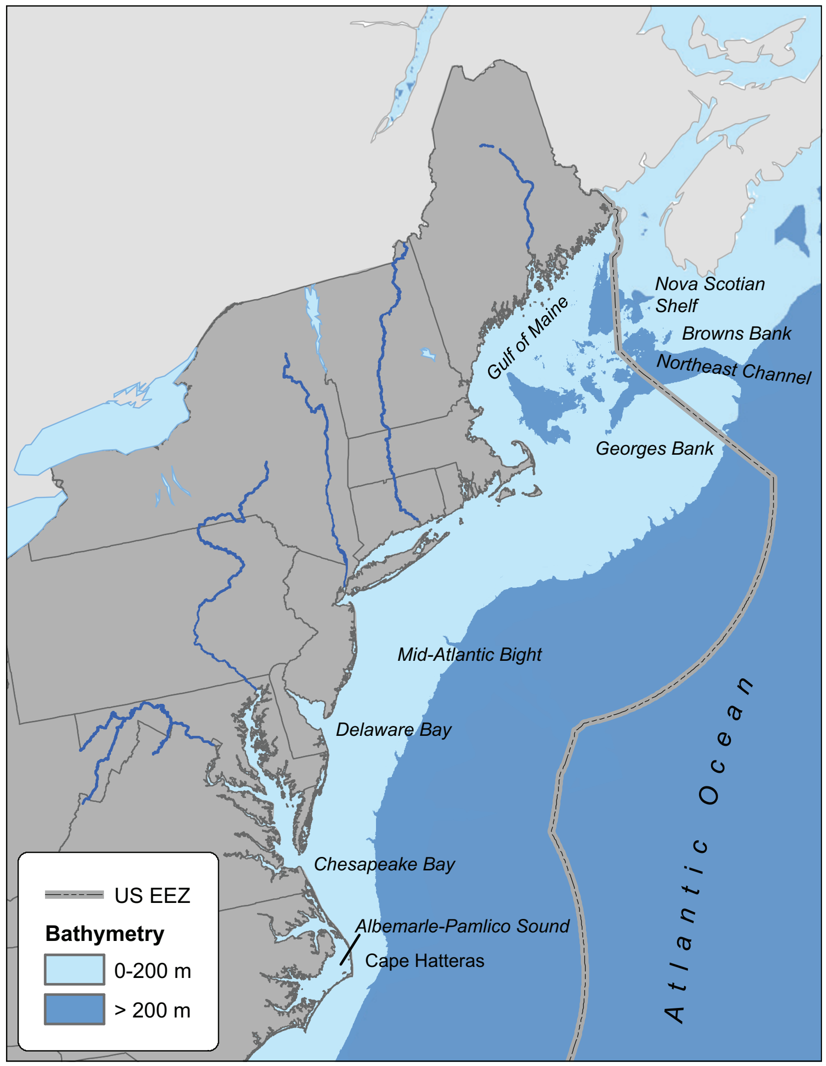
Northeast Region

HABITAT AREAS

The Northeast Region[1] extends from the Gulf of Maine south to Cape Hatteras, and covers about 3% (369,000 km^2 [108,000 nmi^2]) of the U.S. Exclusive Economic Zone (EEZ). East to west, the Region extends from the freshwater habitats in watersheds used by anadromous species, to bays and estuaries, to shallow marine waters extending from the intertidal zone to a depth of 200 m (656 ft; typically the edge of the Continental Shelf), and out to the edge of the U.S. EEZ, including the Continental Slope. States within the Northeast Region include Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, Virginia, Pennsylvania, and West Virginia. The Northeast Region consists of three major areas from north to south: the Gulf of Maine, Georges Bank, and Southern New England/Mid-Atlantic Bight, as well as associated coastal and estuarine areas.

Gulf of Maine

The Gulf of Maine is bordered by Maine, New Hampshire, and Massachusetts. It covers an area of 90,700 km^2 (35,000 mi^2) on the Continental Shelf, extending north to the Nova Scotian Shelf, east to Browns Bank, and south to Cape Cod and Georges Bank. It is characterized by a system of 21 deep basins (three of which exceed 250 m [820 ft] in depth), glacial deposits, rocky ledges, and banks, with limited access to the open ocean. The Gulf is distinct from the Atlantic, separated by ocean fronts that have distinct temperature, salinity, nutrient, and plankton community characteristics. It is essentially an ecologically separate sea within a sea.



Georges Basin is entered through the Northeast Channel (between Georges Bank and Browns Bank). The Northeast Channel is narrow and deep (230 m [755 ft]) and is the principal conduit for water exchange between the Gulf and the Atlantic Ocean. The surface currents in the Gulf are

[1]This report divides the U.S. EEZ into geographic regions. These geographic regions do not correspond to the names of the NMFS administrative regions. Administratively, the geographical region described in this chapter falls under the NMFS Greater Atlantic Region.

Richard K. Kelley, Jr., Maine State Planning Office, for the Gulf of Maine Council on the Marine Environment

The watershed of the Gulf of Maine is international, containing all of Maine and parts of New Hampshire and Massachusetts, as well as parts of the Canadian provinces Quebec, New Brunswick, and Nova Scotia.

typically counterclockwise and nontidal, flowing around the Gulf along the shore. The current is driven by cold, low-salinity water from the Nova Scotian Shelf flowing through the Northeast Channel and by freshwater contributions of the coastal rivers. Dense, relatively warm and saline slope water entering through the Northeast Channel from the Continental Slope also influences gyre formation. Gulf circulation can vary significantly from year to year due to shelf–slope interactions such as the entrainment of shelf water by Gulf Stream rings, strong winds (which can create fast-moving currents), and annual and seasonal inflow variations.

Freshwater Habitats—The Gulf of Maine watershed is extensive, covering 179,000 km^2 (69,000 mi^2) in three states and three Canadian provinces, and stretches from the north shore of Cape Cod, Massachusetts, to Cape Sable, Nova Scotia, in Canada. There are 25 major watersheds and 11 minor coastal drainage areas, 60 counties, 57 U.S. Geological Survey (USGS) Hydrologic Cataloging Units, and 453 subbasins. The U.S. portion includes more than 111,000 km^2 (42,900 mi^2) of land in Maine (86,000 km^2; 33,200 mi^2), New Hampshire (17,000 km^2; 6,500 mi^2) and Massachusetts (8,800 km^2; 3,400 mi^2). Freshwater habitats in the watershed include wetlands, creeks, streams, and rivers; major rivers that empty into the Gulf of Maine include the Penobscot, Kennebec, Androscoggin, Saco, and Merrimack.

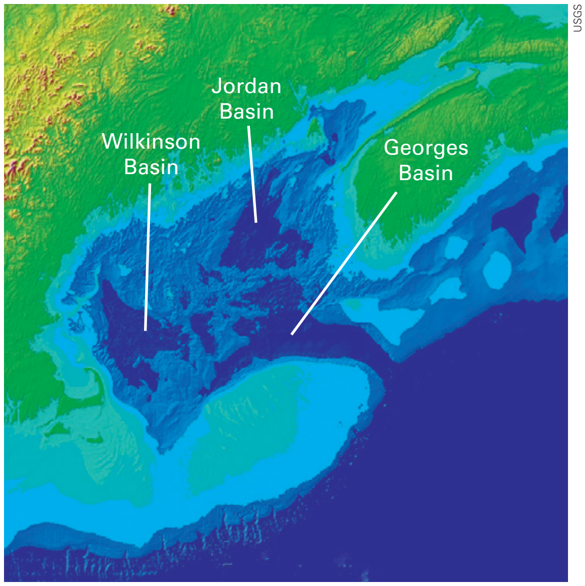
Estuarine Habitats—The Gulf includes more than 59,570 km^2 (23,000 mi^2) of estuarine drainage areas, and the long Maine coast supports the largest number of estuaries. Important examples (listed alphabetically) include Blue Hill Bay, Casco Bay, Cobscook Bay, Englishman Bay, Frenchman Bay, Machias Bay, Merrymeeting Bay, Muscongus Bay, Narraguagus Bay, Passamaquoddy Bay (which straddles the international border), Penobscot Bay, Saco Bay, and Sheepscot Bay. Among the major estuaries in the southwestern part of the Gulf are Massachusetts Bay and Great Bay in New Hampshire. Mud flat, salt marsh, submerged aquatic vegetation, and other estuarine features provide important forage and habitat for coastal and offshore fish populations. Estuaries perform nutrient cycling and primary production, and function as important breeding and feeding grounds for many fish and shellfish populations as well as shorebirds, migratory waterfowl, and mammals. Sheltered areas may support salt marshes at higher tide levels, intertidal mud flats, and seagrass beds and muddy substrates subtidally. Salt marshes and sandy beaches are not as prominent in the Gulf region as they are farther south.

Shallow Marine Habitats (<200 m [656 ft] depth)—The coast of the Gulf of Maine consists of rocky intertidal zones and sand beaches that are important habitats for fishery resources of the Gulf. As with the estuaries, coastal areas are important for nutrient recycling and primary production. Exposed or high-wave-energy habitats with bedrock or boulders support seaweed communities both intertidally and subtidally. Fishery resources, such as American lobster and green sea urchins, may depend upon particular habitat features of the rocky intertidal/subtidal area that provide important refuge sites and nutrient sources.

The productivity of the Gulf is high compared to most other ocean regions of the world, and is due to the combined effects of the Gulf's topography (the depth of the banks and shoals), tides, and climate. There is a rich store of nutrients in the deep waters of the Gulf that are continuously replenished. In the summer, productivity over offshore basins is decreased, while nearshore banks, ledges, and island shores remain productive, particularly in the upper sunlit layers where marine biodiversity reaches a maximum.

The drainage of many rivers contributes an additional abundance of nutrients that also influences productivity. On average, 950 billion liters (250 billion gallons) of fresh water empty into the Gulf each year from more than 60 rivers. The natural productivity of the Gulf itself is also supplemented by the rich productivity of Georges Bank, some of which is exported into nearby parts of the Gulf. Many species migrate into the Gulf to feed upon that abundance of food.

