Southeast Region

HABITAT AREAS

The Southeast Region encompasses about 12% (1.34 million km^2 [391,000 nmi^2]) of the U.S. Exclusive Economic Zone (EEZ). It includes nine inland states (Arkansas, Iowa, Kansas, Kentucky, Missouri, Nebraska, New Mexico, Oklahoma, and Tennessee) and eight coastal states (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas). It also includes the Commonwealth of Puerto Rico, the Territory of the U.S. Virgin Islands, and Navassa Island (located in the Caribbean Wildlife Refuge). Puerto Rico is located about 1,600 km (1,000 mi) southeast of Florida in the eastern Antilles. It includes the main island, measuring 64 km (40 mi) in width by 177 km (110 mi) in length, and the smaller islands of Vieques, Culebra, and Mona. The U.S. Virgin Islands are 80 km (50 mi) east of Puerto Rico and include St. Thomas, St. John, and St. Croix, and smaller islands. St. Thomas and St. John lie in line with the archipelago chain separating the Atlantic Ocean on the north from the Caribbean Sea on the south. St. Croix, however, lies well to the south, entirely within the Caribbean Sea. Habitat types in the Southeast Region include freshwater, estuarine, shallow marine (including barrier islands, coral reefs, and the Continental Shelf), and oceanic (including the Continental Slope, Loop Current, and Gulf Stream) habitats.

Freshwater Habitats

Fresh water follows three broad watersheds. Water in the Atlantic watershed flows from the lower Appalachian Mountains, piedmont, and eastern coastal plains through North Carolina, South Carolina, Georgia, eastern Florida, and into the Atlantic Ocean. Water flows into the Gulf of Mexico from numerous sources, including the

Maritime slash pine savannah on the state line between Mississippi and Alabama.

Mississippi River, whose vast watershed extends deeply into the continent to the headwaters of the Mississippi, Ohio, and Missouri Rivers, but also including many other smaller sources that drain the piedmonts and coastal plains of western Florida, Alabama, Mississippi, Louisiana, and Texas. Water in the U.S. islands in the Caribbean flows from mountainous and hilly areas across narrow coastal plains to enter the Caribbean Sea or the Atlantic Ocean.

Regardless of the watershed, fresh water always passes through a series of wetland environments that partially cleanse and slow the water's flow. These environments are important economically, environmentally, and ecologically. They vary significantly in physical composition; they are diverse in fauna and flora; but they can still be discussed in three broad habitat categories. The first category, palustrine[1] systems, includes marshy or swampy habitats subject to brief, periodic, or partial flooding. Some palustrine habitats are forested and dominated by hardwood trees, and others are forested and dominated by softwood trees. Still others are non-forested and dominated by scrub, shrub, or emergent vegetation.

In the continental Southeast Region, palustrine forested habitats dominated by hardwood trees typically contain species such as water oak, swamp chestnut oak, willow oak, green ash, sweet gum, ironwood, willows, maples, water hickory, cypress, and water tupelo. Palustrine forested habitats in the continental Southeast Region dominated by softwood trees typically contain species such as pine, sweetbay, loblolly-bay, redbay, Atlantic white cedar, pin oak, and black tupelo. Palustrine non-forested habitats dominated by scrub, shrub, or emergent vegetation in the continental Southeast Region typically contain species such as hollies, fetterbushes, buckwheat-tree, titi, buttonbush, hazel alder, rhododendron, cattail, arrowhead, pickerelweed, and pitcher plant.

Another broad category of wetland habitats is lacustrine systems. These include open bodies of water such as lakes, ponds, marshes, swamps, and sloughs. Lacustrine habitats typically contain rooted, submerged, or floating vegetation, particularly around their shallow perimeters. In the continental Southeast Region, typical species include duckweed, mosquito fern, spatterdock, water lilies, pondweeds, and hornworts.

Riverine systems are the third broad category of wetland habitats. They include flowing bodies of water such as rivers, creeks, and streams that transport fresh water along with an inherent load of suspended and dissolved materials. In the continental Southeast Region, riverine habitats converge into about 30 rivers that transport the majority of runoff to the Atlantic Ocean or the Gulf of Mexico.

Prominent along the Atlantic coast are the Neuse, Roanoke, Yadkin–Pee Dee, Edisto, Santee, Savannah, St. Marys, and St. Johns Rivers. Prominent on the Gulf coast are the Suwannee, Apalachicola, Mobile, Pascagoula, Pearl, Mississippi, Atchafalaya, Sabine, Trinity, Brazos, Guadalupe, and Rio Grande Rivers. These, along with upland tributaries, drain vast expanses of palustrine, lacustrine, and riverine habitats in the eastern and central United States.

Alabama, Arkansas, Florida, Georgia, Ken-

[1]Palustrine systems are transitional and more "marsh-like" (e.g. marshes, swamps, bogs), whereas lacustrine systems are more closely associated with open-water areas like lakes or reservoirs.

tucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee account for almost half (47%, or 19.8 million hectares [48.9 million acres]) of the freshwater and brackish water wetlands in the continental United States. The Mississippi River is the second largest watershed in the world. It accumulates water from over half of the continental United States and delivers about 12.5 million liters (3.3 million gallons) per second into the Gulf of Mexico.

In Puerto Rico, the prominent rivers are the Rio Grande de Loíza, Bayamón, La Plata, Arecibo, Culebrinas, and Añasco Rivers. These create a network of about 1,200 tributaries that drain mountain and other upland areas to the coastal plains. There are no major river systems in the U.S. Virgin Islands, but there are freshwater streams and pools, some forming from heavy rains and disappearing in long dry periods. Neither Puerto Rico nor the U.S. Virgin Islands have large naturally occurring freshwater lakes. Puerto Rico, however, has several manmade reservoirs that provide potable water, irrigation, power, flood control, and aquatic habitats for native and nonnative species.

A variety of species that use marine habitats also rely on freshwater habitats for a part of their life cycle. Some examples include the Atlantic sturgeon, threadfin and hickory shad, striped bass, and American eel. Freshwater habitats face many natural and anthropogenic threats that will be discussed later in the chapter. Because of their importance to many economically and ecologically significant species, it is important to protect and preserve them.

NPS

NMFS

Top: The Mississippi National River Recreation Area. Bottom: An Atlantic sturgeon.

Estuarine Habitats

Estuaries exist along the coast where they receive fresh water from the terrestrial environment and seawater from the ocean. In these habitats of brackish water, the topography is relatively flat; the velocity of freshwater flow nearly stalls against a counter tide from the sea; and detritus, sediments, and nutrients suspended in the water column linger in the embayments to become incorporated into the food web or deposited as part of the estuarine building process. Through the millennia this building process has resulted in the creation of broad, shallow zones of open marsh fringed by shrub, scrub, and forested habitats.

Salinity within these areas transitions somewhat gradually from low in the upland zones to high in the seaward zones; however, the salinity variance and delineation of habitat type result from a very dynamic and fluctuating process. At any point in time dominant habitat types can be determined by a number of variables that include the volume of freshwater inflow, basin topography, tidal range, surface winds, and wave action. This dynamic aspect of estuaries, however, does not reduce their value as habitat. Instead, the variability supports some of the most productive and commercially valuable fishery species in the United States. Rooted vegetation (sedges, rushes, delta duck potato, common reed) is common as well as bottomland forests (bald cypress, willow), marsh grasses (smooth cordgrass, marshhay cordgrass, saltgrass), seagrasses (turtle grass, shoalgrass), and mangroves (red, black, and white).

A variety of reptilian, amphibian, avian, and mammalian species uses estuarine waters and the adjacent coastal habitats for breeding, feeding, migrating, and wintering. But perhaps the most striking use of estuaries is the large diversity of recreationally, commercially, and ecologically important invertebrates and fishes that require


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Mangrove roots provide essential habitat for many species, such as in this mangrove habitat at Elliott Key in Biscayne Bay, Florida.

salinities lower than that of the ocean during part or all of their life cycles. These species include white shrimp, brown shrimp, pink shrimp, blue crab, fiddler crab, horseshoe crab, hard-shell clam (or quahog), American (or eastern) oyster, Atlantic croaker, spot, Atlantic menhaden, Gulf menhaden, red drum, spotted seatrout, sheepshead, and southern flounder.

Along the Atlantic coast, North Carolina's Albemarle–Pamlico Sound is a large lagoonal system of interconnecting sounds behind the barrier islands of the Outer Banks. This is the second largest estuarine system on the East Coast. Fresh water from the Chowan, Neuse, Pasquotank, Roanoke, and Tar–Pamlico Rivers drain into this estuary, which averages 4.1 m (13.5 ft) in depth. The tide range near the inlets is about 0.6 m (2 ft). Wetlands are common along the undeveloped shoreline, and brackish and salt marshes occur within the drainage basin. Blue-green algae dominate the planktonic community in the upper zones, while polychaetes and mollusks dominate the benthic community in the mixing and seawater zones. Other estuaries in North Carolina include the Pamlico River and Pungo River estuary and the Neuse River, Bogue Sound, New River, and Cape Fear River estuaries.

In South Carolina, the Winyah Bay estuary receives fresh water from the Pee Dee and Little Pee Dee Rivers. The average depth is 3.4 m (11 ft), and the tidal range is 1.4 m (4.5 ft) at the inlet. The estuarine habitat supports an array of submerged aquatic and salt marsh vegetation. Diatoms dominate the planktonic community; insects, annelids, and other invertebrates dominate the benthic community. Other large estuaries in South Carolina include the North and South Santee River estuary; the Harbor of Charleston estuary, fed by the Cooper, Ashley, and Wando Rivers; the St. Helena Sound estuary, fed by the Ashepoo, Combahee, and Edisto Rivers; and the Broad River estuary, fed by the Coosawhatchee River.

In Georgia, the Savannah River estuary averages 4.6 m (15.2 ft) in depth. It has a large tidal range of 2 m (6.5 ft) that dominates the inshore salinity regime. The estuary supports a diverse planktonic community in the upper zones, an array of crustaceans and annelids in the benthic zone, and large areas of submerged aquatic and salt marsh vegetation on the periphery. Other estuaries in Georgia include the Ossabaw Sound estuary, St. Catherines and Sapelo Sound estuary, Altamaha River estuary, St. Andrew and St. Simons Sound estuary, and St. Marys River and Cumberland Sound estuary (bordering Georgia and Florida).

In eastern Florida, the estuaries are typically shallow lagoonal systems. The St. Johns River is an elongated system composed of large lakes along most of the river's main stem. It flows gradually northward but can flow in reverse in response to the 1.2 m (4 ft) tidal range at its mouth. Diatoms dominate the planktonic community; annelids, arthropods, mollusks, and other invertebrates dominate the benthic community; and submerged aquatic and salt marsh vegetation occur on the periphery. Other estuaries along the eastern coast of Florida include the Indian River estuary near Fort Pierce and the Biscayne Bay estuary near Miami. Due in part to its southerly location and proximity to the Gulf Stream, the Biscayne Bay estuary supports a semitropical assemblage of soft corals and sponges.

On the western coast of Florida along the Gulf of Mexico, estuaries are more expansive and are characterized by vast mangrove islands, tidal channels, and wetlands. Florida Bay, a shallow lagoonal estuary at the southernmost end of the peninsula, adjoins and receives runoff from Florida's Everglades—a network of subtropical wetlands that once stretched more than 322 km (200 mi) north to Orlando in central Florida. Mangrove islands, mangrove forests, and mainland marshes are common in the bay, and although canals, tidal creeks, and other natural passes interconnect these habitats, the salinity regime remains relatively high, being dominated by wind-driven circulation rather than runoff. Farther up the coast from Cape Romano, the Charlotte Harbor, Sarasota Bay, and Tampa Bay estuaries are dominated by mangroves but include sandy beaches, rocky areas, swamps, and tidal marshes. The Big Bend coast of Florida (from Anclote Key north to Apalachee Bay) is dominated by seagrasses in the shallow, subtidal estuaries and nearshore coastal waters. The Suwannee River estuary at the Big Bend (the junction of the Florida Panhandle with the lower peninsula) has a rugged shoreline indented with wide, shallow pools and large freshwater and tidal marshes. Westward of the Big Bend, estuaries in the panhandle exhibit smooth, sandy frontal beaches of white sand with well-developed dunes and inland lagoonal estuaries.

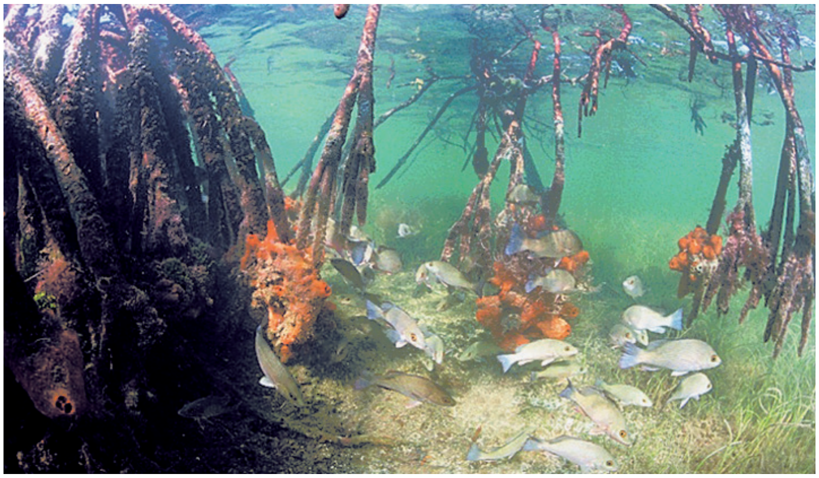
In Alabama and Mississippi, the estuaries are shallow and characterized by mud, sand, and silt deposited principally by the Mobile, Pascagoula, and Pearl Rivers. Additional areas consist of live oysters and banks of dead oyster shells. Sediment type ranges from fine in the upper zones to coarse near the barrier islands. The frontal beaches are developed with white quartz sand. Mobile Bay is the prominent estuary in Alabama. Geologically, it is a drowned river valley that receives extensive freshwater flow from the Mobile and Tensaw River systems draining most of Alabama and parts of Mississippi, Georgia, and Tennessee. Except for the ship channels, the estuary is shallow and the salinity is moderately stratified most of the year. Mississippi Sound, which joins Mobile Bay on its east and Lake Borgne, Louisiana, on its west, is the prominent estuary in Mississippi. Fresh water enters the Sound from the Escatawpa, Pascagoula, Tchoutacabouffa, Biloxi, Wolf, Pearl, and Jourdan Rivers. The sound runs parallel to the coastline and is enclosed behind barrier islands that include Dauphin, Petit Bois, Horn, Ship, and Cat Islands. It also adjoins other coastal estuaries, namely St. Louis Bay, Biloxi Bay, Pascagoula Bay, and Grand Bay.


P. R. Hoar, NOAA/NESDIS/NCDDC

Bayou Heron, in the Grand Bay National Estuarine Research Reserve.

The estuaries of Louisiana are extraordinarily expansive, principally because of the massive estuarine building capabilities of the Mississippi River. Sediment deposited by the river has caused the river's delta to extend well into the Gulf of Mexico. In total, Louisiana wetlands cover about 16,000 km^2 (6,200 mi^2) consisting of about 10,000 km^2 (3,900 mi^2) of marsh habitat and about 6,000 km^2 (2,400 mi^2) of forested wetlands, including mangroves, with some shrub or scrub habitats. (Mac et al., 1998). The wetlands of Louisiana are decreasing, eroding, and sinking due to a combination of natural and anthropogenic factors. Wetland trends will be discussed in more detail later in the chapter.

