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Potowomut River Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
High Banks Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Jenny's Creek Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Bristol Harbor Shellfish Transplant Area	Rhode Island Department of Environmental Management	Sustainable Production
Newcastle Conservation Area I	Maine Department of Marine Resources	Sustainable Production
Harrington River Seed Mussel Conservation Area	Maine Department of Marine Resources	Sustainable Production

Jordan River Seed Mussel Conservation Area	Maine Department of Marine Resources	Sustainable Production
West Bay Seed Mussel Conservation Area	Maine Department of Marine Resources	Sustainable Production
Narraguagus Bay Seed Mussel Conservation Area	Maine Department of Marine Resources	Sustainable Production
Cross Island National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage
Mid-Atlantic Coastal Waters Area	National Marine Fisheries Service	Natural Heritage
Offshore Trap/Pot Waters	National Marine Fisheries Service	Natural Heritage
Southern Mid-Atlantic Waters Closure Area	National Marine Fisheries Service	Natural Heritage
Southern Nearshore Trap/Pot Waters	National Marine Fisheries Service	Natural Heritage
Northeastern United States Closed Area	National Marine Fisheries Service	Sustainable Production
Cape Cod South Closure Area	National Marine Fisheries Service	Natural Heritage
Northern Inshore State Trap/Pot Waters Area	National Marine Fisheries Service	Natural Heritage
Northern Nearshore Trap/Pot Waters Area	National Marine Fisheries Service	Natural Heritage
Coastal Salt Ponds Shellfish Management Area	Rhode Island Department of Environmental Management	Sustainable Production
Gulf of Maine Rolling Closure Areas	National Marine Fisheries Service	Sustainable Production
Northeast Closure Area	National Marine Fisheries Service	Natural Heritage
Mid-Coast Closure Area	National Marine Fisheries Service	Natural Heritage
Hudson River National Estuarine Research Reserve	New York Department of Environmental Conservation & National Oceanic and Atmospheric Administration	Natural Heritage
Jacques Cousteau National Estuarine Research Reserve	Rutgers University, Institute of Marine and Coastal Sciences & National Oceanic and Atmospheric Administration	Natural Heritage
Narragansett Bay National Estuarine Research Reserve	Rhode Island Department of Environmental Management & National Oceanic and Atmospheric Administration	Natural Heritage

Waquoit Bay National Estuarine Research Reserve	Massachusetts Department of Conservation and Recreation & National Oceanic and Atmospheric Administration	Natural Heritage
Wells National Estuarine Research Reserve	Wells Reserve Management Authority & National Oceanic and Atmospheric Administration	Natural Heritage
Delaware National Estuarine Research Reserve	Delaware Department of Natural Resources and Environmental Control & National Oceanic and Atmospheric Administration	Natural Heritage
Great Bay National Estuarine Research Reserve	New Hampshire Department of Fish and Game & National Oceanic and Atmospheric Administration	Natural Heritage
Acadia National Park	National Park Service	Natural Heritage
Fire Island National Seashore	National Park Service	Natural Heritage
Gateway National Recreation Area	National Park Service	Natural Heritage
Cape Cod National Seashore	National Park Service	Natural Heritage
Lydonia Canyon	National Marine Fisheries Service	Sustainable Production
Oceanographer Canyon	National Marine Fisheries Service	Sustainable Production
Other Northeast Gillnet Waters Area	National Marine Fisheries Service	Natural Heritage
Moosehorn National Wildlife Refuge	U.S. Fish and Wildlife Service	Natural Heritage

10. Appendix C: Wampanoag Coastal Resources and Lifeways

Author: Elizabeth James Perry, Senior Cultural Resource Monitor for the Wampanoag Tribe of Gay Head Aquinnah

Wampanoag people have utilized our coastal homes for 20,000 years: for obtaining a large portion of our diet and for recreation, and ceremony. Our traditional stories tell us the lands now submerged under the ocean were once above water village and ceremonial places. Wampanoag derived many of our traditional clans from marine species. Ocean harvests including spearing lobster in the shallows (to use as food and as bait), setting crab traps, gathering heaps of edible seaweeds to eat or for steaming food in a traditional clambake, gathering rushes for weaving patterned mats and baskets. We held and continue to hold celebrations and ceremony and to swim and have boat races for recreation in our ancestral homelands in Massachusetts and Rhode Island into the Gulf of Maine and the Mid-Atlantic. As ocean going people, we have also held memorial Native canoe trips, such as the 22 mile paddle down the Charles River from (the village of Nonantum) out to Deer Island in 2010, the historic Wampanoag paddle in 2002 from Falmouth to Marthas Vineyard; the 2015 paddle in the Connecticut River out to Watch Hill in the largest dugout made in New England for two hundred years (36 feet long); and to commemorate the various Wampanoag crew members onboard the refurbished *Charles W Morgan* whaleship on its historic 38th Voyage in 2014. Aquinnah Tribal men and women continue to make their living off the sea in commercial fishing and shell fishing, in charter boat fishing, as tug boat captains and in related industries such as hatchery work, as marine scientists, scientific illustration, in natural resources, as divers, historians, in restaurants, catering, and as Merchant Marines. Making fakeshaw has replaced scrimshaw as a practice, due to changes in the laws governing the use of ivory and bone.

Spring and Fall anadromous and catadromous fish runs were and continue to be important important parts of our annual harvest from the sea and rivers: species included Atlantic eel, Atlantic salmon, shad, herring, Atlantic sturgeon and whitefish. Additionally, as these fish headed up river to spawn in huge numbers, seals and whales followed them up to feed on them; and this enabled individuals who were not living right on the coast to hunt and fish, too. Small craft warnings were issued on the Merrimac River in the 18th century due to the abundance of large spawning Atlantic Sturgeon. Fish roe was an important part of our diet into the mid-twentieth century when herring became scarce; fall spawning fish were of the right consistency to be dried and stored well for Wampanaog winter food supplies. Seal and whale meat were both eaten fresh and also dried and smoked for storage; whale, sturgeon and seal fat were rendered into oil and used for food as well. One early account talks about a Wampanoag woman who was entertaining some English visitors. She reached up and cut off a chunk of dried whale meat hanging by the fire and added it into a steaming pot of succotash (corn, beans and squash). Whalebone was used for tools and as a wood substitute at times when there weren't many forests, and on islands, where timber was less numerous. Large ocean birds such as Labrador Duck and Great Auk (extinct-see the 18th century Great Auk breastbone spoon from a Papineau Wampanoag man on the Elizabeth Islands in the collection of the British Museum), were sometimes hunted, along with sea mink (also extinct following the fur trade-see various archeological reports). The bones of seagulls, gannets, brown cranes and other species are represented in numerous shell middens, the meat was roasted or stewed with the down feathers being kept for weaving and insulation. Whales and dolphins were harvested on beaches where they would commonly strand on the Cape and islands especially, and represented a community resource (many early accounts, Native land deeds and wills reference clan whale portion rights). They were also speared and towed in by Native crews in dugout and bark canoes.

Travel was accomplished on the coast and rivers via *mushoon*, dugout canoes ranging from small to adequate for a party of 40, some outfitted with sails, presumably woven of basswood or milkweed bast. During severe winters travel was also accomplished on iced-over harbors and rivers via Native wood and sinew snowshoes and wooden toboggan assisted by our dogs. Celestial observation points, lookouts for boats, signal points, lookouts for whales, seals and fish were maintained in certain high places throughout our territory including in Bourne, along with shade arbors and tool storage places at boat launch sites (Jonathan Perry, personal communication, also see MA Archives Billingsgate documents, Nantucket Whaling Museum). The path down to the beach on Chappaquiddick Island for example, is documented as an Ancient Way, and is where Native canoes where launched (MHC, Mass Archives). Blackfish Point on Cape Cod was so named by the Separatists who landed there prior to going to what became Plymouth, Massachusetts. When they saw and tried to approach 10-12 Native people processing a Grampus orc for food on the beach, the Native party picked up their meat and tools and left, declining to engage with the strangers.

Roger Williams, in his "Key Into the Language of America", notes that Natives hunted whales and sturgeons but said the sturgeon was not something they were willing to sell to the 17th century English arrivals; this source mentions fish and shellfish as well. Sharks were also caught and cooked with the teeth of whales and sharks and baleen from whales along with whalebone and fish vertebrae used as ornaments by coast Native people and the inland Nations we traded with; shark skin is abrasive and served as sandpaper. Seal leather with or without fur, eel skins, and whale skins were tanned though few sources mention it; sinew from these species were used for sewing thread, fish line and bow strings. Sea turtles were harvested, for food and the shells were used; eggs being collected for food in spring and summer were mainly bird, and from turtle species that nest in the Northeast such as Terrapin and snapping turtles.

Certain places along the coast and in fresh and brackish rivers are known (or rediscovered with archeology) to have been where Native people built and maintained fish weirs for concentrating and trapping fish; Boston Common is one such place that was wetland and now covered with fill, and Wampanoag people take part in an annual educational celebration there during the Herring Run season each year (www.fishweir.org). In a few ponds and lakes very old dugouts have been found that were preserved from decay by being buried in mud and being underwater, and a few are on display at historical societies and museums.

