National Summary of Findings

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Mangrove roots provide vital habitat for many species, especially young fish.

OVERVIEW

The Nation's marine species depend on a diverse array of freshwater, estuarine, shallow marine, and oceanic habitats at various life stages. These species support commercial and recreational marine fisheries and tourism that in turn generate considerable revenue and provide millions of jobs. Sufficient habitat quantity and quality are essential to maintain healthy stocks of these ecologically and economically important living marine resources and to support fully functional marine ecosystems. Many of the habitats that support the Nation's living marine resources have been diminished from their original size. The condition of habitats also varies considerably, ranging from severely degraded to pristine. Issues affecting U.S. living marine resource habitats vary throughout the country, but many are widespread. Understanding the relationships between species and habitats, knowing where and how much habitat exists, and rigorously monitoring and assessing its condition can provide the scientific basis for managing habitat as well as strengthen the scientific basis for managing the stocks that live within it. Communicating this information in appropriate forms to resource managers, stakeholders, and the public in a timely manner can inform public debate and improve policies for managing living marine resources.

This National Summary chapter consolidates much of the known information about the habitat use of federally managed and protected marine species under the purview of NOAA's National Marine Fisheries Service (NMFS) and the status and trends of the habitats that they use. It also evaluates the level of knowledge regarding habitat use, and in-

Jean Kenyon, NMFS

Bluestripe snapper taking shelter under table coral at French Frigate Shoals in the Northwestern Hawaiian Islands.

cludes overviews of habitat trends; national habitat issues; steps being taken to protect and restore habitats; information on agencies and programs with active habitat-based science, conservation, or restoration programs; NOAA's unique approach to studying and protecting habitats through the Habitat Blueprint; and critical habitat research needed. For our Nation to continue benefiting from abundant living marine resources, society must recognize the value of habitat and place a high priority on managing and conserving it.

HABITAT USE BY FEDERALLY MANAGED FISHERY AND PROTECTED SPECIES

Dedicated research on marine species has been conducted for many decades. This research is usually directed at the more abundant and commercially important species, or protected species with high public interest or high extinction risk. In the early years of research, it was important to know where species were located, so they could be harvested (fishery species) or better understood and protected (e.g. marine mammals). It was also important to learn why there was so much variation in fisheries productivity and in abundance and distribution of marine mammals. With the advent of fisheries management at the international level in the 1950s and the passage of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA) in the 1970s (these laws are described in Appendix 2), it became increasingly important to know how many fish were available for harvest in each year and how many were likely to be available in future years, as well as to know the status of populations of protected species and understand their ecological roles. In conducting the necessary research for stock assessments,[1] important information about the presence or absence of animals in their habitats was recorded, although this information was generally not immediately used in the stock assessment. At present, most stock assessments still do not use habitat-specific data, aside from depth and geographic stratification in fisheries-independent surveys. Information on habitats is now being assembled from past records and from new research undertaken by many different organizations.

Habitat use for the Nation's federally managed fishery and protected marine species is summarized according to the following four habitat categories, as were defined in the introduction of this report:

- freshwater habitat—located between the headwater (water from which a river rises, a source) and the head-of-tide (inland limit of water affected by the tides), with negligible salinity;
- estuarine habitat—located in a semi-enclosed coastal body of water extending from head-of-tide to a free connection with the open sea, and within which sea water is mixed with fresh water;
- shallow marine habitat—less than 200 m (656 ft) in bottom depth, located between the outer boundary of an estuary or coast (continent or island) and the outer boundary of the U.S. Exclusive Economic Zone (EEZ), which is usually 370 km (200 nautical miles [nmi]) from shore. This includes the seafloor and water column over areas shallower than 200 m (656 ft); and
- oceanic habitat—greater than 200 m (656 ft) in bottom depth, located between the outer boundary of an estuary or coast (continent or island) and the outer boundary of the U.S. EEZ. This includes the seafloor and open water column over areas deeper than 200 m (656 ft).

[1]See the NMFS Office of Science and Technology web page for information on stock assessments and links to assessment findings: http://www.st.nmfs.noaa.gov/stock-assessment/index (accessed March 2015).

Management category	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
Fishery management plan and fishery ecosystem plan species	16%	82%	98%	96%
Protected cetacean, pinniped, and sea turtle species	27%	73%	100%	93%

Table 3
National summary of the habitat categories used by the living marine resources managed and protected by NMFS. For fishery species, the information is summarized by 46 FMP and FEP species (the Aquaculture FMP is not relevant to this analysis, so is excluded). For protected species, the information is summarized by groups of cetaceans, pinnipeds, and sea turtles for all five regions covered in this report.

Habitat use is described to the extent that detailed information is available for federally managed species under NMFS purview. Fishery species are managed under the MSA by fishery management plan (FMP) or fishery ecosystem plan (FEP), and may also be referred to as FMP/FEP species. Nationwide there are currently 46 FMPs/FEPs[2] for various fish, shellfish, and other species, many of which are harvested for commercial or recreational use (see Appendix 3 for a full listing). Habitat use information is available in these plans. Protected species of primary concern to NMFS and under NMFS jurisdiction include species such as cetaceans (whales, dolphins, and porpoises), pinnipeds (seals and sea lions), sea turtles (in-water phase), invertebrates (e.g. corals), and fish (e.g. salmon, sturgeon, rockfish), covered under MMPA and/or ESA. Critical habitat is identified for ESA-listed species in their recovery plans.

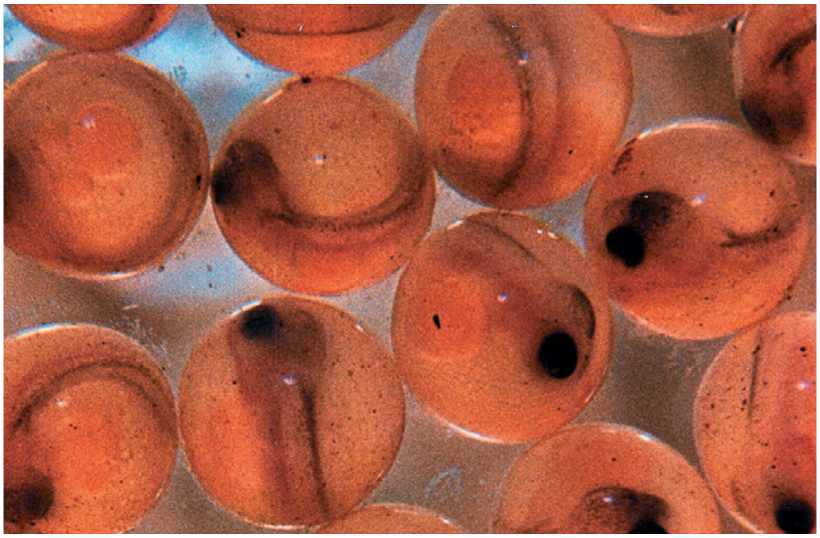
For federally managed marine species in all regions, shallow marine and oceanic habitats are the most commonly used, while freshwater habitats are the least used (Table 3). Anadromous species, namely salmon, are the primary FMP/FEP species that utilize freshwater habitats. FMP/FEP species make extensive use of estuaries for at least one stage in their life cycles in all regions except the Pacific Islands, which have relatively little estuarine habitat. Estuaries provide habitat to at least one life stage of 68% (by dollar value) and 46% (by weight) of the Nation's commercial catch of fish and shellfish. Estuarine species also account for approximately 80% of fish harvested recreationally (Lellis-Dibble et al., 2008). Estuarine habitats are also important for many marine mammals such as Gulf of Mexico and Atlantic bottlenose dolphins, some of which spend a major portion of their lives in these areas.

Habitat use by the Nation's protected cetacean, pinniped, and sea turtle species is broadly similar to that of FMP/FEP species. Cetaceans, pinnipeds, and sea turtles use shallow marine and oceanic habitats in every region. Estuarine habitats are frequently used by many cetaceans, pinnipeds, and sea turtles throughout the United States, although to a lesser degree in the Pacific Islands region where there is relatively little estuarine habitat. Freshwater habitat is the habitat type least used by the Nation's cetaceans, pinnipeds, and sea turtles, with only a few species such as harbor seals and beluga whales occasionally using it.

STATUS OF HABITAT KNOWLEDGE

At the national level, habitat information for most federally managed fishery species consists of presence or absence data for a species or life stage in a particular habitat type—this is distribution information, the most basic level of information. The more detailed and better the information on habitat use, the less of it exists. For example, less information is available that relates species densities or abundances to a particular habitat. Even less information is available on habitat-related growth, reproduction, and/or survival by species or life stage, and habitat-specific productivity information by species or life stage is rare. In general, most habitat-use information is available for adult life stages, which are surveyed for stock assessments. Much less information is available for eggs and larvae, which typically require other, less widely applied surveys and sampling protocols. Some complete data gaps exist on habitat use for one or more species (or life stages) within and across regions. However, the species and species groups with unknown habitat use generally constitute a relatively minor portion of the commercial and recreational catch.

[2]Note that this number includes an Aquaculture FMP in the Southeast Region.



Atlantic salmon eggs require clean freshwater habitat.

The best and most informative type of habitat information, which links species productivity directly to habitat, is not available for most fishery species, even the most economically valuable. Information on habitat-specific productivity is the highest and most quantitative level of information for identifying essential fish habitat (EFH), and provides the most definitive information for understanding relationships between species and their habitats. An example of this productivity information would be the number or weight of a species (e.g. sea trout) produced per unit area of habitat (e.g. seagrass bed) per year. Such information is necessary for quantifying the contributions of specific habitats to the production of a species, but is generally not available for most species. One of the few examples where it is available is for some salmon stocks in freshwater habitats. For marine mammals and sea turtles, the most critical pieces of information are region- and habitat-specific distribution and density, and seasonal changes in time and space. Such information is necessary for other federal agencies and industries applying to NMFS for permits to conduct surveys, exploration, development, or defense activities, as this information can help minimize potential impacts to habitats and the marine mammals and sea turtles found in the habitats.

In most regions, the most common level of habitat-use information for the protected resources covered in this report (cetaceans, pinnipeds, and sea turtles) is also data on the presence or absence of a species or life stage in a particular habitat type. Habitat-specific species densities are also available for some of these groups in each region. Limited information, or no information at all, exists on habitat-specific growth, reproduction, behavior, survival, and abundance for most protected cetaceans, pinnipeds, and sea turtles throughout all or parts of their geographic ranges. Habitat-specific productivity information, the most detailed level of habitat information, is rare for most cetacean, pinniped, and sea turtle species. As is the case with harvested species, higher-level information on habitat use by protected species would be the most useful information for identifying and conserving critical habitat.

In general there is more, and more detailed, habitat-use information available for harvested fishery species than for protected cetaceans, pinnipeds, and sea turtles. Although the laws for fishery management and protecting species are all quite strong, more funding is provided to NMFS for surveys and assessments of fish than for such work on protected species. This difference leads to the noted differences in level of information on habitat use by these respective groups.

HABITAT STATUS AND TRENDS

Over the last several decades, the nature of threats to habitats has changed significantly. Although there have been significant technological improvements in treatment methods for industrial and municipal waste, managing the input of waste nutrients into our waters remains challenging. The Nation's population is growing and agricultural production is expanding, both of which increase the amount of water we are using. In 2000, the United States withdrew 1.3 trillion liters (345 billion gallons) of water per day, an increase of 46% from 1960 (Heinz Center, 2008). These changes also led to increases in the nutrients being released into our Nation's waterways. For example, between 1992 and 2001, streams in farmlands had higher concentrations of phosphorus and nitrate than streams in forested areas (Heinz Center, 2008). These excess nutrients pose a major problem by giving rise to conditions such as eutrophication, wherein excessive nutrients stimulate plant growth in water bodies and can subsequently reduce dissolved oxygen below the levels needed by aquatic animals.

Freshwater Habitats

Freshwater environments like streams and rivers provide habitat for anadromous species, such as salmon, some populations of which are managed or protected by NMFS. Several factors have impacted the quantity and quality of freshwater habitats and the waters draining into rivers and estuaries. Farming, industrialization, residential expansion, and flood control are examples of factors that can reduce the flow of fresh water, change the timing and spatial extent of flood events, and increase the quantity of nutrients and contaminants draining from upland habitats. In terms of some recent trends, the Heinz Center reported that within all coastal states (including some areas in Alaska and Puerto Rico), one or more contaminants were detected in nearly all the streams and stream sediments tested, and that in more than 50% of the stream water and stream sediment samples at least one contaminant was detected at levels above benchmarks set to protect aquatic life. (Heinz Center, 2008). In addition, the draft National Rivers and Streams Assessment for 2008–09, released in February 2013, found that 55% of the Nation's river and stream length was in poor biological condition, a key indicator of overall water-body health (EPA, 2013). This assessment also found some significant national shifts from the U.S. Environmental Protection Agency's (EPA's) 2004 Wadeable Streams Assessment. Changes, both positive and negative, were noted in stream condition: for macroinvertebrates, the amount of stream length in good quality dropped from 27.4% to 20.5%; for phosphorus, the amount of stream length in good condition decreased from 52.8% to 34.2%; for nitrogen, however, the percentage of stream length in good condition rose from 46.6% to 55.4%; and the percentage of stream length in good condition for in-stream fish habitat also rose, from 51.7% to 68.9% (EPA, 2013). The most up-to-date information on this can be found at the EPA website for the assessment.[3]

Diversion of fresh water can also impact aquatic life. It can significantly modify reproductive patterns and success of anadromous fish. Many marine species rely on freshwater habitats for a portion of their life cycle, making conserving freshwater habitats just as important as protecting the saltwater habitats occupied during other stages of their lives.

[3]http://water.epa.gov/type/rsl/monitoring/riverssurvey/ (accessed March 2015).

Mandy Lindeberg, NMFS

Southeast Alaska wetland and estuarine habitat supports many fish species at critical times in their life cycles.

Estuarine Habitats

Estuaries provide habitat to at least one life stage of much of the Nation's harvested fish and shellfish as well as many protected species. These valuable habitats are also strongly affected by human activities on the land surrounding them and the rivers that drain into them. Over 70% of the estuarine habitat in both the Pacific Northwest and California has been lost or degraded due to diking, filling, polluting, and other human activities (Dahl, 1990; Zedler et al., 2001). Much of this change, however, occurred over 50 years ago, and efforts are now underway to protect and restore many of these Pacific Coast habitats. Examples include the removal and relocation of dikes and levees.

Eutrophication is also a common problem for estuarine habitats. Eutrophication is caused by

Divers examining a sewage outflow pipe at Delray Beach, Florida.

excess nutrients in the water, which can lead to dense algal blooms. These blooms can have many adverse impacts on ecosystems. Decomposition of dense algal blooms can reduce dissolved oxygen, which can harm marine life. Blooms can also increase water turbidity (i.e. cloudiness) and block sunlight required by seagrasses for growth.

Bricker et al. (2007) reported that the majority of U.S. estuaries were highly influenced by human-related activities and had moderate to high eutrophic conditions. Mid-Atlantic estuaries from Cape Cod to Chesapeake Bay were the most impacted nationally, with most having a moderately high or high overall eutrophic condition rating and more than one-third having worsened since the early 1990s. The North Atlantic estuaries from Maine to Cape Cod were the least impacted nationally, although future conditions were predicted to worsen. The majority of South Atlantic estuaries (from North Carolina to Florida) had only moderate or low eutrophic conditions, while some Gulf of Mexico estuaries had a high or moderately high overall eutrophic condition. The majority of the Pacific Coast estuaries with high to moderate eutrophic conditions were located in Washington and central California (Bricker et al., 2007).

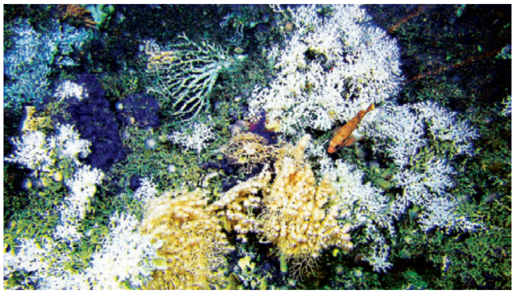
Shallow Marine and Oceanic Habitats

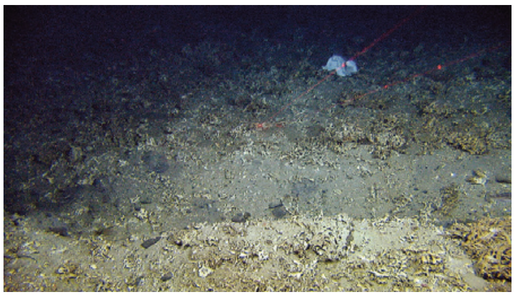
Shallow marine and oceanic habitats cover a wide variety of habitat types including intertidal zones, coral reefs (shallow and deepwater), seagrass meadows, kelp forests, the Continental Shelf, and coastal ocean and upwelling areas. These areas provide spawning grounds, nursery areas, shelter, and food sources critical for many finfish, shellfish, cetaceans, pinnipeds, sea turtles, and other marine organisms. Compared to freshwater and estuarine habitats, shallow marine and oceanic habitats generally have better water quality, and relatively less habitat has been lost to human activities. Nevertheless, several threats exist that can impact habitat quality and quantity. EPA's National Coastal Condition Report IV (EPA, 2012) presented information on the overall condition of the Nation's coastal waters, using monitoring data collected between 2003 and 2006 and indices for water quality, sediment quality, benthos, coastal habitat, and fish-tissue contaminants. The overall condition of the Nation's coastal waters was rated as fair. With respect to regional conditions, the Alaska, American Samoa, and Guam regions were rated good; the West Coast and U.S. Virgin Islands regions were rated fair to good; the Northeast Coast, Southeast Coast, Gulf Coast, Hawaii, and Puerto Rico regions were rated fair; and the Great Lakes region was rated fair to poor.

In looking at trends in U.S. shallow marine coral reef habitats, a 2008 NOAA report indicated that the average condition of most key U.S. coral reef resources has declined over both short- and long-term periods of evaluation. Over a longer, 10- to 25-year time period of evaluation, the level of impact from commonly addressed threats to the coral reef key resources has also increased. These threats include climate change and coral bleaching, coral disease, coastal development, tourism and recreation, commercial fishing, subsistence and recreational fishing, vessel damage, marine debris, and aquatic invasive species (Waddell and Clarke, 2008).

Recent actions have demonstrated a particular concern for some Southeast and Pacific Island corals in shallow marine habitats. In August 2014 NOAA listed 20 new corals as threatened under the ESA.[4] The new coral species listed are found in the Indo-Pacific (15 species) and Caribbean (5 species). They join elkhorn and staghorn corals (listed as threatened in 2006) for a combined total of 22 species of coral that are now protected under the ESA. Three major threats identified—rising ocean

[4]See http://www.nmfs.noaa.gov/stories/2014/08/corals_listing.html (accessed September 2014).





Both photos © Mareano, Institute of Marine Research, Norway

Upper photo, the deep-sea coral *Lophelia* in its natural state; lower photo, a *Lophelia* coral reef after bottom trawling.

temperatures, ocean acidification, and disease—are all directly or indirectly linked to greenhouse gas emissions and a changing climate. These threats can be compounded by other impacts such as trophic effects of fishing, sedimentation, and nutrient pollution, which affects corals on local to regional spatial scales.

Some examples of additional threats to shallow marine and oceanic habitats include sedimentation on reefs and other sedentary bottom-dwelling organisms, the uncertain effects of climate change, and the impacts of fishing and fishing gear, particularly bottom trawls on seafloor habitats and gillnets in the open water. Many seafloor areas are sensitive to the continual scraping effects of trawls and dredges. Fragile, slow-growing, deep-sea corals[5] and sponges, for example, provide important habitat to many species, but can be damaged or destroyed by encounters with mobile fishing gear. (see text box on this page). There are additional effects that can result from marine debris (including discarded or lost fishing gear), oil spills and slicks, oil and gas development, sand and gravel mining, cable deployment, and anchoring, among others. Harmful algal blooms and other toxin-producing

[5]Deep-sea corals refer to those corals found below 50 m (164 ft) and most frequently beyond the Continental Shelf break.

Deep-sea corals and sponges— unique deep-sea habitats

Deep-sea corals and sponges provide unique habitat for deep-sea marine species by providing substrate for attachment, places for feeding and spawning, refuge for juveniles, and dissipation of water flow. Much less is known about deep-sea sponges than corals. Humans gain benefits from these ecosystems through the fish extracted and the bio-compounds derived from these unique organisms. Chemical compounds have been isolated from deep-sea sponges, and are currently undergoing pharmaceutical clinical trials. These sponges have been identified as habitat for managed fish stocks in some regions, and they face many of the same threats as deep-sea corals. Bottom trawl fisheries are the biggest threat to deep-sea coral and sponge habitats that occur in areas where such fishing is allowed. Deep-sea coral that is damaged by trawling has an estimated recovery time of more than 30 years (Rooper et al., 2011). Deep-sea corals grow and reproduce at very slow rates, with some estimated to be hundreds to thousands of years old, thus they are highly susceptible to anthropogenic impacts that make their recovery from disturbances difficult over short time periods. Other activities that may impact these ecosystems include fishing with other bottom-contact gears; coral harvesting; oil, gas, and mineral exploration and extraction; and submarine cable/pipeline deployment. The types of stressors and extent of impact from these activities vary among regions. Additional threats that have not been adequately explored include invasive species, climate change, and ocean acidification.

Wetlands

"At the time of Colonial America, the area that now constitutes the 50 United States contained an estimated 392 million acres of wetlands. Of this total, 221 million acres were located in the lower 48 states. Another 170 million acres occurred in Alaska. Hawaii contained an estimated 59,000 acres.

Over a period of 200 years, the lower 48 states lost an estimated 53 percent of their original wetlands. Alaska has lost a fraction of one percent while Hawaii has lost an estimated 12 percent of its original wetland areas. On average, this means that the lower 48 states have lost over 60 acres of wetlands for every hour between the 1780's and the 1980's."

—Excerpt from Wetland Losses in the United States, 1780's to 1980's (Dahl, 1990)

algae or organisms are a recurring problem in some areas, and can further impact shallow marine and oceanic habitats by killing marine animals and rendering seafood unfit for consumption by people or pets. At least some portion of this problem may be caused by increased nutrient inputs, and the problem could increase if ocean temperatures warm as projected in climate change scenarios. In addition, increases in carbon dioxide emissions are causing the oceans to become more acidic. If this problem increases in the future, acidification will affect habitat-building calcifying organisms, such as corals and shellfish, by interfering with their ability to build and maintain their skeletons or shells.