Large bays, expansive lagoons, and barrier islands characterize the estuaries of Texas. These are typically bordered by broad tidal marshes and mud–sand flats. The Trinity, Brazos, and Guadalupe Rivers provide the primary sources of fresh



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Gray snapper in Biscayne Bay (southern Florida) mangrove habitat.

water, although direct precipitation also contributes significantly. The bays and lagoons usually occur behind chains of barrier islands built upon quartz sand. In southern Texas, the combination of embayed water, low amounts of precipitation and runoff, and high evaporation rates can lead to hyper-saline conditions, particularly during the summer months.

Saline ponds, lagoons, and channels are common along the coast in the U.S. Caribbean Islands. Many of the ponds were created over many years as storm-derived oyster shell and coral rubble, as well as coral growth, gradually formed a partial or complete barrier at the mouth of a large indentation in the shoreline. When ponds are left open to the sea by means of a channel or at high tide, they serve as valuable fish habitat. If completely isolated, they tend to fluctuate greatly in salinity, temperature, and dissolved oxygen, thereby providing less favorable habitat.

Mangrove habitat occurs in subtropical and tropical tidal areas throughout the Southeast Region. Mangroves grow around shorelines of ponds, lagoons, cays, channels, and similar coastal bodies of water. They are found primarily along the coastline of Florida and throughout the Caribbean but also root along portions of Texas and Louisiana shores. The most common types are black mangrove, red mangrove, and white mangrove forests. These trees serve as nesting habitat for migratory waterfowl, songbirds, and shorebirds; and the adjacent open estuarine areas provide an abundance of insects and aquatic invertebrates upon which birds can feed. Mangrove forests stabilize soil against erosion, provide for coastal accretion, and serve as buffer zones against coastal storms. In addition, prop roots of mangroves provide important habitat for numerous economically and ecologically important fish species (e.g. snappers, grunts, parrotfish, and barracuda). It should be noted that mangroves range from estuarine to fully marine habitats, regardless of which section they are grouped under for this chapter.

Shallow Marine Habitats

Shallow marine habitats include a diverse set of habitats ranging from shallow coral reefs to barrier islands to the waters and seafloor of the Continental Shelf. Thousands of species, many of which support valuable fisheries or are protected, rely on these habitats for survival, growth, and reproduction, making protection and conservation of these habitats a priority. Though deep-sea corals can also occur on Continental Shelf habitats, most occur below the Continental Shelf break and will be discussed in the oceanic habitats section.

Coral reefs are one of the primary habitat types found in shallow marine areas of the Southeast Region. Coral reefs are primarily found on rocky areas of the sea bottom and are often dominated by stony, reef-building corals. Corals are considered particularly significant habitats in the Southeast Region because of their inherent diversity of biota; their use by commercial, recreational, and eco-tourism interests; the goods and services provided (e.g. breakwaters and land formation); and their vulnerability to environmental stress and degradation. Species commonly associated with coral reefs number in the hundreds to thousands. The reefs in Florida, Puerto Rico, and the U.S. Virgin Islands encompass a diversity of stony corals, soft corals, sponges, polychaetes, mollusks, crustaceans, echinoderms, fish, turtles, and marine mammals.

Florida's coral reefs are expansive, comprising the third largest barrier coral reef system in the world. This system covers about 3,035 km^2 (1,172 mi^2) and is composed of a mixture of habitat types. These habitat types include nearshore patch reefs, mid-channel reefs, offshore patch reefs, banks or transitional reefs, and deep reefs interspersed with habitats of sand, soft bottom, and seagrass beds. Shallow marine species found in the Florida reefs include staghorn and elkhorn corals (both listed in 2006 as Threatened under the Endangered Species Act [ESA]), star corals, and brain corals. These reef-building corals provide suitable substrate for other colonial species such as soft corals, sponges, tunicates, and algae, and the three-dimensionality of the reefs provides suitable habitat for hundreds of species of marine fish and invertebrates.

On the Atlantic coast, coral reefs in shallow marine habitats exist in a region extending from about Vero Beach southward along the Atlantic side of the Florida Keys to the Dry Tortugas. There are about 60 coral species, subspecies, and forms in the Florida Keys, and these live at depths from less than 1 to 45 m (3–148 ft). Corals from Soldier Key to the Dry Tortugas form important shallow-water reefs that extend to about 13 km (8 mi) offshore. The Florida Keys National Marine Sanctuary, created in 1990, encompasses and protects many of these diverse habitats. The Sanctuary covers 9,600 km^2 (3,707 mi^2), stretching in a southwest arc from the southern tip of Florida and reaching into the Atlantic Ocean, Florida Bay, and the Gulf of Mexico. The Florida Keys National Marine Sanctuary is home to more than 6,000 species of plants, fishes, and invertebrates. The area includes North America's only living barrier coral reef. There are also deepwater bank reefs farther offshore. These banks are typically hard structures composed of calcium carbonate covered with sandy sediments that support benthic fauna and branching corals. Some occur in the Straits of Florida, others off Little Bahama Bank, but most occur on or near the edge of the Continental Shelf and Slope.

Further west in the Gulf of Mexico, the Flower Garden Banks National Marine Sanctuary (named for its brightly colored corals and other reef organisms) is located about 113–185 km (70–115 mi) directly south of the Texas–Louisiana border. In the early 1900s (and still to this day), snapper fishermen could actually see the "gardens" of corals and sponges 15–30 m (50–100 ft) below the surface. The Flower Gardens are perched atop two salt domes rising above the sea floor. The Flower Garden Banks coral reef community probably began developing on top of the domes 10,000–15,000 years ago. The community has thrived sufficiently to obscure all trace of the deformed bedrock on which it developed, forming coral reefs that serve as the basis for a complex, yet balanced, ecosystem, and providing a regional oasis for shallow-water Caribbean reef species. The immense biological diversity and beauty prompted researchers and recreational divers to seek protection for the Flower Garden Banks. In the 1970s they launched what would become a 20-year effort, culminating in 1992 with the designation of the Flower Garden Banks National Marine Sanctuary. The Sanctuary provides habitat to over 20 species of stony corals, over 80 species of algae, over 250 macroinvertebrate species, over 200 species of fish, and loggerhead sea turtles. In October 1996 Congress expanded the Sanctuary to 146 km^2 (56 mi^2) by adding a small third bank, Stetson Bank, which is also a salt dome, located about 113 km (70 mi) south of Galveston, Texas. Because of its location, average temperatures during the winter are several degrees cooler than at the Flower Garden Banks. Consequently, the corals do not thrive and build into reefs. Instead, this bank supports a coral/sponge habitat and rich assemblages of associated animals and plants, where the siltstone bedrock can still be seen in many places.

Joyce and Frank Burek, NOAA Sanctuary Collection

A queen angelfish in the Flower Garden Banks National Marine Sanctuary.

In the U.S. Caribbean, an expansive coral reef habitat exists over a submarine platform surrounding the islands of the Commonwealth of Puerto Rico, and St. Thomas and St. John of the U.S. Virgin Islands. Surveys mapping the reefs to a depth of 20 m (65 ft) have documented a region consisting of four basic habitat types. These include coral reef and colonized hard bottom habitats that cover about 756 km^2 (292 mi^2), seagrass habitat that covers about 625 km^2 (241 mi^2), macroalgae-


USGS

Barrier islands off the Louisiana and Mississippi coastline.

dominated habitat that covers about 97 km^2 (37 mi^2), and mangrove habitat that covers about 73 km^2 (28 mi^2). Large areas of non-structured sand exist in the area as well. Coral reefs also exist in St. Croix of the U.S. Virgin Islands; the eastern end of this island is a barrier reef. Surveys in the U.S. Virgin Islands to a depth of 21 m (70 ft) have mapped a region measuring about 906 km^2 (350 mi^2). The region includes fringing reefs, deep-wall reefs, shelf-edge reefs, and patch reefs. Also, there are biologically productive reefs (bank and scattered patch reefs) in deeper waters offshore.

Barrier islands are another type of important and unique shallow marine habitat in the Southeast Region. Several chains of barrier islands extend nearly 3,000 km (1,864 mi) along much of the continental coast. The islands take the form of elongated sections of land, roughly located end-to-end along the coastline, from North Carolina through Texas. Individual islands are composed of unconsolidated sand, shell, and gravel that have been deposited and redeposited through erosion and accumulation by prevailing oceanic currents, winds, and storms. Many barrier islands exhibit frontal sand dunes and serve as buttresses for the estuaries, protecting against the natural forces of oceanic currents, onshore winds, waves, tides, and tropical storms. They also provide valuable habitats that include salt marsh on the bay sides, marine beach on the seaward sides, and freshwater and brackish marsh within the larger islands. Geologically, they are dynamic, constantly changing shape in response to the effects of wave, wind, and tidal action that causes marine sediments to drift along the shoreline.

Beyond the barrier islands in the Southeast Region is the Continental Shelf—a broad submerged platform that forms the rim of the Atlantic Ocean and Gulf of Mexico. A similar but narrower shelf also exists around each of the U.S. Caribbean Islands. Typically the shelf deepens gradually from the coast to depths of about 200 m (656 ft). It then declines sharply, forming the Continental Slope. The Continental Shelf in the Gulf of Mexico is particularly wide, occupying about 30% of the total area of the Gulf. In geological times it was predominantly a carbonate platform, but during the Cretaceous period the northern and western regions of North America began uplifting from tectonic forces. The subsequent erosion formed sediments that were transported by runoff and deposited over the western and northern areas of the shelf.

The Continental Shelf around the lower peninsula of Florida, however, did not receive similar quantities of silting and has remained more carbonate in composition. Consequently, it still supports extensive coral reef and hard bottom communities, as previously described. Northward along the Atlantic, the shelf again becomes more alluvial[2] from sediments that have accumulated from erosion and deposition from the piedmont and coastal plains. Wherever firm substrates occur on the shelf or slope, a diverse assemblage of sessile, reef-type organisms has developed. Such habitats—depending on their location, water temperature, substrate, and fauna—are called live bottom, hard bottom, or coral reef. These bottom types characteristically support the growth of sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, and corals. One example of the nearshore live bottom reefs in the Southeast Region is Gray's Reef National Marine Sanctuary. This Sanctuary is located off the coast of Georgia and covers approximately 57 km^2 (22 mi^2).

Not all reefs are naturally occurring. For ex-

[2]Alluvial sediment typically refers to sediment such as clay, silt, or gravel transported by flowing water (e.g. streams) and deposited where the water flow slows.

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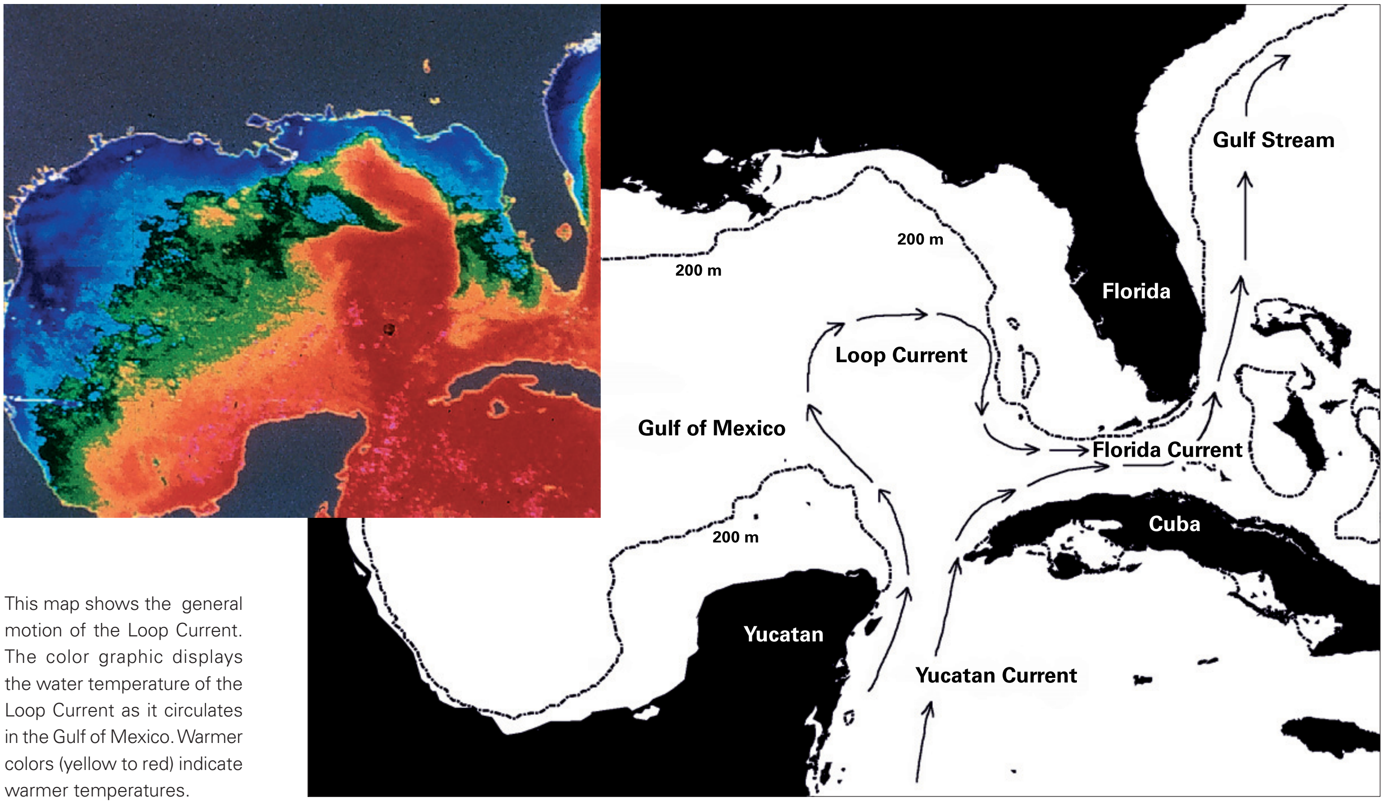


This map shows the general motion of the Loop Current. The color graphic displays the water temperature of the Loop Current as it circulates in the Gulf of Mexico. Warmer colors (yellow to red) indicate warmer temperatures.

ample, the Gulf of Mexico has many man-made artificial reefs, formed by thousands of offshore petroleum platforms and wrecks that serve as suitable hard substrate for the attachment and growth of benthic, sessile organisms. Artificial reefs, like naturally occurring ones, attract a diverse assemblage of invertebrate and vertebrate species. The famous wreck of the USS *Monitor*, which sank during the Civil War in 1862, has become a productive artificial reef used by organisms like black sea bass and great barracuda. The Monitor National Marine Sanctuary now protects this historic shipwreck site located off the coast of Cape Hatteras, North Carolina, to preserve its cultural, archaeological, and ecological significance.