Fishing by hook and line, harpoon, Indian hemp net, dip net, fish traps went on as a regular part of subsistence off the coast of MA and Eastern Rhode Island both at night and during the day, depending upon the species targeted, from land and by traditional dugout vessel (collections at Peabody Harvard museum, Peabody Essex Museum, Robins Museum and various Historical Societies). Echinoderms such as sea cucumbers and urchins were harvested. Men and women fished singly or in groups, and some traded fish to the Separatists at Plymouth. Men and women also gathered shellfish of various species including razor clams, soft shell clams, quahogs and blue mussels; some of this harvest was also dried for winter use, while the shells of quahog, whelk and oyster (and oyster and quahog pearls) were used to manufacture white and purple *peage* or shell beads for ornament, trade and diplomacy termed *wampum* in our language. Several names of North Atlantic fish species continued to be used by Native fishermen and women and were adopted, like many other things, by immigrants to our homes: *scuppoag/scup, tautog, squeategue*/weakfish and *squid* are just a few; our word *squid* first appears in late 16th-very early 17th century written records. Horseshoe crabs and seaweed, along with herring were used as garden fertilizers by Native women on an annual basis.

During the 16th century onwards, Wampanoag men, women and children on the coast were vulnerable to European slave ships. Wampanoag men continued to hunt whales in the Industrial whaling of the 18th to early 20th centuries, and worked as navigators, harpooners, traders, translators, first mates and captains, all over the world. Shipwrecks of Native boats are documented in the region and dealing with piracy was another serious risk, as well as capture and death at sea during the various wars Wampanoag men fought in including King Philips War, the French and Indian Wars and the Revolutionary War. English colonists sent Native prisoners to lifelong and temporary enslavement in places like Barbados during the Colonialization Period wars.

11. Appendix D: Commercial Fishing Activity, Supplemental Maps

These map images are drawn from NE RPB projects on commercial fishing vessel activity (LaPointe Phase 2 report). Figure 56 to 62 illustrate fishing vessel activity density for the period from 2006 to 2010 for vessels permitted to pursue certain species, and include vessel activity in transit to/from port as well as actual fishing on the fishing grounds. Figures 63 to 69 show vessel activity density only below specified vessel speed thresholds (in most cases, 4 knots), and better represent vessels actually engaged in fishing, as opposed to in transit. All data are drawn from NOAA's [Vessel Monitoring System](#) (VMS) Program.