Coastal Wetlands

Wetlands are common in freshwater, estuarine, and shallow marine environments. Wetlands are defined as lands that are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water (Dahl, 2011). Coastal wetlands include marshes, swamps, mangrove forests, and seagrass beds in and near coastal watersheds. Coastal wetlands comprise about one-third of all the wetlands in the continental United States. Wetland loss for the country as a whole was about 183,000 hectares (452,201 acres) annually from the mid-1950s to the mid-1970s, but has decreased significantly due to federal and state laws and policies that discourage wetland destruction and encourage wetland restoration. The most recent (2004–2009) national wetland trend reported by the U.S. Fish and Wildlife Service (USFWS) was an annual average net loss of 5,590 hectares (13,800 acres) per year in the lower 48 states, a substantial decrease from the rate of loss during the 1950s to 1970s (Dahl, 2011). This relatively minor net loss resulted from the increased restoration of some kinds of inland wetlands, partially offsetting continuing losses elsewhere.

In coastal watersheds, however, wetland loss continues to be a substantial problem. A joint NOAA-USFWS report found that wetlands in coastal watersheds experienced a net loss of over 144,000 hectares (360,000 acres) between 2004 and 2009 (Dahl and Stedman, 2013). This amounts to an average annual loss rate of over 32,000 hectares (80,000 acres) per year, which is an increase from the annual loss rate of 24,000 hectares (59,000 acres) between 1998 and 2004. The wetland gains that partially offset the losses in the national study were not as common in coastal watersheds, resulting in a net loss for coastal watersheds that was higher than the net loss for all of the lower 48 states, which includes both coastal and inland wetlands.

Between 2004 and 2009, the coastal watersheds of the lower 48 states experienced a net loss of all types of marine and estuarine intertidal wetlands of an estimated 38,400 hectares (95,000 acres). This included small gains in unvegetated wetlands and scrub/shrub wetlands. Salt marsh declined by more than 51,900 hectares (128,200 acres)—a loss rate that was three times greater than the rate of salt marsh loss from the previous study period of 1998 to 2004. A majority of these losses were conversions to unvegetated bay bottoms or open ocean (Dahl and Stedman, 2013). The loss of wetlands to open water is especially pronounced in coastal Louisiana. Contributing factors include coastal development, sea level rise, coastal subsidence (lowering of the land from compaction, or oil/water extraction), storms, interference with normal erosional and depositional processes within the Mississippi River Delta, and other factors. Specifically, coastal Louisiana lost over 4,877 km^2 (1,883 mi^2) of land area between 1932 and 2010, and based on trend analyses from 1985 to 2010 the estimated annual wetland loss rate is over 41 km^2 (16 mi^2) (Couvillion et al., 2011).

Mangroves and submerged aquatic vegetation (seagrass) are also declining throughout many of the Nation's coastal areas. Submerged aquatic vegetation (SAV) is declining in many estuaries, often due to an excess of suspended sediment associated with poor land-use practices, as well as algal blooms stimulated by excess nutrients, both of which block penetration of the light needed for SAV to grow. For example, SAV beds are almost completely absent from Delaware Bay and nearby coastal bays (Bricker et al., 2007), and although the Chesapeake Bay's SAV has shown a rebound from extremely low levels in 1984 due to some improvements in water quality, these increases have leveled off since 1999 (Chesapeake Bay Program, 2011).

The greatest wetland loss in coastal watersheds is occurring in freshwater wetlands. Between 2004 and 2009, the coastal watersheds of the Atlantic, Pacific, and Gulf of Mexico suffered an average annual net loss of nearly 23,000 hectares (56,000 acres) of freshwater wetlands, the majority of them forested (Dahl and Stedman, 2013). Human activity, particularly development and some activities related to silviculture, is the leading cause of freshwater wetland loss in coastal watersheds, which is not surprising given that nearly 40% of this country's population lives in counties directly on the shoreline (NOAA, 2013b). The southeast United States, which is experiencing the greatest amount of coastal wetland loss, is also where populations are projected to increase in coming years. Specifically, 71% of the Nation's net coastal wetland losses during 2004 to 2009 were in the Gulf of Mexico (Dahl and Stedman, 2013).

NOAA

Degraded and eroded marsh on Staten Island, New York.

NATIONAL HABITAT ISSUES

Many habitat issues are common across regions and habitat types, though manifestations and impacts to species may differ regionally. At a high level, these issues include: water quality and quantity; infrastructure in aquatic habitats; fisheries and other commercial uses of marine habitats; environmental issues; and habitat fragmentation and loss. Table 4 provides a summary of national habitat issues, potential solutions, and examples of actions being taken.

Water Quality

The fact that water itself is habitat is often not considered. Habitat usually conjures up visions of marshes, mud flats, or rocky ocean bottom, but for species that spend much or all of their lives in the water, it is no less essential than any other kind of habitat. Thus, water quality is one of the most significant habitat factors affecting populations and ecosystems. Degradation of water quality is a widespread habitat problem potentially affecting species in any habitat type. Water quality impacts can lead to a number of problems that adversely affect living marine resources, including excessive nutrient concentrations leading to reduced concentrations of dissolved oxygen, fish kills, and toxic algal blooms; oil and chemical contamination, which can have lethal or sublethal

Table 4
Habitat issues, potential solutions, and some examples of actions being taken.

Habitat issue	Potential solutions	Examples of actions being taken
Degraded water quality • reduced flows • reduced water clarity • excess nutrients • toxic contaminants • thermal effluents	• Reduce point source and nonpoint source pollution • Increase streamside buffers • Create and restore wetlands • Improve water management and allocation	Community-based watershed projects; discharge permitting; in-stream improvement; interagency cooperation; enforcement; partnerships: • National Fish Habitat Partnership • NOAA Mussel Watch Program, which monitors status and trends of chemical contamination in U.S. coastal waters [a] • Developing Total Maximum Daily Loads for a "pollution diet" to improve water quality on a regional basis in the watersheds of the Chesapeake Bay [b] • Reducing nutrient inputs into rivers, estuaries, and coastal waters at appropriate scales (e.g. Chesapeake Bay Program)
Loss of habitat complexity	• Place woody debris, boulders, and gravel in stream channels • Create and enhance artificial reefs	Pacific Coastal Salmon Recovery Fund and activities funded under ESA; artificial reefs: • Creating an artificial reef by sinking the USS *Vandenberg* in the Florida Keys National Marine Sanctuary to provide habitat for marine life and help support the local economy • Installing concrete oyster domes and oyster shells along a half-mile of shoreline in Tampa Bay to provide reef habitat for marine life and help reduce wave energy
Effects of fishing gear	• Close sensitive areas • Restrict gear that impacts sensitive areas • Conduct gear research to reduce harmful effects	Regulations to establish closed areas; gear restrictions; habitat conservation areas; gear research: • Aleutian Islands Habitat Conservation Area, which is closed to bottom trawling • Five Habitat Areas of Particular Concern for deep-sea corals in the Southeast, where most fishing gears that contact the seafloor are prohibited and deep-sea coral habitat is protected
Vessel traffic and noise	• Limit vessel speeds and traffic when and where vulnerable animals occur • Limit use of and/or volumes from sonar, air guns, and other loud sources	Awareness campaigns; enforcement; partnerships; implement actions to reduce and mitigate harmful impacts: • Shipping lane modifications on the East Coast to help reduce the threat of collisions with whales [c] • NOAA-led Cetacean and Sound Mapping Project (CetSound) [d]
Climate variability and change	• Establish baseline conditions and monitor changes • Identify sensitive habitats, species, and life stages and develop mitigation or adaptation strategies • Add climate information into stock assessment and ecosystem models • Develop management approaches for stocks and habitats that consider climate	Oceanographic, habitat, and biological assessments that include climate considerations; awareness campaigns; partnerships; ecosystem models that include climate information: • NOAA Sentinel Sites. The Northern Gulf of Mexico Sentinel Site Cooperative leverages a number of activities to better understand the impacts of climate change, particularly sea level rise [e] • National Fish, Wildlife, and Plants Climate Adaptation Strategy,[f] which provides a 5-year roadmap to decrease impacts of climate change on natural resources • Restoring wetlands can help protect vulnerable coastal habitats from climate change
Invasive species	• Prevent or reduce introductions • Detect new introductions early • Eradicate invasive species • Improve education and regulations	Invasive species management plans; early warning systems; outreach and awareness campaigns; partnerships; research and monitoring efforts: • Impact assessment of invasive lionfish in U.S. waters [g] • Maunalua Bay Reef Restoration Project (removing invasive algae from coral reefs in Hawaii) [h]
Marine debris	• Remove debris • Conduct research to identify debris • Increase enforcement of anti-pollution laws and regulations • Increase enforcement of littering laws and regulations • Educate public about sources and consequences of marine debris	Awareness campaigns; enforcement; partnerships (e.g. working with local governments): • Multiagency partnership (supported by various NOAA programs) that has removed over 750 metric tons (1.6 million lbs) of marine debris from Northwestern Hawaiian Islands • International Coastal Cleanup (The Ocean Conservancy and partners coordinate this volunteer-based effort to clean up beaches and waterways) [i]

(table continued on next page)

Table 4
(continued)

Habitat issue	Potential solutions	Examples of actions being taken
Habitat fragmentation and loss	• Protect and conserve intact habitat • Remove obsolete dams and water-control structures that impede fish movement • Design and install new and improved fish ladders • Create and restore wetland, stream, riverine, and estuarine habitat	Awareness campaigns; advocacy for access; increased enforcement; partnerships across sectors: • National Fish Habitat Partnership • Pacific Coast Salmon Recovery Fund[j] and ESA-funded activities • Estuary Restoration Act • Oyster Recovery Partnership Program (in Chesapeake Bay)[k] • Restoring the Elwha River following the removal of two large dams, which began in 2011

[a] See http://ccma.nos.noaa.gov/about/coast/nsandt/default.aspx (accessed May 2015).
[b] See http://www.chesapeakebay.net/about/programs/tmdl (accessed May 2015).
[c] See http://www.nmfs.noaa.gov/pr/shipstrike/ (accessed May 2015).
[d] See http://cetsound.noaa.gov/index.html (accessed May 2015).
[e] See http://oceanservice.noaa.gov/sentinelsites/ (accessed May 2015).
[f] See http://www.noaanews.noaa.gov/stories2013/20130326_climate_adaptation_strategy.html (accessed May 2015).
[g] See http://coastalscience.noaa.gov/projects/detail?key=9 (accessed May 2015).
[h] See http://www.habitat.noaa.gov/highlights/hlmaunaluaproject.html (accessed May 2015).
[i] See http://www.oceanconservancy.org/our-work/marine-debris/ (accessed May 2015).
[j] Congress established the Pacific Coastal Salmon Recovery Fund in 2000 to protect, restore, and conserve Pacific salmon and steelhead populations and their habitats. See http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/pacific_coastal_salmon_recovery_fund.html (accessed May 2015).
[k] See http://www.oysterrecovery.org/ (accessed May 2015).

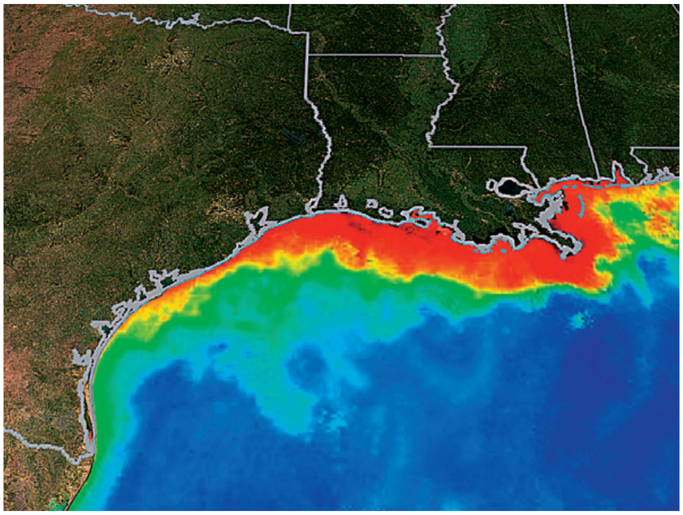
NASA

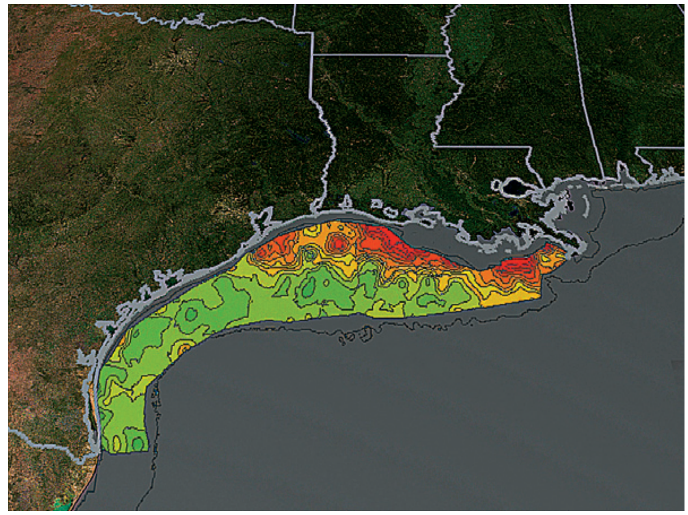
Satellite photo of the southwest part of Lake Erie in 2011 showing a harmful algal bloom (HAB).

effects; and high sediment loads and turbidity resulting in reduced light penetration, lowered primary productivity, loss of submerged aquatic vegetation, and degraded benthic communities. Four key factors that affect water quality are nutrient enrichment and hypoxia, suspended solids and water clarity, point and nonpoint source pollution, and oil spills. These topics are discussed in further detail below.

Nutrient Enrichment, Eutrophication, and Hypoxia—Just as humans and other terrestrial organisms require oxygen, so do aquatic organisms. Nutrient enrichment due to human activities has greatly increased the prevalence of eutrophication and hypoxia, primarily in estuarine and coastal waters. Excess nutrients, mostly nitrates and phosphates, can enter these waters from agricultural (e.g. fertilizer, animal waste), urban and suburban

NOAA





Left: Satellite imagery of the Dead Zone, in which phytoplankton as well as river sediment appear as shades of red and orange when both are in high concentrations.

Right: NOAA ship surveys of oxygen content show low-oxygen areas as reds and oranges.

(e.g. sewage, runoff), and atmospheric (e.g. fossil fuel combustion) sources. When these added nutrients combine with other environmental conditions (e.g. high light levels and temperatures, low levels of circulation and flushing) that favor phytoplankton growth, intense algal blooms can occur, leading to eutrophication and hypoxia. Eutrophication, an ecosystem response to high nutrient concentrations, is characterized by excess phytoplankton production. When these blooms die, the algal cells sink and decompose, consuming dissolved oxygen in bottom waters in the process. This can lead to hypoxia, which translates literally to "low oxygen," and typically indicates a concentration of less than 2–3 milligrams of dissolved oxygen per liter of water (mg/L). Most aquatic organisms are severely stressed in hypoxic conditions, so hypoxic or anoxic (meaning no dissolved oxygen is present) water often leads to fish kills.

An extreme example of hypoxia can be found in the northern Gulf of Mexico, where a seasonal area of reduced oxygen, called the "Dead Zone," forms each summer in the area receiving discharge from the Mississippi and Atchafalaya Rivers. Oxygen levels within this area are so low that they cannot support marine life. The size of the Gulf of Mexico Dead Zone averages 13,000–18,000 km^2 (5,000–7,000 mi^2), and it threatens valuable commercial and recreational fisheries (Rabalais et al., 2002; Nassauer et al., 2007; Kidwell et al., 2009).

Hypoxia can also occur away from estuaries and river mouths, as a natural product of variable ocean processes. For example, scientists working in the Mid-Atlantic Bight concluded that certain recurrent hypoxic events off New Jersey were likely the result of upwelling events interacting with a suite of other factors, including currents, local topography, and the degree of water-column stratification over the Continental Shelf (Glenn et al., 2004). On the West Coast off Oregon, a hypoxic event in 2002 was linked to a similar suite of conditions (Grantham et al., 2004).

Some algal blooms consist of species that produce toxins. Toxic algal blooms, possibly enhanced by nutrient pollution, have been implicated in the mortality of fish and marine mammals along coastal areas and are likely having impacts throughout the food chain. Studies have found linkages between increased nutrient loading and blooms of *Pseudo-nitzschia* spp., the algal species that can produce domoic acid poisoning in some U.S. waters (Parsons et al., 2002). Animals low on the food chain, such as anchovies and sardines, can pass domoic acid up the food chain so that top predators, such as sea lions, are severely affected (Bargu et al., 2012). In addition, significant portions of U.S. fishing areas are closed each year to protect the public from concentrations of potentially dangerous algal toxins in shellfish.

Suspended Solids and Water Clarity—Small particles, such as sediments and algal cells, that are suspended in (i.e. are carried by) the water can have major effects on aquatic organisms and on habi-

Harmful Algal Blooms

Sometimes algae (or in a few cases, animal-like protozoans) grow rapidly in aquatic environments and form dense populations referred to as "blooms." Blooms are common and can occur as a result of natural phenomena or anthropogenic factors. Not all blooms are harmful, but when blooms cause harm to the environment or public health, they are referred to as harmful algal blooms (HABs). HABs can be harmful by producing toxins or through their excessive biomass. HABs that produce toxins can kill aquatic life such as fish or shellfish directly, or affect people who consume contaminated seafood. HABs that produce impacts through sheer biomass do so by reducing dissolved oxygen levels (as the blooms decay) and potentially suffocating aquatic life, or by destroying fish habitat by preventing light from reaching underwater vegetation (Backer and McGillicuddy, 2006; Anderson et al., 2010). For more information on how NOAA is addressing HABs (e.g. preventing, controlling, and mitigating HABs), please see the National Ocean Service's website for the National Centers for Coastal Ocean Science (NCCOS): http://coastalscience.noaa.gov/research/habs/default (accessed March 2015).

tat-forming plants such as seagrasses and kelps. As suspended solid loads and turbidity increase, less light reaches phytoplankton in the water column and submerged aquatic vegetation on the bottom, reducing and even preventing photosynthesis and growth. There are many causes of excess suspended solids. Examples include sediments from terrestrial runoff (which are often greatly exacerbated by human activities), algal blooms that occur with high nutrient concentrations, or natural events such as storms. Excess suspended solids can foul sensitive fish gills and the feeding organs of filter-feeding invertebrates. When large amounts of suspended solids settle to the bottom, they can smother sedentary benthic animals, such as clams, oysters, and other epifauna and infauna. Herbivorous animals, such as the queen conch, are generally restricted to water depths where light is sufficient to support the plants they eat. Thus, increased turbidity may decrease queen conch habitat. Reef-building corals that occur in warm, shallow waters also depend on very clear water that allows light to penetrate. This is because most tropical coral species have a symbiotic relationship with a type of algae called zooxanthellae that live inside the coral polyps. The zooxanthellae require sunlight for photosynthesis, which produces food that is shared with the coral.

Point and Nonpoint Source Pollution—Degradation of water quality often results from point and nonpoint source pollution. The Clean Water Act provides definitions for point and nonpoint source pollution that are summarized as follows. Point source pollution occurs when a harmful substance is emitted from a discreet and identifiable source directly into a body of water. Examples would be pollutants running directly into a waterway from a pipe or vessel. Nonpoint source pollution does not have a discernible, confined, and discrete conveyance from which the pollutants are discharged. It is more diffuse than point source pollution and can be widespread, with significant cumulative impacts over a large area. Primary sources of nonpoint source pollution are land runoff, precipitation, atmospheric deposition, seepage, or hydrologic modification. Pollution from nonpoint sources is usually lower in intensity than point


NOS, NOAA

A point source of industrial pollution along the Calumet River in the Midwest.

source pollution, but it can be ubiquitous and cause both short- and long-term damage to habitats. Nonpoint source pollution is also difficult to detect and may go unnoticed for long periods of time.

Point source pollution can impact water quality by changing water flow, pH, hardness, dissolved oxygen, and salinity as well as by causing scouring and turbidity plumes, and introducing toxic chemicals. Depending on the nature of the polluting flow, it can render habitats unusable, modify nutrient and energy transfer, and affect productivity, species diversity, and biological community structure. Flows rich in nutrients can also cause major changes in species assemblages and lead to eutrophication of the water bodies that receive the inputs. Often toxic contaminants remain in sediments and organisms long after the source of pollution has been removed. For example, polychlorinated biphenyls (PCBs), dichlorodiphenyl-trichloroethane (DDT), and polycyclic aromatic hydrocarbons (PAHs) are chemically stable and bind strongly to soils and bottom sediments, where they can remain for long periods of time. The insecticide DDT was banned in the United States in 1972, but residues from historical use still remain. Many contaminants also bioaccumulate in organisms. They concentrate in fatty tissues and are passed on to higher levels of the food chain. Such bioaccumulation can result in contaminant levels being many times greater in the tissues of top predators than in the surrounding environment.

Oil and chemical spills are accidental and uncontrolled and, depending on the scale, can lead to considerable pollutant inputs. Outflows from industrial and power plants are regulated, so contaminant concentrations are required to stay within permitted limits. However, the cumulative effect of many such discharges on water quality and habitats may still be significant. Thermal effluent from power plants and other industrial operations can also affect water quality and habitat by raising temperatures beyond levels suitable for feeding, growth, and reproduction of the organisms living there. Fish-processing wastes from shoreside and vessel operations may discharge nutrients, chemicals, and fish byproducts that can lead to decreased dissolved oxygen, particle suspension, and increased turbidity and surface plumes. Storm water discharges from communities are another example of a point source and are often contaminated with compounds from roads and cities, settling and storage ponds, and harbor activities.

Runoff is one of the primary contributors of nonpoint source pollution. Land-based sources of runoff can contribute significant amounts of pollutants, such as nutrients, that degrade water quality. Many human activities, including urban and suburban development, can increase runoff and add harmful substances to draining waters. Land use conversions for development often include removal of vegetation and the creation of impervious surfaces, which can exacerbate surface runoff. Pollution sources are widespread in developed areas, and include construction sediments; oil, salt, and other contaminants from roadways; heavy metals; and bacteria from failing septic systems and pet waste. Any of these substances can cause declines in water quality and degrade aquatic habitats.