Sediments in the Gulf are highly variable and, when coupled with the vertical variation of water properties found in the Gulf, result in a great diversity of benthic or bottom habitat types. Over 1,600 species of benthic organisms have been described. Sand, silt, and clay are found throughout the Gulf, with the finer sediments generally found in the deeper basins. Rocky substrates (which include



The three basins in the Gulf of Maine.

gravel, pebbles, cobbles, and boulders) are found primarily in the Northeast Channel, with other smaller, more variable rocky areas interspersed in the Gulf. Rocky outcrops form significant features such as Cashes Ledge, and benthic fauna found on these include sponges, tunicates, bryozoans, and hydroids. Along the northeast coast of Maine, the sediments are generally silt and clay, while south of Casco Bay they are largely sand.

The islands of the Gulf of Maine are another defining feature. An archipelago of over 5,000 islands rings the Gulf, creating immense expanses of subtidal habitat.

Oceanic Habitats (>200 m [656 ft] depth)—-Atlantic Ocean water flows as a cold coastal current over the shallows of Browns Bank to enter the Gulf of Maine near Cape Sable. Deeper, nutrient-rich oceanic water also surges tidally into the central basins of the Gulf of Maine through the Northeast Channel.

Ocean water that has entered the Gulf is directed to the northeast toward Nova Scotia and the Bay of Fundy because of the earth's rotation, and then is deflected to the southwest by the northern coast of the Gulf, resulting in a large, counterclockwise circulation called the Gulf of Maine Gyre. The gyre moves surface waters at a rate of approximately 13 km (8 mi) per day, with a single revolution around the entire Gulf taking about 3 months. Circulation is further driven by the phenomenal tides that flood into the Bay of Fundy along its eastern shoreline and then ebb back into the Gulf. Bottom waters in the deep basins also circulate, but more slowly, and it takes about a year for deep Gulf water to cycle through the basin system. Water exits the Gulf primarily through the 75 m (246 ft) deep Great South Channel, between western Georges Bank and Nantucket Shoals. Water also flows out of the Gulf over the eastern portion of Georges Bank.

Jordan, Wilkinson, and Georges Basins, each more than 200 m (656 ft) deep, are the largest basins and deepest habitats within the Gulf of Maine. Their great depths resulted from glacial erosion of relatively soft rocks. In the summer, the water of these basins becomes layered into warm, nutrient-poor surface water; cold, nutrient-rich intermediate water; and cool, high-salinity bottom water. The bottom sediments of these deep basins are generally very fine featureless muds, but some gravel may also be found; little or no sediment transport occurs here. Unique invertebrate communities are found on the seafloor, including deep-sea or cold-water hard and soft corals, fields of sea pens (which are primitive relatives of soft corals), brittle starfish, tube-building amphipods (crustaceans), burrowing anemones, and polychaete worms. Fish found on the floor of these basins include hake and smooth skate.

Georges Bank

Georges Bank is a shallow (3–150 m [10–492 ft] depth) Continental Shelf extension; thus, the only habitat category applicable on the Bank itself is shallow marine (<200 m [<656 ft] depth). The Bank has a steep northern edge and a flat, sloping southern flank. It is separated from the rest of the Continental Shelf to the west by the Great South Channel. The bottom topography of Georges Bank has some distinct characteristics. The easternmost part has a relatively smooth, gently dipping seafloor, while the southeastern margin is steeper, smoother, and incised by submarine canyons. The nature of the seabed sediments varies widely, ranging from clay to gravel.

Strong tidal currents cause vertical mixing on the shallow top of the Bank, resulting in a tidal front separating the colder, well-mixed waters over the Bank from the warmer, seasonally stratified waters on either side of the Bank. There is a persistent clockwise gyre around the Bank; a strong semidiurnal tidal flow predominantly northwest and southeast; and very strong, intermittent, storm-induced currents; all of which can occur simultaneously. The clockwise gyre helps distribute larval fish and other plankton. Georges Bank has a diverse biological community that is influenced by many environmental conditions, and is characterized by high levels of primary productivity and historically high levels of fish production, which includes such species as cod, haddock, and yellowtail flounder.

Oceanic Habitats (>200 m [656 ft] depth)—Submarine canyons occur near the Continental Shelf break along Georges Bank and into the Mid-Atlantic, cutting into the Continental Slope and occasionally up into the shelf as well. The canyons look similar to land canyons, and include features such as steep walls, exposed rocks, and tributaries. They were formed by erosion of sediments and sedimentary rocks of the Continental Margin and are classed as deep (V-shaped from erosion by rivers, mass wasting, and turbidity currents) or shallow (shallowly eroded into the Continental Margin). They exhibit a more diverse fauna, topography, and hydrography than the surrounding shelf and slope environments. The diversity in substrate types tends to make the canyons biologically richer than the adjacent shelf and slope.

The New England Seamount chain is a line of more than 30 ancient, extinct underwater volcanoes located off the Continental Shelf and Slope, running from the southern side of Georges Bank for about 1,100 km (684 mi) to the east/southeast. Only the four westerly seamounts are within the U.S. EEZ. Bear Seamount is the closest and oldest and rises from a depth of 2,000–3,000 m (6,562–9,843 ft) to a summit that is 1,100 m (3,609 ft) below the surface. The minimum depths of the others are: Physalia (1,848 m; 6,063 ft), Mytilus (2,269 m; 7,444 ft), and Retriever (1,819 m; 5,968 ft). Owing to their isolation and diverse landscapes, seamounts harbor many unique and endemic species such as deep-sea corals, and are considered rare habitats in the northeast.

Mid-Atlantic Bight/Southern New England

This region includes all of Delaware, New Jersey, and the District of Columbia, and parts of Connecticut, Maryland, Massachusetts, New York, Pennsylvania, Vermont, Virginia, and West Virginia. The waters of the Mid-Atlantic Bight extend from Georges Bank to Cape Hatteras, and east out to the EEZ, including the Gulf Stream. The Continental Shelf descends gently out to 100–200 km (62–124 mi) offshore, then becomes the Continental Slope between depths of 100–200 m (328–656 ft) at the shelf break. Features of the shelf include valleys and channels, shoal massifs, scarps, and sand ridges. Most valleys are about 10 m (33 ft) deep, with the exception of the Hudson Shelf Valley, which is a 150 km (93 mi) long physiographic feature that connects the Hudson River to the Hudson Canyon. It begins at a depth of approximately 30 m (98 ft) and ends near the head of the Hudson Canyon around 85 m (279 ft) (Butman et al., 2003; Thieler et al., 2007).


NASA

Satellite map of Chesapeake Bay and surrounding area.

Freshwater Habitats—Rivers in the Mid-Atlantic region and Southern New England discharge into the Atlantic Ocean between New York and Virginia, as well as into Long Island Sound south of the New York–Connecticut state line. There are three major watersheds within the Mid-Atlantic region. These are the Chesapeake Bay, the Delaware River, and the Albermarle–Pamlico Sound watersheds. Major rivers that drain into the Atlantic via estuaries include the Connecticut, Hudson, and Delaware; the Susquehanna, Potomac, Rappahannock, York,


NOAA

Jug Bay, in the Chesapeake Bay National Estuarine Research Reserve in Maryland.

and James, all of which drain into Chesapeake Bay; and the Roanoke, Chowan, Pamlico, and Neuse, all of which drain into the Albermarle–Pamlico estuary.

A wide variety of non-tidal freshwater wetlands exists in the Mid-Atlantic region, including marshes and swamps, bottomland hardwood forests, wet meadows, ponds, and bogs further inland. They often occur on flood plains along rivers and streams, along the margins of lakes and ponds, and in isolated depressions in upland areas. Some freshwater wetlands also occur in the freshwater portions of tidal coastal rivers, such as the Potomac, Nanticoke, and Delaware Rivers.

Estuarine Habitats—The estuarine systems from southern New England to the Virginia–North Carolina border include more than 20,176 km^2 (7,790 mi^2) of surface water area. The shoreline along this region is irregular, with wide sandy beaches and extensive coastal and barrier island formations. Freshwater enters the Mid-Atlantic Bight principally through Hudson–Raritan, Delaware, and Chesapeake Bays. Such freshwater inputs contribute to about 70% of the yearly variations in salinity in the Bight, and significantly influence hydrodynamic conditions as well (Manning, 1991). The area ranging from Chesapeake Bay in Virginia to Buzzards Bay in Massachusetts accounts for at least 124,320 km^2 (48,000 mi^2) of estuarine drainage. Chesapeake Bay is one of the largest estuaries in the world and has the largest total drainage area in the region. The Chesapeake receives nearly half of all fresh water flowing into Northeast Region estuaries (Mac et. al., 1998).

As in the Gulf of Maine, coastal and estuarine features of the Bight such as barrier islands, sand beaches, salt marshes, mud flats, and submerged aquatic vegetation are critical habitats for fisheries resources. Salt marshes are found extensively throughout the region, and often occur behind barrier islands. Salt marshes provide nursery and spawning habitat for many important shellfish and finfish species such as blue crabs and summer flounder. Salt marsh vegetation is also a large source of organic material that is important to the biological and chemical processes of the estuarine and marine ecosystems.

Tidal and subtidal mud and sand flats also occur in estuarine areas. Although these areas lack large vegetation, they are highly productive areas that support large wildlife populations and prevent coastal erosion. Sandy beaches are common along the Mid-Atlantic coast, especially on barrier islands. Different zones of the beach present suitable habitat conditions for a variety of marine and terrestrial organisms. For example, the intertidal zone presents suitable habitat conditions for many invertebrates, and transient fish find suitable conditions for foraging during high tide. Several invertebrate and fish species, such as Atlantic surfclams, are adapted for living in the high-energy subtidal zone adjacent to sandy beaches.

Shallow Marine Habitats (<200 m [656 ft] depth)—A great diversity of shoreline types is found along the southern New England and Mid-Atlantic coasts. Pocket beaches (small sheltered areas between rocky headlands) are the dominant shoreline type in Massachusetts, Rhode Island and Connecticut, and along Long Island Sound. Much of the ocean frontage along Cape Cod and from Long Island south consists of sandy beach–dune and/or barrier beach areas.