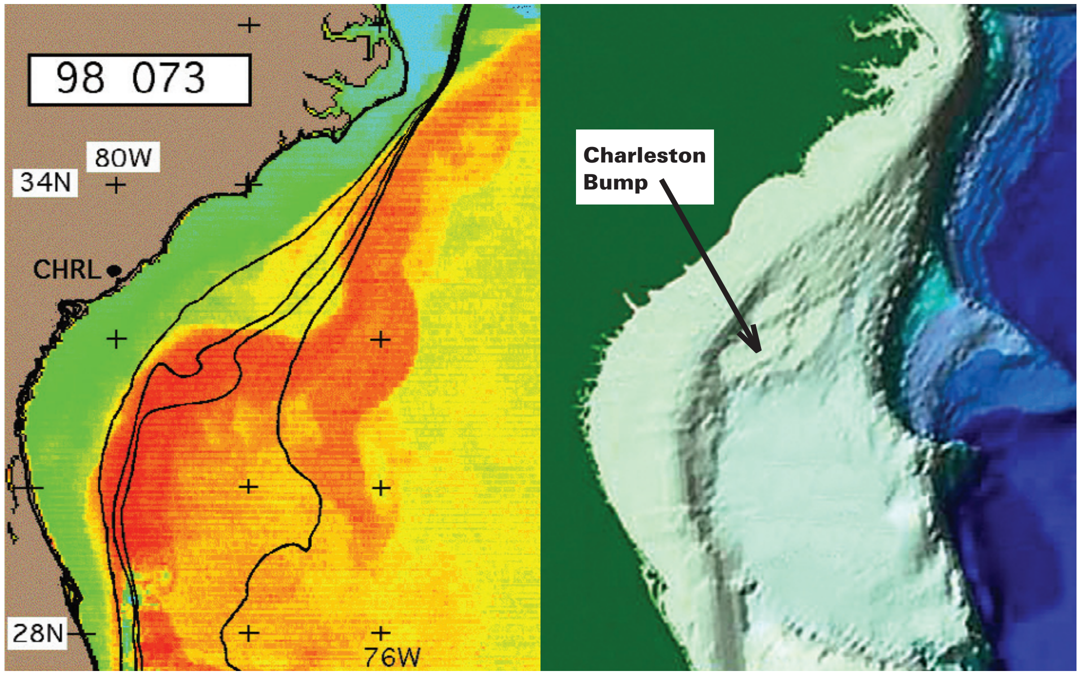
Limited coastal plains, narrow shelves, constant temperature gradients, oligotrophic waters, and sparse zones of upwelling characterize many shallow marine habitats of the U.S. Caribbean Islands and Navassa Island. Among these, St. Croix in the U.S. Virgin Islands and Mona Island in Puerto Rico, both of which are surrounded by very deep waters, have particularly narrow shelves.

Oceanic Habitats

Southeast Region oceanic habitats begin at a bottom depth of 200 m (656 ft), typically near the upper margin of the Continental Slope. Many of the same physical characteristics and biota of the shelf can be found along the upper slope. As the water deepens, plants gradually disappear and animal populations change to those adapted to dark and colder environments.

The Loop Current flows somewhat like a river through the Gulf of Mexico. The Gulf is actually a semi-enclosed oceanic basin with a surface area of about 1.5 million km^2 (0.58 million mi^2) and an average depth of 1,615 m (5,299 ft). It is bounded on the north and west by North America, and on the west and south by Mexico and Cuba. It is connected to the Caribbean Sea by the Yucatan Channel on the south, and to the Atlantic Ocean by the Straits of Florida on the east.

Through the Yucatan Channel—a relatively deep (1,850 m [6,069 ft]), narrow passage between the Yucatan Peninsula and the western edge of Cuba—the warm, saline Loop Current flows



Satellite image (left) showing the warm water of the Gulf Stream (orange color) flowing northward along the coast of South Carolina and deflecting eastward by the Charleston Bump (right).

northward into the Gulf. Sometimes the current turns eastward soon after passing through the channel, but other times it penetrates as far north as the Continental Shelf along Louisiana, Mississippi, and Alabama. The hydraulic activity at the northern boundary of the current promotes an upwelling of nutrient-rich waters towards the euphotic zone, thus promoting primary productivity in localized areas near or above the shelf. It has been estimated that the current annually provides three times as much nitrogen (a key nutrient supporting primary productivity) to the region as does the Mississippi River.

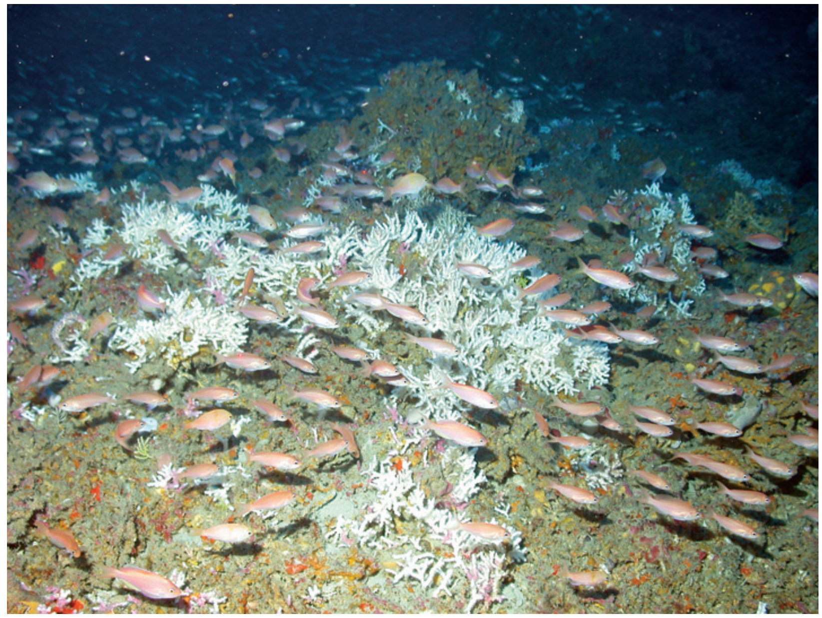
When the Loop Current is north of latitude 27° N, it occasionally bifurcates to produce large eddies measuring 300 km (186 mi) or more in diameter. These rings of high-salinity water break off from the main current and drift westward of the Mississippi River Delta along the northern and western Continental Shelf of Louisiana and Texas. They disintegrate over a period of months, but during this time they gently sweep inshore waters across the shelf. They provide upwelling in the euphotic zone; affect the nutrient, temperature, and salinity regimes above the shelf; and create prime spawning habitat for many commercially and recreationally important species.

The main stream of the Loop Current turns eastward, usually producing numerous eddies, meanders, and intrusions along its northern boundary off Louisiana, Mississippi, Alabama, and Florida. These aberrations produce upwelling, trap high-chlorophyll coastal waters, and provide a transport mechanism for planktonic stages of fauna and flora Researchers have found eggs and larvae representing over 100 families of fish. Eventually many of these fish will enter estuaries as early juveniles to reside in lower-salinity, nutrient-rich waters until they mature enough to join adult stocks offshore.

Once the Loop Current exits the Gulf through the Straits of Florida, north of Cuba and south of the Florida Keys, it becomes known as the Gulf Stream. The warm flow, however, does not immediately mix with the cooler oceanic waters of the Atlantic. Instead, it acts as a river through the ocean as it meanders along the eastern seaboard to Cape Hatteras, North Carolina, where it turns seaward on a transoceanic path to Europe. Sometimes the stream branches to form smaller courses of warm water that extend onto the Outer Continental Shelf of the Atlantic coast. These can create partial or continuous gyres, of which the Charleston Gyre is an example. The Charleston Gyre is a permanent oceanographic feature of the South Atlantic Bight (off North Carolina and Florida) and is formed by the stream striking the Charleston Bump (an irregular, solid formation that rises from a depth of 700 m to 300 m [2,300 ft to 980 ft] on the Blake Plateau). The angle of the bump deflects some of the flow into the Charleston Gyre, causing upwelling in the bight. The degree of upwelling, however, varies with the seasonal position and velocity of the stream.

In the central North Atlantic Ocean (within latitude 20° to 35° N and longitude 30° to 70° W) a large oceanic gyre, known as the Sargasso Sea, occurs. The Sargasso Sea is relatively reduced in biota; nevertheless, it is considered the likely spawning grounds of European and American eels, which travel to their respective continents to mature in freshwater habitats and then apparently return to the Sargasso Sea to spawn. The Sargasso Sea is also abundant in two species of *Sargassum*, a large floating form of brown algae. *Sargassum* also occurs over the Continental Shelf and, depending on prevailing winds and currents, may remain on the shelf, become entrained into the Gulf Stream, or cast onto shore. It exists as irregular mats but can become scattered in small clumps. In either form it serves as important habitat that supports many marine organisms, including fungi, microepiphytes, macroepiphytes, invertebrates, sea turtles, fish, and marine birds.

Deep-sea corals are found in oceanic habitats of the Southeast Region and provide important habitats for many fish and invertebrates. Deep-sea corals are typically found below 50 m (164 ft) and lack symbiotic algae (zooxanthellae). They can reach depths of over 2000 m (6,562 ft) and are found on shelf and slope habitats, though most occur beyond the shelf break. Deep-sea corals are long-lived and slow-growing organisms that are often "hot-spots" for biodiversity in the deep ocean. Within U.S. waters, deep-sea stony coral reefs reach their greatest abundance and development in the Atlantic at depths from 200 to 1000 m (656–3,281 ft) on the Continental Slope and Blake Plateau, from the Carolinas through the Straits of Florida (Lumsden et al., 2007). These habitats are dominated by the coral *Lophelia pertusa*, and are home to a rich invertebrate fauna. Similar habitats also occur in a patchy distribution on hard substrates in the Gulf of Mexico. The shallower Oculina Banks off east-central Florida are home to the only deepwater reefs of the ivory tree coral (*Oculina varicosa*) found in the world, and provide habitat for valuable fish species such as groupers, snappers, and invertebrates (Barnette, 2006). The Oculina Habitat Area of Particular Concern (HAPC) was the world's first marine protected area designated to protect deep-sea corals. In 2010, NOAA and the South Atlantic Fishery Management Council designated deepwater Coral HAPCs totaling 62,717 km^2 (over 24,000 mi^2) to protect complex deep-sea coral habitats.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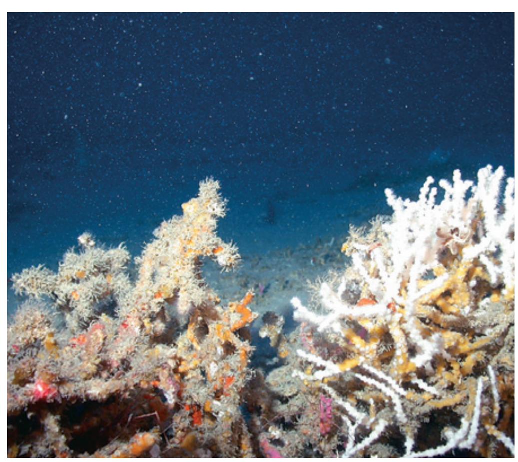
South Atlantic Fishery Management Council

Top photo: *Oculina* coral habitat and a school of fish. Bottom photo: closeup view of *Oculina* coral.

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U.S. Coast Guard

HABITAT IMPACTS OF THE *DEEPWATER HORIZON* OIL SPILL

On 20 April 2010, the *Deepwater Horizon* oil platform exploded 66 km (41 mi) off the Louisiana coast in the Gulf of Mexico, killing 11 crew members. Two days later the rig sank, giving rise to the largest oil spill in U.S. history. By the time the leaking well was capped, almost 3 months later, millions of barrels of oil were released directly into the Gulf of Mexico from the failed blow-out preventer at the well head, about 1.6 km (1 mi) below the surface. Response to the spill included the use of over 1 million gallons of chemical dispersants deployed at the surface and at depth.

NOAA provided scientific expertise and information from across the agency, including spill trajectory maps, forecasts of weather and ocean currents, satellite images, surveillance flights to assess vulnerable stocks of marine mammals and sea turtles, and ship-based sampling to evaluate impacts to fishery stocks and contaminant effects on seafood. NOAA's National Marine Fisheries Service also provided timely fishery closures to ensure that seafood harvested from the Gulf remained safe and wholesome.

Under the Oil Pollution Act of 1990, a Natural Resource Damage Assessment (NRDA) is the legal process of evaluating the nature and extent of injuries to natural resources held in trust on behalf of the public, and determining the type and amount of restoration needed to compensate the public for natural resource injuries resulting from an oil spill. NOAA is a lead federal trustee for protection and restoration of coastal and marine natural resources. The natural resource trustees are developing a Programmatic Environmental Impact Statement to identify restoration types and establish procedures to expedite the selection and implementation of restoration projects.

The *Deepwater Horizon* Oil Spill NRDA is by far the largest ever conducted. Given its geographic size, three-dimensional nature, and ecological complexity, the assessment may continue for years. The state and federal trustees will continue working to determine how the oil spill affected the Gulf of Mexico's natural resources and the human use of those natural resources. The trustees have completed or are participating in more than 100 NRDA investigations spanning every major resource category.

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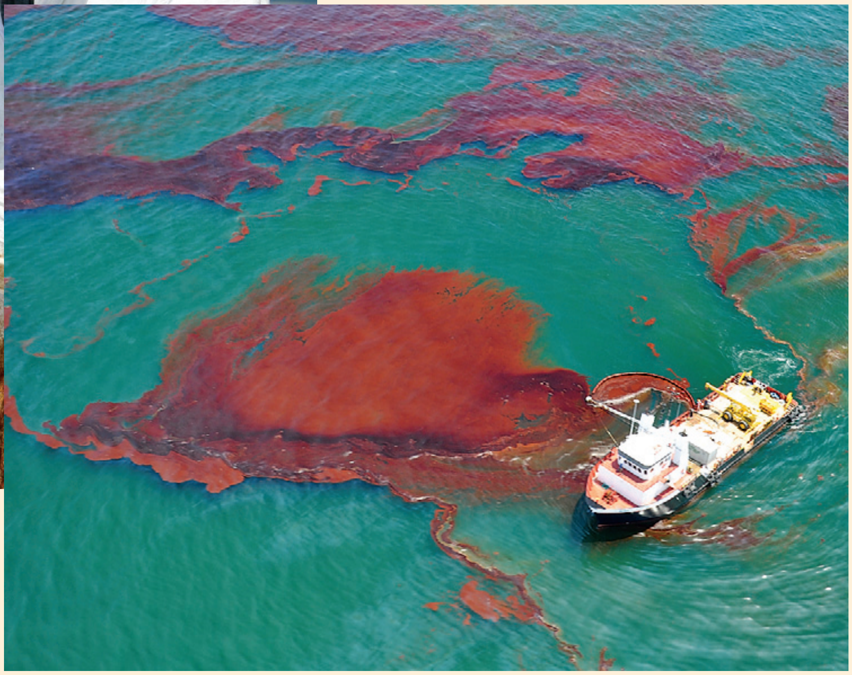

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Photographs from the *Deepwater Horizon* explosion and aftermath, left to right: an oiled beach on the North Chandeleur Islands, off the Louisiana coast; the *Deepwater Horizon* platform in flames; a Kemp's ridley sea turtle covered in oil; and a ship skimming oil from the sea surface.

The work plans that direct these efforts and the bulk of the associated verified data are made available to the public at: www.gulfspillrestoration.noaa.gov/gulf-spill-data (accessed March 2015).

The restoration process consists of three main steps: 1) Pre-assessment, in which it is determined whether injury to natural resources has occurred; 2) Restoration Planning (including Injury Assessment) in which studies are conducted to quantify natural resource injuries, and a restoration plan is developed; and 3) Restoration Implementation, during which restoration projects are implemented and monitored for effectiveness. The responsible party is liable for the assessment and restoration costs. Early restoration plans (Phase I and II) and 10 early restoration projects have been approved. Restoration projects proposed in all five Gulf states intend to provide services that will benefit impacted marshes, coastal dune habitats, nearshore habitats, oysters, nesting birds, nesting sea turtles, and human use of natural resources.

On 6 July 2012, the Resources and Ecosystem Sustainability, Tourism, Opportunities Revived Economies of the Gulf Coast States Act of 2012 was signed into law by President Barack H. Obama. The law creates an essential framework to manage and finance the Gulf Coast's recovery and establishes a trust account with 80 percent of Clean Water Act penalties from the spill to be reserved for Gulf Coast restoration. In addition, British Petroleum (BP), the U.S. Department of Justice, and the Securities and Exchange Commission have agreed on a settlement associated with the oil spill. BP has pleaded guilty to criminal charges and agreed to $4.5 billion in fines, more than half of which will be dedicated to restoration efforts in the Gulf Coast.