Runoff from agriculture, nurseries, and ranching is also a significant nonpoint source of pollutants. Agricultural runoff from farms in the Mississippi River watershed is a major contributing factor to the Gulf of Mexico Dead Zone. Soil compaction associated with agricultural operations reduces infiltration and increases erosion and surface runoff, allowing sediments, nutrients, animal wastes, and salts to directly enter aquatic habitats. This can lead to nutrient loading and eutrophication, smothering of benthic habitats and associated immobile organisms, and lowered overall biological productivity in receiving waters. Levels of nitrate, a key nutrient found in agricultural and urban runoff, have measurably increased in most major U.S. rivers over the past several decades. The Mississippi, which drains over 40% of the area of the lower 48 states, carries roughly 15 times more nitrate than any other U.S. river, and this amount has tripled since the 1950s (Goolsby et al., 2000; Heinz Center, 2008). Silviculture (tree farming) and timber harvest can have impacts similar to those of other agricultural operations.

Pesticides pose a particular threat to water quality. Hundreds of different chemicals are used on forested lands, agricultural crops, tree farms and nurseries, highways, utility rights of way, parks and golf courses, and residences. Many of these chemicals are toxic to aquatic organisms and can have lethal or sub-lethal effects on individuals. Larvae of aquatic organisms are particularly susceptible to the toxic effects of pesticides. Some pesticides also impair ecosystem productivity and reduce aquatic vegetation that provides shelter and food for fish and shellfish. In addition to surface runoff, pesticides can also enter aquatic systems via direct application, spray drift, agricultural return flows, and groundwater intrusions. Many of these sources are difficult and expensive to monitor or remedy.

Other nonpoint sources of pollution include leaking septic and sewage systems, oil and chemical spills, atmospheric inputs, and road building and maintenance. Roads in particular have the potential to substantially impact water quality by increasing sedimentation and chemical contamination. Chemical contamination associated with roads can come from sources such as salt used to melt ice, particles derived from the wearing of tires and brakes, and automobiles leaking gasoline, oil, or coolants.

The impacts of water-quality degradation can be great, but progress has been made to reduce these impacts, particularly from point sources. Technology exists to monitor and regulate point sources of pollution, and the Clean Water Act has regulated point source discharges since 1972. Section 402 of that Act creates the National Pollution Discharge Elimination System (NPDES), a permitting system requiring that identified pollution sources be measured and meet discharge limits. Regulations exist to ensure proper cleanup of contaminants after an oil or chemical spill as well. Strong enforcement of such laws has been successful at reducing the prevalence and impacts of point source pollution on water quality and improving the Nation's waterways, although growth of populations and economic activities are ongoing challenges.

Less progress has been made in controlling nonpoint source pollution, in part because it is much more diffuse than point source pollution. In 1987, the NPDES was expanded to include nonpoint source pollution. In addition to placing limits on discharges from individual drainage pipes, the law requires jurisdictions to reduce surface runoff to the "maximum extent practicable." This allows jurisdictions flexibility in controlling runoff contamination in a manner most appropriate for their particular area.

Individual citizens can personally reduce the amount of pollutants entering aquatic habitats through awareness and environmentally responsible actions (e.g. proper disposal of household chemicals, maintenance of septic systems and cars, etc.). Civic volunteer groups across the United States are working to reduce nonpoint pollution through actions such as education and outreach, water sampling, and labeling storm drains with signs such as "Do not dump, drains to creek."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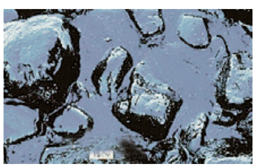
Storm drain in Charlottesville, Virginia, with a warning plaque explaining that everything entering the drain flows to a fish-habitat stream. The lower photograph shows a close-up view of the warning plaque.

J. Stumberg, U.S. Navy



ORR, NOS, NOAA

Upper photo: Oil on the ocean surface from the *Deepwater Horizon* explosion is burned in a controlled manner to keep it from spreading.

Lower photo: Close up of a beach covered with oil from the *Exxon Valdez* spill.

Oil Spills—Oils contain high concentrations of polycyclic aromatic hydrocarbons (PAHs), so aquatic organisms are exposed to the toxic effects of PAHs when oil is dispersed or dissolved in water. Weather or other factors may further affect the level and effects of exposure. PAHs can kill or harm marine mammals, sea turtles, fish, and aquatic invertebrates. Mortality may be caused through smothering or other physical or biochemical effects, while sublethal impacts may include DNA damage, liver disease, cancer, and reproductive, developmental, and immune system impairment. Corals too may be affected by oil, with the reproductive phase, the early life stages, and branching corals being particularly sensitive. PAHs can bioaccumulate and be passed up the food chain. For example, invertebrates such as oysters and clams may accumulate PAHs and then pass these contaminants to the higher-trophic-level fish and marine mammals that eat them. Oil may also directly affect habitats and the organisms that depend on them. For example, oil that reaches nearshore areas may affect nursery habitat and associated fish eggs and larvae. In addition, the presence of oil in the environment may alter migration patterns and food availability, or reduce use of an affected habitat.

Cleaning up spilled oil may also impact aquatic organisms and their habitats. Chemical dispersants are one type of oil remediation measure used to facilitate natural biodegradation by breaking up large slicks into small droplets. Chemical dispersants are less toxic than oil, though dispersant toxicity varies by substance and the environmental conditions at the time of application. Dispersants can decrease oil exposure for organisms found in surface waters such as marine mammals, sea turtles, and birds, but may also increase exposure for many other organisms in the water column such as fish, invertebrates, and corals. Additional research is needed to better understand the long-term environmental impacts of dispersants when used in large quantities.[6]

Water Quantity

In addition to water quality, water quantity is a significant habitat factor that affects populations and ecosystems. Reduced freshwater flows resulting from water removals for domestic and commercial use can impact river habitats and downstream estuarine habitats. Adequate freshwater flow is critical to anadromous species, from eggs to spawning adults. Altering natural flows and the processes associated with flow rates (such as nutrient and sediment transport) impacts shoreline riparian habitats and prey bases, and has the potential to entrap organisms. Water quality may also be reduced by water withdrawals: temperature, salinity, and concentrations of toxic chemicals all increase as water volumes shrink; dissolved oxygen decreases; and pathogens may proliferate. Any of these factors can have a negative effect on anadromous fish populations. Freshwater diversion also can impact estuarine ecosystems, which depend on sufficient flows for flushing and the maintenance of estuarine conditions. For example, a drought extending from 2001 through 2005 in the Klamath River Basin of California and Oregon, combined with above-average withdrawals for agricultural use during the drought, allowed for the proliferation of endemic diseases in salmon, causing high rates of infectious disease and widespread mortality. Coincident with the protracted drought in the Klamath Basin, the Klamath River fall Chinook salmon stock fell below conservation objectives. This triggered the declaration of a commercial fishery failure in 2006 by the Secretary of Commerce, who authorized a

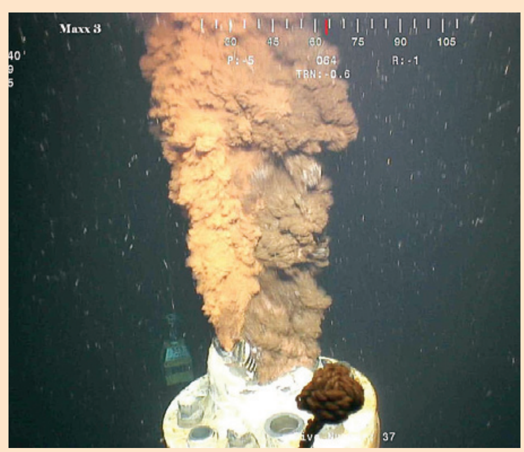
[6]See http://www.habitat.noaa.gov/highlights/oilandhabitat.html (accessed February 2013) for more information.

Oil Spills

Major oil spills are always a concern and can have significant impacts on habitats. Two of the more well-known oil spills are the *Exxon Valdez* and *Deepwater Horizon* events, although they were vastly different incidents.

The *Exxon Valdez* oil spill occurred in 1989, when a tanker by the same name grounded on a reef in Alaska's Prince William Sound, rupturing the hull. Oil spilled out quickly onto the surface of this relatively small and remote coastal water basin. Less than 2 months from the date of the spill, many thousands of barrels had reached the shores of Prince William Sound. The largest deposits of oil were in the upper and middle intertidal zones on sheltered rocky shores. Many of the marine resources affected by the spill have recovered or are well into recovery, though residual oil remains in some habitats and may impact species that spawn or forage in these areas.

The *Deepwater Horizon* oil spill took place in 2010, following an explosion and fire on a mobile offshore drilling unit by the same name. Millions of barrels of oil were released directly into the Gulf of Mexico over nearly 3 months. Unlike the Exxon Valdez spill, the oil was released over an extended time period and not from the ocean surface, but rather from the depths of a large oceanic basin. Considered to be the largest and most prolonged offshore oil spill in U.S. history, the oil and the dispersants used to remediate the spill impacted many habitats of the Gulf of Mexico ecosystem, including the deep ocean floor, water column, coastal areas, and estuaries (along the northern Gulf of Mexico) that are vital to many recreational, commercial, and protected living marine resources. There is also evidence that oil from the *Deepwater Horizon* oil spill impacted deep-sea corals (White et al., 2012). Many years of multidisciplinary research will be needed to fully assess the effects of the *Deepwater Horizon* spill on all these habitats and the ecosystem services they provide throughout the Gulf of Mexico.



USCG

The sheared-off well head of the *Deepwater Horizon*.

New Hampshire Department of Environmental Services/NOAA

The removal, with the help of NOAA funding, of New Hampshire's West Henniker Dam, 5.5 m (18 ft) tall, opened 24 km (15 mi) of riverine habitat in the Contoocook River to migratory fishes such as Atlantic salmon and American eel.

total of $60.4 million for distribution to eligible participants in the West Coast salmon fishery (DOC, 2006). In recent years the combination of more favorable environmental conditions and effective resource management has increased the abundance of Klamath River fall Chinook salmon, and the stock was declared rebuilt in 2011 (NMFS, 2011).

Infrastructure in Aquatic Habitats

Infrastructure in aquatic habitats can affect habitat quantity and quality. Infrastructure includes over-water structures, dams, and other types of water-control structures that can have significant impacts on local habitats in freshwater, estuarine, and shallow marine environments. The siting and construction of facilities such as ports, roads, bridges, shopping centers, and homes often involves the conversion of functioning habitat (e.g. a coastal wetland) to other habitat types with little or no value to fish and other marine organisms (e.g. impervious surfaces such as concrete). Electricity-generating wind farms and other energy-extraction installations (heat-, wave-, and tide-driven) have the potential to affect aquatic habitats as well. While the effects of individual structures may be relatively modest, such structures can be ubiquitous, with substantial cumulative effects. As part of the permitting process, there is active debate about the effects of coastal wind farms on benthic habitats and on fish, birds, bats, and other users of the environment. Over-water structures such as piers and floating docks can reduce ambient light conditions (which affect growth of submerged aquatic vegetation such as eelgrass), alter wave and current energy regimes, or indirectly affect local habitats through physical or chemical processes (e.g. scouring, antifouling treatments). The impacts of dams and other types of water-control structures are discussed in greater detail in the following paragraphs.

Dams—Of all the types of infrastructure in aquatic environments, dams may have received the most attention. Dams can fragment river habitats and present impediments to migrating eels and anadromous fishes such as salmon, sturgeon, striped bass, shad, and river herring. Many of these species have undergone major reductions in population size as a result of damming and other environmental perturbations, and are listed as threatened or endangered under the ESA. By blocking upstream access, dams can greatly reduce the amount of habitat available for spawning and feeding, growth, and out-migration of juveniles. Dams can also change upstream habitat by creating reservoirs that slow water velocities, alter river temperatures, and increase the potential for predation on migrating fishes. In addition, dams can modify downstream water flow and current patterns, which can affect migratory behavior and reduce the availability of shelter and foraging habitats. Dams also can cause river waters to warm and limit the transport of sediments and large woody debris. These factors can have detrimental effects on river bed morphology and the availability of spawning and feeding habitats.

Mitigation measures, such as fish ladders and barging of migrating juvenile salmon, may only be partially effective and are not implemented at all dams. Juvenile bypass systems to guide out-migrating juveniles past turbines also have low efficiencies for some species. Moreover, mitigation has often targeted salmon or eels exclusively, ignoring the impact of dams on other anadromous and riverine species.

In some instances, removal of a dam can reverse habitat damage and restore historical river

J. McMillan, NMFS

J. McMillan, NMFS

Right, the Elwha Dam before it was removed. Left, the site after removal.

flows and fish migration routes. For example, Sennebec Dam, built in 1916 on the St. George River in Union, Maine, blocked passage to over half the St. George watershed for Atlantic salmon, alewife, shad, eel, and river herring. By the end of the twentieth century, this was the only remaining barrier to anadromous species in the watershed. Trout Unlimited, with substantial NOAA funding, removed the dam in 2002 and replaced it with a roughened fish ramp about 0.4 km (0.25 mi) upstream. This resulted in the addition of 27 km (17 mi) of available fish habitat on the St. George River while increasing safety below the former hydropower dam, reducing maintenance costs, and maintaining the recreational value of Sennebec Pond. Success stories such as this demonstrate the value of removing unneeded dams and restoring healthy river habitats.

The Elwha River in Washington State is being restored to its natural state following the removal of two large dams (Elwha and Glines Canyon) that date back to the early 1900s. Removal of the Elwha Dam was completed in 2012, and deconstruction of the Glines Canyon Dam began in September 2011 and concluded in August 2014. These projects represent the largest dam removals in U.S. history, and will allow Chinook salmon (also referred to as king salmon), whose populations prior to removal were a fraction of their historical abundance, to return to their native spawning grounds. These fish sustained Native American communities for millennia. NOAA conducted several studies to predict river flow and sedimentation rates, to ensure that dam removal was phased properly and that influxes of sediment were timed to avoid critical time periods for salmon spawning. Considering the limited amount of electricity that these dams were producing, the economic return from fishing and tourism will far outweigh the cost of the dam removal. Chinook salmon began spawning in the Elwha River in the summer of 2012.

Although dam removal has proved successful at restoring damaged river habitats, it is often not a viable option due to competing river uses (including use of dams for flood control). There is currently a debate about whether dams on the Lower Snake River in eastern Washington should be removed. Removal would restore habitat that historically supported significant runs of salmon returning to the Columbia River Basin, but would also eliminate substantial social and economic benefits that result from the irrigation, electricity, and river navigation that the dams provide. This example is typical of the challenges that occur when trying to remove a dam that is not

NOAA Restoration Center

A tidegate at the mouth of Army Creek in Delaware. The five circular objects at the lower part of the gate open and close to control water flow.

unsafe or obsolete. Where it is not economically or socially feasible to remove dams, creating new fish passages or improving existing fish passages are potentially effective steps towards reducing dam impacts. Legislation requiring that anadromous species receive equal consideration with other aspects of water resource development is reducing impacts as well. However, application of the authority is difficult, because the needs of the fish are not generally as precisely known, demonstrable, and of quantifiable benefit as are the needs for municipal water supply or irrigation.

Other Water-Control Structures—Other types of water-control structures include culverts, pumping stations and tidegates, water-diversion structures, and types of shoreline protection. Culverts are large pipes that allow water to flow beneath bridges and roads, and they sometimes prevent fish passage. Tens of thousands of culverts are found in rivers throughout the United States. Culverts are often placed above stream level, have flow velocities that are too high, allow much of the water to flow beneath them, and may be sited poorly, leading to increased predation by other fish and birds. Pumping stations and tidegates are used to regulate water levels in watershed, coastal, and estuarine settings. Effects of these types of water regulation can include blocked habitat and upstream fish passage, suppressed mixing of fresh and salt water leading to altered water chemistry, decreased sediment and nutrient delivery, and degraded water quality (e.g. higher water temperatures, depleted dissolved oxygen).

Water-control structures are also used to divert river water for municipal use or irrigation, such as from the Sacramento and Klamath Rivers in California. Water diversion can reduce natural flows (water quantity) to levels insufficient to sustain fish populations, or can entrain fish and trap them in the water system. For example, water is often used as a coolant or heat source in flow-through systems for power plants, liquid natural gas (LNG) facilities, and other industrial applications. Intakes associated with these types of facilities pose several threats to aquatic species in these habitats. Injury or death of marine organisms is of high concern, and some installations pump hundreds of millions of gallons of seawater per day. They capture eggs and planktonic organisms as water is drawn in, most or all of which are then killed within the system. It is estimated that California's Diablo Canyon Nuclear Power plant, which takes in over 7 billion liters (over 2 billion gallons) of cooling water per day, can have a significant adverse impact on sea life captured in intake water (PG&E, 2010). Although screens are in place to prevent animals from getting sucked in, larvae smaller than 1 cm (0.4 in) still enter the system. Long-term water withdrawal by industrial-scale systems may have substantial impacts on fish and shellfish populations by increasing mortality during the important larval and juvenile stages. The discharge from these systems is also cause for concern, as heated effluents can cause severe problems by altering the ecology or directly killing marine organisms. Additionally, biocides used in maintenance are a potential source of water and sediment contamination.

It is difficult to substantially reduce the impacts of intake and outflow structures without removing them; however, recent technological advances are making it possible to reduce impingement and entrainment at intakes. For instance, water-permeable barriers have been developed that help seal off marine life from the intake structure, preventing interaction while still allowing operation of the water intake system.[7] The loca-

[7]See http://www.hdrinc.com/about-hdr/knowledge-center/white-papers/2012-understanding-the-clean-water-act-316b (accessed April 2013) for more information.

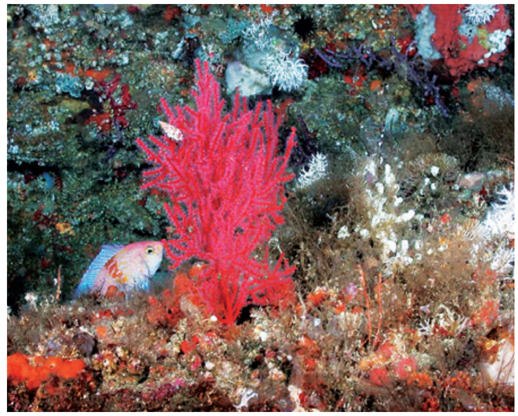
tion of intake and out-flow structures can reduce impacts as well. Placing discharge pipes in areas of high current flow enables effluents to dilute and disperse quickly, lessening impacts on habitats and organisms.

Shoreline protection and flood-control installations (dikes, berms, seawalls, etc.) are other types of water-control structures that can impact habitat by changing habitat types (e.g. converting marsh to upland), creating migration barriers, and preventing flushing, which can lead to degraded water conditions. Such structures can also have serious consequences for sediment-transport regimes, causing simplified habitats, reduced intertidal habitats, and changes to nearshore processes leading to beach steepening and narrowing, land subsidence/submergence, and even conversion to terrestrial vegetation.

Fisheries

This section addresses habitat issues associated with commercial fishing and aquaculture. It does not address any potential habitat impacts from recreational fishing.

Commercial Fishing—Commercial fishing activities can affect habitat quality and quantity. Congress took this into account when including requirements that fishery management councils assess fishing impacts to EFH and minimize the habitat impacts of fishing to the extent practicable.[8] Overfishing and gear impacts on habitat can result in overall ecosystem shifts that include altered species composition, changes in trophic structure, and reduced biodiversity. Effects of fishing can be direct or indirect, and act over both short- and long-term scales. The impacts resulting from both fixed gear (longlines, gillnets, traps, and pots) and mobile gear (trawls and dredges) depend on factors such as the spatial extent of operations, level of effort, type of gear, species present, seafloor features, and the sensitivity of the particular habitat. Depending on the nature of the fishery and the habitat in which it is used, mobile gear is likely to have more significant adverse impacts on benthic habitats. Fixed gear, such as traps, bottom-set longlines, and gillnets, is often used in areas that are too rough for trawling or where trawling is not allowed. Although this type of gear is less of a concern because of its smaller operational footprint, it can have a significant ecological effect on some sensitive benthic habitats.



NOAA

A fish taking cover in deep-sea coral habitat off the Florida coast.

Short-term effects of fishing are usually directly observable and measurable. While the impacts may be immediate, it may take years for recovery to occur. Of great concern are the impacts of trawling and dredging on habitat complexity. By directly damaging or removing biogenic structure-building components of habitat, such as corals, sponges, oysters, and burrowing species, repeated trawling and dredging can reduce productivity of benthic habitats and result in discernible changes in benthic communities. Reduced habitat complexity affects various life stages of many different species. For example, repeated dredging of oyster reefs reduces not only oysters, but all the species that use the reefs for foraging and shelter. It has been well documented that removal of reef-building species will result in large changes to the species assemblages associated with the reef structure itself.

In addition to the impacts on biogenic structure, fishing gear can also result in physical changes to bottom habitat. Habitats that experience low rates of natural disturbance are most vulnerable. The passage of a bottom trawl can resuspend sediment and degrade the quantity and quality of the food resources that benthic habitats provide to higher-trophic-level aquatic animals. Mobile gear may further reduce habitat complexity by dis-

[8]One FMP, the Consolidated Atlantic Highly Migratory Species FMP, is managed by the the Secretary of Commerce (through NMFS) giving the Secretary the responsibility to describe and identify EFH for these species.


NOAA, NURC, U. Conn.


NMFS


NMFS


Doug Costa, NOAA, SBNMS

Past overfishing in Georges Bank of species such as cod (top), haddock (upper middle) and flounder (lower middle) is hypothesized to be responsible for the influx of other species such as dogfish (bottom).

lodging or moving rocks and boulders, smoothing sedimentary bedforms, and reducing bottom roughness. Fixed gear may cause damage to sensitive habitat areas (such as coral reefs) through interactions with the bottom as well. In addition to gear impacts from fixed and mobile types of gear, destructive fishing methods such as the use of poison or explosives cause major damage to marine habitats, particularly coral reefs. Such practices are banned in most countries but are still practiced, primarily in Southeast Asia (McClellan, 2010).

