Our Living Oceans: Habitat

STATUS OF THE HABITAT OF U.S. LIVING MARINE RESOURCES

U.S. DEPARTMENT OF COMMERCE
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Our Living Oceans: Habitat

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Our Living Oceans: Habitat

Status of the Habitat of U.S. Living Marine Resources

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Preface

This publication, *Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources,* is the first comprehensive edition of the *Our Living Oceans* habitat report to be released since the inaugural policymakers' summary report was published in 2009. That publication, *Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources. Policymakers' Summary*, was an abridged version of earlier material developed as the framework for this, far more comprehensive, version.

This 2015 *Our Living Oceans* habitat report will join previous publications, which covered living marine resources and economics, as the third and final subject covered in the *Our Living Oceans* publication series. Taken together, *Our Living Oceans* serves as a report card on the state of U.S. living marine resources, their economic contributions to the Nation, the condition of their habitats, and the availability of habitat-use information.

The *Our Living Oceans* reports are neither mandated nor intended to fulfill any legal requirement. Instead, the purpose of *Our Living Oceans* from the beginning has been to synthesize existing information and provide status reviews on the health of U.S. living marine resources, their economic contributions to the Nation, and the habitats necessary for them to survive. Reports in this series were released in 1991, 1992, 1993, 1995, 1996, 1999, and 2009. Over time, this reporting effort has evolved from a one-year cycle to a multiyear cycle so as to better reflect the extended time periods often required to observe and document change in biological populations, the economy, and the marine environment.

The *Our Living Oceans* habitat report provides a comprehensive summary of habitat information for all fishery and protected species under the purview of NOAA's National Marine Fisheries Service. The report provides information on habitat science, trends, and research needs nationally and on a region-specific basis. The report also provides a conceptual framework for understanding habitat-use patterns of marine species. It also identifies gaps in the available data and information, and describes how these gaps can be addressed through additional research. As with previous reports in the *Our Living Oceans* series, this publication and the data presented are the result of the collective efforts of National Marine Fisheries Service staff from around the country. The principal contributors to this report are listed in Appendix 1.

Foreword

Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources is the third and final part of the *Our Living Oceans* publication series, joining the previously published *Our Living Oceans* reports on living marine resources in U.S. maritime waters and *Our Living Oceans* reports on the economics of the commercial and recreational fisheries conducted in these waters. Taken together, the *Our Living Oceans* series serves as a report card to the Nation, detailing the state of U.S. living marine resources, their contributions to the U.S. economy, the condition of their habitats, and the availability of habitat-use information. This current report on habitat provides the foundation for more targeted research and comprehensive and detailed reports in the future.

The most important laws governing activities of the National Marine Fisheries Service (NMFS) pertinent to habitat are the Magnuson-Stevens Fishery Conservation and Management Act (MSA), reauthorized in 2006, and two laws on protected species: the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). The MSA includes provisions to help conserve and protect essential fish habitat (EFH), which is defined as "… those waters and substrate necessary to fish for spawning, breeding, or growth to maturity," for commercially and recreationally harvested fish and invertebrates within the U.S. Exclusive Economic Zone (typically 6–370 km [3–200 nautical miles] from shore). The ESA, as it applies to NMFS, includes provisions to help conserve ecosystems and habitats required by those marine species threatened with, or in danger of, extinction (e.g. certain species of cetaceans, pinnipeds, sea turtles, fishes, invertebrates, and marine plants). The MMPA also places restrictions on any habitat alteration that could adversely impact marine mammals by disrupting behavioral patterns. In summary, this report covers the habitats of all species managed or protected by NMFS under the MSA, ESA, and MMPA.

The fact that this report is the first comprehensive, nationwide review of the status and trends of these habitats, as well as the first comprehensive summary of information available on habitat use at the species or group-of-species level, underscores the difficulty of the task. In addition to cataloging what is known about our Nation's aquatic habitats and the habitat-use patterns of living marine resources, the report also tracks what remains unknown. This will help guide and prioritize research to address the most important gaps in information. Recent technological advances in autonomous underwater vehicles, multibeam sonar, and satellites have increased our ability fill these gaps in habitat knowledge.

Our living marine resources are in various conditions, ranging from heavily overfished and endangered to very healthy and functioning at a high level of productivity. Although the habitat needs of aquatic species often compete with other societal needs, the National Oceanic and Atmospheric Administration (NOAA) must ensure that the quantity and quality of available habitat is sufficient to support each life history stage of every managed species at sustainable levels. While there are difficulties associated with quantifying the habitat needs of a species, the work is vital because habitat degradation or loss may be constraining some populations.

This report should not be interpreted as one of despair nor of unbounded optimism. Federal and state governments have provided considerable protection by regulating pollution and development activities, and the increasing availability of habitat information is contributing to improved fishery and ecosystem-based management. However, the ever-increasing concentration of human population along the coasts, the growing amount of runoff from urban and other sources, and the emerging pressures from energy development and extraction offshore all continue to place pressure on coastal and marine habitats. The information provided in this report will give readers a chance to assess the current situation facing these habitats and to consider the opportunities that we have today to both protect the habitat that remains and repair or restore habitats that have been degraded or lost.

In addition, this report provides an overview of an important new NOAA initiative, the Habitat Blueprint, which provides a framework for NOAA to think and act strategically across programs, and with partners, to better protect and restore habitat. As the Blueprint matures and becomes more fully implemented, it will enhance NOAA's ability to address many of the important issues described in this report, and will serve as a guide to help create healthy habitats that can sustain resilient and thriving marine resources, help recover protected species, and protect coastal communities from storm damage.

Many scientists throughout NMFS and several other organizations contributed to this report. I extend my appreciation and compliments to all.

Richard L. Merrick, Ph.D.
Director, Scientific Programs and
Chief Science Advisor
National Marine Fisheries Service
Silver Spring, Maryland