The Mid-Atlantic region reflects a transition zone between the glacial till, rocky shores, and steep gradients of the New England states and the wide, gently sloping geology of the coastal plains of the southeastern United States. The Mid-Atlantic is a highly diverse zone, often utilized seasonally by many aquatic and terrestrial species.

The coastline of the Mid-Atlantic is typified by elongated complexes of sand spits and barrier islands, which separate the Atlantic Ocean from shallow, and usually narrow, lagoonal bays. The exceptions to this rule are the mouths of large drowned-river-valley type estuaries (e.g. Chesapeake Bay, Delaware Bay, and the Hudson–Raritan Estuary) and the unique back-barrier lagoons of the Albermarle–Pamlico Sound system. Where large river valley estuarine embayments are absent, the mainland is generally protected from the wave-dominated coastal ocean by coastal barrier islands.

The coastal ocean is a shallow environment, nutrient-rich, generally high energy, and productive. The numerous inlets and other passageways for exchange between estuarine and oceanic waters provide an important conduit between systems for a diverse suite of living marine resources, many of which spend significant portions of their lives in either medium, or require a specific habitat type for growth and development during a specific life stage. The opportunity for movement between two very different systems contributes greatly to the biological productivity.

Sediments are fairly uniformly distributed over the shelf, with sand and gravel 0–10 m (0–33 ft) in thickness covering most of it. While the Hudson Shelf Valley and outer shelf areas have finer sands, most areas are dominated by medium to coarse grains. With the exception of the Hudson Shelf Valley and the shelf break, mud is rare over most of the shelf. The shelf break is sometimes called the "mud-line," because fine sediment content (silt and clay) typically increases rapidly beyond this line toward the slope.

Oceanic Habitats (>200 m [656 ft] depth)—The Continental Slope extends from the Continental Shelf break eastward to a depth of 2,000 m (6,562 ft), with a width that varies from 10 to 50 km (6.2–31 mi). The morphology of the Continental Slope is largely the result of sedimentary processes that occurred during the Pleistocene epoch. The slope is cut by at least 70 large canyons between Georges Bank and Cape Hatteras, and numerous smaller canyons and gullies, many of which may feed into the larger canyon systems. As noted above for Georges Bank, the canyons may contain a more diverse fauna than the adjacent shelf and slope.

M. Hollinger, NOAA

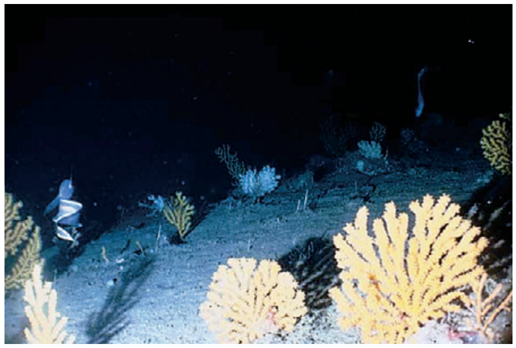
Habitat often includes human-made structures. The Thomas Point lighthouse, shown here, is in Chesapeake Bay, at the mouth of the South River.

Bight shelf and slope waters flow slowly to the southwest, but may be interrupted by Gulf Stream warm core rings or meanders. Slope water tends to be warmer (due to proximity to the Gulf Stream) and more saline than shelf water. The abrupt meeting of these two waters is called the shelf–slope front. The front is usually at the edge of the shelf, reaching the bottom at about 75–100 m (246–328 ft) depths, then sloping eastward and up, reaching the surface about 25–55 km (15–34 mi) further seaward (Stevenson et al., 2004).

Deep-Sea Coral Habitats

There is a great deal of recent interest from both scientists and marine resource managers in deep-sea corals and their habitats. These corals can be found as deep as 6,000 m (19,685 ft), but most commonly occur at 50–1,000 m (164–3,281 ft) depths on hard substrates such as gravel, boulders, and rocky outcrops, as well as on soft substrates. They are a diverse assortment of organisms that include the hard or stony corals, the soft corals and gorgonians, and sea pens. Deep-sea corals can build reef-like structures or occur as thickets, isolated colonies, or solitary individuals. These corals are often significant components of deepwater ecosystems, providing habitat for a diversity of other organisms including many commercially important fish and invertebrate species.

Peter Auster, NOAA



Barbara Hecker, NOAA

Top left: deep-sea coral habitat on Retriever Seamount off New England. Top right: *Paramurecia* coral on a mud-covered rock outcrop at 865 m (2,838 ft) in Oceanographer Canyon, off New England.

Deep-sea corals are often found in the deep canyons along the outer margin of the Continental Shelf and on the slope and rise from Georges Bank to Cape Hatteras, and also occur in the deeper areas of the Gulf of Maine, as noted above. Although their existence has been known for over a century and they are often seen as fisheries bycatch, little has been known about them until recent technological advances in underwater mapping technology and the use of remotely operated vehicles (ROVs) and manned submersibles. These technologies have allowed scientists to begin to map their distributions and abundances as well as collect them for genetic, taxonomic, and life history studies. In addition, habitat suitability modeling is a new and relatively low-cost method to identify potential locations of deep-sea corals and their habitats using presence information only. Associations between deep-sea coral occurrences and pertinent environmental parameters are assessed, and subsequent habitat-suitability maps are then created using various methods. There is concern about their possible critical ecological role as habitat for other species and the threat of anthropogenic impacts on these fragile communities.

Deep-sea corals grow and reproduce at very slow rates, and some are estimated to be hundreds of years old; thus, it takes them a long time to recover from anthropogenic impacts such as bottom trawls.

HABITAT USE

This section contains qualitative descriptions of habitat use for Northeast Region species grouped by fishery management plan (FMP) and by the three protected species groups covered in this report (cetaceans, pinnipeds, and sea turtles). Several state and non-FMP species are also included. Appendix 5 contains a full listing of all species discussed. The Consolidated Atlantic Highly Migratory Species FMP, which includes sharks, tunas, billfish, and swordfish, is discussed in the Southeast Chapter. It should be noted, however, that many of these species also use marine and estuarine habitats of the Northeast Region.

Table 7 provides a summary of typical habitat use patterns in the Northeast Region organized by FMP and protected-species groups of cetaceans, pinnipeds, and sea turtles that are managed by NOAA's National Marine Fisheries Service (NMFS). The table shows patterns of typical use for one or more species within each group. However, it is important to recognize that these groups include many species, all of which have unique habitat requirements by life stage. Habitat information is lacking for many Northeast species, particularly in the earlier life stages, and such critical information gaps are not captured in this table. In terms of the overall availability of habitat information, the most prevalent type in the Northeast is distribution (presence/absence) information for both harvested and protected species. Even at this level, data gaps still exist for some species and specific life stages. Habitat-specific productivity information is rare and often not available for even the most valuable harvested species or for most cetaceans, pinnipeds, or sea turtles.

As the table shows, most federally managed species in the Northeast Region do not use freshwater areas. Only one (8%) of the Region's 13 FMPs, the Atlantic Salmon FMP, has stocks that utilize freshwater habitats, although some forage species, such as river herring, do occur in freshwater habitats. All 13 FMPs have one or more species that use shallow marine and oceanic habitats during one or more parts of their life cycles. Estuarine habitats are also significant in the Northeast, with 11 (85%) out of the region's 13 FMPs having one or more species that use estuarine habitat during one or more parts of their life cycles. Cetaceans, pinnipeds, and sea turtles do not use freshwater habitats in the Northeast Region, but all protected-species groups have species that may be found in estuarine, shallow marine, and oceanic habitats, with specific usage patterns dependent upon species, stock, and life stage.

Table 7
Typical use of the four major habitat categories in the Northeast Region, summarized by FMP and protected-species groups of cetaceans, pinnipeds, and sea turtles.

Habitat use key:
F = Frequent
O = Occasional
N = Never

Fishery management plans [a]	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
1. Atlantic Herring	N	F	F	O
2. Atlantic Mackerel, Squid, and Butterfish	N	F	F	F
3. Atlantic Salmon [b]	F	F	F	F
4. Atlantic Sea Scallop	N	O	F	O
5. Atlantic Surfclam and Ocean Quahog	N	O	F	O
6. Bluefish	N	F	F	O
7. Deep-Sea Red Crab	N	N	O	F
8. Golden Tilefish	N	N	F	F
9. Monkfish	N	O	F	O
10. Northeast Multispecies	N	F	F	F
11. Northeast Skate	N	F	F	F
12. Spiny Dogfish	N	O	F	F
13. Summer Flounder, Scup, Black Sea Bass	N	F	F	O
Total percentage of all Northeast FMPs with one or more species that use each habitat type	8%	85%	100%	100%
Protected species groups [a]				
Cetaceans	N	F	F	F
Pinnipeds	N	F	F	F
Sea Turtles	N	O	O	O
Total percentage of all Northeast cetacean, pinniped, and sea turtle groups that use each habitat type	0%	100%	100%	100%

[a] Appendix 3 lists official FMP titles. Appendix 5 lists the species.
[b] Atlantic salmon are managed as both FMP and protected species, but are listed only once in the table, under the FMP.

Habitat Use by FMP Species

Atlantic Herring—Atlantic herring is a schooling, coastal pelagic species. Herring eggs are usually spawned on horizontal beds at depths of 40–80 m (131–262 ft) on Georges Bank and 20–50 m (66–164 ft) along the Gulf of Maine coast. Eggs are laid on gravel (the preferred substrate), sand, rocks, shell fragments, large algae, and structures such as lobster pots. The larvae are pelagic and free-floating in nearshore and estuarine habitats. Larvae produced in coastal areas of the Gulf of Maine generally remain inshore and disperse in a westerly direction, entering bays and estuaries where they overwinter. Larvae, juveniles, and adults perform extensive vertical migrations in the water column. Juveniles and adults undergo complex north–south and inshore–offshore migrations for feeding, spawning, and overwintering.