Recovery times vary for direct impacts to benthic habitats, depending on the complexity and depth of the habitat and the frequency of natural disturbance. Many shallow habitats tend to experience more frequent natural disturbance (e.g. due to storms), so the communities in these habitats are adapted to recover more quickly from physical disruption. Systems with low rates of natural disturbance (e.g. habitats that are too deep to be impacted directly by storms) tend to be characterized by slow-growing biogenic structures with longer recovery times (Halpern et al., 2007). Deep-sea corals grow very slowly because they exist in cold, dark, low-nutrient environments. When they are physically damaged by trawling, their estimated recovery time is more than 30 years (Rooper et al., 2011). Because most ecosystems face multiple threats that degrade habitat, recovery times following physical disturbance are uncertain.

In addition to the direct impacts of fishing gear, fishing can also have indirect effects on habitats and ecosystems. Excess removal of species can disrupt ecological function and balance, change habitats, and allow other species to increase in abundance. For example, it is hypothesized that an influx of dogfish and similar species on Georges Bank, a rich fishing ground off Cape Cod, Massachusetts, resulted from overfishing commercially valuable species such as cod, haddock, and flounder (Fogarty and Murawski, 1998). In Jamaica, the removal of herbivorous fishes through overharvest, along with a concomitant loss of herbivorous sea urchins due to a Caribbean-wide disease outbreak, helped initiate a massive ecosystem shift from a coral-dominated reef community to a less productive algae-dominated system (Hughes, 1994). Current knowledge suggests that the removal of herbivorous fishes contributes to phase changes in coral ecosystems.

Although fishing can have substantial impacts on aquatic habitats, there are a number of ways to reduce those impacts. Certain gear restrictions or area closures have been successful in protecting critical or sensitive habitats and preventing most ecosystem effects of fishing. The fishery management councils have closed substantial areas of the U.S. EEZ to help protect EFH. They also have taken a precautionary approach by closing areas to trawling where such gear has not yet been used, in order to protect sensitive biogenic habitats. Some of these examples will be discussed later in this chapter. In addition, NOAA's Deep Sea Coral Research and Technology Program is mapping and characterizing deepwater habitats, with a special emphasis on associations of managed fishery species with deep-sea coral and sponge habitats. These efforts will help further protect fragile deep-sea ecosystems from fishing and other activities.

Aquaculture—Also known as fish and shellfish farming, aquaculture refers to the breeding, rearing, and harvesting of aquatic plants and animals. Aquaculture produces food fish, sport fish, bait fish, ornamental fish, crustaceans, mollusks, algae, sea vegetables, and fish eggs. The practice can have both positive and negative impacts on aquatic habitats. Shellfish aquaculture has been widely accepted as a net benefit for ecosystems, because farmed shellfish perform many of the ecological functions that naturally occurring shellfish perform. They improve water quality by filtering the water, stabilize fragile coastal shores, and provide habitat for other aquatic organisms (Shumway, 2011). By removing microalgae from the water column, shellfish farms have been shown to improve light transmission in eutrophic areas. Increased light transmission in these areas benefits submerged aquatic vegetation. Another positive impact can occur through stock restoration ("enhancement"), e.g. when farmed shellfish are used to rebuild coastal habitats such as oyster reefs.

Although aquaculture is expanding globally, marine aquaculture in the United States continues to be very limited. Most U.S. marine aquaculture produces shellfish, with lesser amounts of finfish being produced. Marine fish farming in net pens occupies only a miniscule area of the Nation's aquatic habitats, primarily consisting of farms that rear Atlantic salmon in the States of Maine and Washington. In both states, rigorous federal and state regulations are in place to protect the environment, ensure food safety, and protect public health. For example, to avoid the damaging accumulation of wastes on the underlying sea bottom, net pens are either sited over erosional bottoms, or are fallowed regularly to maintain a healthy benthic ecosystem. Dissolved nutrients are typically at background levels within 10 m (33 ft) of the cages. The few studies that have tracked nutrients from U.S. salmon farms show them ending up in the local flora and fauna around the farm. Federal or state laws and regulations also address use of chemicals and pharmaceuticals, diseases, escapes, food safety, and other aspects of marine fish farming. In addition, impacts to EFH and protected resources are considered before federal or state permits are given for any type of aquaculture.

Christine Fellas, NMFS

A working clamshell dredge and associated turbidity, at a Willamette River port in Oregon.

Other Commercial Uses of Marine Habitats

In addition to fisheries, aquatic habitats are used for many other commercial purposes. Examples include timber harvesting and mining in watersheds; dredging to support harbors and transportation; installation of pipelines and similar structures; discovery, production, processing, and transport of oil and gas; and shipping. These commercial activities can have both direct and indirect effects on habitats. One significant habitat issue, underwater noise, is caused by many of these commercial uses, and is discussed separately.

Dredging—Dredging to clear harbors and nearshore vessel traffic zones can result in a number of habitat impacts: direct removal or entrainment of organisms, increased turbidity and siltation, release of oxygen-consuming substances and contaminants, and alteration of physical habitat and hydrographic regimes. Disposal of dredged material can impact, or even destroy, benthic habitats by smothering them. Effects of disposal carry over to adjacent habitats as well, as turbidity plumes spread out from the disposal site, introduce contaminants or nutrients, and shade the water column. Disposal alters habitat and hydrographic function in a manner similar to dredging. The effects of dredging-related activities continue to impact habitats and populations for long periods of time, and recolonization studies suggest that recovery of dredged areas depends on many factors and may not be predictable.

It should be noted that clean dredged material can have beneficial uses. For example, some of the sediments being removed to maintain the Port of Baltimore and approaches meet environmental standards, and are being used to restore degraded habitats in the upper Chesapeake Bay, including Poplar Island, which has been greatly reduced in size by erosion.[9] More information on habitat restoration is available, starting on page 86 of this report.

Oil and Gas—Activities related to the discovery, production, processing, and transport of oil and gas resources are of particular interest in offshore habitat areas, since the expansion of oil and gas leasing has primarily been in deeper waters over the last decade. The potential for oil and other contaminant spills, both small and large, is one of the greatest concerns. Accidental releases can occur at any stage of exploration, development, or production, and residual contaminants remain toxic for long periods after a spill has occurred. Other activities associated with oil and gas discovery and development, including seismic surveys,

[9]http://www.bayjournal.com/article/dredge_islands_in_bay_giving_way_to_projects_on_shore (accessed December 2013).

Cindy Driscoll, Maryland Department of Natural Resources

A ship-struck sei whale on the bow of a container ship in Chesapeake Bay.

vessel traffic, physical alterations to habitat, and waste discharges (fluid and solid), may have significant impacts on habitat. An issue related to oil production is the decommissioning of structures such as platforms and pipelines. Removal of these structures may help to reverse any damage from their initial installation, and can reduce the chances of future contaminant releases. However, many of these structures provide habitat for communities of fishes and invertebrates that associate with mid-water structures; removal of the structure may reduce available habitat for these communities.

Installation of Utility Lines, Cables, and Pipelines—Activities associated with installation of utility lines, cables, and pipelines directly disturb benthic areas in oceanic habitats and lead to the destruction of habitat-forming organisms. Indirect effects from these activities can include increased turbidity, resuspension of chemical contaminants, and introduction of pollutants. Installation of such underwater structures also creates the potential for dangerous interactions with fishing gear. Similar concerns would also have to be addressed if deep-sea mining (e.g. of manganese nodules, cobalt crusts, or mineral-rich sulfide deposits) were conducted.

Shipping—Vessel traffic can affect marine habitats in a number of ways. Collisions between vessels and marine mammals can have important impacts on fragile populations of these protected species. For some species, such as the highly endangered North Atlantic right whale, collisions with vessels are still a threat to their recovery. Over the 20-year period from 1986 to 2005, 50 documented right whale deaths occurred, 19 of which were attributed to vessel strikes. For the period of 2005 through 2009, the minimum rate of annual human-caused mortality and serious injury to right whales from ship strikes averaged 1.6 per year in U.S. and Canadian waters (NMFS, 2012; Silber and Bettridge, 2012). In collaboration with the U.S. Coast Guard, NOAA established areas to be avoided, created recommended routes, modified other shipping lanes, and established vessel speed restrictions in some areas. These measures are also part of a comprehensive approach NOAA has taken to help right whales recover.[10] Although it is difficult to determine with certainty if these measures are leading directly to sustained right whale population growth (because they are relatively recent actions), indications are that speed restrictions, among other things, are reducing the probability of lethal collisions (Conn and Silber, 2013).

Shipping operations are also responsible for degrading habitat in some areas. The resuspension of sediments by vessel traffic can reduce water quality by increasing turbidity and decreasing light penetration; toxic chemicals in sediments may be released into the water column as well. An additional concern associated with vessel traffic is the possibility of fuel or oil spills originating from ships. In 1989, the *Exxon Valdez* ran aground in Prince William Sound, Alaska, and spilled approximately 260,000 barrels of crude oil, damaging 2,080 km (1,300 mi) of Alaskan shoreline. Although many stocks have recovered from the effects of this spill, some others have not, and residual contamination is still present in some areas.

Timber Harvesting and Mining—Timber harvesting and mining can affect habitats, particularly in freshwater riparian corridors. Such activities can change stream banks and streamside vegetation

[10]For more information see http://www.nmfs.noaa.gov/pr/shipstrike/ (accessed March 2015).

Mining Impacts on Freshwater Habitats

N. Iadanza, NMFS

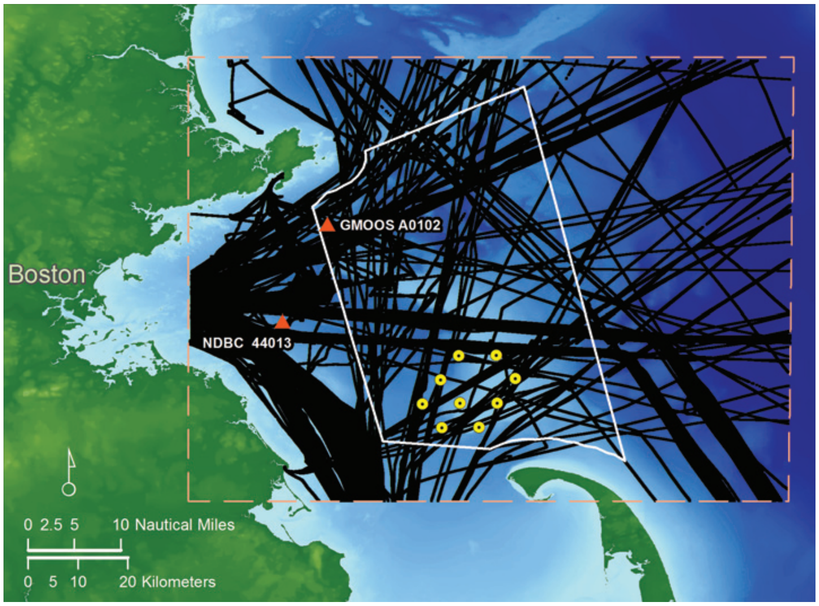
N. Iadanza, NMFS

N. Iadanza, NMFS

Mining can have short- and long-term impacts on habitats in freshwater riparian corridors. The photos present distant (left) and closer (middle) views of an inactive mine in Idaho showing surface areas exposed by mining operations. The right photo shows Bucktail Creek, which runs through the mining area. The bright blue color of the water is caused by copper contamination, which makes the water toxic. The area is part of an ongoing remediation project.

and impact adjacent habitats. Removal of vegetation in riparian corridors through timber harvest or other means alters hydrologic characteristics such as temperature and dissolved oxygen, reduces habitat complexity by lowering the availability of large wood debris, changes flow and channel structure, causes stream bank instability and erosion, and alters nutrient and prey sources. Mining can also cause substantial changes to riparian corridors. Mineral mining causes erosion, increases turbidity, degrades important habitats, and sometimes directly removes habitat substrates. Mining can also release harmful or toxic chemicals into riparian and river areas, including heavy metals and acids. Surface mining has even greater potential effects on habitat by eliminating vegetation, disrupting surface and subsurface hydrologic regimes, and permanently (and sometimes dramatically) altering topography, soil, and subsurface geological structure. These activities can change stream sediment characteristics, and may render streams unsuitable for salmon spawning or juvenile growth and survival. Sand and gravel mining can also have serious impacts on riparian areas by creating turbidity plumes, causing resuspension, and altering channel morphology. Habitat impacts of sand and gravel mining are also a concern in estuarine and coastal habitats.

To reduce human impacts on riparian corridors, activities such as mining and timber harvest should maintain a reasonable distance between rivers and their operations. Forested buffers along streams protect in-stream habitat and shade the water, helping to keep water temperatures within



Map showing a study area (red dashed rectangle) for acoustic research off Massachusetts that included the Stellwagen Bank National Marine Sanctuary (white outline). In this map, the tracks of large commercial vessels in April 2008 are represented by black lines. Red triangles represent fixed buoys that measure wind speed, which can be related to ambient noise. Yellow circles represent the locations of bottom-mounted acousic listening devices for measuring ambient noise, vessel noise, and tracking vocalizing whales. The study found that background noise, mainly due to ships, reduced the ability of whales to communicate with each other by two-thirds compared to historically low-noise conditions (Hatch et al., 2012).

acceptable ranges. Restoration activities, such as native vegetation replanting and the addition of large woody debris, are currently improving river habitats for anadromous species. For example, restoration efforts on the Chewuch River in Washington State have been successful at improving habitat for resident and migratory species of fish, including several threatened or endangered species.

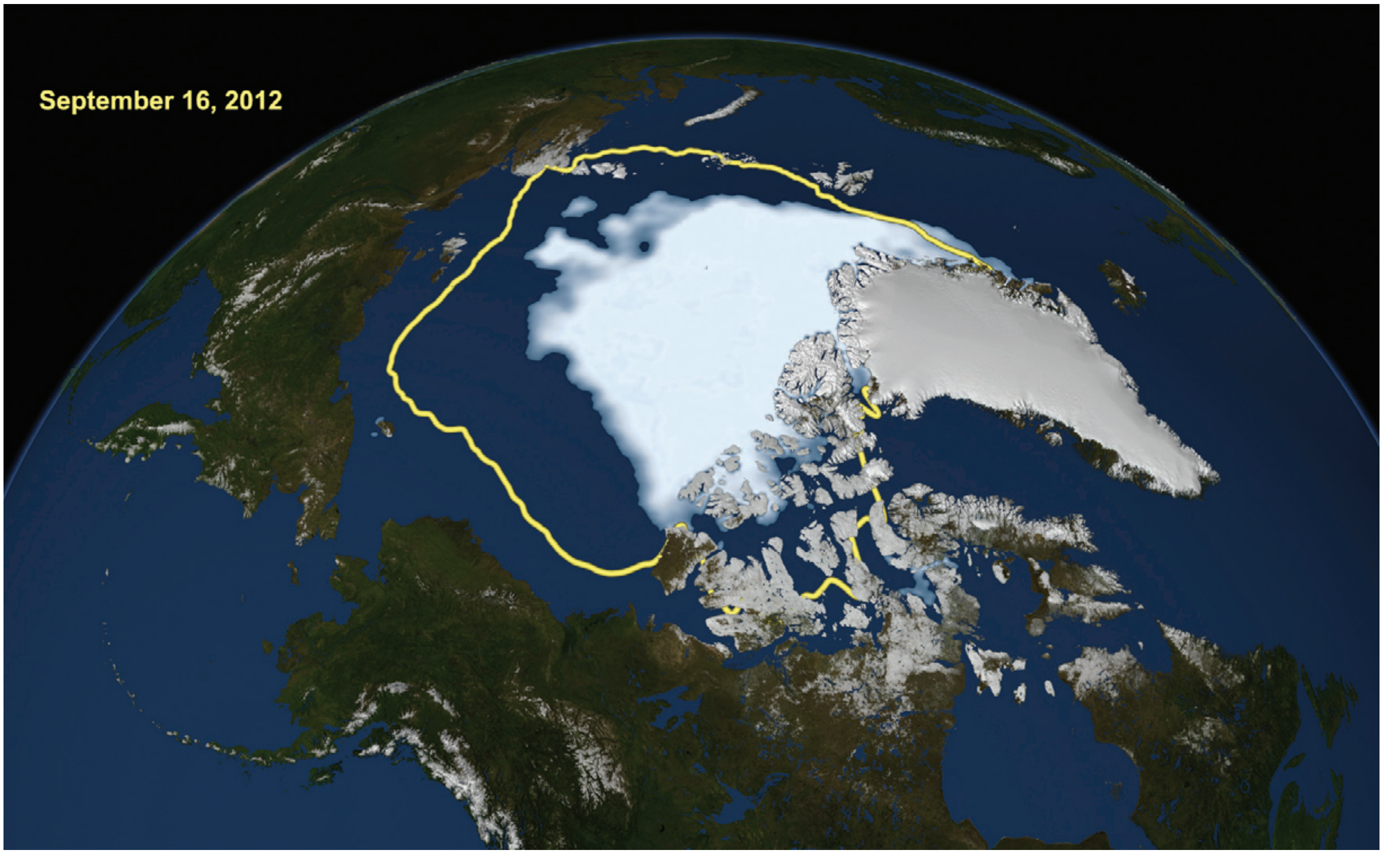
Noise—Noise is fast becoming a pervasive pollutant in some marine habitats. Anthropogenic noise from vessel traffic, geophysical exploration, active sonar, construction activities, and other sources may have various adverse effects on marine life, ranging from relatively benign to severe. Noise from human-related sources is increasing throughout the oceans; in some studied locations noise has increased by an average of 3 decibels (dB) per decade.

Human-made underwater noise can affect marine life through acute impacts due to specific, typically intense, sound sources or through the chronic effects of long-term increases in noise. High-intensity underwater sound production from oil and gas exploration, research operations, military technology, or other industrial activities can reach intensities of over 235 dB (as intense as an underwater earthquake) and may particularly affect susceptible cetacean species. These sounds can travel great distances and often can be heard hundreds or even thousands of miles away from their source. Some mass strandings of beaked whales (such as a March 2000 incident in the Bahamas) have occurred in close association in time and space with military exercises using high-energy, mid-frequency (1–10 kilohertz [kHz]) sonars, demonstrating a direct link between sonar and strandings (D'Amico et al., 2009). It is often difficult, however, to make a definitive diagnosis that a particular activity such as use of low- or mid-frequency sonar or other sound sources was the physical agent leading directly to one or more marine mammal deaths, since analysis of fresh, whole animals is rarely possible and conclusive physical evidence may not be present.

Many whales and dolphins have very sensitive hearing and depend on sound for communication and important social interactions, sometimes over very long ranges. In addition to marine mammals, many species of fish also use sound to follow migration routes, locate each other, find food, and care for their young. While there are many studies demonstrating the effect of sound exposure on marine mammals, the potential impact of anthropogenic aquatic noise on fish is relatively unstudied. It is clear that animals that use sound for communication and navigation can easily be affected, but it is less clear what levels will actually cause detrimental effects on their populations.

Research efforts are underway to determine the acute impacts of noise on marine organisms (Tyack et al., 2011). There has also been an increasing focus on further examining the chronic effects (e.g. stress levels, loss of communication range) of long-term changes in ocean noise and acoustic habitats due to human activities (Hatch et al., 2012). Recent efforts by the NOAA CetSound project[11] to investigate potential changes in underwater soundscapes will be useful in attempts to limit impacts of noise in habitats used by sensitive species. For example, the NOAA CetSound project has produced maps to help examine the potential impact of man-made noise on cetacean habitats. This includes regionally and temporally specific cetacean density and distribution mapping throughout the U.S. EEZ waters,

[11]See http://cetsound.noaa.gov/index.html (accessed March 2015).



NASA

This image shows the extent of sea ice (shown as white with a blue tint) in the Arctic on 16 September 2012, the day identified by the National Snow and Ice Data Center as the minimum extent of Arctic sea ice in 2012. The yellow line represents the average minimum extent of sea ice during 1979–2010.

along with "soundscapes" illustrating the extent of man-made noise sources. NOAA recognizes that managing acoustic habitat for trust species and in protected areas is critical to better addressing underwater noise impacts to living marine resources. The NOAA Ocean Noise Strategy[12] is seeking to better apply the agency's management and science tools to understanding and conserving priority acoustic habitats.

Environmental Issues

Several environmental issues can impact aquatic habitats. One issue likely to affect all habitat types at a multitude of scales is climate variability and change. Two other environmental issues that can impact aquatic habitats on a broad scale are invasive species and marine debris.

Climate Variability and Change—Climate has major impacts on the physical, chemical, and biological conditions of marine, coastal, and freshwater ecosystems, and variability in the climate system is often reflected in changes in ocean conditions over a variety of temporal and spatial scales (Howard et al., 2013). For example, natural variability in climate can operate on interannual timeframes such as the 2- to 7-year cycle of the El Nino/Southern Oscillation, decadal scales such as the North Atlantic and North Pacific climate oscillations, and centennial or even millennial scales such as ice ages. Other unique events, such as a major volcanic eruption, will cause corresponding unique changes in climate and ocean conditions. These normal cycles and events lead to major changes in habitats by physically modifying the environment. Changing temperatures, salinities, currents, cloud cover, and many other attributes cause biological changes throughout ecosystems—modifying the abundance and distribution (in both time and space) of habitats, predators, and prey as well as the very structure and productivity of ecosystems. Climatological events are a natural feature of all ecosystems. Although living marine resourc-

[12]See http://cetsound.noaa.gov/index.html (accessed March 2015).

NOAA Sentinel Site Program: Addressing the Impacts of Climate Change

An example of an integrated, multipartner effort to address the impacts of climate change, specifically sea level change and coastal inundation, is the new NOAA Sentinel Site Program. The NOAA Sentinel Site Program provides a place-based, issue-driven approach to ask and answer questions of local, regional, and national significance that affect both NOAA trust resources and the surrounding communities. NOAA and its partners are joining forces to tackle specific coastal problems, including habitat, by using existing resources, tools, and services to ensure that coastal communities are better prepared for the future.

There are many coastal regions around the Nation with a wealth of NOAA activity in terms of coastal and ecosystem monitoring, measurements, and tools. The Sentinel Site approach is designed to achieve increased management effectiveness through more coordinated and comprehensive science. To date, five regions, called “Sentinel Site Cooperatives,” are participating in the program. The Cooperatives are investigating all of the impacts of sea level change in a given geography, including impacts on habitat. For example, the Northern Gulf of Mexico Sentinel Site Cooperative leverages the ongoing Ecological Effects of Sea Level Rise Project. This effort gathers people from many backgrounds and disciplines to develop novel solutions to address real-world local problems, such as how to secure a housing development from rising sea levels or how to best protect a sensitive shoreline habitat.