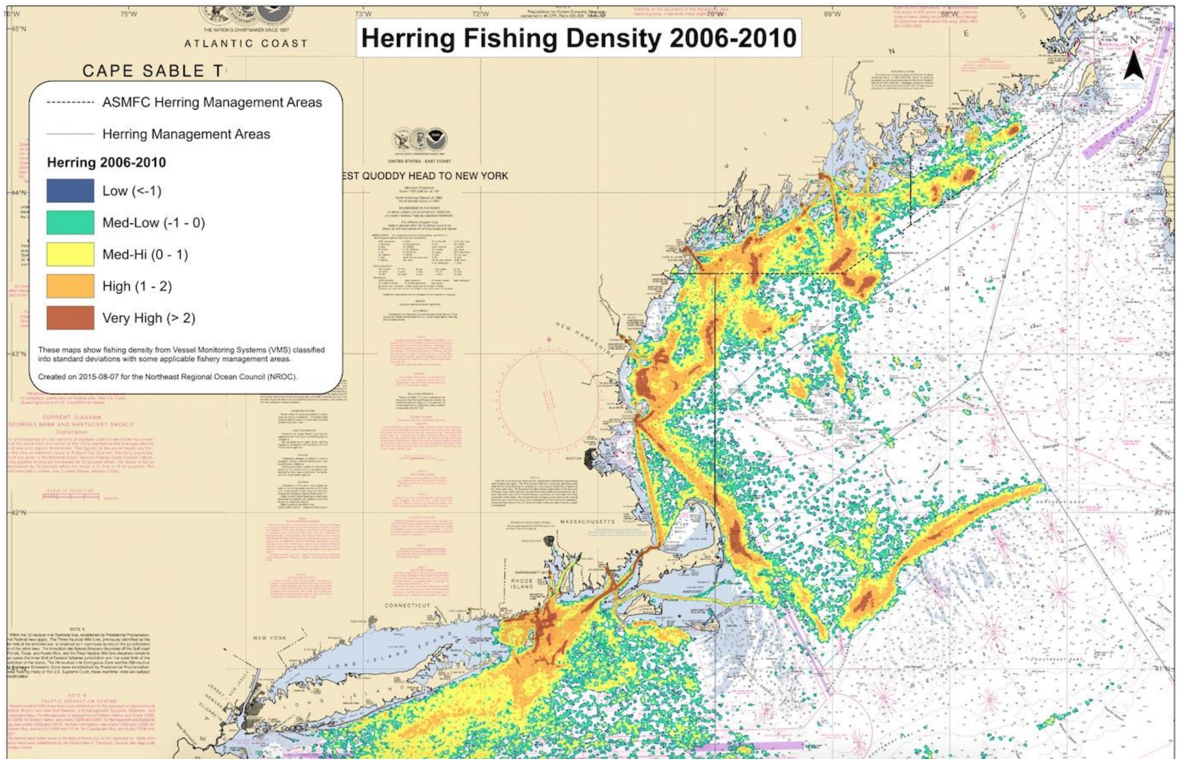


Figure 56 Herring fishing density, 2006-2010

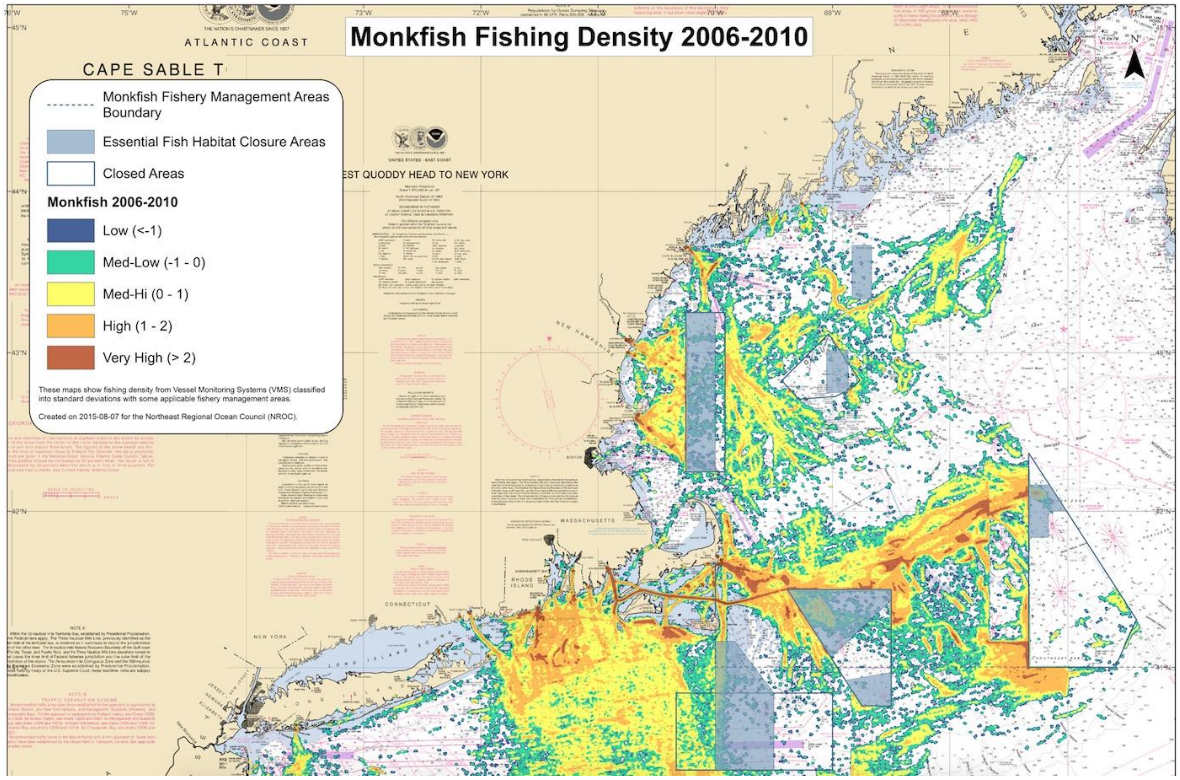


Figure 57 Monkfish fishing density, 2006-2010

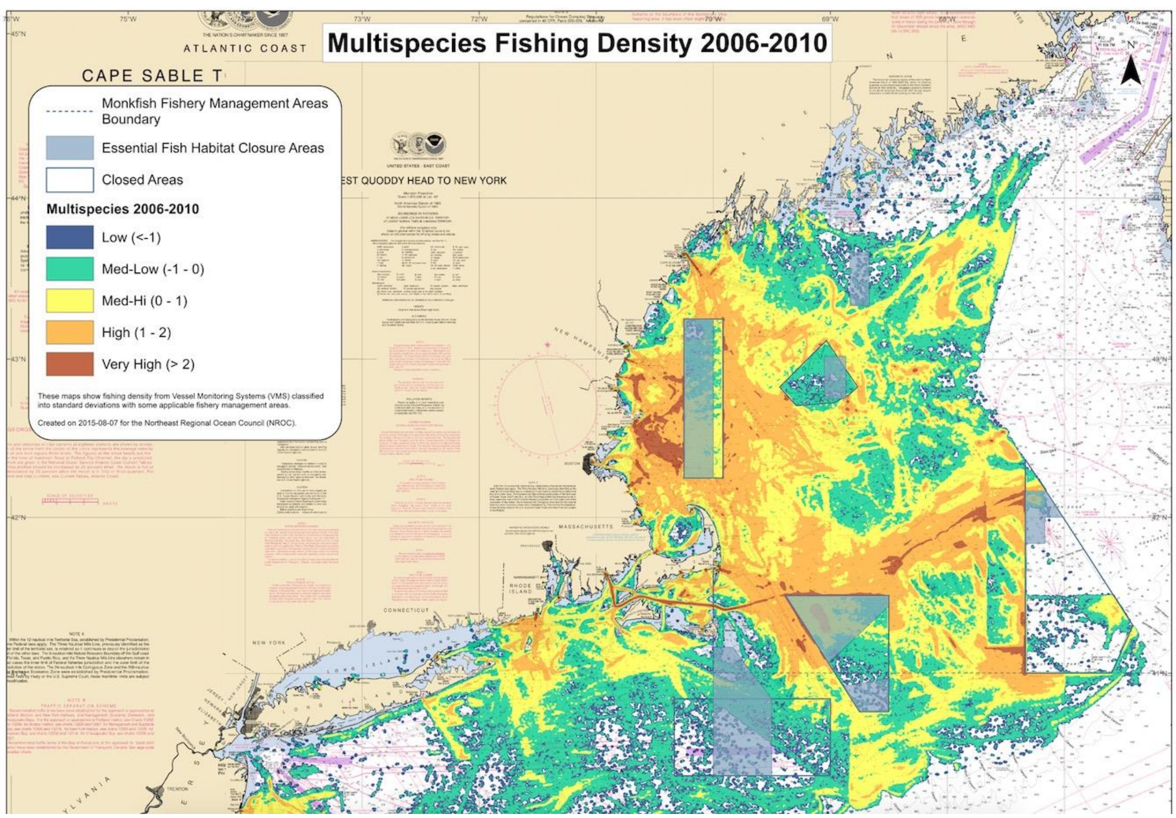


Figure 58 Multispecies fishing density, 2006-2010

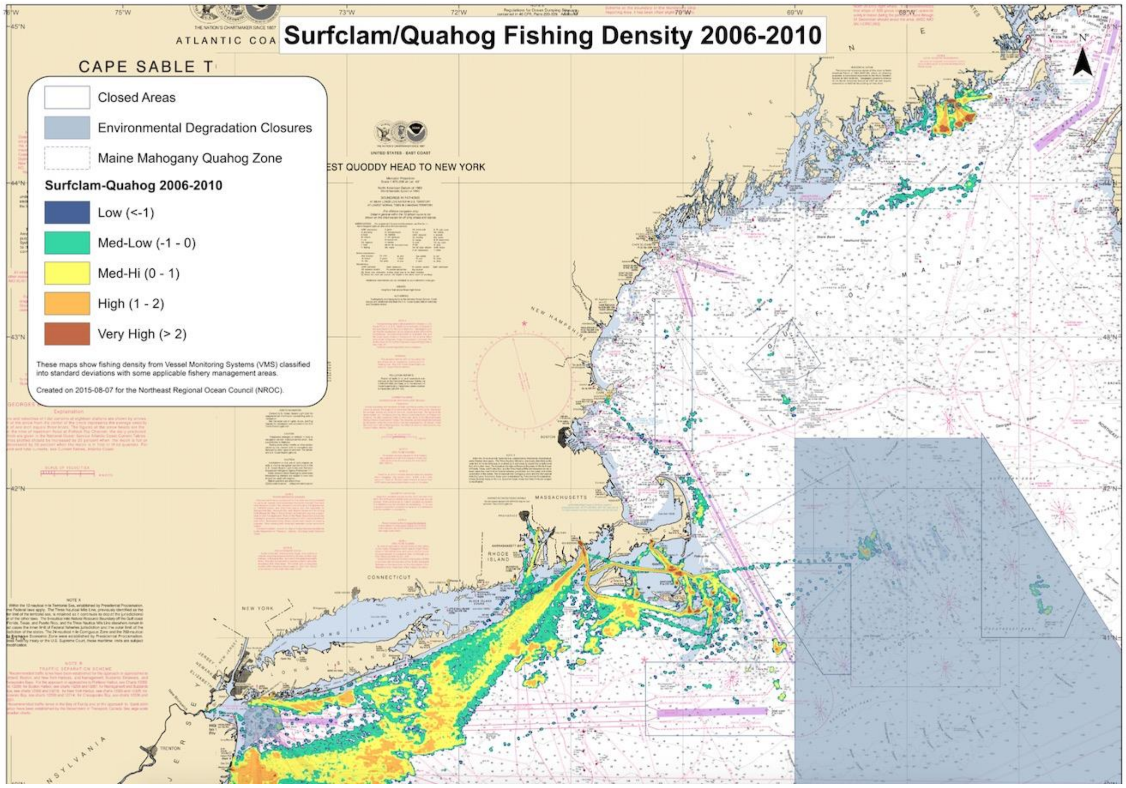


Figure 59 Surfclam/quahog fishing density, 2006-2010