Links for additional information (accessed March 2015):
http://www.noaa.gov/deepwaterhorizon/index.html
http://www.gulfspillrestoration.noaa.gov/assessment/
http://www.gulfspillrestoration.noaa.gov/media-center/publications/ (specifically NRDA Status Update April 2012)
http://www.gulfspillrestoration.noaa.gov/restoration/early-restoration/
http://www.restorethegulf.gov/sites/default/files/documents/pdf/OilBudgetCalc_Full_HQ-Print_111110.pdf

HABITAT USE

This section contains a qualitative description of habitat use for Southeast Region species grouped by fishery management plan (FMP) and by protected species. 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 is included in the Southeast Region, although these species can occur in the Northeast at least during warmer months. Table 9 provides a summary of typical habitat use patterns in the Southeast Region, organized by FMP and the protected-species groups covered in this report (cetaceans, pinnipeds, and sea turtles). There are 18 total FMPs in the Southeast, though the table does not include the Aquaculture FMP, so 17 FMPs are summarized.

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 Southeast species, particularly in the earlier life stages, and such critical information gaps are not captured in this table.

Table 9
Typical use of the four major habitat categories in the Southeast Region, summarized by FMP and by protected-species groups of cetaceans, pinnipeds, and sea turtles. (Some FMPs have habitat use broken out by subgroups of similar species. In these cases, the subgroups are listed below each numbered FMP. [a])

Habitat use key:
F = frequent
O = occasional
N = never

Fishery management plans [b]	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
1. Coastal Migratory Pelagics of the Gulf of Mexico and South Atlantic	N	F	F	F
2. Consolidated Atlantic Highly Migratory Species [c]	O	F	F	F
Billfishes, Tunas, and Swordfish	N	N	O	F
Small Coastal Shark Complex	N	F	F	N
Large Coastal Shark Complex	O	F	F	F
Pelagic Shark Complex	N	N	F	F
Prohibited Species	N	F	F	F
Deepwater Shark Data Collection Complex	N	O [d]	F	F
3. Coral, Coral Reefs, and Live/Hard Bottom Habitats of the Gulf of Mexico	N	O	F	O
4. Coral, Coral Reefs, and Live/Hard Bottom Habitats of the South Atlantic Region	N	O	F	O
5. Corals and Reef Associated Invertebrates of Puerto Rico and the U.S. Virgin Islands	N	O	F	O
6. Dolphinfish and Wahoo	N	N	F	F
7. Golden Crab, South Atlantic	N	N	N	F
8. Pelagic *Sargassum* Habitat of the South Atlantic Region	N	O	F	F
9. Queen Conch Resources of Puerto Rico and the U.S. Virgin Islands	N	O [e]	F	N
10. Red Drum, Gulf of Mexico	O	F	F	N
11. Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands [c]	N	F	F	F
Shallow-water Snappers/Groupers	N	F	F	F
Deepwater Snappers/Groupers	N	N	F	F
Semi-pelagic Species	N	O	F	F
Other Reef Rishes	N	O	F	F
12. Reef Fish Resources of the Gulf of Mexico [c]	O	F	F	F
Shallow-water Snappers/Groupers	O	F	F	F
Deepwater Snappers/Groupers	N	O	F	F
Semi-pelagic species	N	N	F	N

(table continued on next page)

Table 9
(continued)

Habitat use key:
F = frequent
O = occasional
N = never

Fishery management plans [b]	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
13. Reef Fish, South Atlantic [c]	O	F	F	F
Shallow-water Snappers/Groupers	O	F	F	F
Deepwater Snappers/Groupers	N	N	F	F
Semi-pelagic Species	N	O	F	F
14. Shrimp, Gulf of Mexico	N	F	F	F
15. Shrimp, South Atlantic	N	F	F	O
16. Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands	N	F	F	O
17. Spiny Lobster, Gulf of Mexico/South Atlantic	N	F	F	O
Total percentage of all Southeast Region FMPs with one or more species that use each habitat type	24%	88%	94%	88%
Protected species groups [b]				
Cetaceans	N	F	F	F
Pinnipeds	N	N	O [f]	N
Sea Turtles	N	F	F	F
Total percentage of all Southeast Region cetacean, pinniped, and sea turtle groups that use each habitat type	0%	67%	100%	67%

[a] Four of the Southeast Region's larger FMPs (the Consolidated Highly Migratory Species FMP and three reef fish FMPs [Caribbean, Gulf, and South Atlantic]) are broken down into subgroups to describe habitat-use patterns for similarly managed species. Overall habitat-use ratings for each of these four FMPs represent the combined habitat-use ratings for each of the FMP's subgroups.

[b] Appendix 3 lists official FMP titles. Appendix 5 lists the species.

[c] This FMP contains subgroups of species categories (indented), listed here to provide additional information. The data entries for the FMP represent the summation of all data for the subgroups.

[d] Only one species in the "Deepwater Shark Data Collection Complex" category, the smooth dogfish, frequently uses estuarine habitats.

[e] It is possible to find conch in estuarine areas but the limiting factor for conch is bottom type, rather than salinity.

[f] Harbor seals may occasionally be found in Southwest Atlantic waters, spending winter months in areas as far south as North Carolina.

As the table shows, federally managed species in the Southeast Region primarily rely on estuarine, shallow marine, and oceanic habitats and typically do not use freshwater areas on more than an occasional basis. Only four FMPs (24%) have species that use freshwater habitats on an occasional basis. These include the Consolidated Highly Migratory Species FMP (specifically some large coastal sharks), some of the reef fish FMPs, and red drum (Gulf of Mexico). No cetaceans, pinnipeds, or sea turtles in the Southeast rely on freshwater habitats, although manatees, protected by the U.S. Fish and Wildlife Service, occur in fresh water. Shallow marine habitats are the most-used by the Southeast's FMP, cetacean, pinniped, and sea turtle species. In terms of habitat information, the most prevalent type in the Southeast is distribution (presence/absence) information for both harvested and protected species, though data gaps still exist at even this low level of information for some species and specific life stages. Habitat-specific productivity information, however, is not available for most of the species in the Southeast Region (harvested or protected).

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A loggerhead sea turtle swimming near Panama City, Florida.


NOAA

Sunlight on a school of bluefin tuna swimming near the surface.

Habitat Use by FMP Species

The Southeast Region has a particularly broad array of species, and they occur in several areas. Three fishery management councils (FMC) manage the federal fishery resources in the Region. They include the South Atlantic FMC, Gulf of Mexico FMC, and Caribbean FMC. (The Mid-Atlantic FMC is responsible for some migratory species.)

Coastal Migratory Pelagics (Gulf and Atlantic Joint Plans)—The habitat of adult fishes in the coastal pelagic management unit, including king and Spanish mackerel and cobia, covers coastal waters out to the edge of the Continental Shelf. Important habitat (and essential fish habitat [EFH]) for coastal migratory pelagic species includes sandy shoals of capes and offshore bars, coastal inlets, estuaries, and high-profile rocky bottom and barrier island ocean-side waters from the surf zone to the shelf break. The occurrence of these species is affected by temperature and salinity. All species are seldom found in water temperatures less than 20 °C (68 °F). Salinity preference varies, but these species generally prefer high salinity. Eggs and larvae are concentrated in the surface waters.

Consolidated Atlantic Highly Migratory Species—The Consolidated Atlantic Highly Migratory Species FMP includes billfish, swordfish, tunas, and sharks. Sharks are divided into three primary management units, defined mainly by general life history information and similarities in fisheries and market characteristics. The three management categories are large coastal, small coastal, and pelagic. Because of the precautionary approach to fisheries management and the limited ecological and fishery information available for some species, a fourth category, "prohibited (species)," was also created. An additional, fifth unit also exists for deepwater and other species, but primarily for data collection, rather than fishery management, purposes.

- **Atlantic Billfishes, Tunas, and Swordfish**
  This section describes the habitat use of Atlantic billfishes (blue and white marlin, sailfish, longbill spearfish) as well as tunas (bigeye, albacore, bluefin, yellowfin, and skipjack) and swordfish from the Consolidated Atlantic Highly Migratory Species FMP. Atlantic billfishes, tunas, and swordfish are discussed together because of similarities in habitat usage. These three groups of species are also be referred to as oceanic pelagic fishes in this section.

  The habitat of adult oceanic pelagic fishes includes the Outer Continental Shelf and open ocean waters of the Atlantic. Important habitat (and EFH) for these highly migratory species is only vaguely understood, but likely includes several dynamic structures such as oceanic fronts, river plumes, current boundaries, shelf edges, seamounts, and temperature discontinuities. Research indicates that floating mats of *Sargassum* may also serve as habitat for highly migratory species such as billfish.

  Oceanic pelagics are distributed in space and time along water temperature and depth gradients, with the tunas and swordfish generally capable of utilizing deeper, lower-temperature habitats than the istiophorid billfishes (marlin and sailfish). All life stages of all species are generally found in waters with salinities between 33 and 37 parts per thousand (‰). Eggs and larvae are generally concentrated in the surface waters. The distribution and habitat use by the juvenile stages of each of these species is generally unknown due to their extreme rarity in scientific collections. In fact, most information on the juvenile stages is derived from specimens only occasionally found in the digestive tracts of adult coastal and oceanic predatory fishes.

  It is also important to note that roundscale spearfish is now considered to be a separate species, and included under the Consolidated Atlantic Highly Migratory Species FMP. Roundscale spearfish is often confused with white marlin. Data for roundscale spearfish are extremely limited, but available information suggests it is widely distributed throughout the western North Atlantic and found in greater numbers in the Sargasso Sea.

- **Sharks**

It is difficult to define specific habitat needs for species like sharks, which exhibit broad ranges. Sharks are found over a wide range of habitat types, from estuarine ecosystems to open ocean environments. In addition, juvenile and adult sharks may have different habitat requirements and tolerances. Over the last several years, attempts have been made at identifying general shark habitat use throughout the waters of the U.S. east coast and Gulf of Mexico (McCandless et al., 2002). Future research should be directed at better understanding the habitat needs for different shark species at different life stages.

SMALL COASTAL SHARK COMPLEX. The small coastal shark complex presently includes the Atlantic sharpnose shark, blacknose shark, bonnethead, and finetooth shark. Small coastal species are distributed throughout southeast U. S. waters and the Gulf of Mexico, generally in coastal bays and estuaries. There is some evidence of spatial segregation, as adult female Atlantic sharpnose sharks are found offshore while adult males and juveniles occupy coastal areas. Most species prefer warmer water temperatures (20–34 °C [68–93 °F]), but some species such as the bonnethead are captured in water temperatures as low as 15 °C (59 °F). Small coastal sharks are found in a variety of habitat conditions, but some species like the bonnethead tend to prefer shallow seagrass beds.

LARGE COASTAL SHARK COMPLEX. The large coastal shark complex includes the blacktip shark, bull shark, great hammerhead shark, lemon shark, nurse shark, sandbar shark, scalloped hammerhead shark, silky shark, smooth hammerhead shark, spinner shark, and tiger shark. This group inhabits a wide variety of habitats. For example, bull sharks have been known to occur in fresh water, while silky and smooth hammerhead sharks can be found offshore, and are considered


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The blacknose shark is considered a vulnerable species because it bears few young. It is also an important part of the ecosystem in the South Atlantic Ocean, Gulf of Mexico, and Caribbean Sea.

epipelagic species. As such, large coastal sharks are found in a variety of water temperatures, salinities, and other habitat conditions. Adults of many species are found offshore, while juveniles may occupy inshore coastal nurseries.

PELAGIC SHARK COMPLEX. In the southeast Atlantic Ocean and Gulf of Mexico, the pelagic shark complex contains the blue shark, oceanic whitetip shark, porbeagle, shortfin mako shark, and thresher shark. Sharks within the pelagic shark complex tend to occupy habitats greater than 180 m (591 ft) deep, although thresher sharks have been captured in gillnet fisheries close to shore off the east coast of Florida. General habitat information for these species is limited, but pelagic sharks are generally found in water temperatures of 10–25 °C (50–77 °F), although mako sharks have been reported in temperatures to 27 °C (81 °C). Studies using acoustic telemetry have indicated some vertical migrations in the offshore habitat, with blue and mako sharks diving to depths below 100–500 m (328–1,640 ft) during the day and occupying the upper water column at night.

PROHIBITED SPECIES. Prohibited species, those sharks that cannot be retained in commercial or recreational fisheries, include species from the small coastal, large coastal, and pelagic shark complexes, and have habitat-use patterns similar to other species in their respective complexes. Prohibited small coastal shark species include Atlantic angel shark, basking shark, bigeye sand tiger shark, Caribbean sharpnose shark, and smalltail shark. Prohibited large coastal shark species include the bignose shark, Caribbean reef shark, dusky shark, Galapagos shark, nar-

Adult dolphinfish from the NMFS longline observer program.

rowtooth shark, night shark, sand tiger shark, whale shark, and white shark. Prohibited pelagic sharks include the bigeye thresher shark, bigeye sixgill shark, longfin mako shark, sevengill shark, and sixgill shark.

DEEPWATER SHARK DATA COLLECTION COMPLEX. Shark species that fall into the Deepwater and Other Species category are included in the Consolidated Atlantic Highly Migratory Species FMP for data collection purposes only, and are not currently managed. This complex includes several species not easily categorized, though many can be found in deeper waters (below 200 m [656 ft]) beyond the Continental Shelf. The cookiecutter shark, for example, a small shark typically 14–50 cm (6–20 in) in length, can be found at water depths of 200–3700 m (656–12,139 ft). A few exceptions, like the Florida smoothhound and smooth dogfish, can be found in shallower waters closer to shore. In general, little is known about the biology, distribution, or population size for many of the species in this complex.

Corals (Gulf, Atlantic, Caribbean)—Corals are classified as scleractinians (stony corals such as brain or staghorn coral), hydrocorals (fire and lace corals), octocorals ("soft corals," including sea fans), and antipatharians (often referred to as black corals). Corals are sessile invertebrates that require oceanic salinity and inhabit hard substrates. In the Southeast Region, where sedimentary bottom types predominate (especially in the Gulf of Mexico), the availability of hard substrate is the primary determinant of coral distribution. The best-studied corals inhabit (and construct) coral reef ecosystems, which are tropical (or subtropical), light-dependent communities and, thus, restricted to shallow (<200 m [<656 ft] and predominantly <50 m [<164 ft]) coastal and oceanic/bank habitats. Because reef-building corals depend on light, water clarity is also an important habitat characteristic for these species. Coral reefs, in turn, provide habitat for myriads of other fish, sea turtle, invertebrate, and plant species.

Many coral species occupy hard bottom habitats in more marginal environments, where accretional coral reefs do not occur. These marginal environments include areas where turbidity/sedimentation, temperature extremes, or light limitation occur. Examples are inshore waters or bays, middle depths (50–200 m [164–656 ft]), and latitudinally marginal areas (e.g. the South U.S. Atlantic Bight).

Many coral species inhabit deeper, oceanic habitats (>200 m [>656 ft]), but their distribution is poorly described, and their biology is poorly known. Corals, like many sessile invertebrates, have a complex life cycle with a planktonic larval stage. Some of these larvae, particularly from oceanic island or bank-resident adults, are likely to also use offshore waters.