Sentinel Site example—Northern Gulf of Mexico Sentinel Site Cooperative: habitat and sea level rise

Map showing the five Sentinel Site Cooperatives.

Short-term activities of the Gulf of Mexico Sentinel Site Cooperative leverage a number of ongoing activities and projects focused on climate and sea level rise. Several modeling actions build on activities and anticipated products of NOAA’s National Centers for Coastal Ocean Services-funded Ecological Effects of Sea Level Rise (EESLR) project, as well as the newly initiated Gulf Vulnerability Assessment led by NOAA and the Department of Interior’s Landscape Conservation Cooperative. Additional actions focused on outreach will build on activities of the EESLR project, the Climate Community of Practice, and the Gulf of Mexico Alliance Habitat Conservation and Restoration and Resilience Priority Issue Teams.

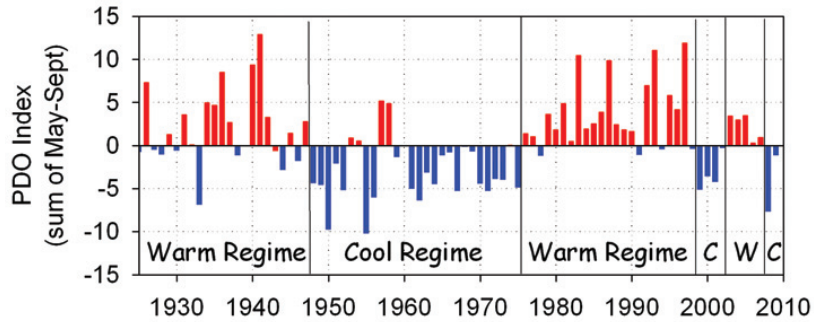
es are impacted by such natural climate variability, species are evolutionarily adapted to these natural cycles and often rebound when favorable conditions return.

El Niño events cause changes in upwelling that decrease food availability for some species and send warm water and the species it contains to more northern waters off the U.S. West Coast. For example, warm waters during El Niño events may favor increases in sardine populations, while anchovy populations may decline along the U.S. West Coast. Less well known are the large-scale climate regime shifts that also cause habitat changes and affect marine species. The multidecadal variability of the Pacific Decadal Oscillation in the northern Pacific results in enhanced biological productivity in Alaska waters and reduced production on the West Coast of the mainland United States during warm phases; this pattern reverses during cold phases. Some natural climate variation can be quite drastic, and changes can occur quite quickly, within a year or two, sometimes with detrimental effects on local or regional populations.

Superimposed on this natural variability is a new threat from human-induced (or anthropogenic) global warming, widely understood to be caused by various activities, most notably the increase of "greenhouse gases" in the atmosphere, primarily carbon dioxide produced by combustion of fossil fuels. The Intergovernmental Panel on Climate Change (IPCC, 2013) concluded that atmospheric concentrations of greenhouse gases like carbon dioxide and methane have increased since 1750 due to human activity to levels unprecedented in at least the last 800,000 years, and the ocean has absorbed about 30% of the human-emitted carbon dioxide, causing ocean acidification (see below). And with increases in greenhouse gases, the atmosphere and oceans have warmed, the amounts of snow and ice have diminished, and sea levels have risen—in most cases the observed changes are "unprecedented over decades to millennia" (IPCC, 2013).

Climate-related changes in ocean ecosystems are impacting valuable marine and coastal habitats, and the living marine resources, coastal communities, and businesses that are dependent upon them. The ocean has absorbed much of the heat trapped by the increasing amounts of greenhouse gases in the atmosphere, and ocean temperatures in the upper ocean (0–700 m [2,300 ft]) have been increasing since 1971, and probably since the 1870s (IPCC, 2013). The IPCC concluded that the global ocean will continue to warm during the 21st century, with heat penetrating from the surface to the deep ocean affecting ocean circulation. There have also been major losses of Arctic and southwest Antarctic ice thickness and extent in the last few decades, although the Antarctic changes are not uniform and they tend to balance throughout the Southern Ocean as a whole.

A few species may benefit from climate change. Positive impacts may include decreased winter mortalities of some species, and increased habitat availability for some warm-water species. Most species, however, are likely to be negatively impacted under most scenarios of human-induced climate change, either directly (e.g. water temperatures too warm), or indirectly due to alterations in habitat and the complex set of species interactions that ensue. Several potential negative impacts from global warming include accelerated loss of beaches and wetlands due to sea level rise, loss of habitat for cold-water and ice-dependent species (e.g. ice seals, polar bears), coral bleaching, and changes in ecosystem productivity and the seasonal timing of physical and life history events. Stronger storms can lead to increased wave heights reaching the shore, thereby speeding coastal erosion and destabilizing or reducing coastal habitats. These many facets of climate change will further stress habitats already adversely affected by human impacts. For example, wetland loss due to development will be exacerbated by wetland loss due to sea level rise.



The Pacific Decadal Oscillation (PDO) is shown here from 1925 to 2009, with the temperatures averaged from May through September. Red indicates positive (warm) years; blue, negative (cool) years (NWFSC, 2009).


NOAA

Brain coral that has been killed by coral bleaching. Coral bleaching tends to occur with elevated water temperatures.

The most recent IPCC report (IPCC, 2013) concludes that since the mid-19th century, sea level has been rising faster than the mean rate during the previous two millennia. Over the period of 1901–2010, global mean sea level rose by 19 cm (7.48 in), and between 1993–2010 the level rose by 3.2 mm (0.16 in) per year. These rates are sufficient to cause erosion and inundation of a variety of coastal habitats including some nesting beaches, wetlands, and pinniped haul-out areas (Parris et al., 2012). Relative sea level rise varies among coastal areas and can be much higher (e.g. 1 cm per year) due to local land subsidence and sediment compaction. The projected increase in sea level by 2100 is between 0.2 and 2 m (8 in to 6.6 ft), due to thermal expansion of the oceans and the melting of freshwater ice (Parris et al., 2012). There is renewed concern that Antarctic ice that is at least partly elevated by land is accelerating its flow to the sea, with the potential to raise sea level significantly. Climate change impacts on habitat may be much greater in some locations than these global figures imply. An important step for mitigating these effects is to identify their scope and determine which will have the greatest impact on habitat.

Human-related impacts, such as overfishing, can exacerbate the effects of a changing climate by reducing the resilience and adaptive ability of species and habitats. An example of harvesting too much of the brood stock needed for the next favorable climate pattern is the fishery for California sardines. During the 1950s the fishery collapsed due to heavy fishing pressure and changing ocean conditions that produced an extended period of cooler water temperatures that are less favorable for sardines. When favorable water temperatures returned, the spawning biomass of the sardines was too small for the population to respond rapidly.

Another effect of increasing carbon dioxide emissions that is only recently beginning to receive attention is ocean acidification. Additionally, the spread of hypoxia in coastal habitats may be associated with increasing carbon dioxide enrichment (Melzner et al. 2013). Over the industrial era, the ocean has absorbed approximately 30% of anthropogenic carbon dioxide emissions. Projections are that ocean acidity could increase by approximately 150% relative to the beginning of the industrial era by 2100 (Orr et al., 2005; NOAA, 2010). Depending on emissions, the increase in ocean acidity over the next few centuries is expected to exceed the changes seen over the past few hundred million years.

Ocean acidification is likely to impact the ability of marine calcifiers, such as corals, mollusks, and planktonic organisms that make their shells and skeletons from the calcium carbonate dissolved in sea water. Ocean acidification may also indirectly affect fish and marine mammals through reduced abundance of marine calcifiers that form the base of the food web and that provide habitat structure. Because of the many potential impacts to marine ecosystems, including habitats, ocean acidification is an emerging concern and an important area for new research.

Overall, there is a need to better understand, prepare for, and respond to climate change and ocean acidification and associated impacts on habitats, living marine resources, and the people and economies that depend on these resources. Efforts are underway to use available information to help reduce risks, increase resiliency, and help species, habitats, and communities adapt to changing climate and ocean conditions (National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012).

Invasive purple loostrife chokes the shoreline, displaces native species, and impedes water flow.

Invasive Species—Invasive, non-native species that have been introduced into a new environment are present in all aquatic habitat types. They can affect habitat by altering physical habitat characteristics, such as water quality and substrate type, or by changing natural community structure and dynamics through food-chain alteration. As human activity has increased in aquatic and coastal environments, the rate of introduction of non-native species has increased as well. Hundreds of non-indigenous species have displaced native species and have damaged ecosystems across the United States. For example, over 200 non-native species have been discovered in San Francisco Bay alone (Cohen and Carlton, 1995). Some invasive species are responsible for reducing native food supplies, eliminating native species, reducing fisheries productivity, and causing substantial habitat alterations. Wilcove et al. (1998) found that invasive species were the second greatest threat to imperiled native species in the United States, second only to habitat loss. For example, purple loosestrife, a plant of European origin, has spread throughout all of the contiguous United States except Florida and has resulted in wetland degradation through the suppression of native plant communities, impeded water flow, and alteration of wetland structure and function. Non-native species can also carry with them novel diseases to which native species lack natural resistance. MSX, a devastating parasitic oyster disease, is thought to have arrived in oysters from Japan that were brought to the United States in the 1950s. Direct economic impacts of invasive species and attempts at their control have cost billions of dollars. In the Great Lakes region alone, millions of dollars have been spent to control the invasive zebra mussel, and to repair the damage it causes to water-intake structures.

Non-native species are introduced into aquatic habitats through a number of pathways, including both intentional and accidental release. Since the 1800s, many bodies of water have been subject to deliberate introductions of species by government agencies and citizens. These species have included various trout and salmon, clams, oysters, and carp, all introduced for recreation, food, or other purposes. These types of well-intentioned introductions can have unintended negative consequences, such as the displacement of native species, and are now greatly reduced and tightly controlled. Industrial shipping, through release of ballast water, is another major source of introductions to coastal and estuarine habitats. Ballast water, taken onboard at one location to stabilize ships for transit and then released at the destination port, may contain millions of non-native eggs, larvae, and microorganisms. The technique of changing ballast at sea to prevent introductions can be both unsafe (ship stability may be compromised by changing ballast conditions while underway) and ineffective (removal of all ballast and associated biota is not usually possible), making the issue of controlling ballast a challenging one. In addition, some of the large debris from the March 2011 Japanese tsunami that reached the U.S. West Coast and Hawaiian Islands in 2012 contained marine organisms not native to the region, such as the Asian shore crab, an aggressive invasive species also found on the East Coast, and North Pacific seastar (Aquatic Nuisance Species Task Force, 2012). Recreational boaters may also introduce invasive species into waterways when they move between areas without proper precautions.

Control of invasive species is very difficult once they have become established in a new habitat. However, it is possible to prevent new introductions through actions such as increasing

Emaciated northern fur seal entangled with a section of fishing net.

control over potential introduction pathways. The 1990 Nonindigenous Aquatic Nuisance Prevention and Control Act and its reauthorization, the 1996 National Invasive Species Act, aim to prevent future introductions and control existing populations of non-native species. Technological advances are improving control of ballast water. Use of newly developed techniques for shipboard treatment (adapted from the waste water treatment industry), such as the use of biocides, filtration, thermal treatment, electronic pulse/pulse plasma treatment, ultraviolet light, acoustics, magnetic treatment, de-oxygenation, biological treatment, and anti-fouling coatings, as well as the development of shore-based treatment facilities, are proving effective at reducing the number of introductions from ballast water into aquatic habitats.

More attention is being paid to deliberate introductions. For example, some parts of the oyster industry favored introduction of the Asian oyster into Chesapeake Bay, because it was thought to be less vulnerable to the diseases that have devastated the native oysters. The National Academy of Sciences recommended a complex research program with strict management controls prior to introduction, to rigorously evaluate the potential benefits and risks (NRC, 2004). As a result of this research and other environmental impact studies, the U.S. Army Corps of Engineers, with support from the Commonwealth of Virginia and the State of Maryland, ruled against the introduction of the Asian oyster and agreed to focus restoration strategies on the native Eastern oyster.[13]

Marine Debris—Marine debris refers to any human-made material discarded, disposed of, or abandoned that enters the marine environment or Great Lakes, regardless of whether the release was direct, indirect, intentional, or unintentional. Interactions with marine debris can kill marine organisms through consumption, entanglement, or smothering. Marine debris poses a serious threat to the survival of certain protected species, including endangered or threatened seabirds, marine mammals, and sea turtles. For example, leatherback sea turtles will ingest plastic bags that closely resemble jellyfish (a typical food of the species) in appearance and can eventually die of starvation due to the plastic blocking their digestive tracts. Marine debris can also smother salt marshes, wetlands, and shallow-water habitats, or make these areas inaccessible to aquatic life or vulnerable to invasive species, which can "hitch a ride" on the debris. Discarded or lost fishing gear such as nets, gillnet panels, traps, and longlines with hundreds of hooks may continue to fish ("ghost fishing") for many years, impacting both local and migratory species as well as non-exploited species such as marine mammals, sea turtles, and seabirds. Debris can also introduce toxic substances and pathogens, which may have an especially significant effect on fragile habitats such as coral reefs.

Accumulation of marine debris is a prevalent problem in some areas. Since 1996, NOAA has removed several hundred tons of debris from the Northwestern Hawaiian Islands. The tsunami that struck Japan in March 2011 swept an estimated 5 million metric tons (11 billion lbs) of material into the ocean. About 70% of that is estimated to have sunk. A portion of the remaining debris was transported eastward, with some reaching the U.S. West Coast and Hawaii in 2012. Based on

[13]See the U.S. Army Corps of Engineers 2009 Record of Decision at http://www.nao.usace.army.mil/Portals/31/docs/civilworks/oysters/oysterdecision.pdf (accessed March 2015) along with a related press release at http://www.army.mil/article/26041/ (accessed March 2015).

ocean current models, more is expected in the coming years, but the magnitude and timing are uncertain.[14]

Marine debris also results from at-sea dumping and from land-based littering and illegal dumping. Strict regulations and enforcement efforts exist to restrict at-sea dumping. Recent analyses show that the top 10 items removed from shores over the past 25 years were all inorganic (including items such as food wrappers and plastic bottles), making up 80% of the total debris found (Ocean Conservancy, 2011). Finally, one area that has received much attention is the North Pacific "Garbage Patch."[15] In this region, converging currents have created an area where marine debris accumulates. Despite its name, this area is not an island of trash; the debris found here primarily consists of tiny bits of floating plastic that are not always visible to the naked eye, but cover a large portion of the North Pacific Ocean.[16]

Local civic actions such as litter removal and beach cleanup can be effective at reducing the amount of debris in the marine environment. However, these actions are generally small in scale. Thus, litter prevention and proper disposal of trash on land are critical to reducing the effects of marine debris on habitats.

Roads through wetlands can fragment habitat, reducing the movement of aquatic species.

Habitat Fragmentation and Loss

All of the issues previously discussed can contribute to habitat fragmentation or loss, whether by physically removing a habitat or by altering its essential characteristics. Continued habitat loss is seen across many types of freshwater, estuarine, and shallow marine habitats. Urban and suburban development has resulted in the loss of substantial amounts of aquatic habitat, with coastal wetland loss continuing to be a significant issue. Placing fill in wetlands or other aquatic habitats to build highways, housing, and commercial areas is a significant cause of habitat loss in coastal watersheds. Other factors, including chemical pollution and dredging, contribute to habitat loss in the subtidal areas of estuaries. Additionally, predicted climate-related sea level rise threatens shallow marine habitats such as mud flats, barrier islands, and marshes. Human activities may not only directly destroy habitat, but also destroy the connections between habitats, leading to fragmentation. Fragmented habitats are separated into isolated areas. The populations of organisms that live in isolated habitat fragments also become isolated, and may not be able to reach portions of habitat necessary for food, growth, or reproduction. This loss and fragmentation affects a wide range of coastal habitats such as freshwater spawning areas, estuarine nursery areas, and seagrass beds.

To prevent further impacts from habitat fragmentation and loss, the habitats that remain can be protected through legislation and enforcement. Habitat mapping and research to define where critical habitats are located are important as well. Restoration activities are also reducing impacts by returning degraded habitats to a usable state for marine species. In Key Largo, Florida, for example, a project to restore Egret Island included removing invasive vegetation and a previously placed landfill, removing a bridge, and replanting

[14]This information came from the Government of Japan. See http://www.kantei.go.jp/jp/singi/kaiyou/hyouryuu/pdf/souryou_eng.pdf and http://www.env.go.jp/press/press.php?serial=14948 (both accessed April 2013; the latter requires Google Translate to read). Also see http://marinedebris.noaa.gov/tsunamidebris/faqs.html (accessed April 2013).

[15]This is also sometimes referred to as the North Pacific Subtropical High or the "Eastern Garbage Patch." It is located midway between California and Hawaii.

[16]See http://marinedebris.noaa.gov/info/patch.html#2 (accessed April 2013) for more information.


NOAA

"Interest in conserving and managing coastal waters is intense and widespread, but funds remain limited and must be targeted judiciously."

—Excerpt from The Role of Nearshore Ecosystems as Fish and Shellfish Nurseries (Beck et al., 2003)

seagrass beds. This project successfully restored important coastal and marine habitats, including salt marsh, mangrove, and seagrass, making them available once again to a variety of commercially and ecologically important species. However, habitat restoration is expensive and may be less effective ecologically than conserving existing intact habitat. Habitat protection and restoration will be addressed in greater detail in the following section.

Steps Being Taken to Protect and Restore Habitat

A habitat conservation program requires components that protect remaining habitat, restore damaged or lost habitat, and build or enhance habitat where there are opportunities to do so. Research that addresses and clarifies the relationships between species and the habitats upon which they depend is especially important for facilitating and justifying habitat conservation. Laws executed by NMFS and other agencies (Appendix 2) have provided the framework for a habitat conservation program that, in partnership with entities undertaking voluntary efforts, aims to reduce the loss of habitats critical for living marine resources. This has enabled resource agencies such as NMFS to identify through the permitting process activities that would cause negative impacts and to prevent or mitigate these impacts. These laws also enable NMFS to advocate for habitats in coastal planning forums, to receive funding to identify habitats (and the means to protect them) that are essential to key marine species, and to undertake educational activities to make people aware of the damage that can be done inadvertently.

In addition to regulatory and enforcement actions, NMFS supports and encourages voluntary mechanisms and partnerships to protect and restore habitat. This approach is particularly effective in coastal areas, where people are often eager to engage in activities that conserve habitats, sustain living resources, and improve their quality of life in their own neighborhoods.

Understanding the relationships between species and habitats, knowing where and how much habitat exists, and knowing its condition are important for effective habitat protection and conservation. Thus, a key ingredient in such programs is providing information to resource managers and the public about habitat status, function, and its relationship to various species. This information can be used to help identify priorities and organize conservation activities. Habitat conservation can include a range of activities, such as protecting pristine habitat and habitat function in areas that are less than pristine, conducting beach or river cleanups, restoring natural water flows, replanting native vegetation, creating new habitat areas, and vigorously enforcing habitat laws.

Cooperative habitat conservation is showing great promise for continuing the progress made through legislation and regulation as specified for long term protection of EFH in MSA, and in the establishment of Habitat Areas of Particular Concern (HAPCs). Since 2004, NOAA has been participating in the National Fish Habitat Partnership (NFHP), a nationwide effort to conserve fish habitat through a network of regional Fish Habitat Partnerships (FHPs).[17] These FHPs develop strategies and priorities to guide fish habitat conservation efforts to where they are most needed, and where their benefits can be measured and documented, thereby increasing the return on investment for existing and new conservation dollars. There are currently 18 FHPs, with at least one FHP active in every state.[18] NOAA scientists worked with the NFHP to produce the first national fish habitat assessment in 2010 (National Fish Habitat Board, 2010), which provided an assessment of coastal and inland habitats across the conterminous United States, as well as Alaska and Hawaii. NOAA, the National Fish Habitat Board, and the FHPs are using this and future assessments to guide conservation and restoration initiatives to ensure the quality of fish habitat necessary to sustain healthy fish populations.

Habitat Protection—Offshore regulations combined with public awareness and voluntary efforts and partnerships in coastal environments form the primary basis for habitat protection. All of the above have led to progress in protecting sensitive habitats from harm around the country, as described in the previous section. The efficacy of these approaches emphasizes the need for sufficient habitat maps, so appropriate and effective actions can be taken. In offshore areas, habitat maps are needed for any gear restrictions and area closures that may be designated to manage fishery-related impacts. The future of habitat protection lies with taking an ecosystem-based approach to aquatic resource management. Federal, state, and local managers are moving toward an ecosystem-based approach to management to improve the effectiveness of habitat conservation efforts. This includes not only protecting the habitat of target species, but also the habitats of those organisms with which the target species interact.

The United States has over 1,700 marine protected areas that cover approximately 40% of the Nation's marine waters. Marine protected areas vary widely in purpose and management and do not apply exclusively to areas with fishery restrictions. They are defined as "… any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural or cultural resources therein."[19] Examples of marine protected areas include National Estuarine Research Reserves, the National Marine Sanctuaries, certain National Parks and Wildlife Refuges, and areas where fishing is closed or restricted for conservation purposes. These designations help to protect significant natural and cultural resources, promote sustainable use of fisheries and other marine resources, provide educational and recreational opportunities, and preserve unique areas for scientific study (NOAA, 2011; NOAA, 2012a; NOAA, 2013a).

Over the last several years, protecting EFH from fishing gear impacts has taken center stage as a component of a larger ecosystem-based approach to fisheries management. There are several examples from across the United States, beginning with the West Coast. In March 2006, NOAA approved a plan that significantly enhanced protection

NOS

The coastline of the Tijuana River National Estuarine Research Reserve, in southern California.

[17]See http://fishhabitat.org/partnerships (accessed March 2015) for more information.

[18]Note that some FHPs apply to multiple states. See http://fishhabitat.org/partnerships (accessed March 2015).