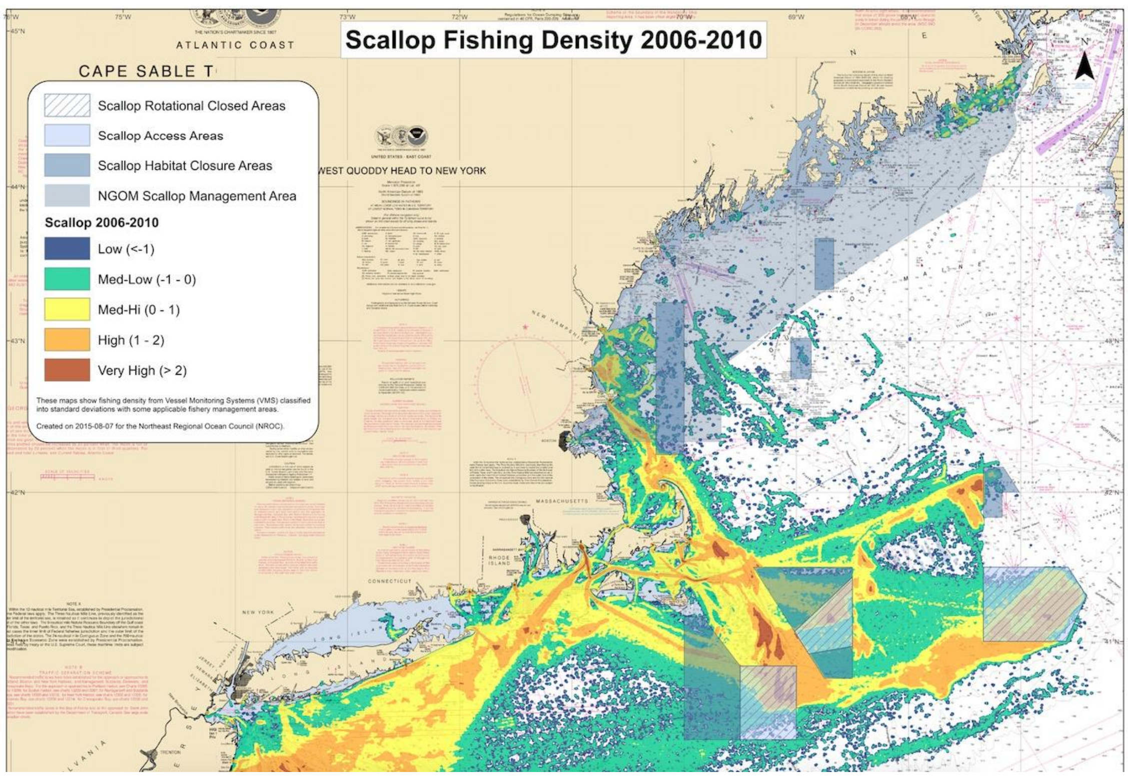


Figure 60 Scallop fishing density, 2006-2010

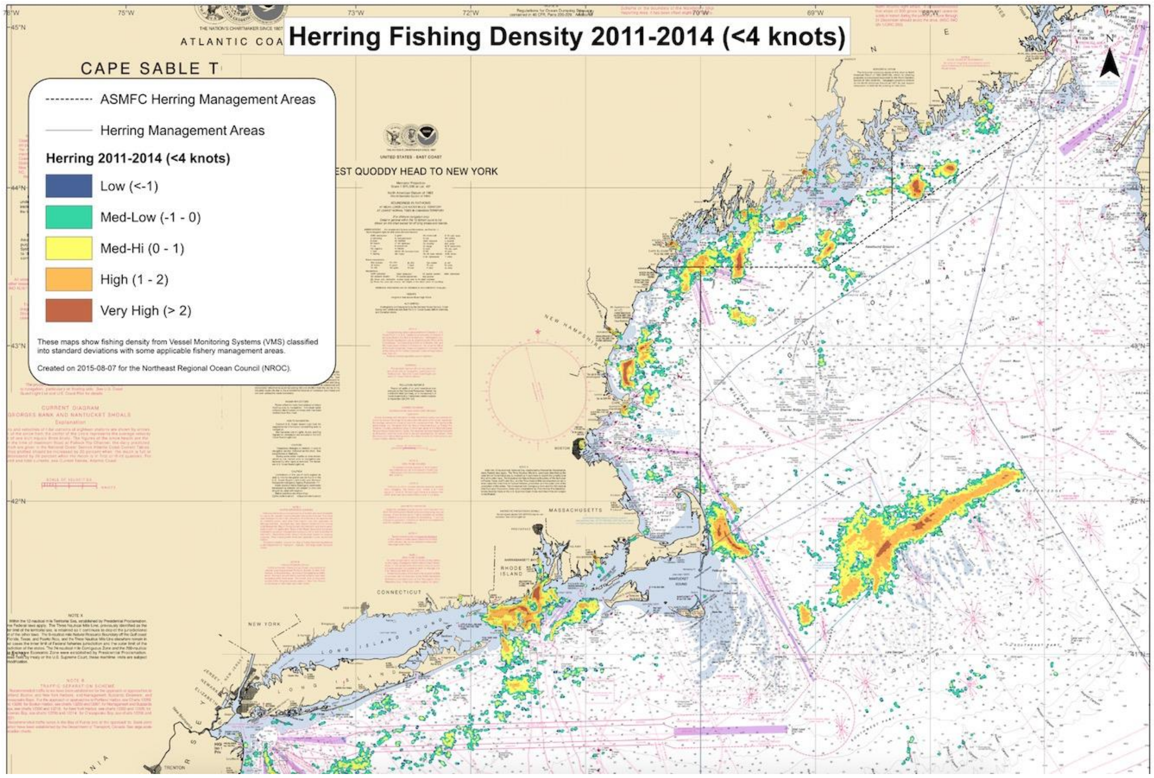


Figure 61 Herring fishing density, 2011-2014 (<4 knots)

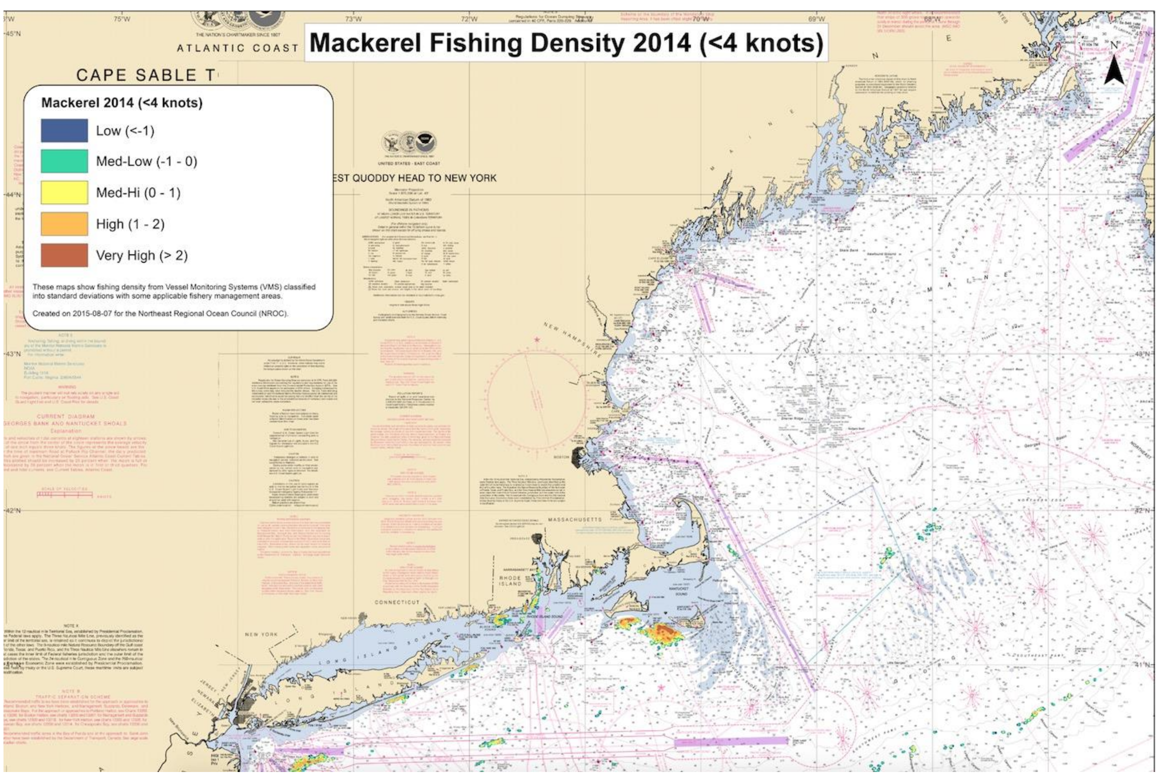


Figure 62 Mackerel fishing density, 2014 (<4 knots)

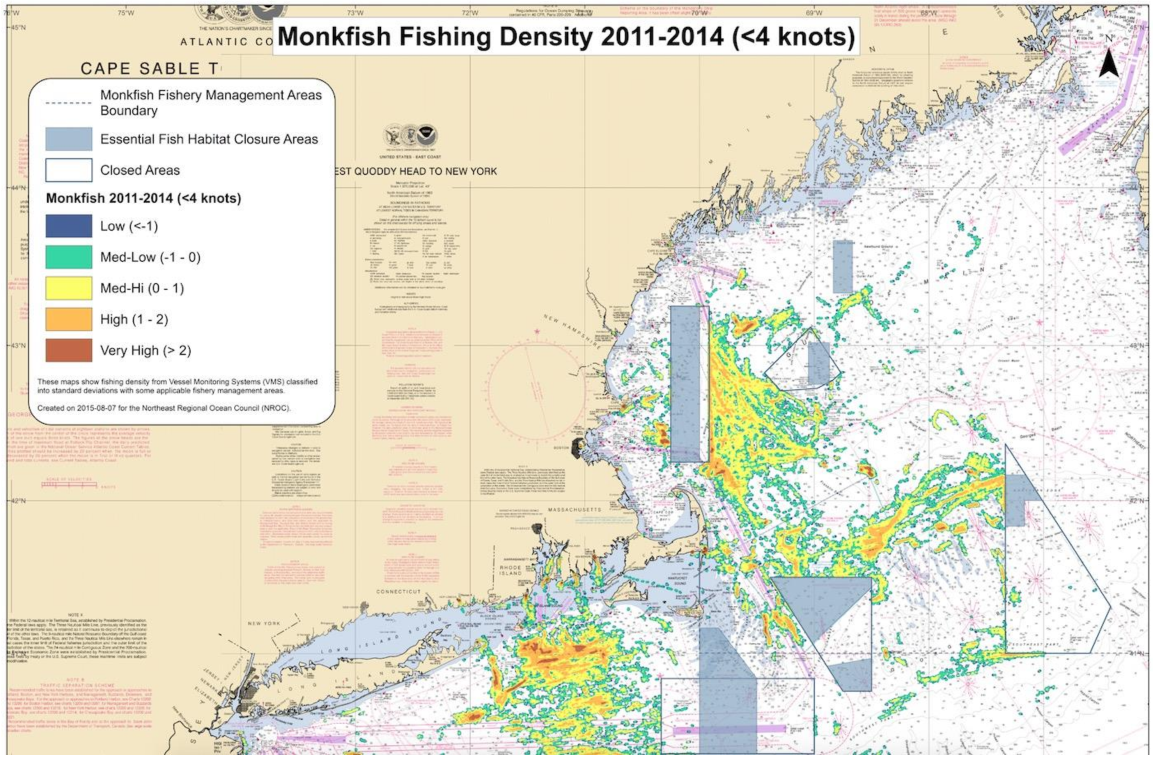


Figure 63 Monkfish fishing density, 2011-2014 (<4 knots)