Part 1
Executive Summary

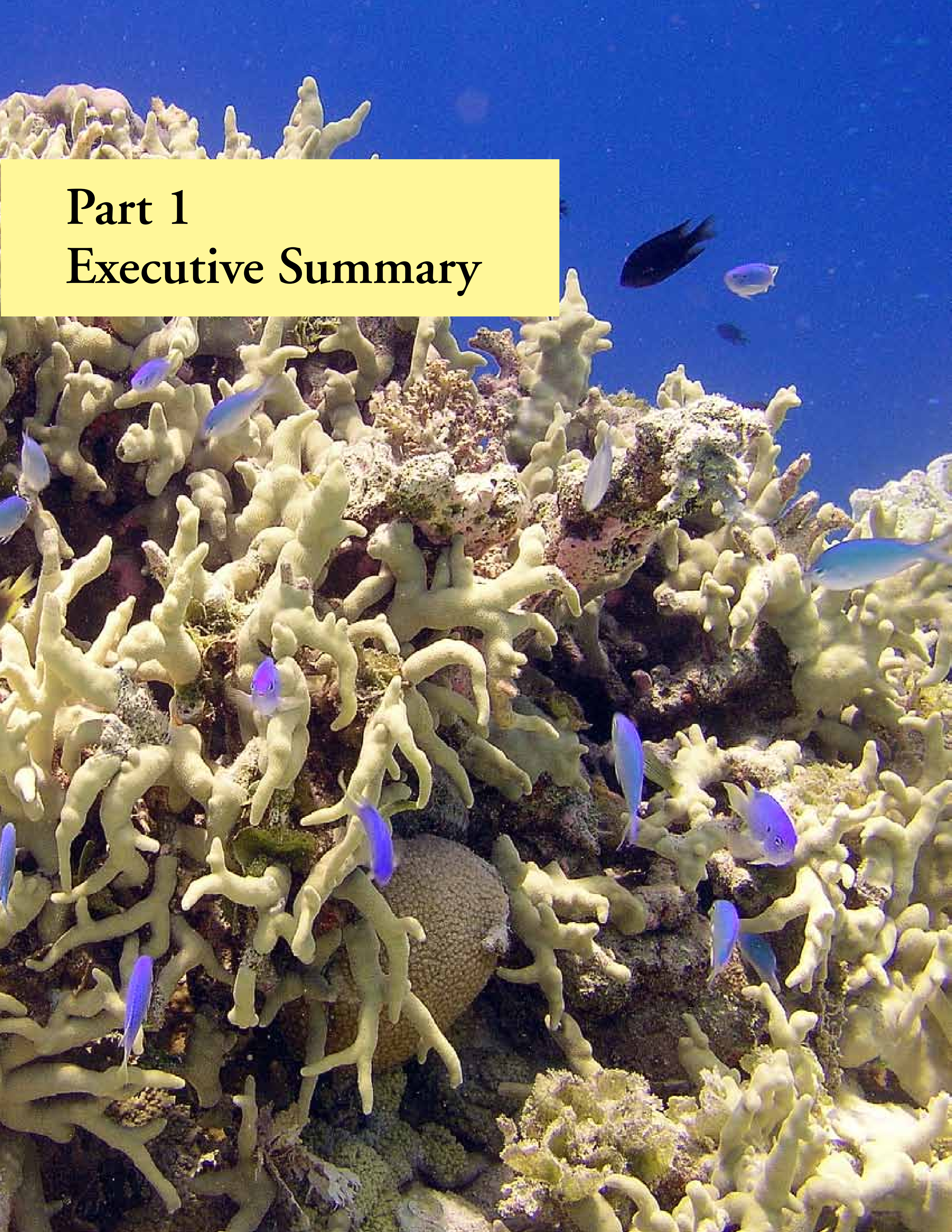


Photo on previous page: Coral and fishes at Ailuk Atoll, in the Marshall Islands. Photo credit: DOI Office of Insular Affairs.

Executive Summary

John Brooks, Channel Islands National Marine Sanctuary

NOAA

Lisa Wedding, NMFS

John McMillan, NMFS

Upper left, kelp forest off California; upper right, salt marsh in Rehoboth Bay, Delaware; lower left, school of yellow tang in Hawaii; lower right, pink salmon spawning in the Elwha River, Washington.

OVERVIEW

Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources is the first comprehensive national summary of the status and trends of the habitats used by the living marine resources under the purview of NOAA's National Marine Fisheries Service (NMFS). This document is part of the *Our Living Oceans* series, which includes *Our Living Oceans* reports on the Nation's living marine resources (NMFS, 1991, 1992, 1993, 1996a, 1999, 2009) and their economic aspects (NMFS, 1996b). This report provides a conceptual framework for understanding habitat-use patterns by the Nation's federally managed marine species, identifying the shortcomings in relevant information, and describing how and why these shortcomings should be addressed through additional research.

Habitat—the place where species live—plays a fundamental role in supporting the production of fishery and protected marine stocks and the ecosystems on which they all depend. However, this role is poorly understood, and demands and impacts on habitats are growing, with potentially large and far-reaching effects on productivity. Lack of knowledge about how marine species depend on and interact with habitats impedes effective management of harvested fishery stocks and protected species. The societal implications include lost or foregone yields for commercial fisheries and reduced opportunities for recreation

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.

Brenda Rone, NMFS

A humpback whale dives among an aggregation of short-tailed shearwaters at Cape Cheerful, Unalaska.

(including fishing) that depends on the affected stocks, as well as increased risk of extinction of protected species.

This report primarily addresses the habitat use of fishery and protected species under NMFS jurisdiction. These fishery species include approximately 500 stocks of fish, shellfish, and other marine organisms managed under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) by fishery management plans (FMPs) or fishery ecosystem plans (FEPs). The MSA has protections in place for essential fish habitat (EFH), defined as "… those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" [MSA, 16 U.S.C. 1802(10)].

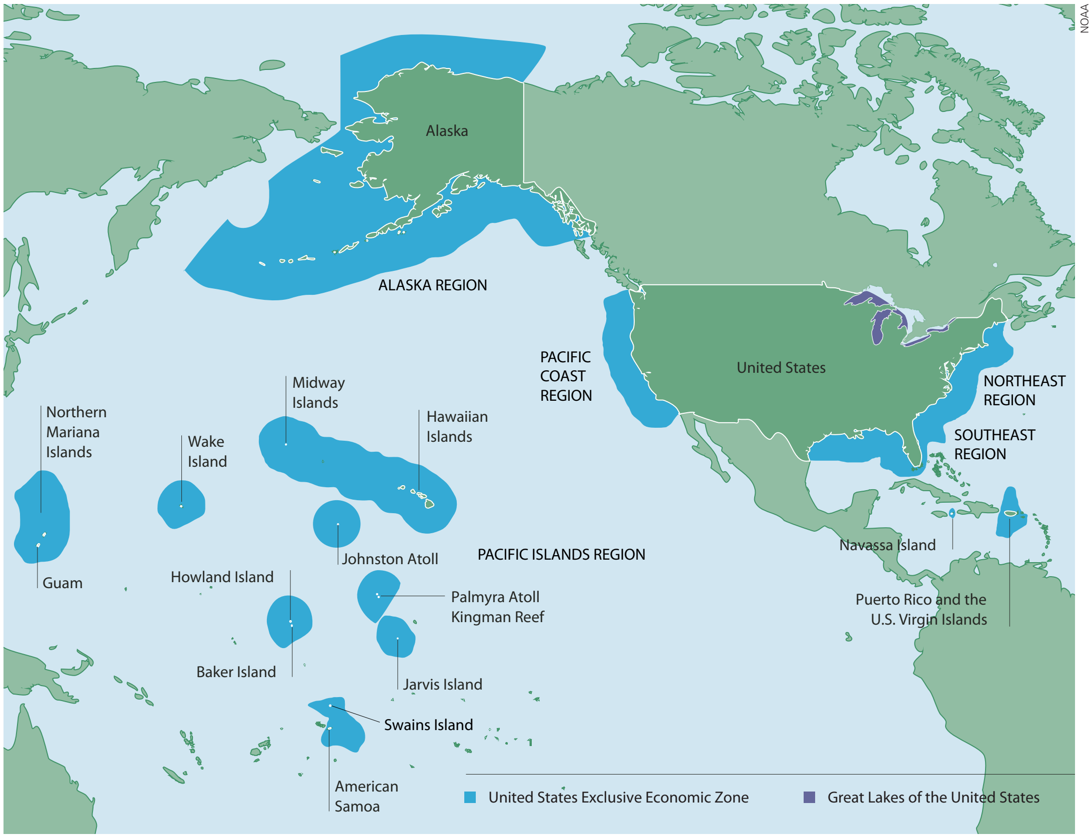
Protecting and conserving nearly all of the Nation's marine mammals is also a NMFS responsibility under the Marine Mammal Protection Act. In addition NMFS is responsible for protecting certain marine mammals, as well as sea turtles and certain fish, invertebrates, and seagrass species that are listed as threatened or endangered under the Endangered Species Act (ESA). These protections include conservation of the habitats designated as critical habitats for these species. The habitats occupied by federally managed marine species range from inland streams used for spawning by anadromous species such as salmon, to the 370 km (200 nautical mile [nmi]) offshore limit of the entire U.S. Exclusive Economic Zone (EEZ), and beyond.