Atlantic Mackerel, Squid, and Butterfish—Atlantic mackerel, longfin inshore squid, northern shortfin squid, and butterfish are covered by the Atlantic Mackerel, Squid, and Butterfish FMP. Atlantic mackerel is a fast-swimming, schooling species occupying pelagic nearshore habitat, although a few, especially small ones, often enter estuaries in search of food. They are also found on Georges Bank. The longfin inshore squid is a pelagic, schooling, seasonally migrating species found in offshore, nearshore, bank, and estuarine habitats. The eggs are laid on the bottom in waters generally <50 m (<164 ft) deep and are commonly found attached to rocks and small boulders on sandy/muddy bottom and on aquatic vegetation. The larvae and younger juveniles are pelagic near the surface, whereas older juveniles and adults are found at greater depths, and adults are found over mud or sandy mud bottoms. The northern shortfin

Dann Blackwood, USGS

A small grouping of longfin inshore squid hover over a soft-bottom substrate.

squid is a pelagic, highly migratory species; its primary habitat is the offshore Continental Shelf and Slope waters, with few being found nearshore or in estuaries. Unlike those of the longfin inshore squid, the egg masses are pelagic. Butterfish are fast-growing, short-lived, pelagic fish that form loose schools, often near the surface. They winter near the edge of the Continental Shelf in the Mid-Atlantic Bight and migrate in the spring into Southern New England and Gulf of Maine inshore waters. During the summer, butterfish occur over the entire Mid-Atlantic Shelf, from sheltered bays and estuaries and Georges Bank out to depths of about 200 m (656 ft). In late fall, butterfish move southward and offshore in response to falling water temperatures. Schools are often found over sand, sandy silt, and muddy substrate.

Atlantic Salmon—The Atlantic salmon is a highly prized game and food fish that was once found throughout rivers in the New England area, but self-supporting runs now persist only in the Gulf of Maine and are listed as endangered under the Endangered Species Act (ESA). Atlantic salmon life history is extremely complex owing to the species' use of both freshwater and marine habitats and long ocean migrations. Atlantic salmon spawn in fresh water during fall. Eggs remain in gravel substrates and hatch during winter, and fry emerge in spring. Juvenile salmon, or parr, remain in fresh water for 2–3 years in New England rivers. When parr grow to sufficient size, they develop into "smolts" and migrate to nearshore and offshore pelagic habitats as far away as West Greenland. After one or two winters at sea, the sexually mature salmon return to their natal rivers to spawn and then return to the sea. However, few survive to spawn again.

Atlantic Sea Scallop—The Atlantic Sea Scallop FMP covers the Atlantic sea scallop, a bivalve mollusk often occurring in dense aggregations called beds. Beds may be sporadic (perhaps lasting for a few years) or essentially permanent (e.g. commercial beds supporting the Georges Bank fishery). The larvae are pelagic in offshore, nearshore, and bank habitats and perhaps some estuaries, while postlarvae ("spat"), juveniles, and adults settle onto benthic estuarine, nearshore, and bank habitats and become relatively sedentary. They usually settle on coarse substrates such as gravel, small rocks, and shells.

Atlantic Surfclam and Ocean Quahog—The Atlantic Surfclam and Ocean Quahog FMP concerns two commercially important bivalve mollusks. Commercial concentrations of Atlantic surfclams are found primarily off New Jersey, the Delmarva Peninsula, and on Georges Bank. In the Mid-Atlantic region, surfclams are found from the beach zone to a depth of about 40–60 m (131–197 ft) in sandy bottoms; they are most common in turbulent areas beyond the breaker zone. The larvae are pelagic. The larvae of ocean quahogs are also planktonic until metamorphosis and benthic settlement in nearshore and bank habitats. Juveniles and adults are usually found in dense beds on level bottoms of medium- to fine-grain sand. Quahogs are rarely found where bottom water temperatures exceed 16 °C (61 °F), and they occur progressively further from shore from Cape Cod to Cape Hatteras.

Bluefish—The Bluefish FMP covers just bluefish, which travels in schools of like-sized individuals and undertakes seasonal migrations, moving into the Mid-Atlantic Bight during spring and south or farther offshore during fall. Within the Bight they occur in large bays and estuaries as well as across the entire Continental Shelf, including Georges Bank. Juvenile stages have been recorded from all estuaries surveyed within the Bight, but eggs and larvae occur in oceanic waters.

Advanced sampling technology helps scientists study sea scallops and their habitats in a non-invasive manner

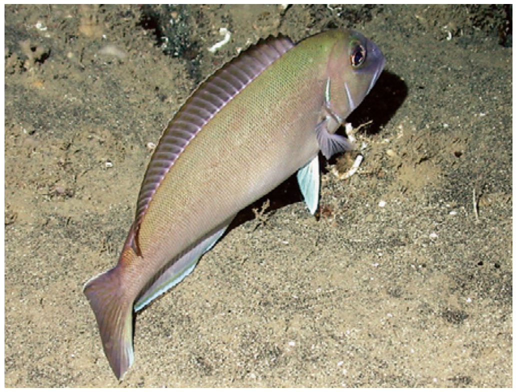
Atlantic sea scallops are one of the most valuable fisheries in the United States. In 2005, scientists started using an advanced sampling technology called the Habitat Camera Mapping System (HabCam) to help study and survey sea scallops and their habitats. Unlike dredge survey methods, which can damage bottom habitats, HabCam collects data in a non-invasive manner. Designed together by fisherman and scientists, Habcam is towed 2–3 m (6.6–9.8 ft) above the seafloor. Rapid photo streams are sent to the ship over a fiber-optic cable—upwards of 500,000 images of the seafloor in a single day.

HabCam images provide a window into species interactions and habitat characterization. These images help scientists understand the behavior of scallop predators like sea stars and whelk, and symbiotic relationships like red hake have with scallops. For example, HabCam photographs reveal that adult red hake are often found in the vicinity of a sea scallop, and are sometimes observed to curl around one. (After their planktonic stage, small juvenile red hake often shelter within the mantle of sea scallops.) While there is a very limited commercial fishery for red hake, the main management implication of the hake's association with scallops is that an increase in scallops gives hake more favorable habitat and probably better survival, especially during juvenile stages. With the new seafloor coverage provided by HabCam, scientists can learn more about scallop populations and much more about what is going on at the bottom of the ocean.

HabCam Group, http://habcam.whoi.edu

HabCam Group, http://habcam.whoi.edu

Left: a close-up of the HabCam before being submersed in the water. Right: a photograph of Atlantic sea scallops on the seafloor taken by the HabCam.



A golden tilefish over sandy bottom habitat.

Deep-Sea Red Crab—The deep-sea red crab (also called red deepsea crab) is distributed along the offshore benthic habitat of the Continental Shelf edge and slope, mostly at depths of 200–1,800 m (656–5,906 ft). Larvae are released into the water column for a typical pelagic existence consisting of several larval stages before settling to the bottom as juveniles. Juveniles and adults live on mostly mud bottoms, and juveniles may move upslope with growth.

Golden Tilefish—The golden tilefish, commonly referred to as tilefish, inhabits the Outer Continental Shelf at depths of 80–440 m (262–1,444 ft). They are generally found in and around submarine canyons, where they occupy burrows in the sedimentary substrates. The larvae are pelagic.

Monkfish—The Monkfish FMP covers this large, slow-growing, bottom-dwelling species that is sometimes called goosefish or anglerfish. The pelagic larvae are found in offshore and nearshore habitat, while the benthic juveniles and adults utilize bank and nearshore bottoms of hard sand, pebbly gravel, mixed sand and shell, and mud. They are infrequently found in estuaries if temperature, salinity, and environmental conditions are suitable.

Northeast Multispecies—The Northeast Multispecies (Groundfish) FMP covers a complex of fourteen species including five flounders (flatfish), three hakes, cod, pollock, redfish, haddock, wolffish, and ocean pout. Most have a pelagic (water column) larval stage that uses offshore, nearshore, and estuarine habitats. Most of these species occur in the Gulf of Maine and on Georges Bank, but several (cod, ocean pout, windowpane and yellowtail flounder, and the hakes) also extend further south into southern New England and the Mid-Atlantic Bight.

Winter flounder inhabit a variety of habitat types in moderate depths. They lay their eggs on the bottom in shallow estuarine and coastal marine waters on a variety of substrates in depositional environments. Witch flounder inhabit deeper water than the other species in this complex. They occur in soft bottom habitats, as do American plaice (a flounder), yellowtail flounder, and three species of hake (red, silver, and white), although these occur in moderate depths. Juvenile and adult windowpane flounder are restricted to nearshore estuarine and coastal waters in relatively shallow, sandy habitats. Early juvenile red and white hakes are common in shallow, nearshore, and estuarine waters, especially where there is eelgrass.

Juvenile Atlantic cod inhabit shallower coastal waters in the Gulf of Maine, but are also common on shallow offshore banks such as Cashes Ledge, where they are seek shelter in kelp. In nearshore waters they are common in eelgrass beds. Older juvenile and adult cod occur offshore in deeper water. Adult pollock are found over a variety of bottom types in deeper water, often in schools, whereas juvenile pollock feed in rocky, vegetated shoreline habitats in the Gulf of Maine. Redfish bear live young and are common in deep water with muddy bottoms, where they are found in association with boulders and structure-forming benthic organisms like sponges and corals. Haddock avoid rocks and muddy bottom, preferring substrates composed of gravel, pebble, shells, and smooth, hard sand. Atlantic wolffish and ocean pout also lay their eggs on the bottom in "nests" in rocky habitats.

Northeast Skates—The Northeast Skate Complex FMP covers seven species of skates: barndoor, clearnose, little, rosette, smooth, thorny, and winter skates. The center of distribution for little, winter, and barndoor skates is Georges Bank and southern New England. The thorny and smooth skates are commonly found in the Gulf of Maine. The clearnose and rosette skates are southern species, occurring primarily in the Mid-Atlantic and off southern New England. Skates are not known to undertake large-scale migrations, but some do move seasonally in response to changes in water temperature, generally offshore in summer and early autumn and inshore during winter and spring. They can be found in various estuaries and nearshore. Several can be found in deeper offshore waters, such as barndoor skate, which occurs down to 750 m (2,460 ft), or thorny skate, which has been found as deep as 896 m (2,940 ft) off of New York. Skates are found over a wide variety of bottom types from soft mud to sand, pebbles, gravel, and broken shells.