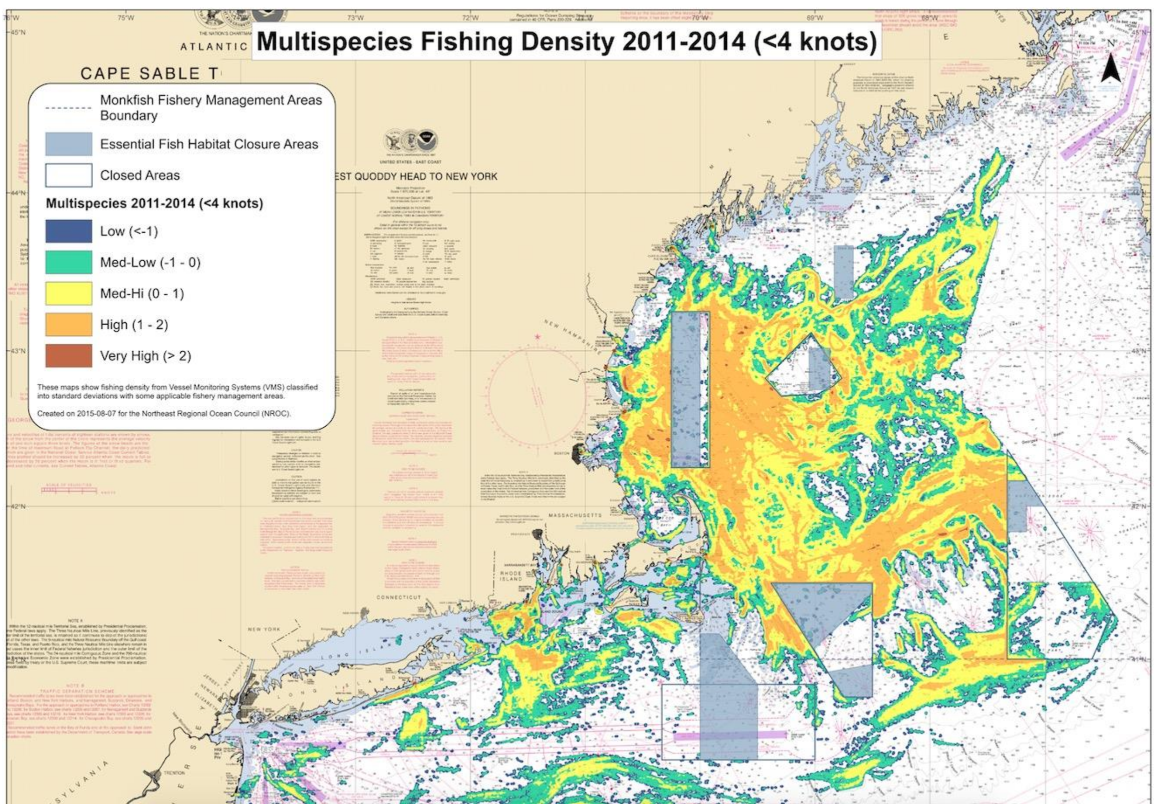


Figure 64 Multispecies fishing density, 2011-2014 (<4 knots)

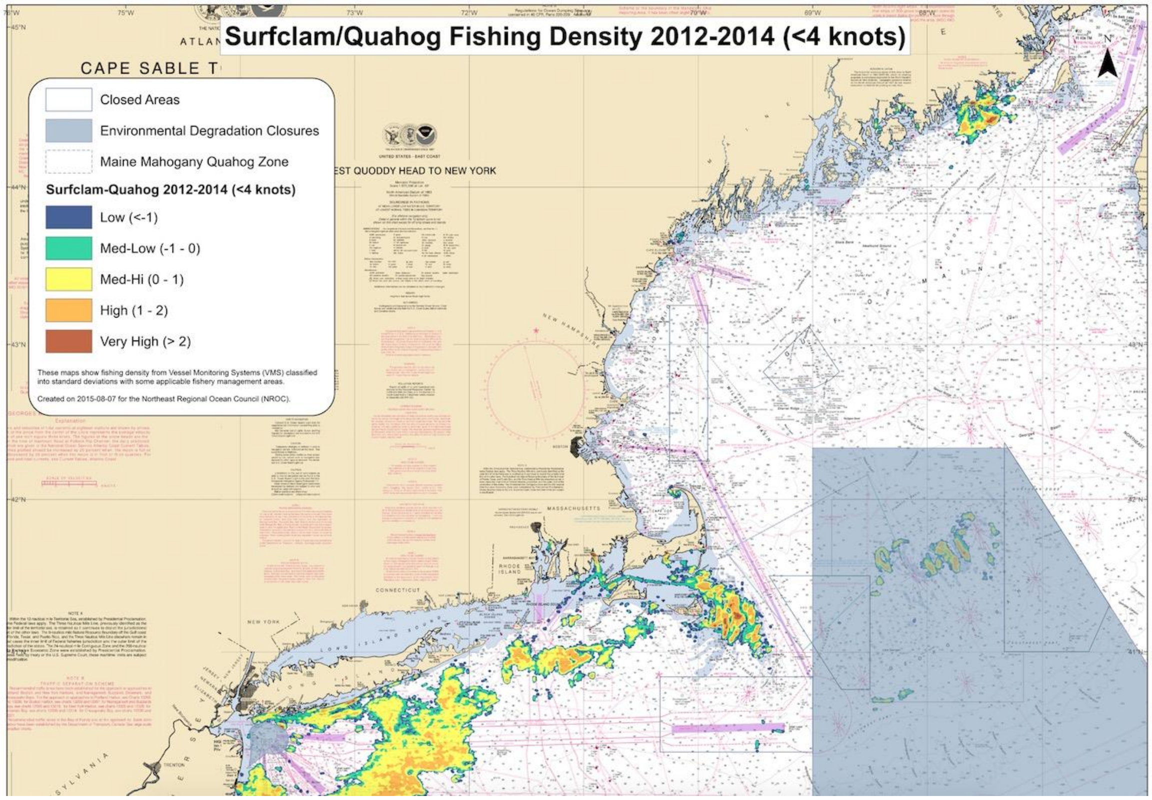


Figure 65 Surfclam/quahog fishing density, 2012-2014 (<4 knots)

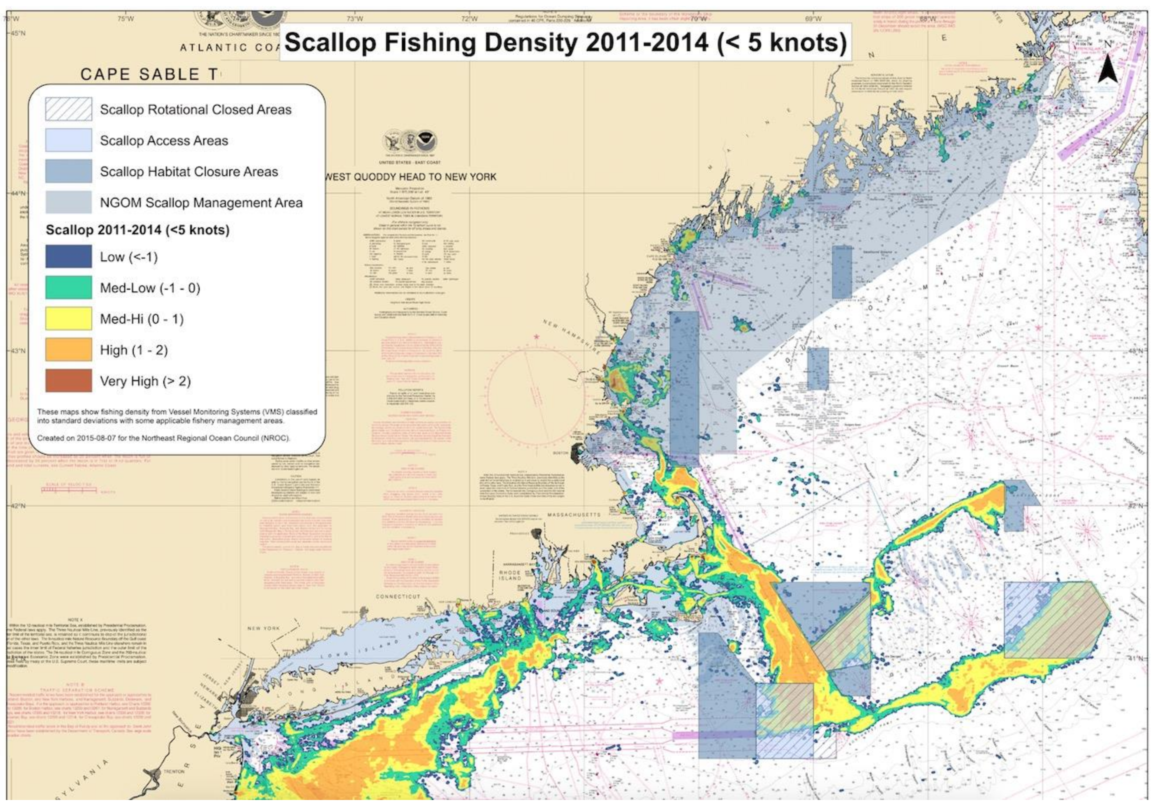


Figure 66 Scallop fishing density, 2011-2014 (<5 knots)