This report contains a national summary and five regional chapters: Northeast, Southeast, Pacific Coast, Alaska, and Pacific Islands. These regions are based on geography and are generally similar to the NMFS regional structure. Four primary habitat categories are used. These broad habitat categories incorporate more specific habitat types such as seagrass beds, coral reefs, mangrove forests, and the open water column. The four habitat categories are defined as follows:

- Freshwater: habitats located between the headwater and the head-of-tide, with negligible salinity. (Headwater is the inland source from which a river originates; head-of-tide is the inland limit of water affected by tides.)
- Estuarine: habitats 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: habitats less than 200 m (656 ft) in bottom depth and located between the outer boundary of an estuary or coast (continent or island) and the outer boundary of the U.S. EEZ, usually 370 km (200 nmi) from shore.
- Oceanic: habitats greater than 200 m (656 ft) in bottom depth and located between the outer boundary of an estuary or coast (continent or island) and the outer boundary of the U.S. EEZ.

In this report, descriptions of habitat use by federally harvested marine species are organized by FMPs and FEPs. At the time this report was developed, there were 46 FMPs and FEPs combined (See Appendix 3 for a full listing). The Northeast Region has 13 FMPs[1]; the Southeast Region has 18 FMPs; the Pacific Coast Region has 4 FMPs; the Alaska Region has 6 FMPs; and the Pacific Islands Region has 5 FEPs. Habitat use by protected species is categorized by group: cetaceans (whales, dolphins, porpoises), pinnipeds (seals and sea lions), sea turtles, or other groupings as appropriate. Please see Appendix 5 for a listing of all species included in this report.

[1]Note that the Consolidated Atlantic Highly Migratory Species FMP is shared by the Northeast and Southeast Regions, but is discussed and counted only under the Southeast Region in this report.



The U.S. EEZ shown on this map is divided into five geographic regions for this report: Northeast, Southeast, Pacific Coast, Alaska, and Pacific Islands.

HABITAT AREAS

The total area of the U.S. EEZ is approximately 11.530 million km^2 (3.362 million nmi^2),[2,3] which is larger than the total land mass of the United States itself. In this report, the U.S. EEZ is divided into five geographic regions: Northeast, Southeast, Pacific Coast, Alaska, and Pacific Islands.

The Northeast Region extends from the U.S–Canada border in Maine, southwest to Cape Hatteras, North Carolina. The region covers about 3% (369,000 km^2 [108,000 nmi^2]) of the U.S. EEZ and includes three major areas from north to south: the Gulf of Maine, Georges Bank, and Southern New England/Mid-Atlantic Bight.

[2]All EEZ figures provided for the United States and its regions in this report are provided in square kilometers and square nautical miles, rounded to the nearest 1,000 square kilometers, and exclude state waters.

[3]Memorandum for the Record from M. Lockwood: Area of the U.S. Exclusive Economic Zone, dated 30 April 1993. Copy on file at USGS–NOAA Joint Office, Mapping and Research, 915 National Center, Reston, VA 22092.

The Southeast Region extends from Cape Hatteras, North Carolina, south to the U.S.–Mexico border in Texas, and also includes the Commonwealth of Puerto Rico, the Territory of the U.S. Virgin Islands, and Navassa Island (located in the Caribbean Wildlife Refuge). The region encompasses about 12% (1.34 million km^2 [391,000 nmi^2]) of the U.S. EEZ.

The Pacific Coast Region lies adjacent to California, Oregon, and Washington and encompasses about 7% (812,000 km^2 [237,000 nmi^2]) of the total area of the U.S. EEZ. The region has two distinct areas: the Oregonian Province, bounded by the Strait of Juan de Fuca, Washington, to the north and Point Conception, California, to the south; and the U.S. portion of the San Diego Province, which extends from Point Conception, California, to Magdalena Bay, Mexico.

The Alaska Region covers areas of the North Pacific Ocean, the Bering Sea, the Chukchi Sea, and the Arctic Ocean and encompasses about 28% (3.258 million km^2 [950,000 nmi^2]) of the U.S. EEZ.

The U.S. Pacific Islands Region includes 50 Pacific Ocean islands, including two archipelagos (Hawaiian and Marianas), part of another archipelago (Samoan), and eight isolated atolls or low-lying islands (Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland Island, Baker Island, Swains Island, and Wake Island). Although the land area of the U.S. Pacific Islands Region is small when compared to North America, the total area of U.S. EEZ waters included in the Pacific Islands Region is over 5.751 million km^2 (1.677 million nmi^2), or almost 50% of the entire U.S. EEZ.

NATIONAL HABITAT-USE PATTERNS

Shallow marine and oceanic habitats are the habitat types most commonly used by federally managed marine fishery species in all regions; freshwater habitats are the least used. Specifically, over 95% of the Nation's FMPs and FEPs have one or more species that use shallow marine and/or oceanic habitats during one or more parts of their life cycles. Nationwide, only 16% of all FMPs and FEPs have species that use freshwater habitats, with anadromous species such as salmon being the primary users. In terms of estuaries, 82% of the Nation's FMPs and FEPs have one or more species that use these vital habitats. Fishery 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 also provide habitat to at least one life stage of 68% of the dollar value (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). In addition, many non-FMP species that serve as important food sources for our managed stocks (they are often called "forage species") use freshwater and estuarine habitats.

A saltmarsh in the Delmarva Peninsula, Virginia.

Habitat use by the Nation's protected species of cetaceans, pinnipeds, and sea turtles is broadly similar to that of FMP/FEP species.[4] 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. Estuaries are important for many marine mammals such as Gulf of Mexico and Atlantic bottlenose dolphins, which spend a major portion of their life in these waters. Freshwater habitat is the 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.

NATIONAL TRENDS IN HABITAT-USE INFORMATION

The significance of the information gaps identified below is that NMFS and its partner agencies and stakeholders are forced to base decisions involving habitat on very limited or, in some cases, non-existent information. The lack of knowledge of how fishery and protected stocks are affected by the quantity and quality of specific habitat types compromises managers' ability to prioritize habitats for protection, restore degraded habitats in a way that maximizes the benefits in terms of increased fishery yields and/or conservation of protected species, and most effectively mitigate the unavoidable impacts of some human activities.

[4]The protected species discussed in this report are limited to cetaceans, pinnipeds, and sea turtles (see Appendix 4). Some of the other species listed under the ESA (e.g. salmon) are discussed in the context of FMPs; but other listed species (e.g. corals) are not considered in detail in this report.