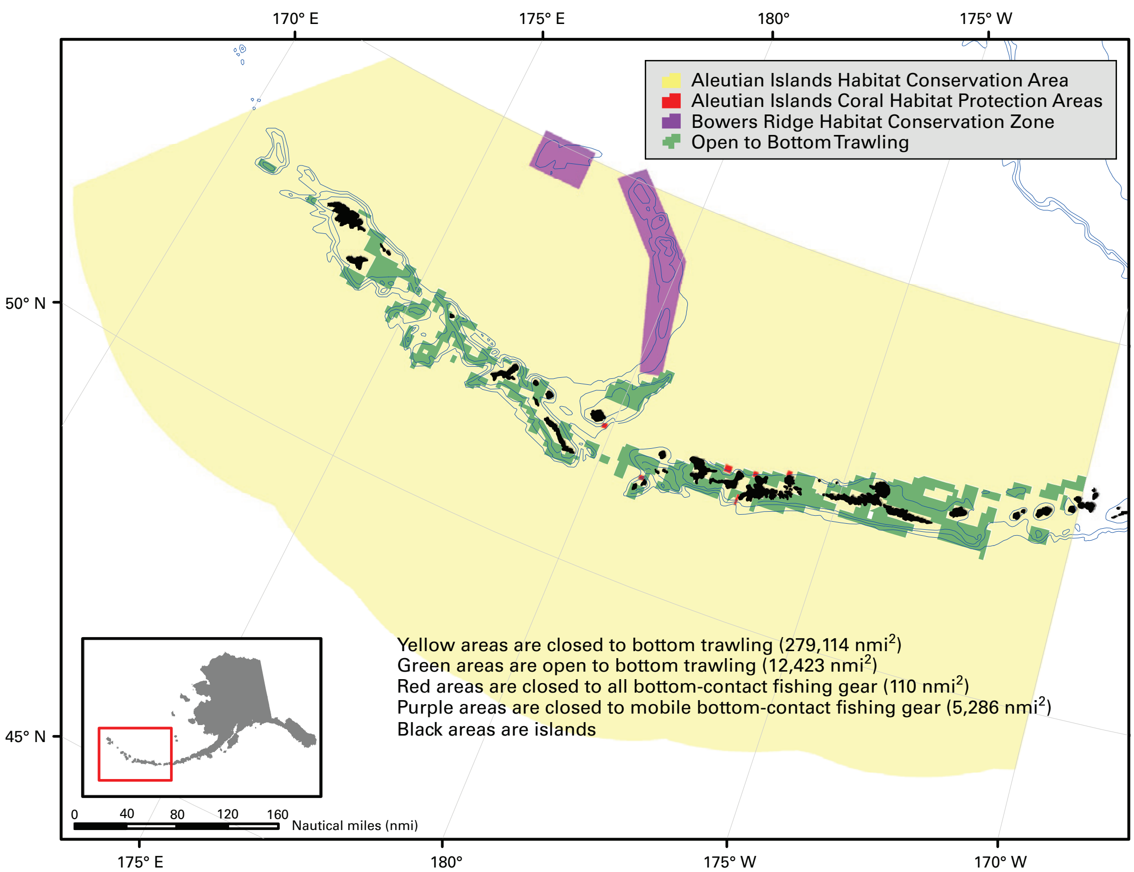
[19]This definition is taken from Marine Protected Areas Executive Order 13158.

Areas in the Pacific Coast region classified as EFH that are closed to certain types of fishing gear in order to protect the habitats of groundfish stocks.

of marine waters off the U.S. continental West Coast by designating EFH for commercially valuable groundfish. This was in addition to closures already in existence (e.g. Rockfish Conservation Areas). Fishing methods such as bottom trawling were prohibited throughout much of this region. The additional protections helped safeguard the habitat of groundfish (bottom-dwelling fish, such as rockfish) that support a multimillion dollar industry along the West Coast. Shortly thereafter, in July 2006, NOAA issued a Final Rule to implement several fishing closures in the Aleutian Islands and Gulf of Alaska to protect deep-sea corals and other fragile parts of the ecosystem (e.g. rockfish habitat, seamounts) from bottom trawling. As part of these regulations, most of the Aleutian Islands Fishery Management Area was closed to bottom trawling, as were designated areas of the Gulf of Alaska. The Aleutian Islands area closed to bottom trawling was designated the Aleutian Islands Habitat Conservation Area and encompasses over 950,000 km^2 (366,797 mi^2). To provide a relative scale, this area would be approximately the size of Texas and Colorado combined. In addition, NMFS issued a final rule in July 2008 that prohibited bottom trawling in designated waters of the Bering Sea, based on changes recommended by the North Pacific Fishery Management Council. This measure protected an additional area of over 440,000 km^2 (169,885 mi^2) of benthic habitat by closing select locations to bottom trawling and established the Northern Bering Sea Research Area for studying the impacts of trawl gear on bottom habitat.

Area closures have also been established in other regions of the U.S. For example, the New England Fishery Management Council closed a number of smaller areas (total area 9,468 km^2 [3,725 mi^2]) in the Gulf of Maine and on Georges Bank to bottom trawls and dredges in 2004,[20] and the Mid-Atlantic Fishery Management Council closed portions of four offshore canyons on the Outer Continental Shelf to bottom trawling to protect vulnerable tilefish habitat in 2009. In 2010, NMFS and the South Atlantic Fishery Management Council established five HAPCs for deep-sea corals, totaling 61,548 km^2 (24,215 mi^2), where most fishing gears that contact the seafloor are prohibited and deep-sea coral habitat is protected. These habitat protections are a central part of the Council's fishery ecosystem plan, which is intended to provide a more in-depth characterization of the South Atlantic ecosystem, including a more comprehensive understanding of habitat and the biology of species. Within these HAPCs are areas where small-scale traditional fisheries that use bottom-contact gear to catch golden crab and deepwater shrimp are allowed. In addition to these HAPCs for deep-sea coral, in 2010 NMFS and the South Atlantic Fishery Management Council also designated several HAPCs to protect snapper–grouper habitat.

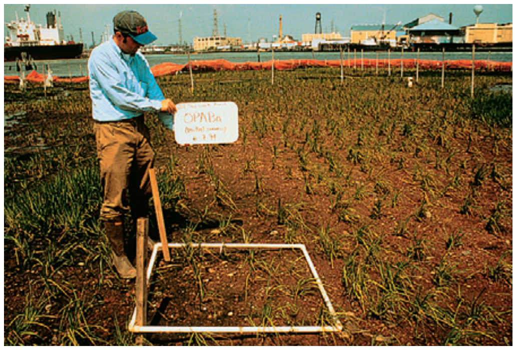
[20]It should be noted that much of the bottom area included in the New England EFH closures was already closed to fishing gear capable of harvesting groundfish.



Map showing gear restrictions in the Aleutian Islands protected area.

Another addition to the areas with protected status came with the establishment of the Papahānaumokuākea Marine National Monument in June 2006, which encompasses over 360,000 km^2 (140,000 mi^2) of emergent and submerged lands and waters of the Northwestern Hawaiian Islands (NWHI)—an area larger than all the national parks in the United States combined. Over 13,200 km^2 (5,100 mi^2) of the Monument are estimated to contain coral reefs. This Monument is home to a large number of critically endangered Hawaiian monk seals and is the breeding ground for approximately 80% of the Hawaiian green sea turtle population. The NWHI also host over 7,000 marine species, many of which are only found in the Hawaiian Archipelago.

Also in the Western Pacific, in one of the largest acts of marine conservation in history, President George W. Bush established three new national monuments in 2009 under the Antiquities Act—the Marianas Trench, Rose Atoll, and Pacific Remote Islands Marine National Monuments. These three monuments encompass an area of over 490,000 km^2 (190,000 mi^2) (White House, 2009). Additionally under the Antiquities Act in September 2014, President Barack H. Obama designated expansion of the Pacific Remote Islands Marine Monument to 1,056,720 km^2 (408,000 mi^2) (White House, 2014). The largely uninhabited areas contain pristine coral reefs, volcanic ecosystems, and the Marianas Trench, which, at a depth of approximately 11,000 m (36,000 ft), is the deepest region of the oceans. Protections for these areas include designated bans on commercial fishing (excluding the Volcanic and Trench Units of the Marianas Trench Marine National Monument) and mining for oil or gas, as well as restrictions on access and tourism. Taking precautionary and ecosystem-based approaches to managing fisheries helps protect habitats, aquatic populations, and natural ecosystem dynamics.



NOAA Restoration Center

NOAA Restoration Center

NYC Department of Parks

NYC Department of Parks

Upper images: Replanting marsh grass as part of habitat restoration at the Arthur Kill Waterway in Richmond County, New York. Photographs were taken 14 months apart.

Lower images: A restoration project at Old Place Marsh, on Staten Island, New York, shown at high and low tides.

Habitat Restoration—Restoration is defined in the Introduction of this report as "the return of an ecosystem to a close approximation of its condition prior to disturbance." (NRC, 1992). Effective restoration requires that the structure and the functions of the ecosystem be recreated, so that the natural system is emulated. For living marine resources, restoration means returning polluted or degraded environments to healthy ecosystems with clean water and other necessary habitat features. Habitat restoration usually does not focus on a single species; instead, the aim is to expedite naturally occurring restorative processes and return systems to their natural states to support many different species and functioning ecosystems. Restoration goals include increasing habitats for living marine resources, recovering disturbed or damaged ecosystems, addressing human interactions with nature, rebuilding fishery habitats, and restoring habitats that provide human benefits such as jobs, a healthy economy, coastal cultures, and recreational opportunities.

Habitat restoration can take many forms: repairing damage caused by accidental loss or degradation of habitat, compensating for losses by replacing the lost habitat functions with new or restored habitat in another location, or re-establishing the former condition of habitat by removing or reversing human alterations. For example, in 1999 the Edwards Dam on the Kennebec River in Maine was removed, allowing salmon and other species of migratory fishes to access spawning habitats above the former dam site for the first time in over 150 years. Another example is a multiyear restoration project in New York that restored native marsh areas of the Arthur Kill, the strait that separates Staten Island, New York, from New Jersey, after an oil spill damaged vegetation and mussel beds in the area.

Creating or restoring habitat can increase the total amount of habitat, but these actions are usually much more expensive and less certain in outcome than protecting existing habitat that is still functioning, but is under some kind of threat. When habitat is created or restored, it should be done with a valid scientific purpose and design. Goals must be clearly defined, so that effectiveness can be evaluated and additional corrective actions undertaken if they prove necessary.

Restoration Monitoring—Monitoring is an important component of restoration, to ensure that

The American Recovery and Reinvestment Act

In February 2009, NOAA received $167 million to create jobs by restoring our coasts as part of the American Recovery and Reinvestment Act. To date, NOAA has restored more than 6,060 hectares (15,000 acres) of habitat; removed obsolete and unsafe dams to open more than 1,127 km (700 mi) of streams, where fish now can migrate and spawn; removed more than 850 metric tons (1.87 million lbs) of marine debris; rebuilt oyster and other shellfish habitat; and reduced threats to coral reefs.

the restoration goals are being met. It can improve effectiveness by detecting early on if a project is not on track, improve project coordination, and even help enhance future project planning. Monitoring protocols tend to be most helpful if they are in place before fieldwork on the restoration project begins. NOAA has compiled key restoration monitoring information applicable to coastal habitats nationwide (Thayer et al., 2003). Prepared by the NOAA National Centers for Coastal Ocean Science, this manual offers coastal resource managers, practitioners, and the public a consolidated set of science-based tools for planning and conducting monitoring associated with restoration of habitats throughout U.S. coastal waters. Along with providing a framework for structuring monitoring efforts, the manual provides an introduction to restoration monitoring related to specific coastal habitats: water column, rock bottom, coral reef, oyster reef, soft bottom, kelp and other macroalgae, rocky shoreline, soft shoreline, submerged aquatic vegetation, marsh, mangrove swamp, deepwater swamp, and riverine forest.

Habitat Enhancement—Habitat enhancement complements other conservation tools such as habitat restoration and protection, and has the potential to increase available habitat for aquatic species. Enhancement activities include placement of artificial structures, such as large woody debris in streams, nesting structures in coastal areas, and underwater reefs. To increase the amount of productive hard bottom habitat available in estuaries and nearshore areas, several states are creating artificial reefs. Artificial reefs are constructed by intentionally placing dense materials, such as old ships and barges, concrete-ballasted tire units, concrete and steel demolition debris, and dredge rock on the sea bottom within designated sites. New Jersey has even deployed decommissioned New York City and Philadelphia subway cars at various nearshore sites. It should be noted that there are many provisions in place for the sighting, construction, and development of artificial reefs and that both benefits and drawbacks of artificial reefs vary depending on the material and structure of the reef (NOAA, 2007a; Broughton, 2012).

An artificial reef is intended to function in the same way as naturally occurring rock outcroppings, by providing hard substrate necessary in the basic formation of a live-bottom reef community. These underwater havens provide hard surfaces required for attachment by encrusting invertebrates such as barnacles, sponges, mussels, tube worms, bryozoans, and hydroids. These reefs are particularly important, since this type of habitat is limited in areas such as the Mid-Atlantic Bight, where there are large featureless seafloors. Once the initial “fouling” community is established, a wide variety of crustaceans, such as crabs and shrimp, and soft-bodied organisms, such as worms, appear. The reefs then attract and provide food and physical protection for reef fish such as scup and black sea bass, as well as other fish such as bluefish.

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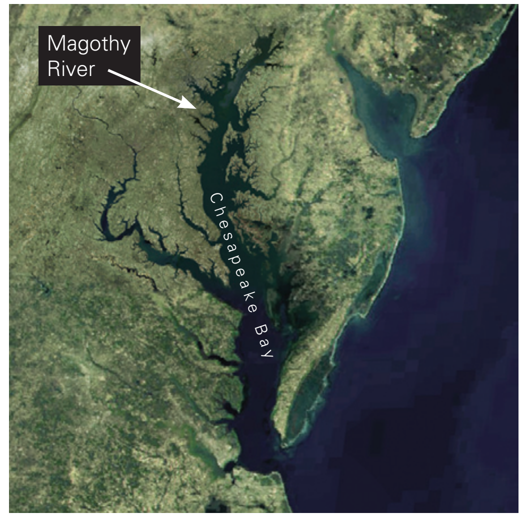

NASA

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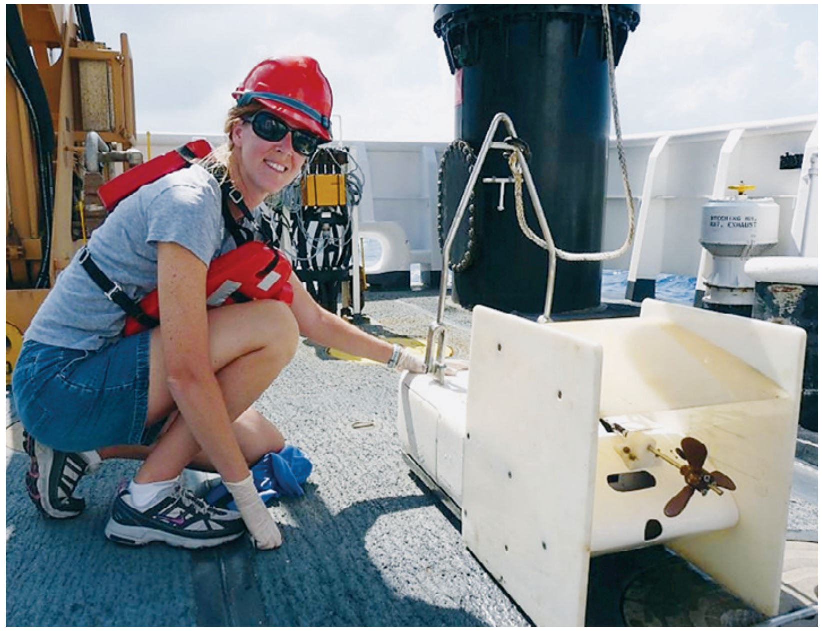
Members of the Magothy River Association planting seagrass in Chesapeake Bay.

A good example of restoring and enhancing existing habitat is the work in Chesapeake Bay to conserve and reestablish oyster reefs. These reefs provide effective habitat for many species, and the oysters help clean the bay's water through their filtering action, letting more light reach submerged plants. Many sectors are involved in this work including federal and state agencies, academia, watermen, and community groups. An example of the latter is the Magothy River Association, which is an effective community group participating in this work. The Association is active in a small watershed on the western shore of Chesapeake Bay. It collaborates with many partners, including federal and state agencies and local academic institutions, to restore both oyster reefs and seagrass beds. The Association also participates in habitat monitoring to ensure restoration activities are effective. It works with local businesses, such as restaurants, and other community groups, such as the Boy Scouts, to promote stewardship and to educate the public about the local environment and conservation issues. Nevertheless, oyster restoration in Chesapeake Bay is a very difficult task to accomplish, and results have been mixed. Siltation, disease, inappropriate location, and poaching can all lead to failure. Working with such groups, the NOAA Restoration Center has funded over 70 oyster restoration projects in 15 states around the country. Nearly 17,000 volunteers have participated in these restoration efforts.

FEDERAL AGENCIES, ORGANIZATIONS, AND PROGRAMS THAT SUPPORT HABITAT PROTECTION, RESTORATION, AND SCIENCE

Many different entities have responsibilities, authorities, and programs related to the habitats of living marine resources. The purpose here is to describe NOAA programs, provide high-level synopses of other major federal agency programs, and provide some illustrative examples of non-governmental organizations (NGOs) and partnerships. It should be noted that important habitat work is conducted by a wide array of state and local governments and other organizations, but summarizing this information is beyond the scope of this report.



NOAA

NOAA scientist working on a continuous plankton recorder aboard the RV *Okeanos Explorer*.

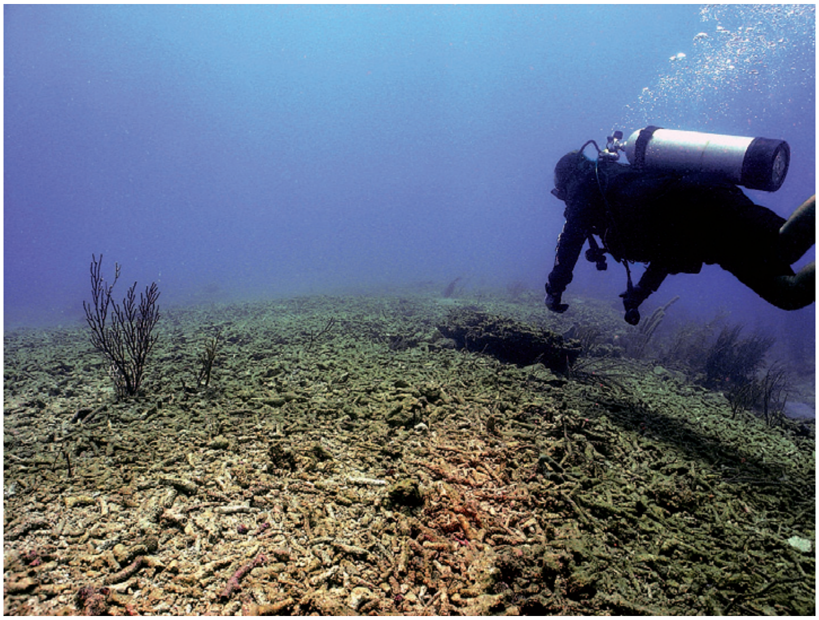
NOAA

Healthy aquatic habitats benefit fish and protected species, commercial and recreational fisheries, and can help protect coastal communities from storm damage. One of NOAA's goals is to protect and conserve these aquatic habitats. Three NOAA line offices—NMFS, NOAA's National Ocean Service (NOS), and the NOAA Office of Oceanic and Atmospheric Research (OAR)—lead many of NOAA's habitat conservation efforts. In addition, an integrated NOAA effort, the Habitat Blueprint, provides a framework to guide and conserve habitat across NOAA programs.

NMFS—The NMFS Office of Habitat Conservation (OHC) ensures that living marine resources have the healthy coastal, wetland, and river habitats needed for sustaining their populations. The OHC and the habitat conservation divisions in the NMFS regional offices provide technical advice to other agencies to minimize impacts from planned projects and bring the latest research to collaborative, ecosystem-based management efforts. Located within the OHC, the NOAA Restoration Center plays a strong role in restoring U.S. marine and anadromous habitats. The Center works to advance restoration techniques, uses ongoing scientific monitoring to evaluate restoration projects and ensure efficient use of restoration funds, and has technical staff to help improve project designs. It also works with several programs that involve numerous offices across NOAA including the Community-based Restoration Program (CRP), the Damage, Assessment, Remediation and Restoration Program (DARRP), and the Restoration Science Program.

Under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA), NMFS and other federal agencies will work together with the State of Louisiana to develop and construct large-scale, multimillion-dollar restoration projects, primarily in coastal Louisiana, which lost over 4,877 km^2 (1,883 mi^2) of coastal land between 1932 and 2010 (Couvillion et al., 2011). If the current rate of loss is not slowed by the year 2040, an estimated 324,000 hectares (800,000 acres) of wetlands could disappear, and the shoreline could erode inland as much as 53 km (33 mi) in some areas of the state. The program's objectives are to slow the high rate of wetland loss in Louisiana, incorporate a regional-based approach to ecosystem restoration, develop and utilize the latest restoration techniques, and foster partnerships with federal and state agencies, landowners, and industry.

The CRP began in 1996 and works with a range of national and regional partners to encourage hands-on citizen participation in habitat restoration projects. On average, the CRP funds more than 200 restoration projects annually, often generating three to five times as much in


NOAA

A NOAA diver assisting restoration activities following a ship-grounding incident in Puerto Rico in 2006. DARRP played a major role in the assessment and restoration of the coral reef area damaged by the oil tanker *Margara*. In addition to coral damage, toxic residue from the strike was removed.

non-federal support and in-kind contributions. Funds are granted through a competitive review process, and the CRP works closely with grantees to implement sound coastal restoration projects and evaluate their success.

Established in the early 1990s, the DARRP deals mainly with ship groundings, oil spills, and long-term releases of hazardous substances. The DARRP collaborates with other federal, state, and tribal natural resource trustees to assess and quantify injuries to natural resources, seek damages for those injuries, implement restoration activities, and monitor progress to ensure restoration goals are met. By providing incentives to the private sector to prevent injury, and making responsible parties more aware of hazardous releases and their impacts on habitat, the DARRP works to protect habitat.