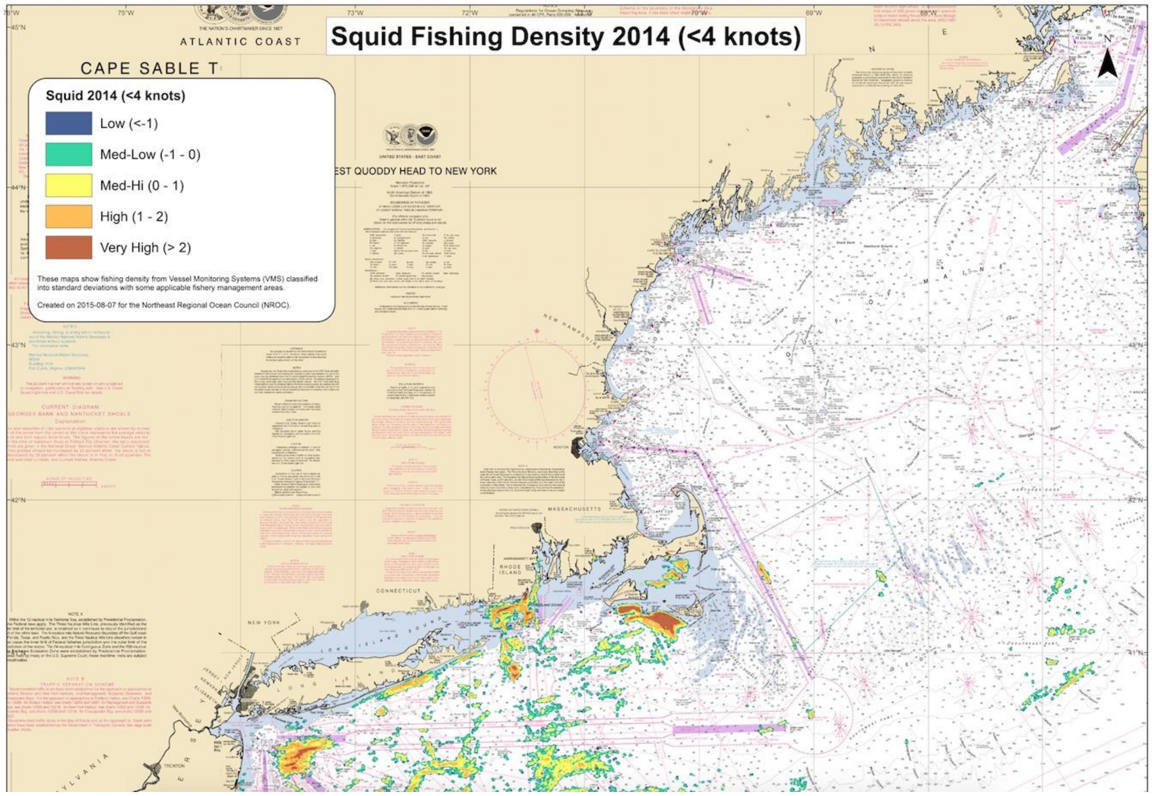


Figure 67 Squid fishing density, 2014 (<4 knots)

12. Appendix E: Ecosystem Services

12.1. The nature of ecosystem service value

This section presents estimates of ecosystem service (ES) values for the coastal and marine resources of the Northeast region. The region comprises physical features or "endpoints," such as wetlands, beaches, bays, estuaries, ocean space, and submerged lands. Many of these features consist of resources that can be used in alternative ways, thereby benefiting different groups, and service values are likely to differ across alternative resource uses and beneficiaries. Some alternative resource uses are compatible in a specific location, implying that ES values are additive; some are incompatible, leading potentially to user conflicts, and implying that some ES values may be diminished or obviated when resource uses overlap.

We have identified and compiled both published and unpublished estimates of ES values, and we have characterized gaps in value estimates that may need filling. In this section, we present the estimates first, then the gaps. The ES values that we present are unit values, expressed in dollars per geographic area per year. The values are broadly indicative of orders of magnitude for ecosystem services, but, as planning tools, they should be used with care. The relevance of these values in any particular allocation context necessitates a careful characterization of specific resources, the ways in which the resources are used and valued, the gains or losses that result from incremental management actions, and the identities of potential gainers and losers (Johnston and Russell 2011).

Following current thinking in environmental economics (*e.g.*, Lipton *et al*. 2014), we focus this assessment mainly on direct human uses of the coastal and ocean ecosystem. These uses may be linked to broader biophysical features of the ecosystem, (Boyd and Banzhaf 2006). It may be helpful to think of the ES values presented here as the valuation of specific uses of broad features, such as ocean used for commercial fishing or for renewable energy generation. Importantly, we do not consider values for "supporting" services, such as, for example, seagrass beds in their specific role as providing habitat for bay scallops, because doing so could lead to double counting when both the habitat value of the seagrasses and the recreational or commercial value of harvested scallops are assessed (Freeman 2013).[2]

The uses are listed in Table 14. These uses involve resources that may or may not be traded in existing markets, implying that the methodologies for developing estimates of value may be non-uniform (Johnston *et al*. 2002). This assessment focuses on estimates of <u>net</u> economic values, such as consumer or producer surpluses, not estimates of <u>gross</u> revenues, such as the output impacts reported in another section.

[2] Some of the studies that we use for comparison purposes constitute composite estimates of the valued characteristics of physical features, such as wetlands, estuaries, or coastal oceans. Unless carefully constructed, such composite estimates may include values for supporting services.

Endpoints	OoM $ 10e__/ha/yr	Sources	Est. % Coverage	Gaps
Navigation		AIS data on shipping routes; avoided costs of route changes	0%	Valuation is limited to specific routing change scenarios
Coastal tourism (beach visits, boating)	4	Compilation of nonmarket estimates	~100%	Limited number of valuation studies
Commercial fishing	0-2	VCR data and cost models	~100%	Estimate is resource rents only; no consumer surplus
Aquaculture	4-7	DCF models	~100%	Nearshore shellfish aquaculture incorporated into NMFS commercial fishing data; open-ocean aquaculture is still hypothetical
Aesthetic views	2	Hedonic pricing models of coastal real estate	~5%	Few studies for the NE Region
Recreational fishing	1-2	Compilation of nonmarket estimates	~100%	MRIP estimates could be distributed over NERBS
Marine wildlife viewing	1-2	Compilation of nonmarket estimates	~100%	Few studies; bird-watching is important
Pipelines and cables		States	0%	State submerged lands license fees could be explored
Ocean science		NERACOOS; NSF; NOAA; oceanographic laboratories; value of information studies	0%	OOS stations and some vessel surveys available; no valuation estimates
Deepwater ports	2	Mitigation payments	100%	Ports not currently operational
Renewable energy	0-2	Lease bonuses	100%	Energy facility siting still hypothetical
Sand and gravel production		BOEM, ACoE, States	0%	BOEM agreements with states to "donate" OCS materials for beach nourishment; limited use in NE Region; some local ACoE dredge and fill activities
Underwater cultural resources		State historic preservation officers for some location data; geographic distribution data are low-resolution	0%	Few non-market values; may be incorporated into recreational boating estimates
C-sequestration		Carbon price and sequestration potential of alternative environmental features (salt marshes, seabeds, etc.)	0%	Can be filled in with sequestration estimates for salt marshes; sequestration potential of other coastal and ocean areas are uncertain
Waste disposal		Avoided costs of sewering or water treatments	0%	Point sources regulated; coastal non-point sources significant in nearshore regions
N-, P-assimilation		Avoided costs of denitrification	0%	Few studies
Hydrocarbon production		n.a.	--	Not applicable in NE Region

Table 14 Northeast region ecosystem service and value estimates

A comprehensive understanding of ES values can help planners assess the compatibility among different human uses (or non-uses) that may be in conflict. This Baseline Assessment focuses on characterizing extant estimates without explicit consideration for how such estimates would be used by planners. In practice, the separation of estimates and applications may be difficult to carry out, as many planning exercises would need to consider not only the identity of relevant beneficiaries but also the nature of dynamic linkages among ecosystems and beneficiaries (Johnston and Russell 2011).

Following international practice (*e.g.*, de Groot *et al*. 2012), we adjust estimates from the literature so that they are expressed in common units, *i.e*., dollars per hectare per year ($/ha/yr).[3] Using the US consumer price index (CPI), we convert all dollar estimates into 2014 dollars. Similar to the recent compilation of ES values for Long Island Sound (Kocian *et al*. 2015), we compile unit, not marginal, values, but, unlike those authors, we do not calculate composite estimates of the "total asset value" of natural capital for the Northeast region. Total asset value estimates have little use to planners in assessing local compatibility of potentially competing uses.

Where relevant, we compare point estimates or ranges from studies (or our own calculations) that compile valuation estimates from a number of sources (Freeman 1995; Pendleton 2008; de Groot *et al*. 2012; Kocian *et al*. 2015). Some of these studies, especially de Groot *et al*. (2012) and Kocian *et al*. (2015), present composite estimates across the broader physical features, such as for wetlands, coasts, estuaries, or oceans.[4] There is some overlap in the coverage of individual studies that comprise composite estimates developed by different authors. While such representations undoubtedly involve some degree of double-counting of ES values, we present descriptive statistics from these studies so that planners can have a sense of the orders of magnitude for what are still quite rough estimates of economic value. These comparisons also demonstrate the extent to which the central tendencies and ranges of ES values from different compilations agree or disagree, and they illustrate the wide variability in estimates from the literature.