At the national level, habitat information for most federally managed fishery species consists of presence or absence data (also called distribution information) for a species or any of its life stages in a particular habitat type—this is the most basic level of information. The more detailed and better the information on habitat use, the less of it exists. The most informative type of habitat information, which links species productivity directly to habitat and is the highest level for identifying essential fish habitat, is not available for most fishery species, even the most economically valuable. A hypothetical example of this productivity information would be the number of individuals of sea trout, or their collective weight, produced per unit area of seagrass bed per year. In addition, most habitat-use information is available for adult life stages, which are surveyed for stock assessments. Much less information is available for the early life stages (e.g. eggs, larvae).

The most common level of habitat-use information for protected species of cetaceans, pinnipeds, and sea turtles in most regions is also data on the presence or absence of a species or life stage in a particular habitat type. As is the case with harvested species, the more detailed and better the information on habitat use is, the less of that information exists, even though it is this higher-level information that would be the most useful in identifying and conserving critical habitat. In addition, for marine mammals and sea turtles that are listed under the ESA, important pieces of information, which are often not available, are region- and habitat-specific distribution and density and seasonal changes in time and space. Such information is necessary for other federal agencies and industry applying to NMFS for permits to conduct surveys, exploration, development, or defense activities.

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 support is provided to NMFS for surveys and assessments on fishery species than on protected species. This difference leads to differences in information on habitat use by these respective groups.

NOAA

Seagrass beds like this one are important habitat for a variety of marine species.

HABITAT STATUS, TRENDS, AND ISSUES

The status and trends of habitats vary widely across regions and habitat types. These differences are due to both socioeconomic and historical factors such as population density, industrial development, and land-use; and to physical factors such as weather and climate, and geological and oceanographic characteristics. Many issues affecting habitat 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.

There are many factors that can affect habitat quality and quantity. A ubiquitous concern is climate change, which affects species distributions, temperatures, the timing of seasonal events (e.g. annual cycles of freezing and thawing), precipitation, and storm severity, as well as the related issue of increasing ocean acidity caused by rising carbon dioxide concentrations. In freshwater habitats, 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.

A cargo ship has a near miss with a large whale.

Estuarine habitats are also strongly affected by human activities on the land surrounding them and the rivers that drain into them. Eutrophication, for example, is a common problem in estuarine habitats, whereby excess nutrients can result in elevated turbidity (i.e. cloudy water) and reduced dissolved oxygen concentrations, both of which adversely affect aquatic life. Habitat fragmentation and loss are some of the primary issues facing vital wetland habitats in freshwater and estuarine coastal environments. Coastal wetlands comprise about one-third of all the wetlands in the continental United States and include marshes, swamps, mangrove forests, and seagrass beds. Although overall wetland loss for the country has decreased significantly due to federal and state laws and policies, it remains a significant problem in coastal watersheds. Two reports published jointly by NOAA and the U.S. Fish and Wildlife Service have concluded that wetland loss in coastal watersheds is substantial—about seven football fields an hour—and increasing (Stedman and Dahl, 2008; Dahl and Stedman, 2013). Human activities, such as development, are a primary cause.

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, there are some widespread threats that can decrease habitat quality and quantity, such as sedimentation on coral reefs, the uncertain effects of climate change and ocean acidification, and the impacts of fishing and fishing gear, particularly bottom trawls on seafloor habitats. More localized degradation can result from, among other things, marine debris (including discarded or lost fishing gear), oil spills and slicks, oil and gas development, sand and gravel mining, cable deployment, and anchoring. Harmful or toxic algal blooms 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 humans or pets. Vessel traffic and ocean noise are also two factors of particular concern, particularly for marine mammals. Human-made underwater noise can affect marine mammals through the chronic effects of long-term increases in ocean noise and through the acute impacts of a specific, typically intense, sound source. For some species, such as the highly endangered North Atlantic right whale, collisions with vessels continue to be a threat to their recovery, although recent speed restrictions in areas where shipping lanes overlap with their habitat, and other protective measures, are helping reduce the probability of lethal collisions.

HABITAT PROTECTION AND RESTORATION

Habitat protection and restoration can help conserve and rebuild fishery and protected species. Protecting habitat maintains existing functions and prevents further losses, while restoration repairs habitat that is degraded or creates new habitat. Restoration is costly, and fully restoring ecological functions may not always be feasible or can take a long time, but restoration can result in a net increase of habitat.

Regulations and conservation easements, combined with public awareness, form the basis for habitat protection. At the broadest level, the United States has over 1,700 marine protected areas that cover approximately 40% of the Nation's marine waters. The size of these areas and their level of protection vary. The most comprehensive level of protection may be "no take," in which all types of harvest are prohibited. This level of protection is in place for only 3% of U.S. waters (NOAA, 2011). However, there are many options for less restrictive levels of protection (e.g. banning the use of bottom trawls) that can provide significant conservation benefits for habitat.

One noteworthy example of habitat protection is the Papahānaumokuākea Marine National Monument, which encompasses over 360,000 km^2 (140,000 mi^2) of emergent and submerged lands and waters of the Northwest Hawaiian Islands—an area larger than all the national parks in the United States combined. This Monument is also home to approximately 80% of the critically endangered Hawaiian monk seal population and is the breeding ground for over 95% of the Hawaiian green sea turtle population. Protecting the Monument's diverse and unique habitats from human impacts helps to ensure the continued existence of the functioning ecosystems and the living resources that occur there.

There are also many examples of habitat protections in place that exist as a result of fishery management. In Alaska, for example, the Aleutian Islands Fishery Management Area was closed to bottom trawling, as were designated areas of the Gulf of Alaska, to protect deep-sea corals and other fragile parts of the ecosystem. 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), approximately the size of Texas and Colorado combined. As another example, NMFS and the South Atlantic Fishery Management Council established five Habitat Areas of Particular Concern in 2010 for deep-sea corals, totaling 61,548 km^2 (24,215 mi^2) off the southeastern coast of the United States, where most types of fishing gear that contact the seafloor are prohibited and deep-sea coral habitat is protected.

Creating or restoring habitat is usually more expensive and less effective than protecting habitat that already exists and functions well. Nonetheless, habitat restoration can be important in recreating the structure and function of habitats and ecosystems and returning them to a close approximation of their original condition. 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. A recent example relates to the Elwha Dam in Washington State, which was removed in 2012, and the nearby Glines Canyon Dam, removed in 2014. These projects represent the largest dam removals in U.S. history, and will allow Chinook salmon (also referred to as king salmon), to return to their historical spawning grounds. In 2012, Chinook salmon began spawning in the Elwha River in the summer.

National Park Service

The Elwha Dam in Washington State was removed in 2012, restoring miles of habitat for spawning salmon that had been blocked for a century.

Monitoring is an important component of restoration, to ensure that the restoration goals are being met. Monitoring can improve effectiveness, for example, by detecting early if a project is not on track. 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.

HABITAT RESEARCH NEEDS

Identifying habitat research needs is a necessary step in tailoring science programs that can comprehensively, yet efficiently, meet these needs. Meeting these research needs will have both immediate and long-term benefits by improving NMFS' ability to target and design habitat protection and restoration measures. These improvements will translate into

Adult male and female Steller sea lions at a haulout site.

higher fishery yields and more effective conservation of protected species. At a high level, many of the research needs are similar around the country, though the finer-scale details of these needs, and how they can best be met, differ across regions, habitat types, and the species that depend on these habitats. No single entity can meet all these needs, but NMFS, with its mandates for the management and conservation of fishery and protected species and its scientific expertise and capabilities in all regions of the country, can play a leading role.