Spiny Dogfish—The Spiny Dogfish FMP covers the most abundant shark in the western North Atlantic. It is also one of the most highly migratory species, migrating northward to the Gulf of Maine and Georges Bank in summer and southward in autumn and winter. It are found in estuarine, nearshore, and offshore habitats between North Carolina and southern New England during spring and autumn. The young are born live from eggs in the female's womb.

Summer Flounder, Scup, and Black Sea Bass—The Summer Flounder, Scup, and Black Sea Bass FMP covers these three species. Summer flounder is a flatfish that exhibits strong seasonal inshore–offshore movements. The larvae are pelagic and hatch in nearshore and offshore habitats, and then migrate into coastal and estuarine nursery areas to complete transformation to a benthic existence. Adults and juveniles normally inhabit shallow coastal and estuarine waters during the warmer months of the year and remain in nearshore, offshore, and bank habitats during the fall and winter. Summer flounder estuarine habitats include flats, channels, salt marsh creeks, and eelgrass beds. The pelagic larvae of scup, or porgy, may use nearshore and estuarine habitat, and then eventually settle to the seafloor in coastal and estuarine waters. In summer, juvenile and adult scup are common in nearshore and estuarine waters on sand, silty sand, shell, mud, mussel beds, and eelgrass. In winter, scup are found in nearshore, bank, and perhaps offshore waters at the edge of the Continental Shelf between Hudson Canyon and Cape Hatteras at depths ranging from 70 to 180 m (230–591 ft). The black sea bass is found in warm temperate waters associated with structured bottom habitat (reefs, oyster beds, and wrecks, for example). The pelagic larvae occur in nearshore habitat from late spring to late summer and, as juveniles, settle into nearshore coastal and estuarine waters. Both juveniles and adults move to deeper waters nearshore during winter.

NOAA

A summer flounder camouflaging itself by changing its skin color to blend in with bottom habitat.

Habitat Use by Protected Species

As of 2013, there are 25 marine mammal stocks under the jurisdiction of the NMFS Northeast Fisheries Science Center (NEFSC). Under the Marine Mammal Protection Act, a marine mammal stock can be further categorized as "strategic" if human-caused mortality exceeds the potential biological removal level, if the stock is listed as endangered or threatened under the ESA, or if the stock is designated as depleted. In 2013, seven marine mammal stocks in the region were considered strategic, including the North Atlantic right whale (one of the most endangered whales in the world), humpback whale, fin whale, sei whale, blue whale, sperm whale (all listed as endangered under the ESA), and harbor porpoise. In addition to the marine mammals, three species of fish listed as endangered under the ESA are protected in the Northeast region.

Cetaceans—Cetaceans in the Northeast and Mid-Atlantic are usually migratory, and their distributions and abundances are linked to the seasons and food resources. Many whales, dolphins, and porpoises, such as the North Atlantic right whale, short-beaked common dolphin, and harbor porpoise, use the nearshore waters of New England, Georges Bank, and the Gulf of Maine as feeding areas, and some also use New England waters as a nursery for calves and as a mating area. The coastal form of the bottlenose dolphin

North Atlantic right whales.

occurs from New Jersey to Florida in estuarine and nearshore waters. In the northern portion of its range, they are usually restricted to waters less than 25 m (82 ft) in depth. The stock structure of the coastal bottlenose is complex, as there are multiple stocks that overlap in times and areas, and there are also year-round residents, seasonal residents, and migratory groups. In contrast, the offshore bottlenose dolphin stock appears to be found primarily along the Continental Shelf break in waters deeper than where the coast stock resides. Some other whales and dolphins occurring in the Northeast and Mid-Atlantic are mostly offshore on the Continental Shelf edge and in deeper waters, such as beaked whales, spotted dolphins, and striped dolphins. Other whales and dolphins occur mostly in Canada and are only occasional visitors to northern U.S. waters, such as blue whales and white-beaked dolphins. There also are species such as killer whales that are rare and uncommon, but have been reported in the past in the Gulf of Maine, including Massachusetts Bay.

Pinnipeds—There are four species of pinnipeds found in this region. Harbor seals are year-round residents of the coastal waters of Maine, and occur seasonally along the southern New England to New Jersey coasts from autumn through spring. Breeding and pupping occur primarily in waters north of the New Hampshire–Maine border. The population trend is unknown. Gray seals from Atlantic Canada populations reestablished breeding colonies and year-round residency in New England waters in the 1990s. The largest colony is in eastern Nantucket Sound, and several smaller breeding colonies have been established in Maine. The population appears to be increasing. Although harp seals occur mostly in Arctic waters, sightings and strandings along the northeast U.S. coast occur in January to May, when the population is at its most southern point of migration. The population is increasing in Canada. The hooded seal occurs farther offshore and in deeper waters than harp seals. They are a highly migratory species, with small numbers at the extreme southern limit of their range occurring from Maine to the Mid-Atlantic. The population appears to be increasing in Canada.

Sea Turtles—Five species of sea turtles occur in the Northeast and Mid-Atlantic: green, loggerhead, hawksbill, leatherback, and Kemp's ridley. They range along the U.S. coast as far north as New England and the Gulf of Maine, often traveling north to feed during warmer months, and returning south with cold weather. All are listed as endangered or threatened. All nest primarily on southern or tropical beaches, though nesting occurs as far north as Virginia.

Atlantic Salmon—Critical habitat for the Gulf of Maine Distinct Population Segment of Atlantic salmon ranges from tributaries of the lower Androscoggin River northward to the Dennys River. Native Atlantic salmon populations persist in eight Maine rivers: the Sheepscot, Ducktrap, Penobscot, Narraguagus, Pleasant, Machias, East Machias, and Dennys Rivers. Other watersheds are stocked with donor fish from these populations across three salmon habitat recovery units: Merrymeeting Bay, Penobscot, and Downeast Coastal. The populations of Atlantic salmon present in these rivers represent the last wild remnant populations of U.S. Atlantic salmon. (A discussion of the Atlantic Salmon FMP and general Atlantic salmon habitat use can be found on page 126.)

Atlantic Sturgeon—The Atlantic sturgeon is an anadromous species whose historic range included major estuarine and riverine systems of the entire east coast. In the Northeast Region they migrate upriver in spring to spawn in fresh water. Juveniles and non-spawning adults live in estuaries and shallow nearshore areas with sand and gravel bottoms, but may make long-distance migrations away from their spawning rivers. Areas where migratory Atlantic sturgeon commonly aggregate include Massachusetts Bay, Rhode Island, New Jersey, Delaware, Delaware Bay, Chesapeake Bay, and North Carolina. In February 2012, NMFS listed the Chesapeake Bay and New York Bight Distinct Population Segments as endangered, and the Gulf of Maine population as threatened under the Endangered Species Act.

Shortnose Sturgeon—The shortnose sturgeon is an anadromous fish that occur in most major river systems along the east coast. They live mainly in slower moving riverine waters, estuarine, or nearshore marine waters, and migrates periodically into faster moving freshwater areas to spawn. The species is ESA-listed as endangered throughout its range. In the northern portion of its range, shortnose sturgeon are found in the Chesapeake Bay system; the Delaware River from Philadelphia, Pennsylvania, to Trenton, New Jersey; the Hudson River in New York; the Connecticut River; the lower Merrimack River in Massachusetts; the Piscataqua River in New Hampshire; the Kennebec River in Maine; and the St. John River in New Brunswick, Canada.

Habitat Use by State-Managed and Non-FMP Species

States manage many of the species that primarily inhabit estuaries or nearshore areas, coordinating their activities through the Atlantic States Marine Fisheries Commission and the appropriate fishery management councils.

Crustaceans—Among the most important Northeast crustaceans are the blue crab, northern shrimp, and American lobster. The blue crab is widely distributed in estuaries along the Mid-Atlantic and South Atlantic coasts and also in the Gulf of Mexico. In the Mid-Atlantic it is most abundant in Chesapeake Bay. Distribution within estuaries and associated tributaries varies with the age and gender of the crabs and with the season, but they generally occur on muddy and sandy bottoms at depths extending from the water's edge to deeper waters, but with the greatest abundance in shallower waters. The species tolerates a wide range of salinity. Seagrass beds are important nurseries.

The American lobster is found from Labrador to Cape Hatteras from intertidal to deep waters,

Louise and Tom Kane, NOAA Restoration Center

A young lobster perched on the fingertip of a scientist.

but most commonly in shallower depths. Lobsters have three distinct, planktonic larval stages, all of which are found at the water surface during daylight hours and bright moonlit nights. Postlarvae settle to the bottom and find shelter in cobble and rocks, eelgrass beds, etc., where they generally remain hidden for the first year. With increasing size and maturity, they begin to forage outside their shelters and also move more offshore.

Northern shrimp are distributed throughout the far northern waters of the North Atlantic. They inhabit soft mud bottom habitat, most commonly in the cold, deep basins of the southwest Gulf of Maine. The Gulf of Maine is the southern limit of the species' distribution in the North Atlantic. Spawning occurs in the Gulf of Maine beginning in late July. Egg-bearing females move inshore in late autumn and winter, where the eggs hatch; juveniles remain in coastal waters for a year or more before migrating to deeper offshore waters, where they mature as males, then transform into females at roughly 3 years of age.

Mollusks—Several mollusks support substantial fisheries in the Northeast, including the eastern oyster, softshell clam, northern quahog, bay scallop, and blue mussel. The range of the eastern oyster extends from Canada to Mexico. Its preferred habitats include shallow bays and estuaries. In the Mid-Atlantic, the oyster is most common in Long Island Sound, Delaware Bay, and Chesapeake Bay. The species occurs typically on broad, shallow (2–7 m [6.6–20.0 ft] deep) grounds. Individuals attach to shells in dense clusters to form beds or bars. The softshell clam occurs in eastern Canada and southward into the United States to Chesapeake Bay. This clam has been most abundant in Maine,

NY State Department of Environmental Conservation

An eastern oyster.