Dolphinfish and Wahoo— Dolphinfish and wahoo are covered under the same FMP. Dolphinfish are primarily oceanic, and many fisheries are concentrated at the shelf edge. Though typically found further from shore, dolphinfish have occasionally been found in estuaries and harbors. They often occur from the surface to about 27 m (90 ft) depths and in water temperatures above 20 °C (68 °F). They are also commonly found near floating objects or *Sargassum* patches, where many of their prey species occur. Dolphinfish are tropical and subtropical and frequently found in the Gulf of Mexico, off the North Carolina coast, in the Florida Current, off Puerto Rico, and throughout the Caribbean Sea within the U.S. EEZ. At the extremes of their range in the Western Atlantic, dolphinfish have been found as far north as Georges Bank and Nova Scotia and as far south as Rio de Janeiro, Brazil.

Fewer studies on wahoo have been completed, so details of their life history are not as well known. Much of what is known comes from older studies and from observations made by commercial and sport anglers. Wahoo typically inhabit tropical and subtropical waters, but may also be found in temperate regions during the summer, when surface water temperatures reach approximately 20 °C (68 °F).

Wahoo are frequently encountered far offshore, often as far as mid-ocean regions. They can also be found in deeper water just outside sharply sloping coral reefs and offshore banks. Like many predator species, they are attracted to current edges and temperature breaks, especially when these occur in or very near drop-offs or deep water.

Golden Crab (South Atlantic)—The golden crab (also called golden deepsea crab) inhabits offshore waters from Chesapeake Bay south through the Florida Straits and into the Gulf of Mexico. It uses a variety of habitats, including unconsolidated foraminiferan ooze, mounds of dead coral, sediment ripples and dunes, and low-relief rock outcrops. Based on exploratory trapping, golden crab maximum abundance occurs between 367 and 549 m (1,204–1,801 ft) depths in the South Atlantic Bight. Information on sediment composition suggests that golden crab abundance is influenced spatially by sediment type, with highest catches on substrates containing a mixture of silt–clay and foraminiferan shell or on low rock outcroppings. There is insufficient knowledge of the biology of golden crabs to identify spawning and nursery areas and to identify HAPCs at this time.

Pelagic *Sargassum*—*Sargassum* is a free-floating seaweed found throughout the waters of the South Atlantic and the western edge of the Florida Current/Gulf Stream. The greatest concentrations are found within the North Atlantic Central Gyre in the Sargasso Sea. It is commonly found where ocean currents meet. Fish such as dolphinfish, wahoo, billfish, and other pelagic species gather to feed and take shelter where floating *Sargassum* is abundant in the open ocean. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, become entrained into the Gulf Stream, or come ashore. The seaweed itself provides habitat to a wide variety of marine organisms including invertebrates, fish, sea turtles, and marine birds.

Queen Conch—Queen conch generally occur on expanses of shelf habitat in tropical or subtropical waters, from the shoreline to depths of about 76 m (250 ft). Adult queen conch commonly inhabit

Heather Dine, Florida Keys National Marine Sanctuary

A conch in a bed of seagrass in the Florida Keys National Marine Sanctuary. The Caribbean Queen Conch FMP manages conch species in waters of Puerto Rico and the U.S. Virgin Islands. Florida prohibits taking any queen conch commercially or recreationally.

sandy bottoms that support the growth of seagrasses, primarily turtle grass, manatee grass, shoal grass, and epiphytic algae, upon which they feed. They also occur on gravel, coral rubble, smooth hard coral or beach rock bottoms, and sandy algal beds. Since queen conch are herbivorous gastropods, they are generally restricted to waters where light can penetrate to a depth sufficient for plant growth. Queen conch are often found in sandy spurs that cut into offshore reefs. Larvae require certain substrate conditions to metamorphose and settle to the bottom. Habitat condition at the larval stage seems critical, although the requirements are largely unknown.

Red Drum Fishery (Gulf of Mexico)—Red drum in the Gulf of Mexico occur from depths of about 40 m (131 ft) on the Continental Shelf to very shallow estuarine waters. Spawning occurs near the mouths of bays and inlets, and pelagic larvae are transported into estuarine nurseries. Juveniles are associated with seagrass beds and marsh edge habitats in some areas, but appear to use quiet, mesohaline (5–18‰) backwaters in others. Adult red drum use estuaries, but spend more time offshore as they age. Schools of large red drum are common in Gulf waters.

Yellowtail snapper, a shallow-water reef fish included in all Southeast reef fish FMP's for the South Atlantic, Gulf of Mexico, and Caribbean, is shown here in the Florida Keys National Marine Sanctuary.

Reef Fishes (Caribbean)—The management unit for the Caribbean Reef Fish FMP includes over 100 reef fish species from Puerto Rico and the U.S. Virgin Islands. Because these species collectively occur in all habitats of the U.S. Caribbean, reef fish EFH includes coral reefs; octocoral reefs; hard bottom areas; subtidal vegetation (seagrasses and algae); adjacent intertidal vegetation (wetland and mangroves); and nonvegetated bottoms such as sand, shell, and mud. These habitats can be found from the shoreline to the seaward limit of the EEZ. Estuaries (nursery grounds for many reef fishes), nearshore reefs, and hard bottom areas are essential to the life cycle of several important reef fishes, many of which have significant fishery value. The Caribbean Fishery Management Council has identified the area southwest of St. Thomas, U.S. Virgin Islands, known as Hind Bank, as a habitat of particular importance (designated as a HAPC). The Hind Bank has also been established as a no-take marine protected area.

Reef Fishes (Gulf of Mexico)—This management unit covers a large group of snappers, groupers, and associated species in the Gulf of Mexico, with habitat use ranging from freshwater and estuarine areas out to deep hard bottom areas at the edge of the Continental Shelf. Habitat use for these species is described in terms of shallow-water, deepwater, and semi-pelagic species.

- **Shallow-Water Reef Fishes**
  The shallow-water snappers (i.e. red, lane, vermilion, and gray) and groupers (i.e. red, black, gag, and scamp) are important reef fishes in the Gulf of Mexico for both commercial and recreational fisheries. Shallow-water reef fishes are distributed widely in the Gulf of Mexico, using both pelagic and benthic habitats during parts of their life cycles. Typically, adults are found in offshore habitats closely associated with high- or low-relief hard bottom, patch reefs, or sandy areas near reefs. Spawning occurs in these same habitats, and the planktonic eggs and pelagic larvae can be found within the water column.

  Larvae and early juveniles settle into shallower areas and may enter bays and sounds. Early juveniles may occupy habitats such as seagrass beds, marsh areas, or shallow hard bottoms; or be found around piers, jetties, or artificial structures. Late juveniles move into deeper waters and occupy habitats similar to adults. Some juveniles are closely associated with specific coral heads or crevices and can be colored to blend in with their surroundings. Late juveniles and adults are typically demersal[3] and usually associated with nearshore habitats such as coral reefs, hard-bottom substrates, wrecks, or artificial structures on the shallower areas of the Continental Shelf. Interestingly, however, several species such as red snapper are common on mud bottoms, especially in the northern Gulf.

- **Deepwater Reef Fishes**
  These species support commercial fisheries of lesser volume and value than the shallow-water reef fishes. Deepwater reef fish in the Gulf of Mexico include snappers, groupers, and tilefishes. Less is known about their life histories, due in part to the distance from shore of their deeper habitats in the Gulf. The groupers (especially snowy, warsaw, and yellowedge) and the snappers (especially blackfin and silk) tend to occur on shelf edge habitats or rocky outcroppings and

[3] Demersal species are located at or near the seafloor.

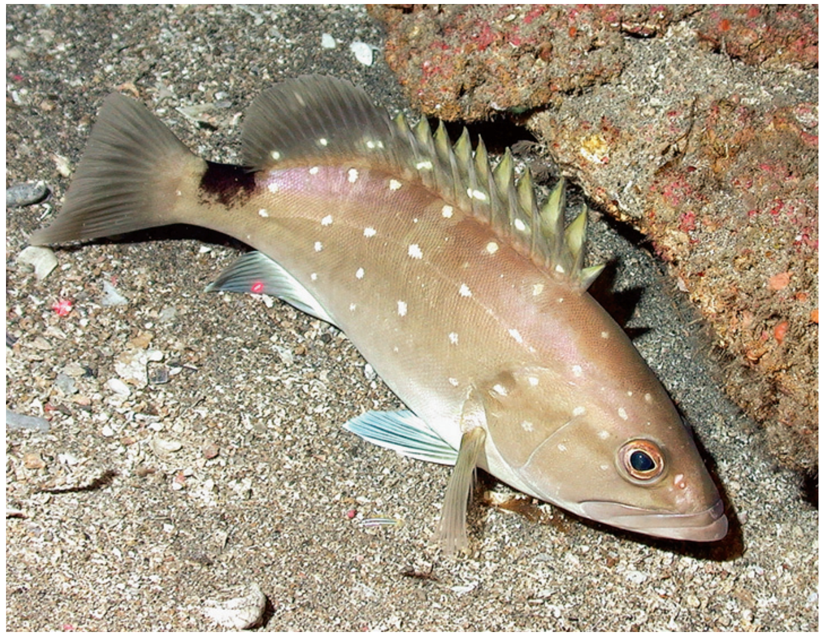
hard bottom with high vertical relief. Adults are usually found in the deeper waters, out to depths of 200 m (656 ft) or more, while juveniles and subadults sometimes inhabit hard bottoms in much shallower depths. The tilefishes are bottom dwellers, preferring clay and mud substrates, living in burrows at depths from 80 to 450 m (262 to 1,476 ft), but most commonly between 250 and 350 m (820 and 1,148 ft).

- **Semi-pelagic Reef Fishes**

  Semi-pelagic reef species covered by the Gulf of Mexico FMP include four species of jacks, with only the greater amberjack having adequate life history data available in the scientific literature. Adult jacks are pelagic and epibenthic, occurring around reefs, oil and gas rigs, buoys, and irregular bottoms with high relief. Adult greater amberjack occur out to depths of 400 m (1,312 ft). The juveniles of these species are also pelagic and are attracted to floating debris and *Sargassum* communities. The greater amberjack is the primary species in this group with significant commercial or recreational value.

Reef Fishes (South Atlantic)—Habitat for snapper, grouper, and triggerfish species includes coral reefs, live/hard bottom, submerged aquatic vegetation, artificial reefs, and medium- to high-profile outcroppings on and around the shelf break zone from shore to at least 183 m (600 ft) depths (at least 610 m [2,000 ft] for wreckfish), where the annual water temperature range is sufficiently warm to maintain adult populations. Most eggs and larval reef fish are suspended in the water column with the exception of the triggerfishes, which spawn benthic eggs in sandy depressions adjacent to hard-bottom ledges.

A variety of coastal environments provide habitat for juveniles. The following habitats are representative examples. Submerged rooted vascular plants (seagrasses) provide shelter for gag, Nassau grouper, and several species of snappers in Florida waters. Emergent vegetated wetlands (salt and brackish marshes) are used by black sea bass and gag. Tidal creeks are used by mutton snapper in Florida. Estuarine scrub/shrub areas, such as mangrove fringe areas, are used by gray snapper and lane snapper. Unconsolidated bottoms, such as soft sediments, are used by juvenile red grouper and black grouper. Artificial reefs are used by red snapper and white grunt. Coral reef/live-bottom/hard-bottom ledge areas are used by species such as red porgy, vermilion snapper, and many species of grunts and groupers.



Andrew David, NMFS; Lance Horn, UNCW/NURC

A snowy grouper photographed by a remotely operated vehicle (ROV).

Important habitat (and EFH) for species in the snapper–grouper management complex includes medium- to high-profile offshore hard bottoms, where spawning normally occurs; localities of known or likely periodic spawning aggregations; nearshore hard-bottom areas; the Point, the Ten Fathom Ledge, and Big Rock (North Carolina); the Charleston Bump (South Carolina); mangrove habitat; seagrass habitat; oyster/shell habitat; all coastal inlets; all state-designated nursery habitats of particular importance to snapper and grouper (e.g. primary and secondary nursery areas designated in North Carolina); pelagic and benthic *Sargassum*; Hoyt Hills for wreckfish; the Oculina Bank HAPC; all hermatypic coral habitats and reefs; manganese outcroppings on the Blake Plateau; and Council-designated Artificial Reef Special Management Zones (SMZs).

Shrimp—Separate FMPs are in effect for shrimp in the Gulf of Mexico and the South Atlantic. The Gulf Shrimp FMP includes brown shrimp, white shrimp, pink shrimp, and royal red shrimp, and the South Atlantic Shrimp FMP includes brown shrimp, white shrimp, pink shrimp, and


Flower Garden Banks National Marine Sanctuary, NOAA

A Caribbean spiny lobster.

rock shrimp. The most common species in the commercial fisheries of the Gulf of Mexico and Southeast United States are the brown shrimp, white shrimp, and pink shrimp. Adults of these three species generally live and spawn in waters on the Continental Shelf; the planktonic larvae are carried by currents to estuarine nursery habitats, where postlarvae grow to become subadults over a period of several months. Subadults then migrate back offshore.

All three common shrimp species occur along the Atlantic coast of the southern United States, but brown shrimp and white shrimp are concentrated in waters and estuaries of the northern Gulf of Mexico (mainly off Texas and Louisiana), and pink shrimp are most abundant near southern Florida. Within estuaries, high densities of all three species are associated with vegetation (either emergent marsh or submerged aquatic vegetation). Offshore, adult white shrimp occur to depths of about 40 m (131 ft), pink shrimp to about 65 m (213 ft), and brown shrimp to about 110 m (361 ft). Other shrimp species under FMPs in the Southeast Region include the rock shrimp and the royal red shrimp. Rock shrimp are concentrated off the coast of northeast Florida, on sand bottom, and in waters from 25 to 65 m (82–213 ft) in depth. The highest concentrations of royal red shrimp have been reported in the northeastern part of the Gulf of Mexico at depths between 250 and 475 m (820–1,558 ft). Little information is available on life histories or nursery grounds of these species.

Spiny Lobster—Spiny lobster occurs throughout the Caribbean Basin, approximately from Brazil to Florida and Bermuda. Important habitat for this species includes nearshore (shallow subtidal bottom and seagrass areas), coastal, and offshore waters. Adult and juvenile spiny lobster are found in unconsolidated bottom (soft sediments), coral and live/hard bottom areas, sponges, algal communities (especially *Laurencia* spp.), and mangrove habitat (prop roots). Oceanic waters and currents play an important role in the growth, survival, and dispersion of pre-settlement spiny lobster life history stages—planktonic phyllosome larvae and swimming postlarval pueruli.

Aquaculture FMP (Gulf of Mexico)—Since the demand for protein in the United States is increasing and commercial wild-capture fisheries will not likely be adequate to meet this growing demand, aquaculture is one method to meet current and future demands for seafood. The Gulf of Mexico Fishery Management Council has developed an Aquaculture FMP to maximize benefits to the Nation by establishing a regional permitting process to manage the development of an environmentally sound and economically sustainable offshore aquaculture industry in the EEZ. To evaluate the potential impacts of aquaculture proposals in the Gulf, the Council initiated a programmatic approach to provide a comprehensive framework for regulating such activities. The Aquaculture FMP considers ten actions, each with an associated range of management alternatives included in a Programmatic Environmental Impact Statement (PEIS).

Additional Information—Two important resources regarding habitat use and information in the Southeast Region should be noted if readers require additional information. First, the South Atlantic Fisheries Management Council (SAFMC) created the Final Habitat Plan for the South Atlantic Region. This document details EFH requirements for fishery management plans for multiple fisheries managed by the Council. It also documents the distribution and description of EFH in the South Atlantic Region, focusing on estuarine and inshore habitats of North Carolina, South Carolina, Georgia, and the Florida east coast, as well as adjacent and offshore marine habitats (e.g. coral, coral reefs, and live/hard bottom habitat, artificial reefs, *Sargassum* habitat, and the water column). More details can be found at the SAFMC website.[4]

[4]See http://safmc.net/ecosystem-management/safmc-habitat-plan (accessed February 2014).