For most species, key questions related to fish–habitat linkages remain unanswered. Limited information on the habitat linkages of marine mammals and sea turtles presents many of the same research needs as for fishery species. Overall, research needs vary somewhat among regions, and can be found within the regional sections of this report. Nevertheless, there are overarching gaps in knowledge that reach across all regions. One key research need is to conduct more life history studies in relation to habitat for all fishery and protected species, particularly on early life stages. Another need is to determine essential habitat requirements, particularly habitat quantity and quality, for each species and life stage. A universal need is to further delineate and map important habitats, including coastal areas, 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.

There is also a need in all regions to monitor natural and human-caused changes in habitat quality, quantity, and use, and the effects of these changes on fishery and protected species. Particular factors to study and monitor are the direct and indirect effects of climate change and ocean acidification, the impacts of severe storms and sea level rise, and the ecological effects of fishing, invasive species, and toxic algal blooms on species and their habitats. Improving the understanding of the effects of underwater sound is of particular interest for marine mammal protection and conservation. Additional research is also needed to enhance and develop habitat restoration methods; to evaluate approaches for habitat protection, such as innovative fishing gear designs that minimize habitat impacts; to develop and implement advanced methods for research, surveys, and monitoring; and to determine the societal and economic benefits of conserving and restoring habitat.

SOLUTIONS—THE WAY FORWARD

NOAA developed the Habitat Blueprint[5] to provide a framework to think and act strategically across NOAA programs and thereby conserve, protect, and create healthy habitats that sustain resilient and thriving marine resources, help recover protected species, and protect coastal communities from storm damage. The Blueprint is helping to guide NOAA's habitat strategy and actions going forward. The Habitat Blueprint has a three-pronged approach that includes these features:

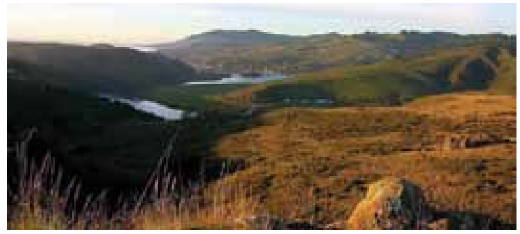
- establishing Habitat Focus Areas in each NOAA region, where collaboration among NOAA's management and science programs and external partners can address multiple habitat-dependent objectives;
- implementing a systematic and strategic approach to conducting habitat science that ultimately guides effective decision-making; and
- strengthening policy and legislation at the national level to achieve meaningful habitat conservation results.

A key example of the Blueprint's effectiveness and utility can be found in California, where the Russian River watershed was selected as the Blue-

[5]Please see http://www.habitat.noaa.gov/habitatblueprint/ (accessed March 2015) for more information.

print's first Habitat Focus Area. The Russian River drains an area of over 3,600 km^2 (1,400 mi^2) and is a vital resource for agriculture, vineyards, and the local water supply. Endangered and threatened salmon species use the river for habitat. Once considered a prime fishing area, by 2000 its aquatic habitats were significantly degraded and its salmon were nearly extinct. There are many competing uses, and high demand, for the river's water. By combining expertise across NOAA in areas such as salmon ecology and habitat requirements, flood and weather forecasting, habitat protection and restoration, and coastal management, NOAA is more effectively addressing issues that face this watershed. Efforts currently underway in the Focus Area include restoration projects to reduce flooding, open coho salmon breeding grounds, and recover fish populations. Important lessons learned from this project will be applied elsewhere, both regionally and nationally. Additional Habitat Focus Areas include the Penobscot River watershed (Maine), Choptank River watershed (Maryland/Delaware), Muskegon Lake (Michigan), St. Louis River estuary (Minnesota/Wisconsin), Kachemak Bay (Alaska), Biscayne Bay (Florida), Northeast Reserves and Culebra Island (Puerto Rico), Manell-Geus watershed (Guam), and West Hawaii (on the Island of Hawaii).

The Habitat Blueprint incorporates scientific concepts developed in the NMFS Marine Fisheries Habitat Assessment Improvement Plan (NMFS, 2010). The Marine Fisheries Habitat Assessment Improvement Plan is a national plan that focuses on habitat science needs for fishery species and other living marine resources. This plan identifies current gaps in NMFS' habitat science, steps to improve habitat assessments (the process and products associated with providing the best available information on habitat characteristics relative to the population dynamics of living marine resources), and the need for a nationally coordinated habitat science program. The plan also addresses the current lack of knowledge regarding the association of marine species and their habitats, which impedes effective fisheries and habitat management, protection, restoration, and stock assessment. The plan is intended to serve as a guide for NMFS to coordinate its diverse habitat research, improve habitat assessments, and guide efforts to increase support for habitat science.



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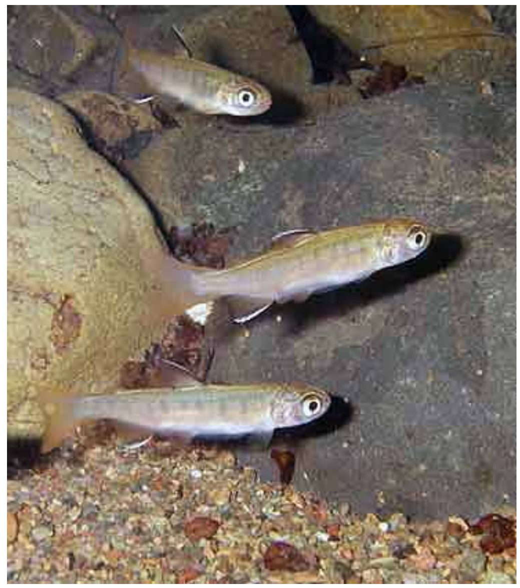

NMFS

Above, the Russian River Valley, in California; below, juvenile coho salmon in the river.