Figure 68 depicts a typology of human uses of coastal and marine resources. At the top of the figure is "total economic value," which consists of both active and passive uses. Active uses include the direct or indirect physical uses of ecosystem resources. Direct uses involve uses that can be valued in market contexts, such as commercial fish yields, electricity generation by ocean wind farms, or the aesthetic views priced

[3] A hectare is 0.01 square kilometers, or approximately 2.5 acres, 0.004 square miles, or 0.003 square nautical miles.

[4] The studies that develop composite estimates for broader categories ("endpoints") tend to compile estimates across the four categories of ES values that were identified through the Millennium Ecosystem Assessment (MEA 2005). These categories comprise provisioning, regulating, supporting, and information services.

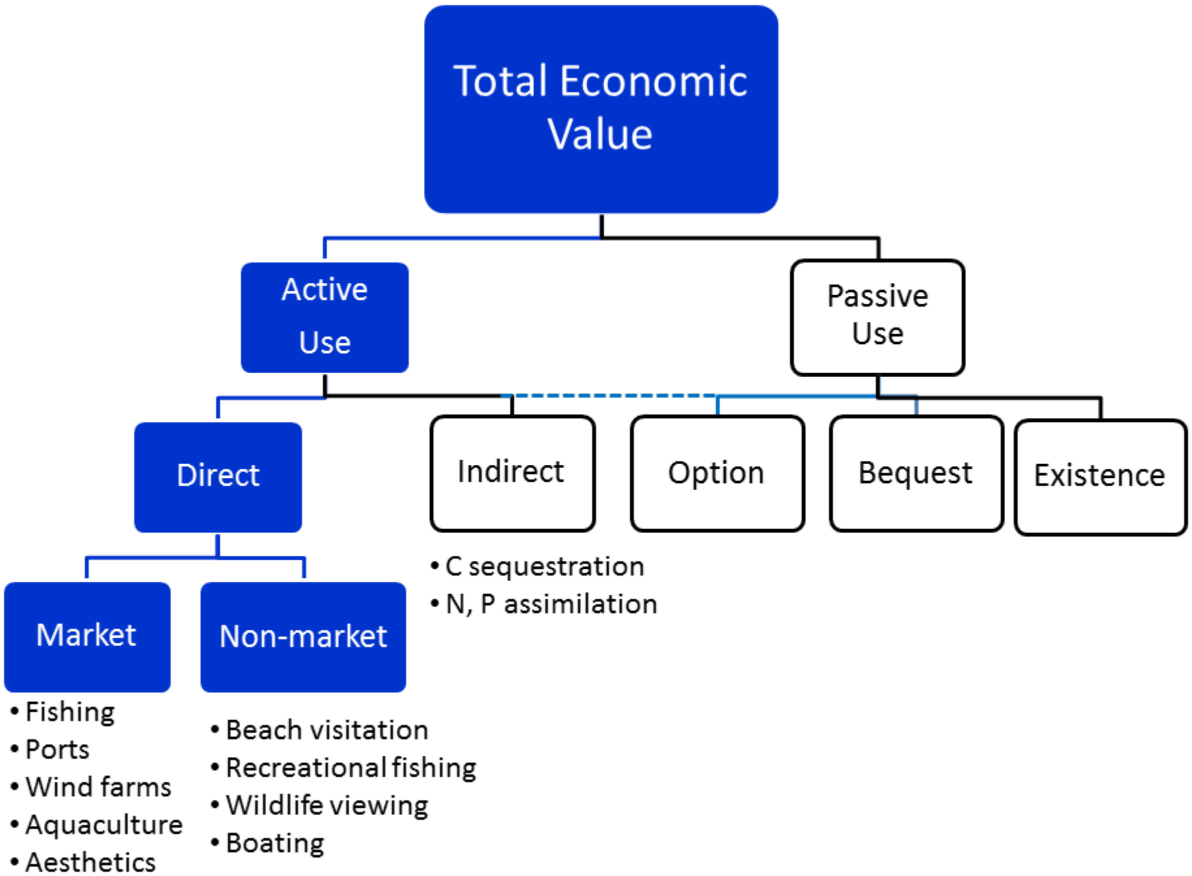


Figure 68 Typology of ecosystem service (ES) values
The Baseline Assessment focuses on those categories in blue.

into coastal real estate. Direct uses also involve non-market uses, such as beach visits or recreational fishing, typically do not involve explicit markets, and they must be valued using methods that examine travel costs or that question the user about her willingness-to-pay (WTP) for the particular use. Indirect uses involve waste assimilation, such as carbon sequestration, denitrification, or phosphorous removal. Passive uses involve no physical use of ecosystem services, but they recognize that humans may value the existence of these services or may value options to use them in the future or to ensure that they are available for future generations.

This assessment focuses mainly on values of direct, active uses (both market and nonmarket) for the coastal and marine resources of the Northeast region. This coverage is indicated by the solid blue elements of the typology in Figure 68. The values of passive uses are more uncertain, and little work has been undertaken to develop estimates of the scale of these uses in the Northeast. Passive uses are an obvious gap in ES valuation in this region, and they present a clear, albeit low priority, target for future valuation research.

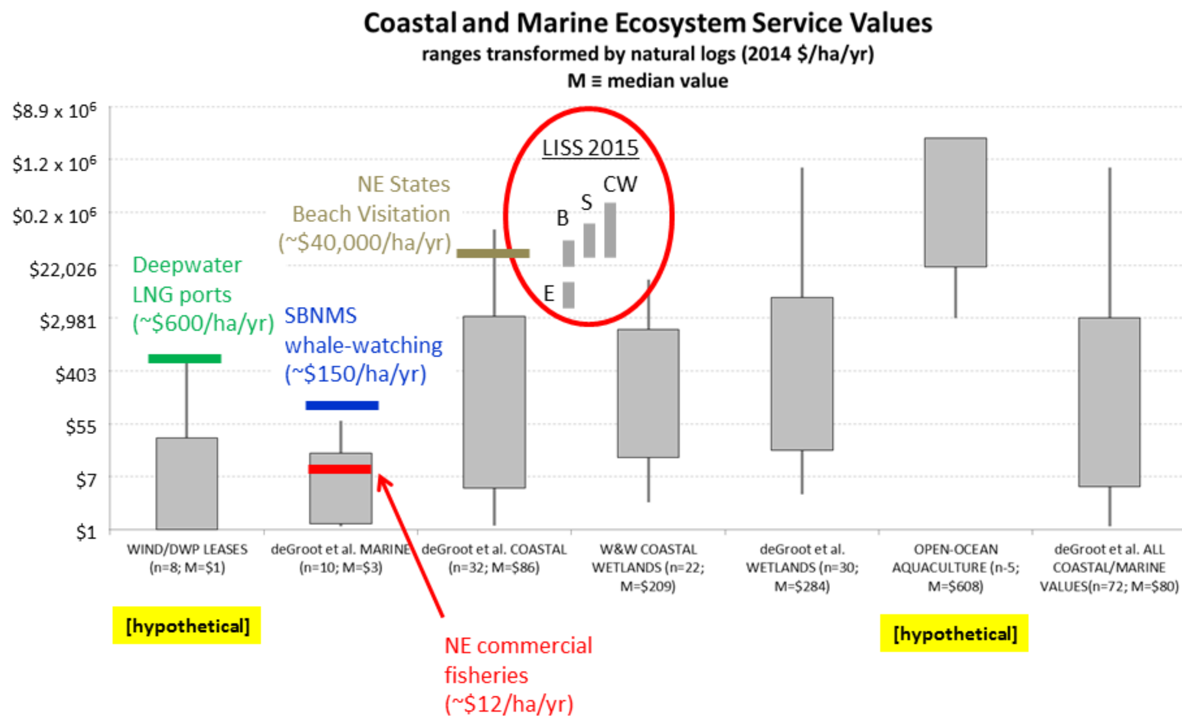


Figure 69 Comparison of coastal and marine ES values ($/ha/yr) from studies that develop composite resource estimates and with point estimates or ranges relevant to ES values in the Northeast region. Ranges in the red ellipse are from the recent study of ES values for the Long Island Sound Basin (E=estuary; B=beaches; S=seagrasses; CW=coastal wetlands). The values on the ordinate are log transformed but presented in real 2014 dollars. Sample size (n) and median values (M) are reported for each box-and-whisker plot. “Hypothetical” values relate to uses that have not yet been realized.

12.2. Assessment of Northeast region ecosystem service value studies

Figure 69 summarizes the general results of the assessment. The box-and-whisker plots comprise ± one standard deviation around mean values (the boxes) and minimum to maximum values (the whiskers). For comparison purposes, we report relevant composite (endpoint) estimates from de Groot *et al*. (2012), including marine, coastal, wetlands, and an all-combined category. For reference with respect to wetland ES values, we include also a box-and-whisker plot from an earlier compilation by Woodward and Wui (2001). The values on the ordinate have been transformed by natural logs, but they are expressed in real (2014) dollars. Sample sizes and median values are reported in the labels along the abscissa. These plots were transformed for comparison purposes because the ranges are so broad; this figure highlights the very wide range (several orders of magnitude) of ES value estimates for coastal and marine ES values in the literature.