In addition, the SAFMC also developed the Fishery Ecosystem Plan for the South Atlantic Region. Building on the Habitat Plan, the Ecosystem Plan provides a more in-depth characterization of the overall South Atlantic ecosystem. More information can be found at the SAFMC website.[5]

Habitat Use by Protected Species

The Southeast Region contains many species protected by NOAA's National Marine Fisheries Service (NMFS), most prominently cetaceans, sea turtles, and fishes. Manatees, which also occur in this region, prefer shallow, marshy fresh and saltwater habitats, and are protected by the U.S. Fish and Wildlife Service. Many of these protected species are rare and have wide distributions, making habitat relationships for these species difficult to study.

Cetaceans—Southeast Region marine cetaceans include three geographic groups of animals found in the southeastern portion of the U.S. EEZ: Southeast Atlantic (Cape Hatteras to the southern tip of Florida), Gulf of Mexico, and Caribbean. The nearshore and offshore waters are the zones most frequently used by all Southeast Region cetaceans. Bottlenose dolphins are the only ones likely to be found in estuarine habitats, and they are found in freshwater habitats occasionally.

- **Southeast Atlantic**
  Nearshore habitats are used by all Southeast Atlantic species and stocks; the same is true of offshore habitats, with the exception of the bottlenose dolphin (coastal western North Atlantic stock) and the Atlantic spotted dolphin, which are not found offshore. Southeast Atlantic habitats may be important for calving, raising juveniles, and wintering for many species found further north, as illustrated by the following examples. The North Atlantic right whale has wintering and calving grounds in the coastal waters of the Southeast Region; sperm whales tend to winter offshore from Cape Hatteras; and coastal waters off Virginia and North Carolina may be important habitat for juvenile humpback whales.

- **Gulf of Mexico**
  Nearshore habitats are used by several Gulf of Mexico cetacean species, including the bottlenose dolphin, Atlantic spotted dolphin, rough-toothed dolphin, Risso's dolphin, dwarf sperm whale, pygmy sperm whale, Bryde's whale, fin whale, and humpback whale. Bottlenose dolphins and Atlantic spotted dolphins are the species most commonly found in these nearshore waters. There are bottlenose dolphin stocks along the Continental Shelf and in oceanic waters, but relatively less is known about these stocks. Species found beyond the shelf break include Risso's dolphins, sperm whales, pygmy and dwarf sperm whales, killer whales, and several other species. Relatively little is known of the minke whale's habitat use patterns in the Gulf of Mexico. Gulf of Mexico habitats are thought to be used year-round by many species. However, it is not known whether some of the species, especially the large whales and mobile smaller cetaceans such as pilot whales, have migratory patterns that may result in their leaving the Gulf during part of the year.

- **Caribbean**
  The largest gaps in habitat knowledge for Southeast Region cetaceans exist for Caribbean cetaceans. Habitat use of Caribbean nearshore and offshore habitats is unknown for several species, including the Clymene dolphin and pygmy killer whale. Of the species with known habitat use, the type of information is typically distribution information. Caribbean habitats are thought to be used year-round by many species. However, it is not known whether some of the species, especially the large whales and smaller cetaceans such as pilot whales, have migratory patterns that include leaving the Caribbean during part of the year.

Pinnipeds—Pinnipeds are not common in the Southeast Region. The only pinnipeds likely to be found in the Southeast are harbor seals that occasionally spend winter months in areas as far south as North Carolina. Caribbean monk seals were once abundant in the Southeast Region, but were hunted to extinction.[6]


M. Herko, NURP Collection, NOAA

The bottlenose dolphin is found in marine and estuarine habitats in the Southeast Region.

[5]See http://safmc.net/ecosystem-management/fishery-ecosystem-plan-1 (accessed February 2014).

[6]http://www.nmfs.noaa.gov/pr/species/mammals/pinnipeds/caribbeanmonkseal.htm (accessed March 2014).

A Kemp's ridley sea turtle tamping down sand over a nest on Galveston Island, Texas, in which eggs have just been laid. This turtle hatched at Rancho Nuevo, Mexico, and was then reared in a NOAA laboratory for 10 months. It was tagged and released in 1992 off Galveston, Texas. The turtle returned to nest near the location where it was released 14 years earlier.

Sea Turtles—Six species of sea turtles (loggerhead, Kemp's ridley, olive ridley, green, leatherback, and hawksbill) occur in waters of the Southeast Region. Sea turtles inhabit estuarine, shallow marine, and oceanic habitats of the U.S. Atlantic, Caribbean, and Gulf of Mexico coasts throughout different life stages. There are four genetically distinct loggerhead nesting subpopulations in the southeastern United States: 1) Florida Panhandle; 2) southern Florida; 3) Amelia Island (Nassau County, Florida) and northward; and 4) the Dry Tortugas. Another subpopulation exists on the Yucatan Peninsula of Mexico.

The southern Florida loggerhead subpopulation is the species' largest nesting assemblage in the Atlantic. The Kemp's ridley inhabits coastal waters throughout the U.S. Atlantic and Gulf of Mexico; however, nesting occurs almost exclusively on one stretch of beach at Rancho Nuevo, Tamaulipas, on the Gulf coast of Mexico. Green sea turtles occur in U.S. Atlantic waters around the U.S. Virgin Islands, Puerto Rico, and from Texas to Massachusetts, but they nest mainly along the east coast of Florida, with some nesting occurring in the U.S. Virgin Islands and Puerto Rico. The leatherback is widely distributed throughout the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, often foraging in the open ocean. The most significant leatherback nesting activity in the United States occurs in the Virgin Islands, Puerto Rico, and the Atlantic coast of south Florida. The hawksbill is primarily found throughout the Caribbean, typically associated with coral reefs. They are commonly observed in the Florida Keys, the Bahamas, and the southwestern Gulf of Mexico. Nesting within U.S. waters occurs mainly on beaches in the U.S. Virgin Islands and Puerto Rico, with some nesting in southern Florida. The olive ridley has been documented occasionally in the Caribbean, including the Florida Keys.

Although sea turtles likely occur at much lower abundances now than during historic times, their role in aquatic ecosystems can be significant. Hawksbill turtles, for example are important reef-dwelling carnivores,[7] grazing on a variety of sponges and other benthic reef-dwelling species. By preying on sponges and tunicates in coral reef habitats, hawksbills may affect diversity, biomass, and succession in coral reef communities. Green sea turtles are another example. They are often associated with seagrass beds, their primary forage in the Southeast Region, and have been shown to increase the productivity of seagrass beds on which they graze.

Fishes—Gulf sturgeon is a threatened subspecies under the ESA. Adult Gulf sturgeon feed within the Gulf of Mexico and adjacent estuaries, primarily on bottom invertebrates such as brachiopods, insect larvae, mollusks, worms, and crustaceans. Adults then return up the rivers to reproduce and spawn in deep fresh water over bottoms of clean rock and rubble. Dams on several of the rivers block access to habitats for reproduction, thus hindering recovery. The Atlantic sturgeon, another subspecies similar to the Gulf sturgeon, was listed as endangered in 2012. It includes two distinct population segments (DPSs) in the Southeast region, the Carolina and South Atlantic DPSs.[8]

The shortnose sturgeon (endangered) is anadromous, living mainly in the slower moving riverine waters or nearshore marine waters, and migrating periodically into faster-moving freshwater areas to spawn. They occur in most major river systems along the eastern seaboard. The Atlantic sturgeon has similar habitat affinities, occurring along the east coast as far south as Florida.

Smalltooth sawfish (endangered) inhabit shal-

[7]Only very young hawksbills (hatchlings/neonates) could be considered omnivorous.

[8]A distinct population segment (DPS) represents a vertebrate population or group of populations considered to be discrete from other populations of the species, and significant in relation to the entire species. The ESA provides for listing species, subspecies, or distinct population segments of vertebrate species.

low waters very close to shore over muddy and sandy bottoms and are often found in sheltered bays, on shallow banks, and in estuaries or river mouths. Historically, the U.S. population was common throughout the Gulf of Mexico from Texas to Florida, and along the east coast from Florida to Cape Hatteras. The current range is peninsular Florida, and they are relatively common only in the Everglades region at the southern tip of the state.

The largetooth sawfish was listed as an endangered species in 2011. Habitat use is similar to that of the smalltooth, but historical distribution is mainly along the Texas coast east into Florida waters. No estimates exist of current or historic population sizes.

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 and the Gulf of Mexico Marine Fisheries Commissions and the appropriate fishery management councils. Many key examples of these species are discussed by category (crustaceans, mollusks, and fish).

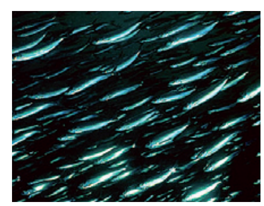
Crustaceans—The blue crab is widely distributed in estuaries along the coast of the Southeast Region. Distribution within estuaries and their associated tributaries varies with the age and gender of the crabs and with season. Smaller blue crabs generally occur in shallow estuarine waters with bottoms of soft detritus, mud, or mud shell; larger crabs are found in deeper estuarine waters with harder bottom substrates. The species tolerates a wide range of salinity, from fresh water to hypersaline, and grass beds often serve as important nursery habitat. Juveniles generally are most abundant in seagrass beds or emergent marsh vegetation. Two species of stone crabs, the Florida stone crab (*Menippe mercenaria*) and the Gulf stone crab (*Menippe adina*), are found in the Southeast Region. Adults of both species are often found in burrows under rock ledges, coral heads, dead shell, or seagrass flats (primarily turtle grass). They occasionally inhabit oyster bars and rock jetties. Juvenile stone crabs (less than 30 mm [1.125 in] carapace width) do not dig burrows; they use readily available hiding places that offer close proximity to food. Juveniles have been reported to be abundant on shell bottom, sponges, and *Sargassum* mats as well as in channels and deep grass flats.

Mollusks—The eastern oyster occurs in a wide range of salinities throughout estuaries in the Southeast Region. In the U.S. southern Atlantic, the species tends to be intertidal south of Cape Lookout, North Carolina, and subtidal to the north. In the Gulf, where the species is most abundant in the estuaries of Louisiana and Texas (north of Corpus Christi), preferred habitats are intertidal areas, shallow bays, mud flats, offshore sand bars, and shell substrates.

The calico scallop occurs in the Southeast Region at depths of 18–73 m (59–240 ft). Beds are distributed on the Continental Shelf parallel to the coastline. They are found on unconsolidated sediments, including hard sand and shell substrates, in salinities ranging from 31 to 37‰. In the Atlantic, scallops are most abundant off the coast of Florida, with the next highest concentrations found off Cape Lookout, North Carolina. In the South Atlantic Bight, the most productive area is the open shelf zone at depths of 33–40 m (108–131 ft).

Bony Fishes—Mullets, shads, flounder, herring, sardines, ballyhoo, spot, scad, croaker, menhaden, and red drum (in the South Atlantic) are among the state-managed and/or commission-managed fishes that occur in the Southeast Region. Mullet are widespread, occupying virtually all nearshore shallow marine and estuarine habitats including beaches, flats, lagoons, bays, rivers, salt marshes, and grass beds. Spawning occurs near the surface of offshore waters, and juveniles enter the bays and estuaries to mature. The hickory shad, indigenous along the southeastern U.S. Atlantic coast as far south as the St. Johns River, Florida, is an anadromous species that enters the freshwater reaches of coastal rivers, including tributary streams and backwater swamps, to spawn. Juveniles have been collected in waters with salinities ranging from 10 to 20‰. 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 essentially a freshwater fish, although the young move downstream to brackish waters.


W. F. Hettler, NMFS


NMFS


USGS

Top: Menhaden swimming in a tight school. Menhaden depend upon estuaries.

Middle: Atlantic herring in a large school. This species is important commercially.

Bottom: Gizzard shad is a species found in estuarine waters. This species is a filter feeder of plankton.

A bigeye scad.

The summer flounder, gulf flounder, and southern flounder occur throughout the Southeast Region. Juvenile and adult gulf flounder are estuarine and marine, preferring higher salinity waters (above 20‰) and typically occurring over hard sand bottoms. Adults can be found on the shelf at depths up to 50 m (164 ft), although they prefer nearshore waters and bays. Southern flounder are euryhaline, inhabiting estuarine and coastal habitats to a depth of 40 m (131 ft), generally in areas containing fine unconsolidated substrates of clays and muds. Juveniles of both species are associated with seagrass beds.

The round herring, a pelagic marine species, occurs throughout the Southeast Region in depths of 50–150 m (164–492 ft). They usually occur in large schools and feed mainly on euphausiids and copepods. Atlantic thread herring occur throughout the Southeast Region, generally in depths less than 37 m (121 ft). Schools prefer shallow coastal waters and are found frequently in the upper 3 m (10 ft) of the water column, and adults follow an inshore–offshore, north–south movement in response to water temperature. Spanish sardines occur in the Atlantic and eastern Gulf of Mexico from the beach to depths of 30–40 m (100–131 ft). Most, however, are in waters 5–20 m (16–66 ft) in depth. The Spanish sardine schools near the bottom during the day and becomes more dispersed in the water column at night. Ballyhoo occur throughout the Southeast Region. They are a marine epipelagic species, and they spawn off Florida in the spring and early summer.

Bigeye scad are coastal pelagic fish distributed throughout the Southeast Region and feed primarily on large zooplankton at night. The Atlantic flyingfish is a marine pelagic species in the Southeast Region that can be found in the open ocean, although it sometimes enters bays and other inland waters. It generally remains near the surface but can leave the water column for short periods by gliding several feet above the surface using its large, outstretched, aerodynamic pectoral fins. Atlantic croaker are distributed throughout both the Northeast and Southeast Regions 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 typically move offshore and south along the Atlantic coast in the fall, spawn over shelf waters in fall and winter, and spend spring and summer in estuaries. They tolerate a wide range of salinities and temperatures. (Diaz and Onuf, 1985; Wenner and Sedberry, 1989; Whitaker, 2013)

Atlantic and Gulf menhaden are pelagic, nearshore, estuarine-dependent clupeid species. Atlantic menhaden range from northern Florida to the Gulf of Maine, while Gulf menhaden range from southern Mexico to the panhandle of Florida. For most of their range, they use oceanic, nearshore, and estuarine habitats, consisting of unconsolidated bottom (primarily sand and mud, but with some rocky bottom in the more northern portion of the Atlantic menhaden's range). Both species occasionally utilize waters greater than 200 m (656 ft) deep: Gulf menhaden during winter months when schools move offshore, and Atlantic menhaden during summer months in the Gulf of Maine region. Critical habitats for both species include coastal inlets, which are used by larvae as estuarine nursery areas, and the upper estuarine reaches from 0 to about 10‰ salinity, where transformation and early juvenile growth occur.

Red drum occur in estuarine and shallow marine areas, and they are currently managed by the states along the Atlantic coast (and federally managed in the Gulf of Mexico). The distribution of red drum between estuarine habitat and oceanic waters is dependent mainly on stage of development and temporal and environmental factors. Juvenile red drum use the shallow backwaters of estuaries as nursery areas and remain there until they move to deeper water portions of the estuary associated with river mouths, oyster bars, and front beaches. Estuarine wetlands are especially important to larval red drum. Young red drum are found in calm, shallow, protected waters with grassy or slightly muddy bottoms. Shallow bay bottoms or oyster reef substrates are preferred by subadult and adult red drum. In the fall and spring, red drum concentrate around inlets, shoals, and capes from the surfzone to several kilometers offshore.