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Part 2
Introduction

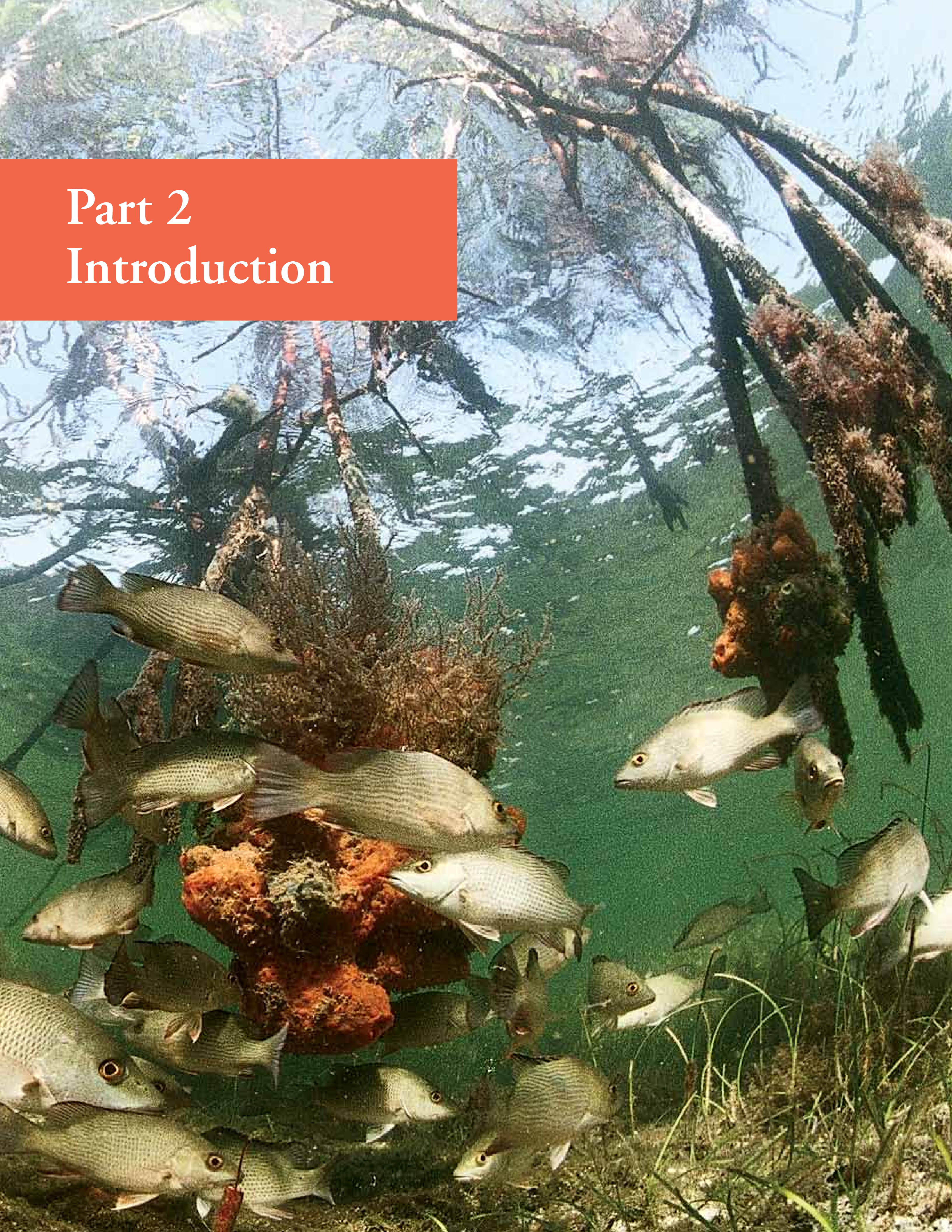

Photo on previous page: Fish and mangrove roots, Elliott Key, Florida. Photo credit: © Jiangang Luo, University of Miami.

Introduction


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Fishing and fish habitat in the United States. Top left, commercial salmon fishing in Alaska; top right, sport fishing on the Atlantic coast; bottom left, spawning habitat for Alaskan salmon; bottom right, mangrove habitat essential to juvenile fish species in tropical Atlantic coastal waters.

OVERVIEW

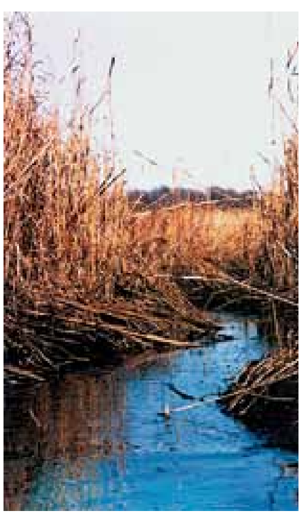
Commercial and recreational fisheries contribute billions of dollars annually to the United States economy. In 2012, commercial and recreational marine fisheries generated $199 billion in sales impacts, contributed $89 billion to the U.S. Gross Domestic Product (GDP), and supported 1.7 million jobs in the fishing sectors and across the broader economy (NMFS, 2014a). Until quite recently, most people considered marine fishery resources to be abundant and inexhaustible. Overfishing, natural environmental changes, and habitat loss and degradation, including poor water quality, have put increasing pressures on coastal, anadromous, and oceanic resources. River, lake,

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.

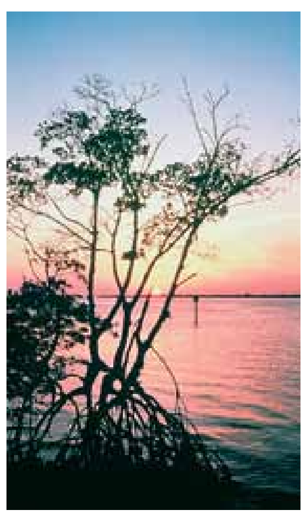
"Coastal ecosystems provide many vital ecological and economic services, including shoreline protection, productive commercial and sport fisheries, and nutrient cycling. Key nearshore ecosystems such as seagrass meadows, marshes, and mangrove forests are particularly valued for their extremely high productivity, which supports a great abundance and diversity of fish as well as shrimp, oysters, crabs, and other invertebrates. Because of the abundance of juvenile fish and shellfish they contain, nearshore ecosystems are widely considered 'nurseries.' The nursery role of coastal estuaries and marine ecosystems is well accepted by scientists, conservation organizations, fisheries managers, and the public, and it is often cited to support protection and conservation of these areas. Nonetheless, comparatively little money and effort is being directed at protecting and managing these ecosystems. Until recently, even fisheries managers have largely ignored the issue of identification and conservation of juvenile habitat."

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

Photos, left to right: Marsh habitat at the Patuxent River at low tide, and a mangrove tree showing the habitat-enhancing root system of this species.



Mary Hollinger, NODC, NOAA



William B. Folsom, NMFS

estuary, coast, and deep ocean habitats provide essential services—such as food, shelter, and space for reproduction and growth—to many species including fish, shellfish, crustaceans, birds, marine mammals, and sea turtles. Habitat damage and loss threaten the sustainability of the Nation's fisheries and the recovery of protected resources. It also makes coastal areas much more vulnerable to hurricanes and coastal storms.

One need not be a scientist to understand that plants and animals are affected by development of coasts, rivers, and lakes. Any trip to the water makes this perfectly clear. What is not clear, however, is how much habitat is needed to sustain fishery yields, the extent to which species depend on these habitats for growth and reproduction, or the status of these habitats in terms of pollution, loss, and fragmentation.

One of the first steps in developing a conservation program is to "take inventory" by determining the quantity and quality of available habitats, the abundance and health of species residing in the habitats, and the extent and severity of habitat loss and degradation. By assessing the situation and providing this information to decisionmakers at all levels of government and to the concerned public, appropriate actions can be formulated and implemented.

In 2009, an initial, abbreviated summary was published on the status and trends of those habitats used by the living marine resources under the purview of NOAA's National Marine Fisheries Service (NMFS). It was entitled *Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources. Policymakers' Summary* (NMFS, 2009a). The new report presented herein is the first comprehensive national summary of the status and trends of the habitats used by the living marine resources under the purview of NMFS. It is considerably updated from the 2009 summary report. The document is part of the *Our Living Oceans* series, joining the later versions of *Our Living Oceans* reports on living marine resources (NMFS, 1999b; NMFS, 2009b) and economics (NMFS, 1996). For the first time, there are now comprehensive reviews of the Nation's living marine resources, the habitats they use, and the economic vitality and value of the industries that depend on them.