NOS—The NOS's general contributions to habitat research and restoration include (but are not limited to) classifying habitat, establishing baseline habitat distributions, creating maps of the U.S. shoreline and important fisheries habitats, responding to hazardous material releases like oil spills and marine debris, and monitoring harmful algal blooms, water quality, and coastal change. Such information helps identify and define the habitats for marine organisms and aids in the evaluation of habitat change over time. A few specific NOS contributions include 1) mapping over 12,100 km^2 (4,672 mi^2) of coral reef ecosystems in the United States and its Territories over the past 12 years in conjunction with partners (Monaco et al., 2012);[21] 2) maintaining Mussel Watch, a contaminant-monitoring program in U.S. coastal waters and estuaries, which was established in 1986; and 3) characterizing sediment toxicity in over 30 estuaries in the United States.

The NOS also provides oversight for the National Marine Protected Areas Center and three other notable types of protected area systems: the National Marine Sanctuary (NMS) system, National Estuarine Research Reserve System (NERRS), and NOAA's Sentinel Sites. National Marine Sanctuaries contain important habitats like breeding and feeding grounds of whales, sea lions, sharks, and sea turtles; coral reefs; kelp forests; and historic shipwrecks. There are 13 of these sanctuaries that, with the inclusion of the Papahānaumokuākea Marine National Monument, cover more than 390,000 km^2 (150,000 mi^2) of marine and Great Lakes waters. The NERRS (run in conjunction with coastal states) are a network of U.S. estuarine habitats protected for long-term research, water-quality monitoring, education, and coastal stewardship. These areas are representative of different biogeographic regions. The NOAA Sentinel Site Program (see page 76) is designed to address the impacts of climate change through federal, state, and local partner collaborations. Sentinel sites are areas in coastal and marine environments that have the operational capacity for intensive study and sustained observations to detect and understand physical and biological changes in the ecosystems they represent. Currently, there are five sentinel sites: Chesapeake Bay, North Carolina, the Northern Gulf of Mexico, San Francisco Bay, and the Hawaiian Archipelago. In addition, NOAA created the Coral Reef Conservation Program in recognition of the value of both shallow and deep-sea coral habitat conservation. Administratively this program resides in NOS, but it is a cross-cutting program designed to reduce harm to, and restore the health of, corals.

[21]Note that the 12,100 km^2 figure includes approximately 5,000 km^2 (1931 mi^2) of hard bottoms, such as coral reefs, and another 7,100 km^2 (2741 mi^2) of soft bottom habitats, such as sand and mud.

OAR—The OAR includes the National Sea Grant College Program (Sea Grant) and the Office of Ocean Exploration and Research (OER), which have many notable habitat conservation and research efforts underway. The National Sea Grant Program conducts ecosystem and habitat research to sustain and renew America's coastal and Great Lakes ecosystems. Sea Grant has supported habitat research and activities including 1) removal of marine debris, primarily derelict fishing gear, from the fragile and unique coral reef ecosystems of the Northwestern Hawaiian Islands; 2) characterization of Pacific wetlands and their response to disturbances from dams, freshwater runoff, dredging, and loss of tidal flushing; and 3) recycling of rubble from the former Cleveland Municipal Stadium into artificial reefs in Lake Erie, which now attract 20–60 times as many fish as the surrounding non-reef areas and have an economic impact of approximately $1 million annually through enhanced tourism.

The OAR also contains the Office of Ocean Exploration and Research (OER), which supports habitat research and exploration. OER includes four cornerstone activities: systematic telepresence-enabled expeditions that allow a multitude of scientists and other interested parties to engage in real-time virtual exploration via the Internet; an extramural grant program that targets specific locations or phenomena; interagency partnership expeditions; and a major interagency and international initiative to map areas outside the U.S. EEZ. Through each of these efforts the office focuses on unknown and poorly known areas, characterizing new habitats, features, and phenomena to establish a foundation to catalyze new lines of scientific inquiry and follow-on research, and to help inform decisions related to the conservation and management of marine areas and resources. In relation to habitat, the office has contributed to efforts that help 1) determine impacts of trawling and other fishing gear types on seafloor essential fish habitats; 2) define essential fish habitat for several marine species of economic importance; 3) define areas designated as deep-sea Coral Habitat Areas of Particular Concern off the U.S. east coast; 4) determine baseline characterizations in the Gulf of Mexico prior to and after the Deep Water Horizon oil spill; 5) provide data to NMFS and ocean resource managers; 6) provide data in support of the Marianas Trench Marine National Monument and the extension of marine sanctuaries; 7) support NOAA's Habitat Blueprint initiative to facilitate conservation actions; and 8) provide a platform (such as the NOAA ship *Okeanos Explorer*) for fisheries research.[22]


NOAA

Wetlands and tidal streams in the Ashe Island area of the ACE Basin National Estuarine Reserve, in South Carolina.

The Habitat Blueprint: NOAA's Developing Approach to Managing and Conserving Habitat—NOAA's Habitat Blueprint[23] is a framework to think and act strategically to conserve and restore habitat across NOAA Line Offices and programs. It serves as a guide to help create healthy habitats that can sustain resilient and thriving marine and coastal resources, help recover protected species, and strengthen coastal communities and economies. The Habitat Blueprint has a "three-pronged" approach.

The first prong is to establish Habitat Focus Areas in each NOAA region by identifying geographic areas where collaboration among NOAA's management, science programs, and external partners can address multiple habitat-dependent objectives. In the selected areas, NOAA will direct its expertise, resources for science, and on-the-ground conservation efforts to maximize its investments and the benefits to marine resources and coastal communities.

[22]For more information see http://www.noaa.gov/features/02_monitoring/planktontow.html (accessed March 2015).

[23]See the NOAA Habitat Blueprint website for more information: http://www.habitat.noaa.gov/habitatblueprint/ (accessed March 2015).

The first Habitat Focus Area under NOAA's Habitat Blueprint—California's Russian River Watershed

California's Russian River watershed was selected as the first Habitat Focus Area under NOAA's Habitat Blueprint. The Russian River drains an area of over 3,600 km^2 (1,400 mi^2) that includes large portions of Sonoma and Mendocino Counties. It is a vital resource for agriculture, vineyards, and the domestic water supply. Endangered coho salmon and threatened Chinook salmon and steelhead trout use the river for habitat. Once considered a prime fishing area, by 2000 its aquatic habitats were significantly degraded, and coho salmon were nearly extinct. There are many competing uses and high demand for the river's water. If too much water is extracted from the river and its tributaries, fish can get stranded. Too much water, however, can be detrimental to Russian River Valley communities, as the area is also affected by frequent flooding. By combining expertise across NOAA in areas such as flood and weather forecasting, habitat protection and restoration, and coastal management, NOAA can better address the issues that face this watershed. Specific objectives for the Russian River Focus Area include 1) rebuilding endangered coho salmon and threatened Chinook salmon and steelhead stocks to sustainable levels through habitat protection and restoration; 2) improving frost, rainfall, and river forecasts in the Russian River watershed through improved data collection and modeling; 3) increasing community and ecosystem resiliency to flooding damage through improved planning and water management strategies. Efforts are already underway in the Focus Area, including restoration projects to open coho salmon breeding grounds (see story on turning gravel pits into habitat for salmon at http://www.nmfs.noaa.gov/stories/2012/09/09_06_12gravel_pit.html, accessed March 2015), reduce flooding, and recover fish populations. The Russian River effort demonstrates the utility of prioritizing resources and activities across NOAA to increase effectiveness and improve aquatic habitats for communities and their living marine resources.

California Department of Fish and Wildlife

NMFS

Fish passage can be improved by installing new culverts and bridges to replace older ones that become clogged with sediment (picture at left). Fish trying to go up the stream in the right picture were stopped by a blocked culvert, and only when the blockage caused flooding could the fish pass by swimming over the flooded road to rejoin the stream.

As a first step in implementing the Habitat Blueprint, NOAA and NMFS launched regional habitat initiatives to explore new collaborative approaches for habitat science and conservation. Strategies were developed to improve habitat conditions within seven defined geographic areas to address specific challenges to living marine and coastal resources. These areas included Puget Sound (Northwest), the Southern California Bight (Southwest), the Northwest Atlantic Ocean (Northeast), Guam (Pacific Islands), Harris Creek (Chesapeake Bay), Manistique River (Great Lakes), and the Charleston Harbor watershed (Southeast). Efforts to support these place-based initiatives served as an initial framework in allowing for the designation of the recently selected Habitat Focus Areas.

Presently, ten Habitat Focus Areas have been selected: the Russian River watershed (California), the Penobscot River watershed (Maine), the Mannel-Geus watershed (Guam), West Hawaii (on the Island of Hawaii), the Choptank River watershed (Maryland/Delaware), Muskegon Lake (Michigan), the St. Louis River estuary (Minnesota/Wisconsin), Kachemak Bay (Alaska), Biscayne Bay (Florida), and the Northeast Reserves and Culebra Island (Puerto Rico).

NOAA selected the ten Habitat Focus Areas based on the potential to yield measurable benefits for the following:

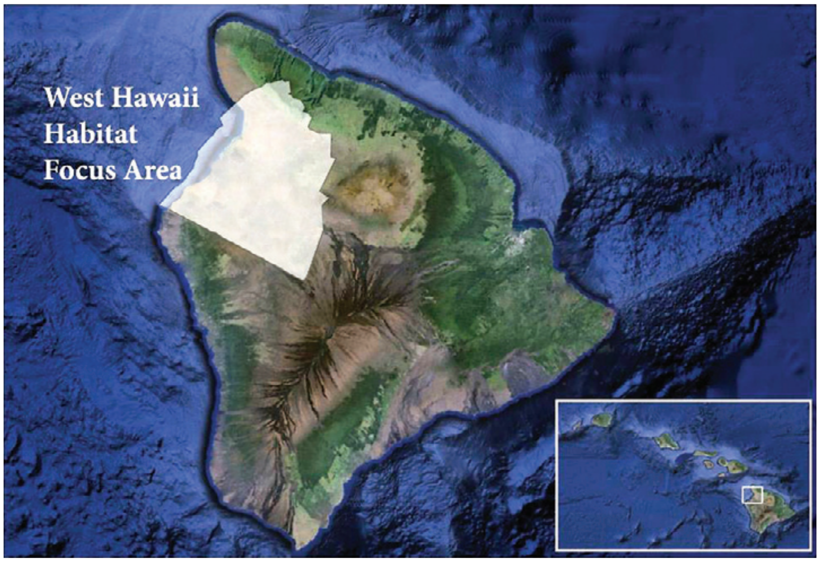
- harvested federally managed fish species for which increased habitat availability and/or improved conditions will increase harvest levels and remove limiting factors for rebuilding stocks;
- protected species for which increased habitat and/or improved condition is a limiting factor for recovery or is needed to prevent the listing of a species as threatened or endangered;
- protected coastal and marine areas and at-risk habitats identified for their significant ecological, conservation, recreational, historic, cultural, or aesthetic values;
- coastal communities in which habitat conservation will increase protection of life and property from the impacts of hazards such as storm surge, coastal flooding, and changes in sea level; and
- coastal and ocean tourism, access, and recreation, such as fishing, diving, and beach access, which create jobs and strengthen the local economy.

Scott Bendtson, USGS

A restored area of the Penobscot River in 2013 after removal of the Great Works Dam.

Implementation plans are in development for the Habitat Focus Areas through which NOAA will define measurable targets for habitat conservation in these priority areas, coordinate with ongoing related activities, and implement actions using all available programs, authorities, partnerships, and tools. NOAA will also measure and evaluate progress, and share lessons learned across the agency and with external partners. In addition to the Russian River watershed, NOAA's first Habitat Focus Area, all ten Habitat Focus Areas are described in the following pages.

- **Penobscot River Watershed (Maine)**
  The largely forested Penobscot River watershed encompasses approximately 22,196 km^2 (8,570 mi^2). With many lakes and multiple tributaries, it offers important habitat for 11 sea-run or migratory fish species and other wildlife, including the largest Atlantic salmon run in the United States. The Penobscot River is home to the Penobscot Indian Nation, which occupies Indian Island, part of its ancestral homeland, surrounded by Penobscot waters. Dams, culverts, water pollution, and overfishing have nearly eliminated many sea-run fish species from this watershed, and the decline of sea-run fish has contributed to a loss of recreational activities and economic opportunities. Improving access to habitat on this river is particularly important for the recovery of endangered Atlantic



NOAA

The West Hawaii Habitat Focus Area reaches from the mountains to the sea and supports a wide variety of marine species, some of which are found nowhere else on the planet.

salmon. NOAA and its partners are committed to a watershed approach to conservation and restoration, focusing on the connections between river, estuary, and ocean habitats, and working together to better manage the Penobscot River ecosystem and recover threatened and endangered fish populations. Goals for the Focus Area include improving river flow, restoring sea-run fish, increasing fishing and recreational activities, generating jobs and revenues for Maine communities, and preserving the cultural heritage of the Penobscot Indian Nation.

- **Manell-Geus Watershed (Guam)**
  The Manell-Geus watershed, primarily located in the village of Merizo, contains extensive seagrass beds and coral reefs, which support the area's strong fishing tradition. The extensive seagrasses and patch reefs in Cocos Lagoon provide important forage and resting habitat for green and hawksbill sea turtle aggregations and valuable nursery habitat for a variety of desirable food fish. Although Manell-Geus has amazing marine resources, the reef ecosystems are impaired by poor water quality. The conditions are a result of erosion on the steep hillsides and along the stream banks, intensifying downstream flooding and sedimentation that has affected local communities and the adjacent reef in Merizo. NOAA is currently working with partners and the local community to develop and test watershed restoration techniques and to enhance the propagation of native plants suitable for erosion control and streambank stabilization. Goals for the Focus Area include decreasing sedimentation impacts to coral reefs, maintaining or increasing the extent and density of seagrass beds, establishing monitoring plans to detect changes in the health of the mangrove forests, improving stream habitat, and increasing community engagement in conservation programs.

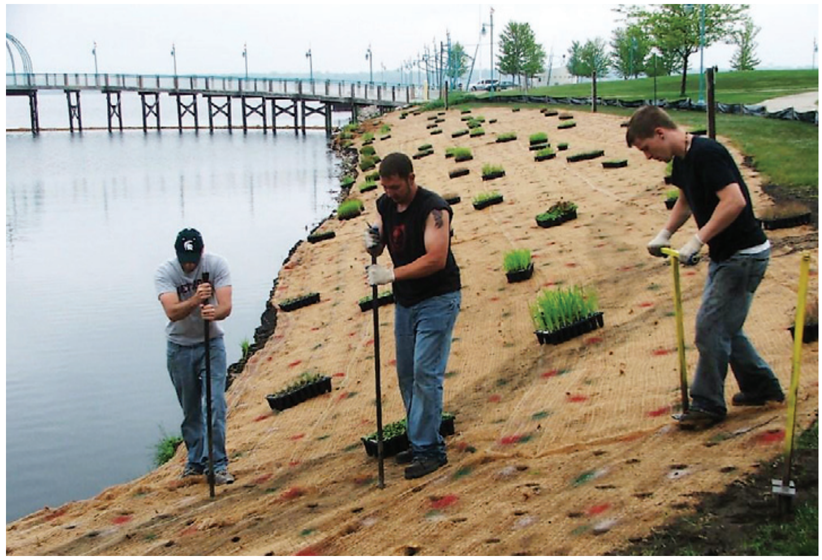
- **West Hawaii (Hawaii)**
  The West Hawaii Focus Area, located on the northwestern coast of the Island of Hawaii, contains several marine and cultural resources of concern that are important to Hawaii's economy, culture, and environment, including one of the longest contiguous coral reefs in the state. Nearly a quarter of the corals and fish that live along this coast are found nowhere else in the world, and the area is also home to several endangered or threatened species such as Hawaiian monk seals, humpback whales, and green sea turtles. The coastal zone also includes culturally significant Hawaiian fishponds. West Hawaii's unique marine resources face a growing threat from increasing coastal development and runoff, land-based pollution, recreational and commercial overuse, invasive species, and climate change. The West Hawaii Focus Area has merged with the NOAA-designated Hawaii Island Sentinel Site to form a single initiative working to improve habitat and community resilience to climate change and other threats. Communities in the area are actively partnering with various organizations and agencies to host regular coastal marine debris clean ups, invasive species removal efforts, and a range of activities including revegetation and erosion control. Goals for the Focus Area include preventing land-based pollution in coral reef ecosystems, improving coral reef habitat, fostering the wise use of marine resources, and improving local capacity for future management.

- **Choptank River Watershed (Maryland/Delaware)**
  The Delmarva Peninsula Choptank River Complex is located on Maryland's Eastern Shore. With headwaters in Delaware, the Choptank

River is the longest river on the Delmarva Peninsula. This area is a treasured part of the Chesapeake Bay ecosystem, representing critical habitat for spawning striped bass and river herring, as well as historically abundant oyster reefs. Continued human population growth and land development threaten key habitats for fish and aquatic resources. The historical loss of wetlands in the upper Choptank River subwatershed is estimated to be 19,182 hectares (47,400 acres), while climate change and sea level rise, combined with land subsidence, further threaten losses of nearshore marshes and coastal environments. While the Choptank and Little Choptank Rivers and Chesapeake Bay have supported major annual seafood harvests in previous years, fishery resources are at risk, and native Chesapeake oysters have declined dramatically over the past century due to overfishing, habitat loss (including poor water quality), and disease. By designating the Delmarva Peninsula Choptank River Complex as a Habitat Focus Area, NOAA will concentrate agency resources and leverage the many activities already under way in this watershed to improve and sustain ecological health, including oyster restoration efforts in Harris Creek. Goals for the Focus Area include rebuilding shellfish and finfish populations, restoring degraded habitats, and improving coastal communities through the delivery of NOAA's habitat and climate science.

- **Muskegon Lake (Michigan)**

Muskegon Lake is a 1,679 hectare (4,149 acre) inland lake located on the west shoreline of Michigan's Lower Peninsula and connected to Lake Michigan by a deep-draft navigation channel. This lake has suffered water quality and habitat degradation from extensive shoreline filling and sediment contamination from chemicals such as mercury and polycyclic aromatic hydrocarbons. Efforts through NOAA's NMFS, NOS, and Great Lakes Environmental Research Laboratory have achieved more than 40 percent of the fish and wildlife habitat restoration targets for Muskegon Lake as identified by the community. The next steps for the region include an implementation plan for Muskegon Lake, building off recently completed projects funded under the Recovery Act and the Great Lakes Restoration Initiative. Shorelines have been stabilized and wetlands restored at 15 separate locations around Muskegon Lake and the surrounding area. More than 3,960 m (13,000 ft) of hardened shoreline have been replaced with native vegetation, and nearly 13.4 hectares (33 acres) of wetland were restored. Additional goals for the Focus Area include ongoing efforts to fund and monitor targeted restoration projects, rebuild sport fisheries and aquatic organism populations through habitat protection and restoration, engage in socioeconomic research, and increase coastal tourism, access, and recreation opportunities.


© West Michigan Shoreline Regional Development Commission

Native vegetation being planted as part of shoreline restoration at Muskegon Lake, Michigan.

- **St. Louis River Estuary (Minnesota/Wisconsin)**

The St. Louis River runs along the border of Minnesota and Wisconsin, draining into western Lake Superior. Current and former industry have left a legacy of toxic substances including mercury, dioxins, polychlorinated biphenyls and polycyclic aromatic hydrocarbons, along with extensive habitat alteration and degradation. Multiple NOAA offices join an already active community of partners working on these issues in the St. Louis River estuary. NOAA is developing an implementation plan for the St. Louis River estuary, which will include a major focus on fish and wildlife habitat rehabilitation and restoration, along with identifying non-degraded areas in need of protection. The NOAA

Kachemak Bay, in south-central Alaska, is a Habitat Focus Area as well as a National Estuarine Research Reserve.

Restoration Center is in the process of restoring 30.4 hectares (75 acres) of sheltered habitat in Radio Tower Bay in the St. Louis River estuary, which has historically served as productive spawning, nursery and foraging habitat for many fish including walleye, lake sturgeon, and smallmouth bass. Additional goals for the Focus Area include addressing loss of fish and wildlife habitat through the funding of targeted restoration projects throughout the estuary, rebuilding sport fisheries and populations of aquatic organisms to sustainable levels through habitat protection and restoration, reducing the risk of flooding through improved planning and water management strategies, engaging in social science research, and increasing coastal tourism, access, and recreational opportunities.

- **Kachemak Bay (Alaska)**
  Kachemak Bay, located in southern Cook Inlet, has been recognized as a State of Alaska Critical Habitat Area and as a National Estuarine Research Reserve. It is the largest reserve in the National Estuarine Research Reserve System, and provides unique opportunities for long-term monitoring and research activities, habitat mapping, watershed studies related to salmon habitat, and training and education programs in the area. Because of its water circulation patterns, the bay provides a remarkably fertile environment for both finfish and shellfish. Marine mammals, some of which are threatened or endangered, live in the bay year round, including otters, seals, porpoise, and various species of whales. The bay supports important recreational, subsistence, and commercial fishing, marine transportation, and tourism.

  Although Kachemak Bay has amazing marine resources, the region has experienced significant declines in shrimp and crab that have not recovered despite fisheries closures. The ecological richness is vulnerable to impacts from development activities in Cook Inlet and to changes in ocean acidity and hydrodynamics due to retreating glaciers. Goals for the Focus Area include fostering sustainable and abundant fish populations, working to recover threatened and endangered species, protecting coastal and marine areas and habitats at risk, allowing for resilient coastal communities, and increasing coastal and marine tourism, access, and recreation.

- **Biscayne Bay (Florida)**
  Biscayne Bay, located in south Florida, is a shallow-water, subtropical ecosystem with extensive seagrass cover and a mangrove fringe along most of its shoreline. The bay contains nearly 60,700 hectares (150,000 acres) of essential fish habitat, which supports important species such as grouper and snapper. A wealth of living marine resources such as sea turtles,

dolphins, and corals is also sustained by the bay and its reef. Recreational and commercial fishing, water sports, marine transportation, and tourism are just some of the activities popular in Biscayne Bay and its connecting reef. Scientists and resource managers worry that Biscayne Bay may reach a “tipping point” toward eutrophic conditions, where excess nutrients could lead to dense algal blooms that would subsequently decay and deplete the shallow waters of oxygen. The possible accompanying loss of seagrass cover could be impossible to halt or reverse. Goals for the Focus Area include furthering investigations into algal blooms, reducing nutrient inputs, and maintaining clean, clear waters for the dependent bay fishery and protected species. Tourism and recreational activities are major industries and sources of revenue, jobs, and income for the Biscayne Bay area, and both are directly and indirectly influenced by the ecological health of the bay.