Massachusetts, New York, and New Jersey. It occurs both intertidally and subtidally, most commonly in muddy sand where salinities are mostly low. The northern quahog (hard clam) also occurs in eastern Canada and ranges along the entire East and Gulf Coasts into Mexico. The bay scallop occurs in bays from Massachusetts to the mid-coast area of eastern Mexico on sand bottoms commonly covered with eelgrass beds. Both the northern quahog and bay scallop inhabit mostly sand and sand-mud bottoms in salinities above 15 parts per thousand (‰); they often occur in the same bottom habitats. The blue mussel is usually found in dense clusters attached to intertidal and subtidal hard substrates (e.g. rocks) from Maine to Chesapeake Bay. It also occurs on sand, rocks, and shells.

Other Invertebrates—The green sea urchin occurs intertidally and subtidally on hard substrate in or near northwest Atlantic estuaries, usually in salinities greater than 29‰). Horseshoe crabs range from New England to Florida. Although known to occur in deep water on the shelf, they generally prefer shallow depths. During the spring spawning season, adults inhabit areas adjacent to sandy spawning beaches within bays and coves that are protected from wave energy; in the fall, they remain in the bay areas or migrate onto the Continental Shelf. Juveniles inhabit nearshore, shallow-water intertidal flats, migrating to deeper waters as they mature. In areas where they are highly abundant, such as Delaware Bay, horseshoe crab eggs are an important food source for northward migrating shorebirds.

Fishes—Several fish species are important in estuaries and inshore waters of the Northeast Region, particularly shads, certain sharks,[2] white perch, eels, croakers, tautog, striped bass, river herring, and weakfish. The anadromous hickory shad occurs from New York to Florida and spawn from Maryland southward in the fresh waters of coastal rivers. The juveniles leave in late fall to mature in the ocean. The gizzard shad is abundant in tidal fresh and brackish waters, spending most of the year downstream in moderately saline water and migrating upstream to tidal fresh waters to spawn. The threadfin shad is found in large rivers with a noticeable current. The white perch ranges from Nova Scotia to South Carolina. It is a semi-anadromous species, overwintering in the downstream portions of estuarine tributaries and deeper saline waters, and migrating to tidal fresh and slightly brackish waters to spawn.

The American eel is a catadromous species commonly found in estuaries, rivers, and lakes along the Atlantic coast. Adults migrate to the ocean to spawn in the Sargasso Sea. The young migrate to estuaries and freshwater tributaries to mature, occupying shallow shoreline waters, swiftly moving channels, creeks, and large tidal ponds with muddy bottoms. The Atlantic croaker occurs along the coast from Massachusetts to Mexico. It is one of the most abundant inshore fish species, especially along the southeast U.S. Atlantic coast and northern Gulf of Mexico. Adults generally spend the spring and summer in estuaries and move offshore and south along the Atlantic coast in the fall, spawning over shelf waters in fall and winter. They can be found on muddy bottoms and tolerate a wide range of salinities and temperatures. Tautog are often associated with rocky reefs, eelgrass, and mollusk beds, and other areas with significant habitat structure and high salinities.

Striped bass, or rockfish, is one of the most sought-after commercial and recreational finfish from the St. Lawrence River, in Canada, to Florida, in rivers, bays, estuaries, and nearshore areas. Their migratory behavior is very complex, and depends on their age, gender, degree of maturity, and the river in which they were hatched. In late winter and spring, adults move from the ocean into tidal freshwater to spawn, then return to the coast, and most spend summer and early fall in middle New England nearshore waters. In late fall and early winter they migrate south off North Carolina and Virginia. The juveniles move downstream to areas of higher salinity.

River herring is the collective term for alewife and blueback herring. Both are anadromous fishes that spend most of their adult lives at sea, returning to fresh water in the spring to spawn. Alewife are most abundant in the Northeast and Mid-Atlantic,

[2]Many of the same species of sharks are managed federally or by the states, depending on where they are caught (states: 0–5.6 km [0–3 nautical miles {nmi}] from shore; federal: 5.6–371 km [3–200 nmi] offshore). In 2008 the Atlantic States Marine Fisheries Commission adopted an Interstate Fishery Management Plan for Atlantic Coastal Sharks to help complement federal management actions and increase protection for sharks in nursery areas closer to shore.

while blueback herring have a more southerly distribution and are most abundant from Chesapeake Bay south. Alewife spawning migrations begin in the southern portion of their range and move progressively northward as water temperatures warm; they spawn over a wide variety of substrates in rivers, lakes, and tributaries. Blueback herring return to nearshore in late spring about a month later than alewives, and prefer to spawn in swift flowing rivers and tributaries over a wide variety of habitats from late March through mid-May, depending on latitude. Adults of both species migrate quickly downstream after spawning, while the juveniles remain in tidal freshwater nursery areas in spring and early summer; they may also move upstream with the incursion of salt water, but move downstream to more saline waters with declining water temperatures in the fall. While at sea, river herring are highly migratory, pelagic, and schooling; however, little is known about their life history in this environment.

Weakfish occur from Nova Scotia to Florida, but are most abundant from Long Island to North Carolina. During summer, most occur north of North Carolina in nearshore and estuarine waters, where they are often found near eelgrass beds. In the fall, as water temperatures decrease, adults leave the estuaries and begin a southerly, offshore migration to the Continental Shelf between Chesapeake Bay and Cape Lookout, North Carolina, where they overwinter. Spawning occurs during May to September in nearshore areas and the mouths of estuaries. Estuaries provide feeding areas and spawning grounds for adult weakfish and serve as nursery areas for juveniles.

HABITAT TRENDS

One of the major habitat trends in the Northeast Region continues to be nearshore habitat loss and fragmentation. Although losses of freshwater habitats (e.g. rivers) have slowed in recent decades from previous historical highs, due to federal and state regulation of development activities (e.g. dams, dredging), freshwater habitats remain under increasing pressure for development as the human population increases.

USGS

An American eel captured for research purposes.

Freshwater Trends

In the Gulf of Maine watersheds, population growth and land use changes such as urbanization have produced the most visible impacts. Habitat loss and degradation from sprawling development, wetland and associated upland loss, pollution, and other cumulative effects of development threaten the integrity of watersheds. Population in the watersheds is growing rapidly, and the increases are leading to habitat loss. Along the southwestern Gulf coast, agricultural lands have been converted to residential development, and this process extends up to the middle of the Maine coast. In New Hampshire, forested land is being lost to various types of development.

Agriculture (fertilizer, animal wastes), urban stormwater runoff, combined sewer overflows (CSOs), and illegal discharges of untreated sewage are the major sources of organic material, nutrients, and pathogens that contaminate streams and rivers in New England. Point sources of pollution come from industrial plants, such as pulp and paper mills, fish processing plants, textile mills, metal fabrication and finishing plants, municipal sewage treatment plants, and chemical and electronic factories, all of which are found along the Gulf of Maine. Traces of industrial heavy metals such as copper, zinc, iron, and mercury, and organic compounds such as polychlorinated biphenyls (PCBs) and pesticides can be found in some sediments; however, the discharge of these pollutants has decreased to some extent due to pretreatment of industrial wastewater (Pesch and Garber, 2001; Pesch et al., 2011). Other issues include the maintenance of flows in rivers and streams sufficient to

Plymouth Pond Dam, in Maine, is one of several dams that received remedial action as part of the river and stream improvements that accompanied the removal of Edwards Dam.

support aquatic ecosystems, and the atmospheric deposition of nutrients and trace metal pollutants, such as mercury, into water bodies.

All of these issues also affect the Mid-Atlantic area. Urbanization and industrialization in particular have led to habitat loss and degradation. Other stressors of freshwater ecosystems in the Mid-Atlantic area include nutrient enrichment from agricultural and urban runoff, sedimentation, acid deposition (acid rain) and acidification of streams and rivers, mine drainage (a source of toxic chemicals, sedimentation, and in fewer instances acidification), nonpoint sources of toxic contaminants, and decreases in the quality and quantity of riparian habitat.

One major issue common to both regions is the effects of dams and impoundments on fish and other aquatic life. There are thousands of large and small dams in the Northeast and Mid-Atlantic regions. The impacts of a dam can extend over the entire length of the river and beyond, to a regional and watershed level. Dams can irrevocably change the riverine ecosystem by altering the river's natural course and flow, affecting water temperatures, changing the nutrient load, blocking anadromous fish migration, flooding spawning habitat, destroying riparian habitat, and transforming the floodplain and downstream delta wetlands. However, a growing appreciation of the ecological benefits of removing dams and the rapid aging of much of the Nation's dam infrastructure have led to the removal of numerous dams in the Northeast and Mid-Atlantic regions since 1999, when the Edwards Dam on Maine's Kennebec River was deliberately breached. Of the 60 dams removed or slated for removal in 2010, 43 were in the Northeast and Mid-Atlantic states (American Rivers, 2010). Unfortunately this is a tiny fraction of the hundreds or perhaps thousands of obsolete, relic, or abandoned dams that could be removed and the local river and riverine habitat restored or rehabilitated. It is difficult to develop firm numbers, because many smaller dams are undocumented or unregulated; these estimates also apply to functional dams that could be potential candidates for anadromous fish passageways.

Estuarine and Coastal Habitat Loss and Fragmentation

While comprehensive statistics on trends are not available for the Northeast Region, there have been studies at a smaller scale, such as the state or estuary level, that help in assessing habitat status and trends. In addition, Dahl and Stedman (2013) have documented continuing losses of coastal wetlands for the Atlantic Coast as a whole.

Coastal Wetlands—The Northeast Region contains about 15% of the coastal wetlands (freshwater and estuarine wetlands in coastal watersheds) in the continental United States. The most common wetland type in these coastal watersheds is forest scrub, such as red maple swamps. Salt marsh is also a common wetland type, particularly in the southern part of the region (Field, 1991).

Historical salt marsh loss in New England since the late 1700s and early 1800s has been estimated at 37% (Bromberg and Bertness, 2005). Rhode Island has lost the largest proportion of salt marshes by state (53%), and Massachusetts has also experienced large losses (41%) since 1777. A wetland trend analysis by the Connecticut Department of Environmental Protection, using charts and maps from 1880 and 1970, showed some Connecticut towns with over 60% tidal wetland loss. Based on this analysis, the average annual loss rate for Connecticut over this 90-year period was approximately 28 hectares (70 acres) per year. The total loss of wetlands in Connecticut state-wide was estimated at 30% (Rozsa, 1995).