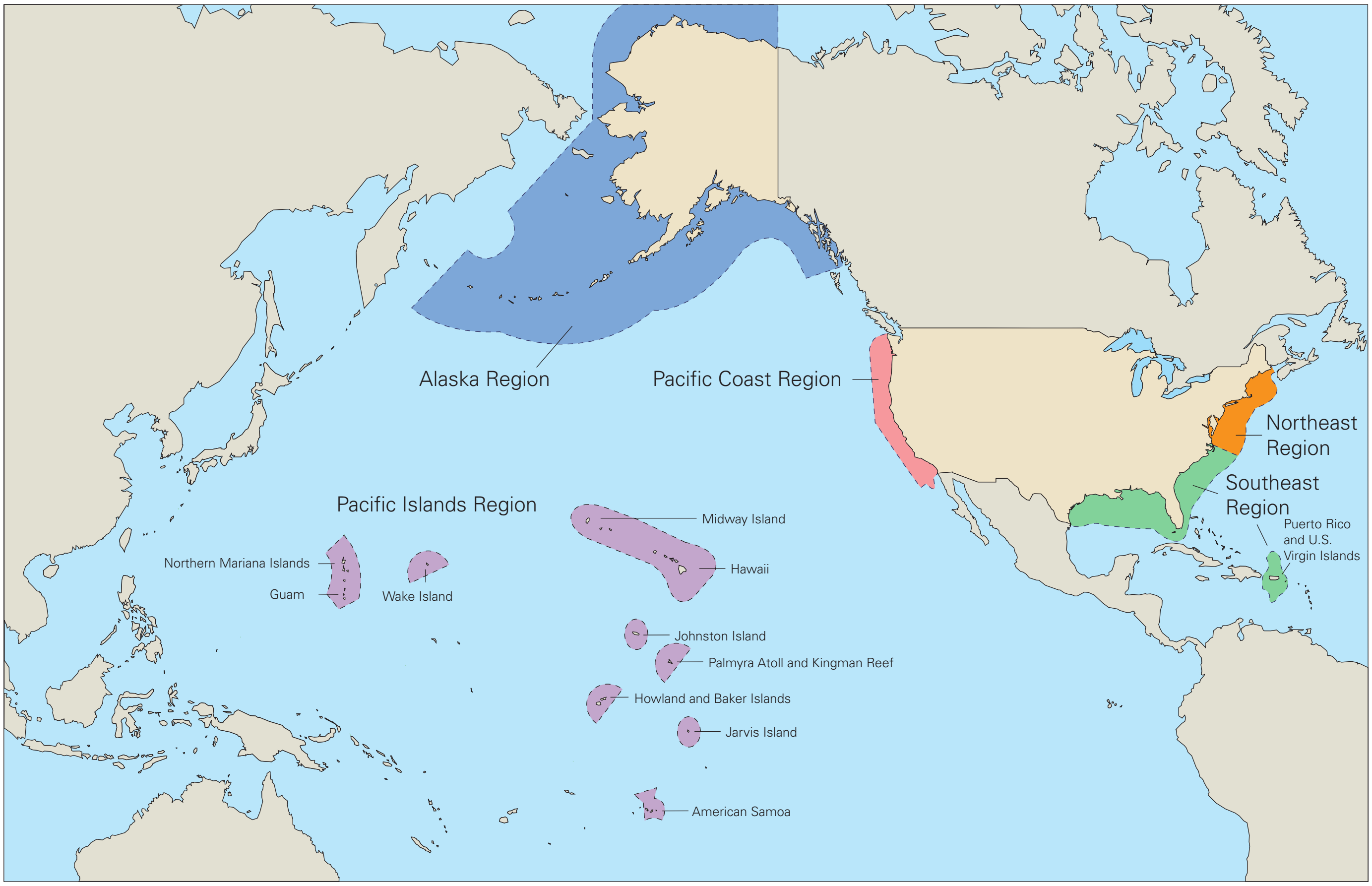


Figure 1

Living marine resources in the Exclusive Economic Zone (EEZ) of the United States are managed by NMFS. The EEZ is divided into five regions in this report.

This report primarily addresses the habitat use of commercially and recreationally harvested living marine resources and of protected species under NMFS jurisdiction. Harvested marine resources include various fish and shellfish. Protected species include marine mammals, sea turtles, and certain fish, invertebrates, and seagrasses. It is beyond the scope of this report to present a comprehensive review of the habitats used by all nearshore species. However, the report does highlight habitat use by some of the more important commercial and recreational species and groups that are managed by the states. Habitats of animals managed by federal agencies other than NMFS, such as sea otters and seabirds, are important components of marine ecosystems, but are not included in this report.

The habitats occupied by federally managed marine species range from inland streams used for spawning by anadromous species, such as salmon, to the entire U.S. Exclusive Economic Zone (EEZ) bounded by the 370 km (200 nautical mile [nmi]) limit (Figure 1), and beyond. This report provides a conceptual framework for understanding habitat-use patterns by the Nation's federally managed and protected species, identifying the shortcomings in relevant information, and describing how these shortcomings can be addressed through additional research.

The habitat needs of living resources compete with societal needs for the same areas. The difficult question of how much area to dedicate to fisheries' and protected species' habitats, as opposed to other uses, is increasingly coming to the forefront as coastal human populations increase such that habitat quantity is becoming more important as a limiting factor on species abundance. For example, partitioning of freshwater resources among competing interests can affect salmon that rely on upstream habitats for key life stages. The adjacent text box contains some essential concepts that must be considered by resource managers. As will be discussed throughout this report, enough habitat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Coral reef and fish in the Pacific Islands Region.

is needed to support every life stage of a species at levels sufficient to maintain populations and to allow flexibility to cope with the vagaries of nature during high-recruitment and/or low-resource years.

ECOSYSTEM-BASED APPROACHES TO MANAGEMENT

Over the past 10 to 20 years, there has been an evolution from management of single sectors and species toward the implementation of ecosystem-based management (EBM) of our ocean and coastal resources, including fisheries (Mooney, 1998; NMFS, 1999a; NRC, 1999; Link, 2010; WHCEQ, 2010; UNEP, 2011). A scientific consensus statement that describes EBM for the oceans can be found in the text box on the next page. In its basic form, the single-species approach to fisheries management relies on an assumption that abundance of a target stock is affected only by factors such as the abundance of its spawning adults, natural mortality, mortality caused by fishing, and the recruitment of juveniles to its population. This implies that the stock exists in isolation from the ecosystem in which it resides. These assumptions enable a mathematically tractable approach for stock assessment modeling and are appropriate for a single-sector decision-making process when environmental conditions are consistent. Other ecological and environmental factors can also affect the distribution and abundance of stocks, such as oceanographic conditions, predation rates, prey availability, competition, interactions with other species, habitat availability and condition, direct and indirect effects of climate change, and effects of other, non-fishing, human activities. Under EBM these factors also would be directly considered and analyzed when making management decisions, including those for fisheries.

NOAA is adapting its scientific methods and capabilities to meet the needs of ecosystem-based approaches to management. EBM should not be considered an add-on but rather a way to refine how we do business to be more efficient in marine resource management and to account for ecological and environmental factors more directly. EBM is still evolving, but generally embodies a more comprehensive and holistic philosophy. It includes a broader focus on ecological relationships and processes, and interactions with humans, such that a wide range of scientific disciplines is involved. EBM also includes a broader consideration of management tradeoffs by placing the management of natural resources, such as fish stocks and their habitats, into a broader context of societal priorities such as ecosystem services (e.g. improved water quality, scenery, employment, and economic activity).