U.S. FWS

The Arthur R. Marshall Loxahatchee National Wildlife Refuge in the Florida Everglades.

HABITAT TRENDS

Freshwater Quality and Quantity

Freshwater habitats in the Southeast have declined both in quantity and quality through centuries of increased civilization. Water quality has declined due to agricultural, industrial, and domestic discharges of nutrients and other pollutants. Data from the U.S. Environmental Protection Agency's (EPA) most recent National Rivers and Streams Assessment provide information on ecological conditions for a large portion of the Southeast Region's rivers and streams called the Coastal Plains Ecoregion.[9] The Coastal Plains Ecoregion covers eastern Texas, Florida, the Gulf Coast, the Mississippi River Delta, and the Atlantic seaboard of the Southeast Region. According to a key indicator of biological condition, the Macroinvertebrate Multimetric Index, 71% of river and stream length in the Coastal Plains ecoregion was considered to be in poor condition, and 12% in good condition. Another indicator of biological condition, the Fish Multimetric Index, showed that 52% of river and stream length was in poor condition for fish (EPA, 2013). The most up-to-date information on this can be found at an EPA website.[10]

Diversion of Freshwater Flow

Wide-scale diversions of fresh water also have created environmental degradation, particularly in large wetland habitats like the Everglades swampland in southern Florida. Traditionally, much of the region drained as a slow-moving, shallow course, kilometers wide but only centimeters deep. This broad, shallow plane of surface water passing through palustrine vegetation towards Florida Bay on the tip of the peninsula has been termed sheet flow, or simply a "river of grass."

But, during the early 20th century the hydrography of the Everglades was significantly altered when the prevailing sheet flow was channeled and drained, primarily for mosquito control, flood control, and residential construction, through the construction of an extensive inland and coastal canal system known as the Central and South Florida Flood Control Project (Light and Dineen, 1994). Changing salinity regimes and freshwater flows resulted in widespread environmental degradation and loss of estuarine habitat (Browder and Ogden, 1999). In consequence, a long-term, multi-billion-dollar restoration program known as the Comprehensive Everglades Restoration Plan (CERP)[11] was initiated to restore the Everglades watershed to approximate pre-industrial conditions. One objective was to convert some of the channel flow back to sheet flow, thus restoring much of the palustrine environment and improving water quality and quantity of wetland habitat in the Everglades and in Florida Bay.

Wetland Loss

The Southeast contains about 80% of the coastal wetlands in the United States. However, the Southeast has experienced a significant loss of

[9]The Coastal Plain Ecoregion also includes the Atlantic seaboard up to New Jersey (and thus a part of the Northeast Region) and extends north along the Mississippi River to the Ohio River. Since the majority of it is found in the Southeast Region, the trends are discussed in the Southeast Region chapter.

[10]For further details, see http://water.epa.gov/type/rsl/monitoring/riverssurvey/ (accessed December 2013).

[11]For more information on the CERP see the full Environmental Impact Statement available at http://www.evergladesplan.org/pub/restudy_eis.aspx (accessed October 2013).

Kathryn Smith, USGS

Coastal Louisiana wetlands, photographed as part of a wetland study.

wetlands, including marsh, seagrass, and mangrove habitats, from human-induced activities such as residential construction and industrialization, and from more naturally occurring phenomena such as land subsidence. Wetland degradation has also occurred due to the diversion of fresh water for agricultural, domestic, and industrial uses as well as channeling, dredging, damming, ditching, and the draining of rivers and their floodplains.

Although Dahl and Stedman (2013) did not specifically analyze the NMFS Southeast Region, they did find that coastal wetlands are still being lost along both the Atlantic and Gulf coasts. They showed that about 45% of the total loss of U.S. coastal wetlands from 2004 to 2009 occurred in Gulf of Mexico watersheds.

State-wide losses of wetlands along the southern U.S. Atlantic coast from 1780 to 1980 are estimated at 40%, ranging from 23% in Georgia to nearly 50% in North Carolina. State-wide losses along the Gulf of Mexico coast for the same period are estimated at 50%, ranging from 46% in Florida and Louisiana to 59% in Mississippi.

Coastal development, a rise in sea level, coastal subsidence, and interference with normal erosion and deposition within the Mississippi River Delta have contributed to the wetland loss. Louisiana marshes in particular have experienced habitat loss rates that once exceeded 100 km^2 (39 mi^2) per year. Rates of Louisiana wetland loss have since decreased, but the cumulative loss remains substantial. Specifically, coastal Louisiana lost over 4,877 km^2 (1,883 mi^2) of land area between 1932 and 2010 (Couvillion et al., 2011). If the current rate of loss is not slowed, an estimated 323,749 hectares (800,000 acres) of wetlands could disappear by the year 2040, and the shoreline could erode inland as much as 53 km (33 mi) in some areas of the state.[12]

East Timbalier Island, off the southeastern coast of Louisiana, is part of a barrier island chain that helps protect interior marshes of the Louisiana coast. The island is shrinking and being pushed shoreward due to the combined effects of sea level rise, land subsidence (sinking), and Hurricanes Rita and Katrina. These forces cause the sediments from the seaward margins of the island to erode. Some of those materials are redeposited on the landward side, and some are carried away. The island lost over 35% of its above-high-tide area between October 2002 and September 2008.

Extensive canal networks were constructed through the Mississippi Delta in the latter half of the last century to support the nearshore petroleum industry. Besides removing large quantities of habitat, such as wetlands, the canals also created pathways for saltwater intrusion to further exacerbate the situation. Other unintentional threats to the marsh have occurred. In the 1930s, nutria (a large muskrat-like herbivorous rodent from South America) was introduced in Louisiana. Its subsequent spread in range and abundance has apparently contributed significantly to habitat loss. For example, it is thought that the voracious grazing of nutria prevented reestablishment of much of the bald cypress forests in the Delta after losses from logging and other causes.

The overall quantity of mangrove forest acreage in Puerto Rico suffered significant declines during the 1950s and 1960s (a similar trend occurred on the continental coast) due to coastal development. However, since the 1970s, dedicated efforts to restore and protect the mangrove forests have proven effective, and by 2002, the area of Puerto Rico's mangrove forests had increased from 6,745 hectares (16,667 acres) in 1971 to 8,323 hectares (20,526 acres) in 2002, a 23% increase (Martinuzzi et al., 2009). Barrier islands have also been subject to dredging, filling, municipal growth, pollution, and similar human-induced consequences of civili-

[12]See http://lacoast.gov/new/About/FAQs.aspx for more details (accessed April 2013).

zation. Seagrass meadows across the northern Gulf of Mexico have also undergone losses of 20–100%, depending on the estuary, in the last 50 years. Although strides are being made in seagrass restoration (e.g. because of water-quality improvements in Tampa Bay), the pressures of human development continue to cause losses.

Coastal Development

Human habitation, agriculture, and industrialization in or near rivers, estuaries, and wetlands have consumed or significantly altered habitats used by aquatic organisms. Farms, homes, streets, buildings, cities, industries, bridges, tunnels, causeways, canals, jetties, shipping channels, and similar structures have altered natural hydrologic flows and are sources of pollutants. These factors have greatly affected the dynamics of sediments and nutrients, reducing the quality and quantity of wetlands and estuarine habitat. The effect of each has resulted in estuarine and coastal zones that differ from those of centuries past, with habitats that are less pristine, smaller, more polluted, and reduced in functionality for aquatic organisms.

Flood Control

Structures such as dams, levees, and weirs that were constructed for flood control have significantly affected anadromous fish populations in the Southeast. These structures have also altered the hydrology, dynamics, and function of wetland habitats in the Region.

A significant factor in the decline of anadromous fishes worldwide has been the construction of dams on rivers and tributaries used by such fishes for spawning grounds. Although anadromous species spend the majority of their adult lives in salt water, they migrate into rivers and lakes to reproduce. Consequently, dams and weirs can inhibit their upsteam and downstream migrations and restrict access to their spawning habitats. Dams on the Pearl River in Mississippi, the Alabama River in Alabama, and the Apalachicola River in Florida, for example, are limiting access to freshwater habitats for reproduction and hindering the recovery of the ESA-listed Gulf sturgeon.

Flood control structures have also contributed to wetland loss in the Region. Sediment trapped by upstream dams is one of many factors that has caused the historic loss of sediment in the Mississippi River that originally built the Mississippi Delta. Levees, particularly those along the Mississippi and Atchafalaya Rivers, channel historical runs of spring floodwater into the Gulf of Mexico, rather than allowing them to inundate and nourish adjacent marsh habitats with nutrients and sediments. Levees also increase the volume of sediment- and nutrient-laden water shunted into the Gulf of Mexico. Thus, distant estuaries like Mississippi Sound, which once received annual floodwaters from the Mississippi River, are now more saline. The Mississippi Delta, lacking a periodic supply of sediment from the River, continues to experience erosion and subsidence of habitat. The combination of less sediment coming down from the Mississippi River from damming and levees diverting sediment away from wetland habitats on top of sea-level rise all contribute to wetland loss in the region.

Jacinta Quesada, FEMA

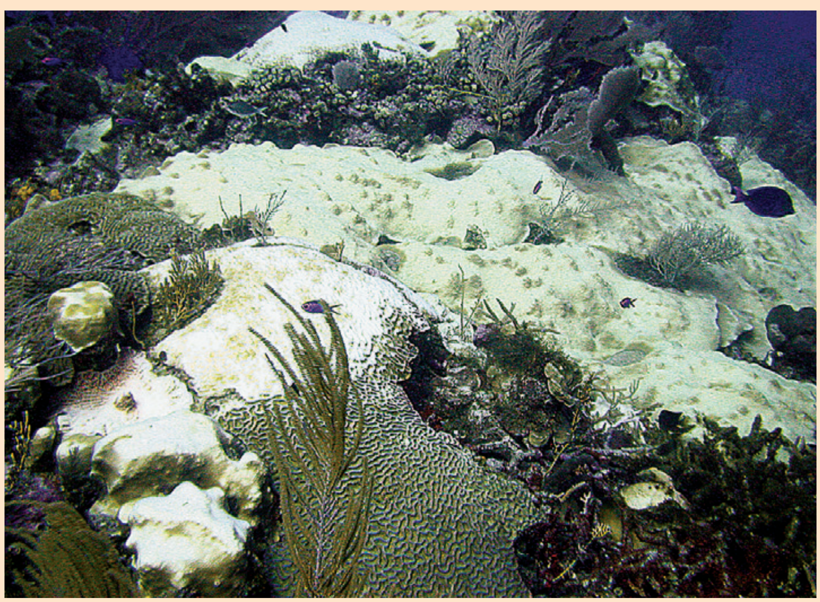
Levees on the 17th Street Canal in New Orleans, Louisiana, in August 2008, reconstructed after Hurricane Katrina.

Coral Reefs

Declines in coral populations have been well documented throughout the Southeast Region. Population declines in branching corals (acroporids) of over 90% were estimated at some sites (*Acropora* Biological Review Team, 2005) and two species, staghorn and eklhorn corals, were listed as threatened in 2006 under the ESA. In addition, pillar coral, rough cactus coral, and three species of star corals were listed for the region in October 2014.

Coral Bleaching

Coral bleaching is a phenomenon in which corals expel their symbiotic unicellular algae called zooxanthellae. The zooxanthellae normally live within the tissue of coral polyps, providing energy and the coral's characteristic color. When the coral experiences environmental stress, the zooxanthellae leave the coral host. The result is that the stressed coral lose a critical energy source and also lose their characteristic color (hence the term "coral bleaching"). Several different stressors can lead to coral bleaching, including extreme temperatures, diseases, excessive shade, increased ultraviolet radiation, sedimentation, pollution, and salinity changes, but the mass bleaching events of greatest concern are associated with ocean warming. Coral bleaching is being observed in areas throughout the world, including Florida and the U.S. Caribbean. Bleaching events had not been documented anywhere before the early 1980s, so this problem is a recent phenomenon.



Andy Bruckner, NMFS

This photo of coral reef bleaching off Desecheo Island, Puerto Rico, was taken in December 2005. Over 89% of the live coral cover was bleached, including brain coral (in the foreground) and mountainous star coral (large colonies in the distance), which are two critical reef builders in the western Atlantic.

Weeks Bay NERRS

Josh Harper, Texas Department of Parks and Wildlife

Left: Algal bloom caused by eutrophication in Alabama's Weeks Bay National Estuarine Research Reserve System.

Right: Gulf menhaden killed by hypoxia in Matagorda Bay, Texas.

In the summer and fall of 2005, the Caribbean experienced record warm temperature anomalies and significant coral bleaching and mortality events. Some monitoring sites in the U.S. Virgin Islands showed a 50% decline in live coral cover on average, with up to 90% mortality of coral colonies (Miller et al., 2009; Rogers et al., 2009). In 2005, several hurricanes, including Katrina and Rita, likely protected Florida reefs from this severe bleaching event (Manzello et al., 2007), but also caused significant physical damage, especially to elkhorn coral (Williams and Miller, 2012). Subsequently, a severe cold weather event also caused substantial coral mortality in southern Florida in January 2010 (Lirman et al., 2011).

Expanding access and work in deeper areas has led to a growing appreciation of the extent and potential refugia value of mesophotic reefs (generally defined as 30–150 m [98–492 ft] depths) in this region (Lesser et al., 2009; Bongaerts et al., 2010). However, despite their greater buffering from surface-based threats, these deeper reefs are not immune to disturbances, and coral mortality events have been reported (Smith et al., 2010). There is also evidence that oil from the *Deepwater Horizon* oil spill impacted deep-sea corals at sites within offshore ecosystems of the Gulf of Mexico (White et al., 2012).

Coral reefs are vulnerable to environmental stress brought about by natural and anthropogenic factors. Hurricanes, disease, predation, algal blooms, invasive species, pollution, sedimentation, human sewage, toxic pollutants, destructive fishing, boat anchoring, and vessel grounding have also contributed to a degradation of coral habitat. The most serious threats posing extinction risk to corals are considered to be ocean warming, disease, and ocean acidification (Brainard et al., 2011). Due to these serious global and local threats, five additional Caribbean coral species were listed as threatened under the ESA in September 2014.

Eutrophication and Hypoxia

Eutrophication is caused by excess inputs of nutrients into receiving waters. The excess nutrients may cause intense algal blooms with extremely high amounts of primary productivity, often accompanied by large fluctuations in dissolved oxygen and low species diversity. When these blooms die, the cells sink and are degraded by bacteria. This process consumes oxygen, leading to hypoxia (low dissolved oxygen, usually considered to be less than 2–3 mg/L) and sometimes anoxia (the absence of dissolved oxygen), particularly in bottom waters. Eutrophic conditions have been reported as moderate or low for most estuaries in the southern U.S. Atlantic and Gulf of Mexico regions (Bricker et al., 2007). High or moderately high eutrophic conditions have been observed in two South Atlantic estuarine river systems (Neuse River in North Carolina and St. Johns River in Florida) and seven Gulf systems, four of which are found on the Florida peninsula (Bricker et al., 2007). For both regions, the outlook has not changed since the 1990s and future conditions are expected to worsen in most of the assessed systems (Bricker et al., 2007).