The large-scale destruction of tidal wetlands stopped with the adoption of the Tidal Wetlands Act in Connecticut in 1969 and in New York in 1973. These laws do not prohibit development in tidal wetlands, but rather require individuals proposing to conduct activities in wetlands to obtain authorization from the state agencies (Rozsa, 1995).

Tidal wetland loss is also occurring in the Mid-Atlantic Region. Large sections of Jamaica Bay salt marshes in New York City are disappearing. The relatively recent salt marsh losses may be caused by reduced sediment input, dredging for navigation channels, boat traffic, and regional sea level rise. Historic aerial photographs show that marshes decreased by approximately 12% in size since

1959. Losses in overall island low-marsh vegetation averaged 38% since 1974, though smaller islands lost up to 78% of their vegetation (Hartig et. al, 2002). From 1989 to 2003, the average rate of loss was 13 hectares (33 acres) per year, compared to a fairly consistent rate of approximately 7 hectares (18 acres) per year from 1951 to 1989. It appears that the marsh loss rate started to accelerate rapidly in the 1990s. By 2003, it was calculated, just 37% of the salt marsh islands that had been present in Jamaica Bay in 1951 were left (NPS and NYC, 2007). Projected rates of future sea level rise suggest that these salt marshes will continue to deteriorate, particularly if predictions of accelerated rates of rise turn out to be accurate (Hartig et al., 2002).

A large proportion of the coastal wetlands in the Mid-Atlantic Region is associated with the Chesapeake Bay and Delaware Bay watersheds. Between 1956 and 1979, the estimated net loss of estuarine vegetated wetlands in the Chesapeake Bay watershed was 5,093 hectares (12,585 acres). This net loss decreased between 1982 and 1989 to an estimated loss of 366 hectares (904 acres) of estuarine vegetated wetlands (Tiner et al., 1994). In 2005, tidal wetlands in Chesapeake Bay were estimated to be 114,909 hectares (283,946 acres), though long-term data suggest a declining trend. Non-tidal coastal wetlands are being lost at a higher rate. With human population growth in the Chesapeake Bay watershed greater than 50% since 1950, increasing stress is being placed on the bay system and its wetlands. As an example, impervious surfaces, hard surfaces that do not allow water to pass through, such as roads and sidewalks, increased by almost 101,171 hectares (250,000 acres) during 1990–2000. Restoration, however, plays an important role in reducing wetland losses and increasing available habitat for the bay marine life. In 2011, more than 1,498 hectares (3,700 acres) of wetlands in the bay watershed were restored. This builds on the 5,975 hectares (14,765 acres) of wetlands established during 1998–2010 and goes towards meeting the goal of restoring 12,141 hectares (30,000 acres) and rejuvenating 60,703 hectares (150,000 acres) by 2025 (Chesapeake Bay Program, 2012a).

Subtidal Estuarine Areas—Submerged aquatic vegetation (SAV) in estuaries provides food, shelter, and nursery grounds for many species. Changes or losses in SAV can adversely affect animals dependent on bay grasses. For example, research has documented several habitat and distribution changes in some waterfowl species such as redhead and canvasback ducks. These species are known to feed on bay grasses, and they have shifted from the Chesapeake to other regions as SAV has declined in the bay (Erwin, 1996). Such changes can result in further changes in the food chain and can have ecosystem-level effects. Unfortunately, SAV is very sensitive to disturbance and pollution. Historic levels of SAV along the Chesapeake Bay shoreline were estimated at 80,937 hectares (200,000 acres), based on photographic evidence. Declines of various SAV species in the bay have been estimated or documented at various dates between the 1930s and 1970s, with dramatic reductions observed during 1970–75 (Orth and Moore, 1984). Total acreage of Chesapeake Bay grasses reached a low point in 1984, when coverage was estimated at only 15,378 hectares (38,000 acres) due to factors such as declining water quality, disturbance of SAV beds, and alteration of shallow water habitat. Goals were set in the early 1990s to help restore the bay grasses to historic levels. Total SAV acreage increased in 2000 to over 27,923 hectares (69,000 acres), reaching a high in 2002 of approximately 36,284 hectares (89,659 acres). In 2003 the Chesapeake Bay Program adopted a bay SAV restoration goal of 74,867 hectares (185,000 acres) by 2010. From 2002 to 2011, the bay-wide SAV acreage

NOAA National Estuarine Research Reserve Collection

Wetlands in the North Carolina National Estuarine Research Reserve.

Eelgrass meadows in the Waquoit Bay National Estuarine Research Reserve, Massachusetts.

decreased from 36,284 hectares (89,659 acres) to 25,525 hectares (63,074 acres). During this period, acreage averaged 29,703 hectares (73,399 acres) and ranged from 23,941 hectares (59,160 acres) to 36,284 hectares (89,659 acres) (Chesapeake Bay Program, 2012d). Clearly, reaching the SAV restoration goal in the Chesapeake is proving challenging. In estuaries throughout the rest of the Northeast Region, the loss of SAV continues, often due to an excess of suspended sediment associated with boating and construction. Withdrawal of fresh water for municipal use and nutrient inputs (leading to phytoplankton blooms and excessive algal growth) can also contribute to the loss of SAV.

Eutrophication and Estuaries—Eutrophic conditions throughout the Northeast Region are highly variable. As reported in Bricker et al. (2007), most estuaries in the Mid-Atlantic from Cape Cod to Chesapeake Bay had moderately high or high overall eutrophic conditions and were the most impacted nationally, while estuaries in the North Atlantic from Maine to Cape Cod were the least impacted nationally. In the North Atlantic and Mid-Atlantic regions, conditions are predicted to worsen overall due to such factors as increased nutrient loads in some locations from wastewater, septic tanks, agriculture, and urban runoff, as well as from coastal population increases. Some improvements may occur as a result of factors such as improved stormwater management, restoration of eroding streambeds, sewer overflow improvements, and reductions in upstream nutrient sources (Bricker et al, 2007).

Effects of Fishing Gear

While many factors negatively affect habitat, a major habitat issue in the Northeast Region is the effects of mobile fishing gear, such as scallop dredges and bottom trawls. Mobile gear may cause the loss or dispersal of physical features in the environment such as sand waves, cobbles, boulders, and reefs (National Research Council, 2002). These changes may lead to an overall reduction in habitat diversity, which can lead to the local loss of species productivity and species assemblages dependent upon such features. For example, the loss of attached bryozoan/hydroid turf reduces important fish habitat that provides shelter from predators for juvenile cod and haddock. The loss of structure-forming organisms such as colonial bryozoans, sponges, deep-sea corals, and shellfish beds can also negatively impact species that depend on these structures.

Fishing is known to have had significant impacts on deep-sea coral populations. Deep-sea corals are especially susceptible to damage by fishing gear because of their complex, branching form of growth above the bottom and slowness of regrowth after damage. Of the various fishing methods used, bottom trawling has been found to be particularly destructive.

Fishing gear can have effects on other species besides deep-sea corals. For example, oyster population declines in Chesapeake Bay, Pamlico Sound, and other Atlantic and Gulf of Mexico estuaries are attributed to reef destruction and degradation caused by oyster dredges, among other factors

(Lenihan and Peterson, 2004). In addition, fishing gear, particularly gear that disturbs ocean bottoms, can impact ecologically valuable SAV habitat through factors that include physical disturbance and increases in turbidity (Stephan et al., 2000).

RESEARCH NEEDS

To manage living marine resources using an ecosystem-based approach, it is of prime importance to understand the relationships among species and habitats. Three main objectives must be met to achieve this goal. The first objective is to gain a better understanding of the basic biology and ecology of our living marine resources. For all life stages of a species, detailed information is needed on abundance, distribution, growth, reproduction, and survival rates. This can be achieved by conducting laboratory investigations in conjunction with field surveys, and one focus of such work must be the elucidation of habitat suitability (e.g. importance of a particular habitat for the survival, growth, and reproduction of the associated species) for managed fish species. The second critical objective is to characterize and map habitats. A third, and particularly complex, objective is to document the threats (e.g. fishing gears, chemical contamination, climate change, offshore wind-turbine installations) to habitats, the vulnerability of specific habitats to disturbances, the the ability of habitats to recover following a disturbance, and the impact of such habitat disturbances on the ability to survive, and the productivity of living marine resources. Table 8 presents an overview of habitat-specific research needs for the Northeast Region, with more detailed information and focal areas provided in the text that follows. Ultimately this information is essential for understanding the links between stock productivity and habitat, and for the successful incorporation of habitat data into management decisions and stock assessment processes.

Atlantic Salmon Ecology

Improving the ability to protect threatened and endangered species such as Atlantic salmon is a major research need in the Northeast Region. For example, while freshwater habitat requirements for Atlantic salmon are known, and effects of habitat alteration (e.g. dams, loss and fragmentation of habitat) have been fairly well investigated in relation to this species, non-acute anthropogenic impacts are a major source of uncertainty. Current marine survival rates are very low, and ongoing research is focused on estuarine mortality rates, ocean migration and mortality, and interactions with other anadromous fish populations. Salmon life history has been conceptually broken down into time/space divisions, so as to develop management tools specific to conservation of fish in rivers, estuaries, and the ocean.

Table 8
Overview of research needs for Northeast Region fishery and protected species.

Research Needs	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
Conduct life-history studies (e.g. growth, maturity, and fecundity) for all fishery and protected species, particularly for the early life stages	x	x	x	x
Delineate and map pelagic and benthic habitats	x	x	x	x
Determine effects of invasive species on pelagic and benthic habitats	x	x	x	
Determine habitat suitability for all life-history stages of managed species	x	x	x	x
Expand research on restoring habitats for fishery and protected species	x	x	x	
Improve understanding of the functional roles of pelagic and benthic habitats and the ecosystem services they provide		x	x	x
Improve understanding of the sensitivity of benthic habitats to natural and human disturbances including fishing gear effects	x	x	x	x
Improve understanding of the resilience /recovery of benthic habitats to natural and human disturbances	x	x	x	x
Protect habitats of fishery and protected species	x	x	x	x


NOAA

Paragorgia coral on basalt substrate of a seamount off the New England coast.