Estimates of annualized rents associated with leases of outer Continental Shelf (OCS) lands for renewable energy (wind power) are included in the first box-and-whisker plot on the left. The minimum value is zero (*i.e.*, Cape Wind was not required to compete for a lease, and so there exists no estimate of resource rent for that proposed project). The green line above this plot shows the approximate level of annualized "mitigation payments" for the two deepwater liquefied natural gas (LNG) ports located off Boston. Just to the right, the red line in the "marine" plot shows the approximate mean level of net revenues (2014 $/ha/yr) for New England commercial fisheries. The blue line above the "marine" plot shows the point estimate of the approximate level of nonmarket (travel cost) value for whale-watching at the Stellwagen Bank National Marine Sanctuary. The brown line above the "coastal" plot is a mean for beach visitation across states in the Northeast. In the second box-and–whisker plot from the right, we include the range of model-based estimates of the per hectare value of open-ocean aquaculture (OOA). Both the deepwater ports and the OOA plots are characterized as "hypothetical," because these uses have not yet occurred in the Northeast region's ocean area. (Atlantic salmon is grown out in nearshore netpen operations in Downeast Maine, and the results from salmon growout models are included in the OOA range.) Note that nearshore shellfish aquaculture occurring throughout the region typically is incorporated into estimates of commercial fisheries values.

The red ellipse in Figure 69 surrounds recent ranges of estimates of composite values (endpoints) for the Long Island Sound estuary (E) and its beaches (B), seagrass beds (S), and coastal wetlands (CW) (Kocian *et al*. 2015). As composite values, these estimates are at the high end of values reported in the literature, particularly those for coastal wetlands, although the values for beaches are very close to the regionwide average for the Northeast.

As one prominent example of ES values for a marine resource, we present our calculations for commercial fisheries here. Figure 70 summarizes the results of Jin *et al*. (2013), who analyze the spatial and temporal distributions over 674 ten-minute squares (TMS or 10' squares) during 1999-2008 for all commercial fisheries (including all gears and species) in New England (the Gulf of Maine, Georges Bank, and Southern New England).[5] Data are log-transformed but the labels on the abscissa are expressed in real (2014) dollars. Commercial fishing in about four percent of TMSs comprise net losses (zero or negative rents) during this period. Figure 70 also includes an earlier estimate of potential resource rents over two large-scale NAFO statistical areas (5Y and 5Ze) during 1976-1989 (Edwards and Murawski [E&M] 1993). This older study comprises the results of a bioeconomic

[5] Jin *et al*. (2013) discuss sampling issues, including the absence of data on trips that are considered to be proprietary.

optimization model for all groundfish landed by the otter trawl fishery (Atlantic cod, haddock, and yellowtail flounder comprised about half of the resource rents in this analysis). This work emphasizes the spatial and temporal variability in ES value data that must be taken into account when such values are employed in planning decisions.

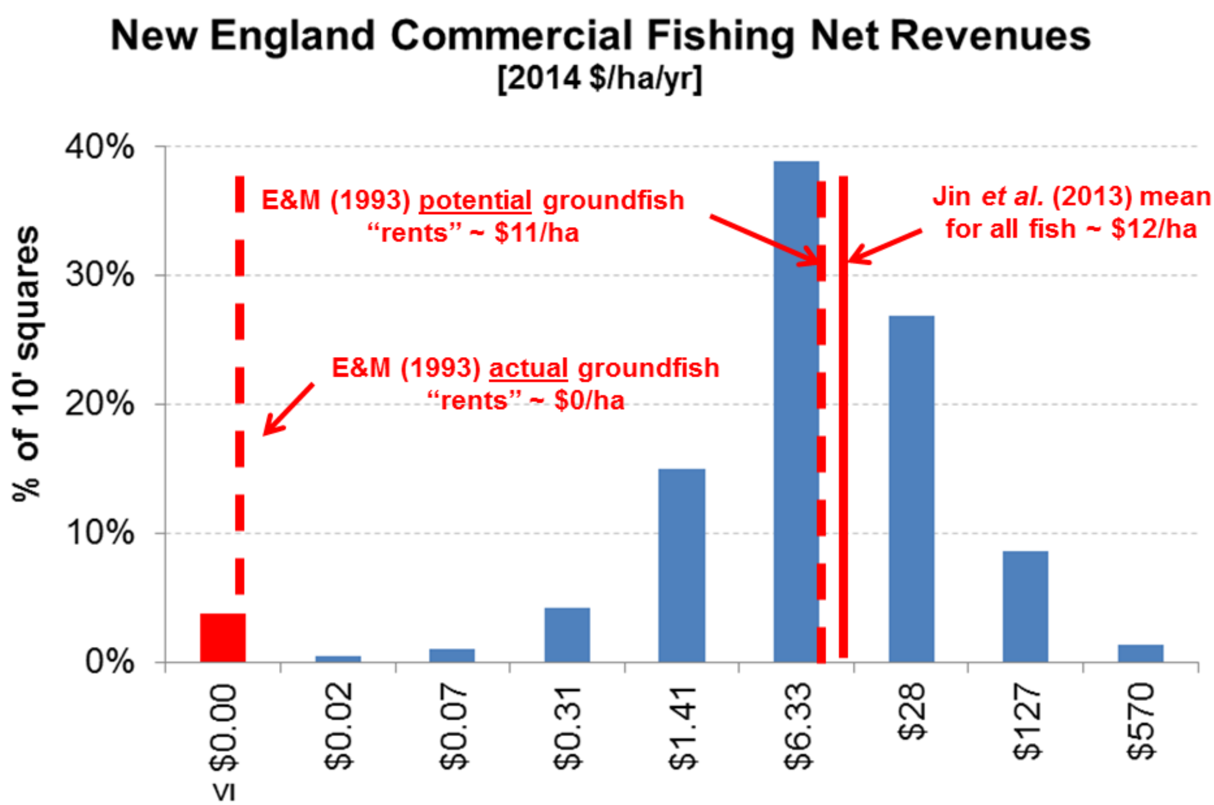


Figure 70 Histogram of the distribution of commercial fishing net revenues across ten-minute squares (10' squares or TMS) for all species in the Northeast region. Values along the abscissa have been transformed by logs but the labels constitute real 2014 dollars. Source: Jin et al. (2013). Included is a comparison with a modeling study by Edwards and Murawski (E&M 1993) for New England groundfish. The mean values from both studies are very close in value.

12.3. Gaps in present knowledge

Details on the calculations for each of the uses reported here and some of the issues that arise can be found in the appendix to the Baseline Assessment. Discussions for each of the uses include characterizations of the gaps in ES values. A literature exists on some of the drawbacks associated with benefits transfers and meta-analyses (e.g., Walsh *et al*. 1992; Allen and Loomis 2008), which we do not review here. We summarize some of the most important gaps:

- ***Incomplete coverage***. Very few studies of the ES values in the Northeast region have been undertaken to date. Some ES values are difficult to estimate (navigation, underwater cultural resources, waste assimilation, ocean science, among others). Consequently, relevant values must be transferred from other studies pertaining to similar ESs from other locations and times. Such transfers often are subject to significant uncertainties, and the wide ranges of estimates from compilations of studies render planning problematic.
- ***Influential studies***. A corollary to the problem of incomplete coverage is that some local studies may be relied upon extensively to estimate ES values for the region. One the most important and influential set of studies include those that develop estimates for the Peconic Estuary System undertaken by researchers at the University of Rhode Island in the late 1990s (Johnston *et al*. 2002). These studies are still quite influential, forming one basis for recent estimates of the ES values for the Long Island Sound Basin (Kocian *et al*. 2015).
- ***Hypothetical future uses***. Many projected human uses of the coasts and oceans are only hypothetical at present (wetland restoration, renewable energy, OOA). The potential emergence of such uses is a fundamental driver of contemporary coastal and ocean planning. Estimates for ES values associated with such uses are few in number, and there is a clear priority for modeling studies and benefit transfers for these uses.
- ***Non-uniform spatial and temporal distributions***. ES values may arise at different locations and different points in time. Variables comprising geography (distance), environment (weather, climate, water quality, seabed features, currents, natural hazards), human uses (congestion, permanent vs. temporary occupation), or human preferences (cultural norms) can influence ES values strongly.
- ***Estimating unit values is difficult***. Many nonmarket valuation studies have focused mainly on developing WTP estimates without explicit reference to the spatial extent of coastal or ocean area that is being valued.[6] In many cases, careful characterization of the relevant areas can be developed through combining information about use patterns with valuation studies. Such work is a clear priority for establishing ES values for important human uses of the coasts and oceans, such as those for recreational fishing or boating.
- ***Passive uses unstudied***. Almost no work has been undertaken on the passive use components of total economic value. Indirect, active uses, such as waste assimilation, sometimes also are categorized as a component of passive uses, and developing estimates of ES values for C-sequestration and denitrification in near coastal waters is a clear priority. For the former, the effectiveness of

[6] In a meta-analysis of international wetland ES values, for example, Brouwer et al. (1999) estimate that two-thirds of the studies that they examined did not include information about the size of the area.

sequestration across coastal and marine environments (salt marshes, intertidal zones, seabeds, ocean waters) will be important.