- **Northeast Reserves and Culebra Island (Puerto Rico)**

The habitats of the Northeast Reserves, encompassing the watersheds of the Northeast Ecological Corridor of Puerto Rico, and Culebra Island are home to coastal forests, wetlands, a bioluminescent lagoon, seagrass beds, shallow and deep coral reefs, and miles of pristine beaches. Leatherback sea turtles nest on the beaches, while manatees, green and hawksbill turtles, and bottlenose dolphins are frequently sighted. A variety of coral species, including those protected under the ESA, can be found along with diverse fish species that depend on these valuable habitats. As a result of unsustainable coastal development, land-based sources of pollution, recreational and commercial overuse, and rising sea surface temperatures, this lush region has experienced significant declines in coastal and marine habitats, including those of mangroves, corals, and seagrasses. NOAA is working to protect and restore coastal habitats and resources within the Northeast Reserves and Culebra Island through conservation projects, management-based monitoring and research, and training and education programs. Goals for the Focus Area include protecting and enhancing coral reef ecosystems and nearshore habitats; preventing further habitat, ecosystem and landscape fragmentation; reducing pollution; strengthening local and federal agency collaborations and partnerships; increasing sustainable tourism and the economy of the area; and actively involving the community in habitat conservation.

NOAA

Shoreline habitat on Culebra Island, Puerto Rico.

Within all of NOAA’s Habitat Focus Areas, efforts are helping to test aspects of each of the three Habitat Blueprint approaches: focusing efforts in discrete places, linking science to management, and seeking policy efficiencies to inform future habitat-conservation actions. The initiatives are implementing habitat-based solutions to increase the long-term productivity of living marine resources and improve resilience of coastal communities. The areas selected represent immediate opportunities to strengthen place-based activities through the NOAA Sentinel Site Cooperatives and increase collaborative efforts between the NMFS regional offices and science centers.


USCG

A USCG cutter prepares a derelict ship for destruction. The abandoned ship drifted across the Pacific after the 2011 tsunami in Japan washed it away from its mooring. The ship was a hazard to navigation and presented a potential threat to habitat areas as well.

Other Federal Agencies

Other federal agencies also have goals to conserve and protect aquatic habitats. Outside of NOAA, some of the major federal departments and agencies with relevant responsibilities include the Department of Defense (DOD), Department of Homeland Security (DHS), Department of the Interior (DOI), Environmental Protection Agency (EPA), Federal Energy Regulatory Commission (FERC), and the U.S. Department of Agriculture (USDA).

DOD and DHS—Within the DOD, the U.S. Army Corps of Engineers (USACE) provides several services that benefit society, the environment, and habitats. These services include coastal protection (e.g. from hurricanes or coastal storms) and habitat restoration, protection, and conservation, such as helping to establish wetlands that are essential for the survival of a species. Additionally, under DHS, the U.S. Coast Guard (USCG) takes steps to protect the marine environment and living marine resources. Among these natural resources services, the USCG helps combat the negative impacts from oil and other chemical spills. On occasion, the USCG has sunk floating debris that represented a hazard to navigation, such as from the 2011 tsunami in Japan, and taken measures to protect coral reef ecosystems. The USCG also helps monitor and manage ballast water discharge, a significant pathway for the introduction of invasive species. Toward this end, the USCG helped establish regulations for a national mandatory ballast water management program for all vessels equipped with ballast water tanks that enter or operate in U.S. waters.

DOI—Within DOI, there are several agencies that work on issues related to coastal and marine habitat including the Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE), National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), and the U.S. Geological Survey (USGS).

BOEM and BSEE focus on offshore energy exploration, development, safety, and associated habitat impacts. BOEM manages the exploration and development of the Nation's offshore energy and mineral resources and is responsible for offshore renewable energy development. BOEM's Environmental Studies Program develops, conducts, and oversees scientific research to inform development decisions. Identification and assessment of marine habitats is an important component of that research. BOEM regularly works together with NOAA on research related to coastal and marine habitat. This includes participation in several long-term habitat monitoring programs. BOEM and NOAA also work together on ocean renewable energy, where NOAA contributes technical knowledge and data in support of efforts to pursue offshore wind energy development, especially off the Atlantic Coast. Arrays of wind power turbines may be installed in fields that occupy many square miles of ocean and may have physical, chemical, and ecological ramifications for living marine resources and their habitats.

The National Park Service (NPS) is responsible for management of the National Park System, which includes 85 parks located along the coast or in the Great Lakes. These parks conserve 1 million hectares (2.5 million acres) of ocean and

Great Lakes waters as well as more than 17,700 km (11,000 mi) of coastline. The Bureau of Land Management (BLM) manages the National Conservation Lands, which are nationally significant landscapes recognized for their outstanding cultural, ecological, and scientific values. They include more than 880 monuments, conservation and wilderness areas, and wild and scenic rivers.

The USFWS also has numerous programs that work with a variety of partners to conserve habitats that support the recovery of federal trust species like interjurisdictional fish, migratory birds, and some marine mammals. Examples include the removal of dams and culverts that are barriers to fish migration, restoration and protection of coastal wetlands, restoration of stream and riparian habitat, and creation of living shorelines. The USFWS, in cooperation with NMFS and other agencies, is also engaged in analyzing data and producing reports on the status and trends of wetlands. In addition, the USFWS maintains the National Wildlife Refuge System, which contains 180 ocean and Great Lakes refuges that encompass approximately 8 million hectares (20 million acres) and include over 48,000 km (30,000 mi) of shoreline. Individual refuges work on active habitat restoration and enhancement projects. The USFWS's National Fish Hatchery System operates 70 hatcheries, 7 Fish Technology Centers, and 9 Fish Health Centers. Several of these hatcheries are engaged in recovering ocean-going species like salmon and steelhead.

The DOI also includes the USGS, which conducts scientific research, monitoring, and assessments that assist in maintaining healthy ecosystems and natural resources by helping resource managers, planners, and citizens understand and respond to changes in the environment. Across the country, the USGS provides hydrologic, geologic, geographic, and ecological information and models that assist long-term planning for restoring ecosystem functions, sustaining the quality of coastal waters, and improving water supply reliability. The primary focus of the USGS is on the "interior" of the country, which generally complements NOAA's marine focus. However, the USGS does contribute valuable scientific information for the oceans and coastlines, focusing on geology and physical oceanography.[24]

[24]See http://www.usgs.gov/science/ for more information on USGS science (accessed May 2013).

EPA and Clean Water Act Nonpoint Pollution Success Story

Urbanization and development of Washington D.C. left the Anacostia River with little ability to process pollutants flowing downstream from Maryland and the District. In 2003 the District of Columbia Department of the Environment, and the USACE collaborated on a 7 hectare (17 acre) wetland restoration project called the River Fringe Wetlands. The EPA provided funding through the Clean Water Act to return the tidal portion of the Anacostia River to historical conditions, primarily by pumping in sediment to rebuild areas for planting native wetland vegetation, engaging the local community on the effort, and putting up fences to deter invasive Canada Geese. For additional details on this effort and other examples of Clean Water Act nonpoint pollution success stores, see http://water.epa.gov/polwaste/nps/success319/ (accessed March 2015).

EPA—The EPA is involved in numerous habitat protection and assessment efforts, some of which involve corals, artificial reefs, ballast water (to protect against invasive species introductions), water quality, marine debris, wetlands, and estuaries. Notable examples include EPA's National Estuary Program (NEP),[25] the National Coastal Condition Report,[26] and the National Wetland Condition Assessment.[27] The NEP, a partnership

[25]See http://water.epa.gov/type/oceb/nep/index.cfm (accessed May 2013) for more information on the National Estuary Program.

[26]See http://water.epa.gov/type/oceb/assessmonitor/nccr/index.cfm (accessed May 2013), for the latest National Coastal Condition Report.

[27]See http://water.epa.gov/type/wetlands/assessment/survey/index.cfm for more information on the National Wetland Condition Assessment (accessed May 2013).


EPA

A wetland near the ocean provides habitat to a wide variety of marine species.

between the EPA and federal, state, and local organizations, is designed to improve the quality of estuaries of national significance and address coastal watershed management challenges. The NEP has helped restore and protect over 647,497 hectares (1.6 million acres) of wetlands and other important habitats. The EPA, with assistance from NOAA and other agencies, also produces the National Coastal Condition Report series and is conducting the first-ever National Wetland Condition Assessment to provide assessments of the ecological and environmental conditions in U.S. coastal waters and wetlands, respectively. These assessments are based upon monitoring data collected every 5 years. In addition, the EPA recently completed a series of Coastal Wetland Reviews[28] to collect information regarding coastal wetland stressors, local protection strategies (including restoration), and key gaps that, if addressed, could help reverse the trend of wetland loss. Also, the EPA supports community-based wetland and stream restoration through the Five Star Restoration Grant Program[29] and underwater cleanup and environmental data collection through participation in the Ocean Conservancy's International Coastal Cleanup (ICC), as well as through many marine debris assessment and monitoring efforts. Additionally, the EPA implements a number of programs to reduce land-based sources of pollution that can impact coastal habitats. Among these programs is the National Pollutant Discharge Elimination System (NPDES) permit program, which controls urban stormwater as well as discharges from municipal and industrial wastewater treatment plants, and a grant program that the states use to control agricultural runoff and stormwater discharges.

USDA—Within the USDA, the Natural Resources Conservation Service (NRCS) and the U.S. Forest Service (USFS) conduct activities that support and protect aquatic habitats. The NRCS has programs that benefit society and the environment through services that help improve water quality (e.g. decreasing sediment and farm runoff) and increase wildlife habitat. The USFS provides for the protection, restoration, and management of natural resources on National Forest System lands, provides assistance and support for the conservation and management of state and private forest lands, and conducts research on the role that forests play in providing watershed ecosystem services from headwaters to oceans.

FERC—As an independent agency, the FERC regulates the interstate transmission of electricity, natural gas, and oil. This includes the licensing of hydropower projects and reviewing proposals to build liquefied natural gas terminals and interstate natural gas pipelines. As part of these responsibilities, the FERC oversees environmental matters related to natural gas projects and hydroelectric projects.

Non-Federal Organizations—The task of conserving and protecting habitats goes well beyond the abilities and funding of federal agencies. State resource agencies play a significant role in habitat protection efforts, as do individual citizens, communities, many non-governmental organizations, and all manner of partnerships. It is beyond the scope of this report to summarize the wide array of state and local programs that protect habitat. Several examples of NGOs are described below to illustrate some of the diversity of these programs.

One example is the Surfrider Foundation, which is a national non-profit organization dedi-

[28]See http://water.epa.gov/type/wetlands/cwt.cfm.#activities (accessed June 2013) for more information on the Coastal Wetland Reviews.

[29]See http://water.epa.gov/grants_funding/wetlands/restore/index.cfm (accessed June 2013) for more information on the Five Start Restoration Grant Program.

cated to protecting oceans and beaches through a grassroots community-based approach. Activities include environmental education, local activism, and dissemination of up-to-date, science-based information at the community level.

Another example is the Nature Conservancy, a leading conservation organization that works in all 50 states and over 30 countries to help protect ecologically important environments. This includes work in coastal and oceanic habitats, as well as in freshwater rivers and lakes. The Nature Conservancy also works with partners like NOAA to help restore aquatic habitats around the Nation.

Two regional examples of environmental organizations that support habitat efforts can be found within the Chesapeake Bay area: the Chesapeake Bay Foundation and the Chesapeake Wildlife Heritage. Volunteers for the Chesapeake Bay Foundation can get involved in restoration activities on a wide range of habitat elements including riparian zones, oyster reefs, and underwater grasses. The Chesapeake Wildlife Heritage is a regional non-profit group that works to protect habitats in the Chesapeake Bay watershed through direct action, education, and research. Numerous other nongovernmental organizations across the United States work to protect marine and anadromous habitats as well.

Research Needs

Fishery Species—In providing guidance to resource managers and officials charged with protecting habitat, information is needed on how species use habitat, where habitat exists, its quantity and condition, the best practices to conserve it, and how marine communities and, ultimately, sustainable fishery yields depend on the amount and condition of available habitat. For most species, key questions related to fish-habitat linkages remain unanswered. These include the following issues: seasonal habitat usage; relationships between habitat alteration and fish survival and production; lethal and sublethal effects of pollutants; effectiveness of restoration techniques; and, of course, the relationship of a species' survival, growth, and reproduction to its habitat during its various life stages. Marine species in the open ocean are vulnerable to human actions when their habitat requirements, availability, and dynamics are not known. For example, the lack of


NMFS

A common thresher shark with a research tag attached behind the dorsal fin.

knowledge about congregation areas for pregnant females, pupping grounds, and core nursery areas of the common thresher shark and shortfin mako shark precludes protection, making aggregations of females and pups vulnerable to fishing and other adverse effects. At a time when there are increasing demands for information, some critical needs are not being met. For example, there is diminishing information over time of physical and biological data on southeast coastal pelagic finfishes, leading to degraded time series on these variables. To address needs for improved habitat science for fisheries, NMFS developed the Marine Fisheries Habitat Assessment Improvement Plan (HAIP), which was published in May 2010 (NMFS, 2010). This is the first nationally coordinated plan to focus on the marine fisheries aspects of habitat science.

The HAIP defines a habitat assessment as both the process and products associated with consolidating, analyzing, and reporting the best available information on habitat characteristics relative to the population dynamics of fishery species and other living marine resources. Indicators of the value and condition of marine habitats can be developed through a habitat assessment by investigating the relationships between habitat characteristics, the productivity of fishery species, and the type and magnitude of various impacts. The ultimate goal of a habitat assessment is to support management decisions by providing information on how habitats contribute to species productivity.

Habitat assessments require both collection and synthesis of multiple data types at a variety of temporal and spatial resolutions. To date, research efforts to collect habitat data have been fragmented and limited, with our greatest success demonstrated in the physical characterization of habitats. A survey of NMFS scientists indicated that most habitat

Corals protected under the Endangered Species Act

In September 2014 NOAA listed 20 new corals as threatened under the Endangered Species Act (ESA). The new coral species listed are found in the Indo-Pacific (15 species) and Caribbean (5 species). They join elkhorn and staghorn corals (listed as threatened in 2006) for a combined total of 22 species of coral that are now protected under the ESA. Three major threats identified—rising ocean temperatures, ocean acidification, and disease—are all directly or indirectly linked to greenhouse gas emissions and a changing climate. These threats can be compounded by other impacts such as trophic effects of fishing, sedimentation, and nutrient pollution, which affect corals on a local to regional spatial scale.

The purpose of the ESA is to protect species that are in danger of extinction, or likely to become in danger of extinction, and the ecosystems on which they depend. Corals, however, are more than just individual species. Many are also ecosystem engineers, with individual coral polyps laying down calcium carbonate skeletons, and collectively building reef habitat. Coral reefs support some of the world's most productive and diverse ecosystems and provide habitat for thousands of marine species. Beyond supporting substantial commercial and recreational fisheries, coral reefs also provide other measurable economic values. They provide approximately $483 million in annual net benefit to the U.S. economy from tourism and recreation activities and $1.1 billion from all goods and services (Cesar et al., 2003). Beyond the sheer number of species, though, listed corals present a new challenge to NOAA. Unlike sea turtles or whales that are directly affected by fishing or ship strikes, two problems that can be mitigated through fishing or shipping modifications, the most severe risks to corals come from factors beyond NOAA's purview that are difficult to control, such as climate change.

data presently are inadequate or completely lacking and occur at low spatial and temporal resolutions (NMFS, 2010). Major obstacles to producing and using credible habitat assessments include lack of habitat-specific biological information and population abundance; inadequate numbers of technical and scientific staff; insufficient research on environmental effects and multi-species effects; and ineffective management of habitat data.

Overall, the HAIP outlines current gaps in the Agency's habitat science, steps to improve habitat assessments (Table 5), and the need for an integrated, national habitat science program. Implementing the HAIP will enhance the ability

Table 5
Recommendations from the Habitat Assessment Improvement Plan.

1. Develop new budget and staffing initiatives to fund habitat science that is directly linked to NMFS' fisheries mandates.
2. Develop criteria to prioritize stocks and geographic locations that would benefit from habitat assessments.
3. Initiate demonstration projects that incorporate habitat data into stock-assessment models.
4. Identify and prioritize data inadequacies for stocks and their habitats, to bridge information gaps identified in the HAIP.
5. Increase collection of habitat data on fishery-independent surveys and develop a plan for better utilizing new technologies aboard the NOAA fleet of Fishery Survey Vessels.
6. Engage partners within and outside of NOAA to exchange information about programs and capabilities. Coordinate habitat data collection, and upgrade and expand data management systems.
7. Develop strategies to integrate habitat science and assessments, stock assessments, and integrated ecosystem assessments.
8. Establish a habitat assessment fellowship program and provide funds to graduate students and post-doctoral associates to advance habitat modeling, evaluation, and assessment efforts.
9. Unite with other NOAA line offices to develop a NOAA-wide strategic plan for habitat science and assessments in support of the Nation's ocean policy priorities.

of NMFS' science programs to meet several high-priority needs, including the following:

- providing information for habitat management, conservation, and restoration activities;
- supporting consultations and evaluating environmental impacts for proposed activities, including aquaculture and energy projects;
- assessing risk and injury to living marine resources after environmental disasters;
- improving the design of fishery-independent surveys and the interpretation of survey data;
- providing information for stock assessments;
- understanding of the role of habitat in trophic and community interactions as necessary for ecosystem-based approaches to managment;
- addressing conflicting demands on limited marine resources through effective coastal and marine spatial planning and integrated ecosystem assessments; and
- understanding and predicting the effects of climate change and other anthropogenic impacts on ocean resources.

Protected Species—Our limited understanding of marine mammals, sea turtles, and other protected species presents many of the same research needs as fishery species. A primary research need is to understand year-round and seasonal habitat use, movement, and distribution patterns of marine mammals correlated with environmental, oceanographic, and prey data. Marine mammals are apex predators and, as such, their status is a useful indicator of ecological and climatic conditions. Therefore, it is important to characterize their role in maintaining ecosystem structure and function, and how these factors will be affected by the declining or changing distribution of marine mammals in sensitive habitats exposed to natural and human-made stressors.

For endangered and threatened sea turtles, the primary need is to characterize habitat use during migration and while foraging (for example, through tracking studies), and also to determine seasonal and annual abundance and trends at key offshore and nearshore foraging areas and nesting beaches. Most sea turtle species still have many information gaps for their water-habitat use patterns, particularly males and immature life stages. Such knowledge will enable mitigation or reduction of sea-turtle bycatch in commercial fisheries and other impacts in these habitats. Information is also limited on the impacts of climate change on many of the Nation's protected species and their habitats. For example, rising ocean temperatures and ocean acidification related to climate change are considered to be some of the most significant threats to many coral species in the Pacific and Caribbean. Improved understanding of the impacts of sound on marine species such as marine mammals and fish is also needed. Maps such as those produced by the NOAA-led CetSound project[30] that show cetacean density and distribution in U.S.

[30]See http://cetsound.noaa.gov/index.html (accessed March 2015) for more information.

EEZ waters along with man-made noise sources will provide a better understanding of important habitats and the potential for influence by human activity, but continued investment in such activities and further research is still needed.

Summary—Table 6 presents an overview of the most critical habitat-related research needs at the national level for both fishery and protected species. Requirements vary somewhat among regions, and can be found within the regional sections of this report. Nevertheless, there are two overarching gaps in knowledge: the quantity and quality of habitats, about which we do not have enough information at present; and species/habitat relationships, about which we do have some limited, but useful, information.

Meeting these research needs will improve the scientific understanding of how the quantity and quality of habitat affects the Nation's marine fishery and protected species, and how to more effectively protect, conserve, and restore their habitats as the

Table 6
The most critical needs for habitat-related research at the national level for all habitat types.

Needs	Actions
Life history studies and habitat requirements	• Conduct life history studies (including studies of age, growth, maturity, and fecundity) in relation to habitat for all fishery and protected species, particularly the early life stages. • Determine productivity by life stage and habitat type for fishery and protected species. For fishery species this will help achieve Level 4 EFH information. For ESA-listed species, this will help improve the definitions of Critical Habitat. • Determine the most important habitat requirements (e.g. habitat type, quantity, and quality) for each species and life stage. • Characterize and describe benthic and open-ocean habitats and associated species assemblages on spatial scales relevant to fishery management, habitat protection, and protected species conservation.
Mapping	• Delineate and map important habitats, including coastal shorelines, estuaries, salt marsh wetlands, streams used by anadromous species, riparian zones, submerged aquatic vegetation (e.g. eelgrass), deep-sea corals, pinnacles, seamounts, and fishing grounds on the Continental Shelf and Slope.
Understand and monitor natural and anthropogenic impacts to species and habitats	• Determine the direct and indirect effects on fishery and protected species and their habitats of: – climate change and ocean acidification; – severe storms and sea level rise; – natural habitat variability (climatic and oceanographic); – toxic algal blooms; and – fishing. • Develop methods to reduce damaging practices. • Improve understanding of the effects of underwater sound on marine mammals. • Monitor changes in habitat quality, quantity, and use.
Habitat restoration	• Develop and test practical methods to protect and restore habitat for fishery and protected species.
Habitat conservation and protection	• Evaluate approaches for habitat conservation and protection, including development of innovative gear designs and fishing methods that minimize habitat impacts, as well as the use of marine protected areas.
Advanced methods and technologies	• Develop remote sensing and autonomous platforms for oceanography and stock and habitat assessment.
Economics and social analysis	• Determine societal and economic benefits of conserving and restoring habitat.

pressures on those habitats increase from expanding human populations, economic development and resource extraction, and climate change. The improved knowledge will enable improved management of these self-renewing living resources, sustaining and increasing the economic and cultural benefits they provide to society.

Obtaining this knowledge is an expensive, long-term proposition. Part of the solution will be to grow NMFS' internal capabilities through improved efficiencies and targeted increases of staff and technical resources. Another important component of the long-term solution will be to enhance and expand our partnerships and collaborations across NOAA, and with our sister federal agencies, state and local governments, academic institutions, commercial and recreational fishing groups, non-governmental organizations, and the private sector.


USFWS

A river in Alaska's Arctic National Wildlife Refuge. The rivers and streams in this fragile northern Alaskan refuge contain 12 species of anadromous fish, such as salmon and smelt. The coastal waters are known to hold 17 species of marine fish (ANWR, 2006).

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