In addition, studies are needed in both freshwater and marine environments to better understand the interactions of threatened and endangered species with other species—both introduced and depleted native anadromous fish. For example, studies are needed on predators of salmon that may also prey on co-occurring species, effectively taking some predation pressure off of salmon (this phenomenon is called "prey buffering"). There is also a need to understand competition with small pelagics for forage and other resources. The impacts of environmental changes on the freshwater and marine ranges of this broadly distributed species must also be studied.

Deep-Sea Corals

Deep-sea corals are a species group that requires study in basic biology, habitat mapping and characterization, and an assessment of anthropogenic threats. Basic life history studies on deep-sea corals are required, as there still are fundamental questions about their growth, physiology, reproduction, recruitment, recolonization rates, and feeding. In addition, deep-sea coral habitat biodiversity should be assessed, food web relationships need to be defined, and the role that the corals play in the life histories of associated species should be described and quantified. Also, despite recent mapping efforts, our knowledge of the distribution and abundance of deep-sea corals off the northeastern United States remains severely limited. Mapping these deep-sea coral habitats is a critical research need. More information is also needed on whether the growth, reproduction, and/or survival of coral-associated fish species are affected by the presence or absence of coral. Finally, while it is known that deep-sea corals grow very slowly and recovery of a damaged coral habitat will occur only over long periods of time, a better understanding of the vulnerability or resilience of coral habitats to various anthropogenic threats is needed. This information would help to inform managers on the relative importance of protecting coral habitats, particularly as coral protection relates to biodiversity and productivity of associated living marine resources.

Effects of Fishing Gear on Benthic Ecosystems

The effects of fishing gear on benthic habitats is a topic extensively investigated globally, yet questions still remain, meriting further research. One such question is how and to what extent bottom trawling gear may affect the exchange of material or the "connectivity" between different parts of the seafloor. Does bottom trawling gear promote the spread of species over large areas of the seafloor by resuspending settled eggs and larvae upward in the water column, thereby promoting the dispersal of organisms? Or does the disturbance caused by bottom trawling reduce the suitability of some seafloor habitats for colonization by some benthic organisms, constraining those species' distribution? More research is needed that would show the cumulative effects of repeated tows on the same area of bottom; that is, what is the impact of the initial tow on undisturbed habitat features (physical and biological) compared to the impacts of subsequent tows? More studies are also needed on the recovery times for various bottom types and the impacted organisms therein. These questions, and the question of to what extent these processes might impact living marine resources, remain to be answered by future research. This would be assisted by the creation of designated habitat research areas where fishing is not allowed and such experiments and baseline gear impact studies could be done.

Habitat Mapping

Habitat mapping is another research task strongly needed in the Northeast Region. Mapping usually requires collection of high-resolution acoustic data of the seafloor from sonars, photographic documentation, and samples of the sediments with their associated biota. High-resolution acoustic seafloor mapping capabilities depend on availability of ships with high-resolution multibeam sonar and commensurate data-processing capabilities. Thus, habitat mapping will be limited if adequate ship time and data-processing capacity are constrained. Further, most of the visual observations and sediment sampling completed so far have been conducted by a variety of research groups, who have employed diverse standards for data acquisition and quality control. The result of this piecemeal approach is that cohesive broad-scale sets of data useful for habitat mapping and classification are rare in the Northeast, and no shelf-wide or basin-scale attempts have yet been made at biological habitat classification. However, efforts are being made to foster collaborative efforts to map and classify fisheries habitat. For example, for several years the Gulf of Maine Mapping Initiative, a U.S.–Canadian multiagency effort associated with the Gulf of Maine Council for the Marine Environment, has advocated for coordinating benthic mapping activities in New England. Continued funding, however, is needed to sustain and support such efforts.

Invasive Species

A significant research need in the Northeast Region is a better understanding of the mechanisms of introduction and establishment of invasive, nonindigenous species, and how these introduced species impact native communities. For example, the tunicate *Didemnum vexillum* was first documented offshore during a 2003 NEFSC cruise to Georges Bank, one of the most productive and important areas for Northeast Region marine fisheries, including the scallop industry. This invasive tunicate appears to be spreading across parts of Georges Bank, where scallops thrive, and along the U.S. east coast from Maine to New Jersey (Bullard et al., 2007; Daley and Scavia, 2008; USGS, 2012). Researchers are faced with two challenging questions: first, what caused the sudden appearance and proliferation of this organism offshore? (perhaps sudden changes in oceanic conditions such as temperature?); and second, how is the native biota affected? One major concern is that the tunicate's carpet-like colonies may smother or somehow reduce the size of otherwise thriving, commercially valuable, scallop populations. Laboratory or field experiments will be necessary to assess the potential negative impacts of the tunicate on scallops. Also, since small fragments of these colonies are able to survive and grow, research should be conducted to describe the mechanisms that could promote colony fragmentation and spread of this organism over larger areas. For example, resource managers need to know whether bottom trawling hastens the spread of *Didemnum* by breaking the colonies into small pieces that can be carried with the currents to settle in new, uninfested areas.


D. Blackwood, USGS

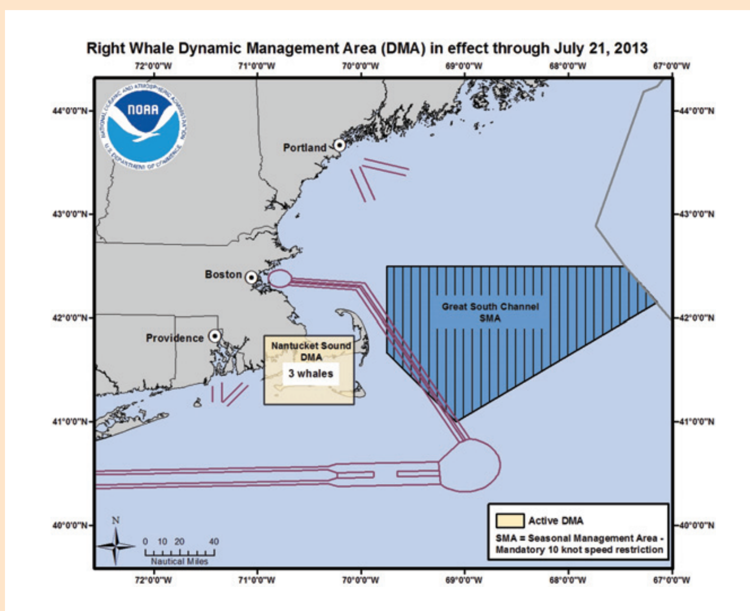
This invasive tunicate *Didemnum* sp. covers scallops as well as parts of the sea floor on Georges Bank in New England.

Oyster Disease Control and Habitat Restoration

In the face of increasing habitat loss and fragmentation, the restoration of habitat is an important research and management task. In response to this need, the NOAA National Sea Grant College Program has made a substantial commitment to support research to combat oyster disease. The ultimate goals are to restore oyster-reef habitat and the valuable ecosystem services it provides, and to rebuild a strong oyster industry. Leffler and Hayes (2003) describe how oysters have been subjected to diverse stresses that have impacted population sustainability and survivability. While

Reducing Ship Collisions with North Atlantic Right Whales

North Atlantic right whales are one of the most endangered whales in the world. They are slow moving and highly vulnerable to ship collisions given that their feeding and migration areas overlap with major East Coast shipping lanes. In fact, each year tens of thousands of trips are made by ships in areas used by right whales. To help reduce the likelihood of collisions between large ships and whales, NOAA worked with the U.S. Coast Guard to develop and propose changes in shipping operations. Some of these measures were endorsed by the International Maritime Organization. One change was to ask operators of large ships to avoid an area in the Great South Channel (off the coast of Massachusetts) where North Atlantic right whales typically feed from April through July. In addition, recommended routes were established in waters off Massachusetts, Florida, and Georgia, and vessel traffic lanes that service Boston were modified. In 2008, restrictions on vessel speed were also put into effect for certain areas and times in which relatively high whale and vessel densities overlap, primarily near port entrances. For more information, please see http://www.nmfs.noaa.gov/pr/shipstrike/ (accessed March 2015).



May 2013 map of ship restrictions related to reducing ship collisions with whales hydrographic variability, overfishing, habitat loss, and pollution have all had great impacts, disease has become one of the most intractable problems. Parasitic protozoans like Dermo and MSX affect oysters in Chesapeake Bay and the Mid-Atlantic region, while "juvenile oyster disease" claims many hatchery-produced oysters in the Northeast. These diseases have devastated the once-flourishing oyster industry and degraded key ecological functions that oysters play in estuarine systems.

Research goals for oyster restoration include the following activities:

- intensifying the current breeding program of disease-resistant oysters to expedite identification of regionally relevant oyster strain(s), while field testing the end products in large-scale resource restoration;
- initiating hypothesis-driven studies that support sustainable use of oyster resources; and
- evaluating oyster restoration and habitat reconditioning techniques.

Oyster reefs provide many important ecosystem services. These services may be ecological (e.g. water filtration in aquatic environments, creation of hard substrate, concentration of contaminants, creation of refugia from predators) or economic (e.g. wild harvest and aquaculture). Oyster reefs provide habitat that promotes the success of other recreationally harvested species, as well as other services that add to the quality of life. Estimating the value of these services in monetary or other terms will require close collaboration between marine researchers and economists.

Protecting Marine Mammals and Sea Turtles from Ship Strikes and Fishing Gear

Finally, a major challenge for the research community in the Northeast Region is improving ways to protect marine mammals and sea turtles from encounters with ships and fishing gear. The factors contributing to gear and vessel interactions vary and are not always known, but habitat-related factors affecting mammal and sea turtle distribution are clearly involved. The NEFSC evaluates bycatch of marine mammals and sea turtles in fishing gear to determine the impact of bycatch on those species, as well as to better understand the habitat, gear, or other factors that contribute to such bycatch. In addition, recent steps were taken to help reduce collisions between large ships and whales along East Coast shipping routes. See the text box on the previous page.

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