Large hypoxic zones form in the waters of the Gulf Continental Shelf in the region receiving discharge from the Mississippi and Atchafalaya Rivers (see map on p. 60). This is the second largest hypoxic zone associated with eutrophication in the world (Committee on Environment and Natural Resources, 2010). Analysis of sediment samples cored from the area of the shelf where the hypoxic zone occurs indicates that algal production was significantly lower in the first half of the 20th century than in the latter half. This suggests that human-induced changes may have significantly increased primary productivity in the region, leading to seasonally recurring widespread hypoxia. These hypoxic zones are lethal to organisms with limited mobility, and greatly disrupt the ecology of the region. Although the extent and duration of the Gulf of Mexico hypoxic zone varies based on several factors, the average size in 1985–92 of 6,900 km^2 (2,664 mi^2) more than doubled between 2004 and 2012 to over 15,000 km^2 (5,791 mi^2) (Rabalais and Turner, 2006; Committee on Environment and Natural Resources, 2010; Louisiana Universities Marine Consortium, 2014). For more information on Gulf hypoxia, see the Louisiana University Marine Consortium website.[13]

RESEARCH NEEDS

Resource officials charged with managing, protecting, conserving, and restoring fishery habitat should be provided with the best scientific information. Research is particularly needed on habitat associations and habitat quality and quantity. Managers generally need to know where habitat–species associations exist, the condition of habitats and their associated species, and the best practices to conserve and restore critical habitats.

Table 10 presents an overview of habitat-specific research needs for the Southeast Region, with more detailed information provided in the text that follows.

Estuarine Habitat Condition

The estuaries of the Gulf of Mexico and southeastern U.S. Atlantic coast are extensive and provide irreplaceable nursery habitat for many species of recreational and commercial importance, including shrimp, blue crab, oyster, menhaden, red drum, southern flounder, and spotted seatrout. Complex physical, chemical, and biological links exist between estuarine and marine habitats, impacting life in each system. For example, the functional value of estuaries is influenced by the quantity and quality of fresh and salt water entering the estuary. Human activities such as dredging; filling; construction; industrial and municipal discharges; highway, lawn, and agricultural runoff; exotic species introductions; and artificial changes in the composition of sediments have disrupted the biological function and value of estuarine systems.

[13]See http://www.gulfhypoxia.net/ (accessed March 2015).

Table 10
Overview of research needs for Southeast Region fishery and protected species.

Research Needs	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
Characterize and monitor habitat condition.	x	x	x	x
Conduct studies on the ecology of coral reefs and deep-sea corals and determine their importance as habitat.			x	x
Delineate and map important fishery and protected species' habitats.	x	x	x	x
Determine habitat requirements of early life stages of managed and protected species (e.g. habitat type, quantity, and quality).	x	x	x	x
Determine the impacts of severe storms and sea level rise on fishery and protected species and their habitats.	x	x	x	x
Improve methods and determine efficacy of habitat restoration for fishery species and marine mammals and sea turtles, and determine the economic and sociological benefits of conserving and restoring habitats.	x	x	x	x
Improve understanding of transboundary biological and hydrological linkages.			x	x
Improve understanding of the effects of underwater sound.			x	x
Study and determine human impacts on habitat and any subsequent effects on fishery production and marine mammal and sea turtle biology and behavior.	x	x	x	x

In addition, tropical storms, sea level rise, land subsidence, and saltwater intrusion have degraded estuarine habitat in many areas. Habitat managers must monitor and assess damage and the threats of future damage to make decisions that will protect habitat quality. To this end, priority should be placed on expanding research into the causes and extent of habitat degradation: examples include assessing the effects of diminished water quality (e.g. eutrophication) and other types of degradation on ecosystem function, such as secondary production; studying the biological uptake and fate of toxins; monitoring to detect systemic ecosystem changes; and providing advice on best-use management practices (such as wetland loss mitigation).

Coral Reef Ecology

Corals and coral reef resources are of particular concern. The beauty of coral and subsequent human interest in it makes coral reefs very popular places, and more susceptible to human interactions. Coral reefs are used as habitat by numerous species of flora and fauna, and they support ecotourism and commercial and recreational fishing. They are also extremely vulnerable to climate change (ocean warming, ocean acidification), disease, overharvest, physical damage caused by ships and hurricanes, and changes in water quality. Much research has been conducted on corals, but the research need is ongoing in order to better understand and protect this resource; research is particularly needed on deep-sea corals and for studying the efficacy of marine protected areas in the recovery and preservation of coral reefs.

Habitat Mapping

An enhanced, integrated system of categorizing and mapping broad habitat categories and subcategories would provide managers with a useful tool for evaluating and monitoring ecological, hydrological, meteorological, and geological effects on the living marine resources in the Southeast. More detailed mapping is needed for all major fishery species. Mapping at the coarsest scale (e.g. broad habitat categories within a limited number of estuaries) is probably adequate for a few species, but current tools and information are insufficient to map habitats at finer scales. For example, aerial image analysis is not refined enough to distinguish among marsh types based on plant species or flooding patterns. Geospatial information on secondary productivity and other ecosystem parameters is also presently insufficient to create models for comparing habitat quality across regions and habitat types. Habitat mapping and modeling could also provide a resource for restoration planning, public education, and disaster assessment and recovery.

NOAA / GTMNERR

Moses Creek, in the Guana Tolomata Matanzas National Estuarine Research Reserve, Florida. This reserve is part of the NOAA National Estuarine Research Reserve System, which focuses on scientific research, stewardship, and education—an integrated program encouraging informed management of estuarine and coastal habitats.

Habitat Requirements of Adult and Early Life Stages of Commercially Important Fish and Invertebrates and Protected Species

More information is needed on the habitat requirements of commercially important fish and invertebrates and protected species. This applies to all life stages but in particular the earlier life stages.

Harvested Fish and Invertebrates—Certain marine invertebrates and fish are prized for their commercial, recreational, or ecotourism value. The dependence of these species on various habitats in southeastern ecosystems, particularly during their vulnerable early life stages, requires more study to characterize and understand critical associations, characteristics, and functions. For some important species—such as penaeid shrimp, blue crab, and red drum—much data exist, but the quality and quan-


Karen Roeder, Gray's Reef National Marine Sanctuary

Black sea bass at Gray's Reef National Marine Sanctuary off the coast of Sapelo Island, Georgia.

tity of information are not spatially or temporally uniform, hindering its utility. For example, most of the available habitat-specific density data were derived from the northwestern Gulf of Mexico, and more data are needed for estuarine habitats from other coastal areas, where these associations may differ. Additional information is needed to evaluate the effects of habitat quality on variables beyond species densities, including growth and survival rates and productivity. Research also is needed to understand the relationships between fishery production and land–water configuration in tidal marshes.

Expanded research into the early life stages of fishes is also required to understand the success of adult fishes. The mechanisms and habitat conditions under which an age class of fish successfully reaches the next stage are not well known. Information is needed about the location and characteristics of adult spawning sites and aggregations, and the factors that affect hatching success. For the larval planktonic stage, it is necessary to study larval sources, transport mechanisms, and optimal conditions for successful settlement and survival in order to understand the conditions for successful recruitment into a given nursery area. Questions about juvenile nursery areas, such as whether and to what extent these nurseries contribute recruits to the adult population, are currently being investigated for only a limited number of species. Another important area that has received little research is the transition between juvenile and adult life stages, including the migration from juvenile nurseries to adult habitats.

Coral reef fishes like snappers and groupers are good examples of managed species that need additional habitat-related information and research, particularly on their early life stages. These fishes have complex early life histories that include spawning aggregations, complex factors affecting movement into nurseries, and transition migrations that ultimately bring juveniles to adult populations in adult habitats. The Dry Tortugas is an example of an area that has become a recognized spawning site for several species of fish managed under the grouper–snapper complex. Tunas are another example. They are highly migratory pelagic species that spawn in the open ocean. Their young develop in the same habitat as the adults, and then the juveniles move out to migrate over extremely wide geographic regions. Bluefin tuna spawn in either the Gulf of Mexico or the Mediterranean Sea, where the planktonic stages develop regionally, and then the juveniles follow an extended migration throughout the North Atlantic Ocean. Additional research is needed to determine whether the distinct spawning areas and localized planktonic development mean that the bluefin tuna migrating throughout the Atlantic are divided into more than one stock, and what implications the habitat differences and variability in these distinct areas may have for recruitment and management.

Protected Species: Marine Mammals—Marine mammals are impacted by a variety of human activities, including interactions with commercial fishing, pollution, and exposure to high levels of anthropogenic sound associated with oil exploration and military activities. For each of these factors, information on marine mammal habitat requirements and spatial distributions is needed to predict and mitigate the impacts on these protected populations. Managers need improved habitat characterization studies, involving expanded environmental data collection, including abiotic hydrographic variables and the distribution of prey resources likely to influence marine mammal movements and aggregations. These data can then be combined with spatially explicit modeling to better characterize exposure levels and predict the impacts of anthropogenic stressors on marine mammal populations.

Protected Species: Sea Turtles—Most sea turtle datasets focus on nesting females, and in-water data are especially lacking for immature life stages of all species, limiting knowledge of specific habitat needs. Research is also needed into the effects of habitat alteration on sea turtles. Changes to freshwater flow may affect the extent and composition of seagrass beds, coral reefs, and other marine communities by changing either salinity or nutrient conditions, which may, in turn, affect sea turtle distribution and habitat use. Collection of baseline data on the contaminant loads in sea turtles has only just begun, and research is needed to understand the lethal and sub-lethal effects of such exposure on individuals and on populations of sea turtles.

Protected Species: Fishes—Protected fish species such as Atlantic sturgeon have many priority research needs.[14] Examples include the identification of spawning, nursery, and overwintering areas, the need for long-term monitoring programs that can determine distribution and abundance patterns, and an improved understanding of the effects of dredging (both direct and indirect). There is also a need to improve and facilitate fish passage in habitats where obstacles such as dams remain.

Impacts of Severe Storms and Sea Level Rise on Fishery and Protected Species and Their Habitats

Winds, storm surge, and associated flooding from hurricanes and lesser storms can significantly impact biological resources of the affected region. Some impacts to coastal Louisiana caused by Hurricanes Katrina and Rita in 2005 included wetland and timber loss, and declines in fisheries (specifically oysters) and wildlife populations. Using geographic information system (GIS) analysis, the U.S. Geological Survey estimated that over a 4-year period (2004–08), Hurricanes Katrina, Rita, Gustav, and Ike resulted in an approximate loss of 850 km^2 (328 mi^2) of marsh (Barras et al., 2008; Barras, 2009). Few comprehensive surveys have been conducted to definitively investigate damages from inadvertent pollution, erosion, habitat destruction, and other consequences of severe storms like the 2005 hurricanes on inshore and nearshore habitats, fishery species, and associated wildlife.

Land subsidence, saltwater intrusion, wetland dredging and filling, and severe storm events act in concert with a projected rise in sea level. These factors reduce the quantity and quality of available estuarine and coastal wetland habitats. Integrated ecosystem research is needed to project these potential impacts on commercial, recreational, and protected species and the fisheries and ecotourism industries that depend on their existence.

NOAA

A New Orleans levee that was breached by Hurricane Katrina, and resultant flooding.

Habitat Restoration

Many impaired habitats important to fisheries, particularly those occurring within estuaries, can be restored or improved with technology. The primary concern is mitigating habitat loss such as losses from the dredging and filling of wetlands and polluted runoff, and inundation of intertidal habitats due to sea level rise and land subsidence. Essentially all coastal development will impact aquatic habitat and its fauna and flora, but these impacts can be reduced or mitigated. Understand-

[14]See http://sero.nmfs.noaa.gov/pr/sturgeon.htm (accessed April 2013) for more information.

NMFS

NMFS

Before (upper) and after (lower) photos of Bahia Grande (Big Bay) in south Texas. Originally, this area consited of three estuarine basins covering about 4,450 hectares (11,000 acres). Dredging the Brownsville ship channel in the 1930s cut off the water supply for the tidal system, drying up the Bahia Grande and reducing it to a salty sand flat whose drifting sands caused health problems for people in the area and difficulties for machinery.

In 2005, channels were cut to reestablish tidal flow, and native vegetation was replanted. The successful restoration returned about 4,000 hectares (10,000 acres) to original conditions, relieving the local community of health and machinery problems and producing an ecosystem abundant with aquatic plants, fishes, and other marine life.

ing ecosystem-level effects of restoration is also important. For example, restoration of marine habitats, such as seagrass and coral reefs, is likely to benefit sea turtles.

Expanded research is needed to assess the efficacy and examine the impacts of existing methods and to develop new cost-effective approaches for habitat building and restoration. For example, marsh creation, nourishment, and terracing are being used in the northern Gulf of Mexico to restore intertidal marsh in areas that recently converted to shallow open water. Additional research is needed to improve the ecological functioning of created marsh to that of natural marshes. Diversions of river water into adjacent coastal wetlands are a part of all plans to mitigate for the extensive loss of Louisiana's coastal wetlands. Diversions can be broadly characterized as "sediment diversions," designed for significant land-building in areas that currently are open water, and "freshwater diversions," designed to flow into existing but degrading marsh systems to reverse or slow the rates of degradation. Large river diversions are being planned for sites along the lower Mississippi River to reintroduce sediments and fresh water into nearby estuaries to restore coastal wetlands shown to be valuable for fishery species. While there is recognized potential for diversions to combat Louisiana's coastal land loss, there exists substantial uncertainty about the possible ecological responses to, and our ability to predict wetlands creation from, diversions. A necessary step in the development of this restoration technology is research into the habitat requirements of fishery species and other living marine resources that could potentially be impacted by a large freshwater influx, so that the design and operation of these diversions maximizes the restoration of wetlands and minimizes the adverse impacts on important NOAA trust resources.

Another approach to reducing eutrophication and restoring impacted Gulf coastal ecosystems is to reduce watershed nutrient loading. This is the management strategy of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, which was established in 1997 and is still active (as of January 2014). The Task force, which includes NOAA, was established to reduce and control hypoxia in the Gulf of Mexico. Since this time, they have undertaken several actions and developed a plan to address, reduce, mitigate, and manage hypoxia in the Northern Gulf of Mexico as well as improve water quality in the Mississippi River Basin. It is important to keep in mind that, while the benefits of conservation, restoration, and management are clear for organisms that rely on important habitats, the economic and sociological benefits to humans are less well-documented and need to be understood.

Transboundary Biological and Oceanographic Linkages

Transboundary biological and oceanographic linkages between Mesoamerica (the coastal and offshore waters of southern Mexico and Central America) and the northern Gulf of Mexico need additional research. Spawning conditions in the Caribbean affect the "downstream" recruitment of important fishery populations in the Gulf of Mexico, particularly along the coast of Florida. U.S. and Mexican scientists along the Caribbean coast of Mexico (the Mexican State of Quintana Roo) are cooperating on research into the genetic relationships between Mexican and Floridian populations of the same coral reef fish species. This type of research should be expanded into new areas and be applied to additional species.

Effects of Underwater Sound

Additional information is also needed on the intensity, variability, and transmission of anthropogenic noise through marine mammal habitats. Underwater sound can affect marine life through long-term increases in ocean noise (chronic effects) or through acute impacts in response to a specific, typically intense, sound source. Oil and gas exploration, research activities, military operations, and industrial activities can produce high-intensity underwater sounds reaching intensities of over 235 decibels (as intense as an underwater earthquake) and may affect susceptible cetacean species. Developing tools to monitor and characterize sounds from the above sources, describe their transmission through the habitat, and evaluate the direct and indirect impacts on marine mammals are critical long-term research needs. This is particularly relevant to the Gulf of Mexico, as offshore energy exploration, development, and use of deepwater oil reserves and liquid natural gas extraction increases.

Additional Research Needs

There is an ongoing need to determine human impacts in all habitat types and any subsequent effects on fishery production and marine mammal and sea turtle biology and behavior. There are also ongoing research needs to identify and characterize essential habitat for fishery species and protected species and to collect information on ecosystem structure and function.

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