There are many ways to characterize EBM. For example, as described by Murawski and Matlock (2006), EBM:

- is geographically specified;
- is adaptive in its development over time as new information becomes available or as circumstances change;
- takes into account ecosystem knowledge and uncertainties;
- considers the fact that multiple simultaneous factors may influence the outcomes of management (particularly those external to the ecosystem); and
- strives to balance diverse social objectives that result from resource decision-making and allocation.

Additionally, because of its complexity and em-

phasis on stakeholder involvement, Murawski and Matlock (2006) also describe the process of implementing EBM as needing to be:
- incremental; and
- collaborative.

The United Nations Environment Programme provides another example that includes descriptions of five core elements that are fundamental to EBM (UNEP, 2011). These elements are a useful illustration of the concepts underlying the still-developing field of EBM of coastal and marine resources, including fisheries. The five core elements are:
- recognizing connections among marine, coastal, and terrestrial systems, as well as between ecosystems and human societies;
- using an ecosystem-services perspective, where ecosystems are valued not only for the basic goods they generate (e.g. food or raw materials) but also for the important services they provide (e.g. clean water and protection from extreme weather);
- addressing the cumulative impacts of various activities affecting an ecosystem;
- managing for and balancing multiple and sometimes conflicting objectives that are related to different benefits and ecosystem services; and
- embracing change, learning from experience, and adapting policies throughout the management process.

NOAA's Integrated Ecosystem Assessment (IEA) Program

NOAA's IEA program[1] is developing into an effective tool to advance ecosystem-based approaches to management. The IEA approach is a decision-support system that uses diverse data and models to forecast future conditions and evaluate alternative management scenarios. Additionally, it assesses economic and ecological tradeoffs to guide decisions and implementation and evaluation of management actions relative to pre-determined objectives. This approach enables NOAA to manage resources to achieve ecological, economic, and societal objectives by providing a science-based framework for implementing EBM (Levin et al., 2012). Habitat, as a functioning element of ecosystems, is one of many important considerations when applying EBM and therefore conducting an IEA.

[1]See http://www.noaa.gov/iea/ (accessed March 2015).

"What is ecosystem-based management for the oceans? Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive, and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors. Specifically, ecosystem-based management:

- emphasizes the protection of ecosystem structure, functioning, and key processes;
- is place-based in focusing on a specific ecosystem and the range of activities affecting it;
- explicitly accounts for the interconnectedness within systems, recognizing the importance of interactions between many target species or key services and other non-target species;
- acknowledges interconnectedness among systems, such as between air, land, and sea; and
- integrates ecological, social, economic, and institutional perspectives, recognizing their strong interdependences."

—*Scientific Consensus Statement on Marine Ecosystem-based Management from McLeod et al. (2005)*

"CMSP is a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. CMSP identifies areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives. In practical terms, CMSP provides a public policy process for society to better determine how the ocean, coasts, and Great Lakes are sustainably used and protected—now and for future generations."

—Final Recommendations of the Interagency Ocean Policy Task Force, July 18, 2010 (WHCEQ, 2010).

In the Pacific Islands a current management initiative of the Kona, Hawaii, IEA is to provide scientific information to reduce interactions between pelagic longlines and insular cetacean stocks, particularly false killer whales and pilot whales. The Kona IEA has used cetacean satellite tagging data and oceanographic data to build species-specific models of forage habitat and spatial distribution. This has the potential to enable managers to forecast probability of whale presence and assess critical habitat, and to develop ecosystem-based protection measures. This approach could be expanded to any species for which satellite tagging data are available, thereby providing an ecosystem context for informing environmental assessments and project planning.

Coastal and Marine Spatial Planning

Coastal and marine spatial planning (CMSP) is an EBM-based planning process. The Interagency Ocean Policy Task Force that developed recommendations to enhance national stewardship of the ocean, coasts, and Great Lakes identified CMSP as a priority area in their recommendations (WHCEQ, 2010). CMSP offers a comprehensive, integrated approach to planning and managing competing uses and activities over the long term (see CMSP text box). CMSP emphasizes ecosystem-based approaches to management, ecological sustainability, and multi-disciplinary scientific information. The spatial domain identified for CMSP extends from the mean high-water line, through the territorial seas under the jurisdiction of states, out to the EEZ boundary and the Continental Shelf. Regional planning bodies are being implemented at the scale of regional ecosystems. The scope and scale of CMSP are designed to encompass and support NMFS' habitat mandates and the science requirements associated with them.

IMPORTANCE OF HABITAT FOR LIVING MARINE RESOURCES

Living resources are valuable assets of the United States. Part of this value can be measured in economic terms. In 2012, the most recent year for which global data are available, the United States was the world's third leading nation for commercial fisheries, with 5.6% of the world's landings. In 2013, landings by U.S. commercial fishermen (at ports within the 50 states) totaled 4.5 million metric tons (9.9 billion lb). These landings were valued at $5.5 billion (NMFS, 2014b). Living marine resources also generate considerable revenue. In 2013, U.S. consumers spent an estimated $86.5 billion on fishery products (including restaurant, industrial fish products, and other expenditures).

Another element of the value of living marine resources lies in recreation. In 2013, 11 million people made over 70 million recreational fishing trips in the continental United States, Hawaii, and Puerto Rico. The total catch was more than 430 million fish, with 61% being released alive. The total weight of the harvested recreational catch was estimated to be over 108,000 metric tons (239 million lb) (NMFS, 2014b). In addition, ecotouring activities, such as SCUBA diving and snorkeling on coral reefs and whale watching, are growing in the United States and worldwide.

An equally significant component of the value of living marine resources can be termed "ecosystem services." Fully functional marine ecosystems sustain and bolster the economic value of the habitats. Functioning marine ecosystems provide many services to humans, such as converting carbon dioxide, a leading greenhouse gas, to biomass through primary productivity; sustaining the marine food chains that support commercial and protected species; protecting coastal areas from storms and other marine hazards; and absorbing pollutants. In addition, the existence of marine species such as coral reef fish, sea turtles, and large whales, many of which are protected through legislation such as the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA), appeals to many people on an aesthetic or philosophical level. These marine resources and ecosystem services are clearly important to society, though their value is usually not reflected through traditional market prices. To quantify the value of marine resources and ecosystem services, non-market valuation tools are often used. These tools allow economists to quantify values for things like marine protected areas, threatened or endangered marine species, storm protection, or erosion control (Wallmo and Edwards, 2007).

Habitat is essential for maintaining healthy stocks of living marine resources and to support fully functional marine ecosystems. Minello et al. (2003) defined habitat as "all places that a population of a species (or life stage) lives." The Marine Fisheries Habitat Assessment Improvement Plan (NMFS, 2010) specifies marine habitat as the place where an organism lives as defined by its spatial and temporal distributions, which may include the physical, chemical, biological, and geologic components of both benthic and pelagic realms. This includes areas used for spawning, feeding, growth, and shelter from predators. Habitat structure may be of biotic or abiotic origin. Geological features are a key abiotic element of habitat. Examples include intertidal rocks, subtidal or deep-sea sediment, and seamounts that rise steeply from the deep-sea floor. Water itself is a critical abiotic component of the habitat for marine species. Attributes of seawater, such as salinity (determined by the mixing of fresh and sea waters), play a major role in defining the habitat of estuarine species. Farther away from shore, ocean frontal zones, where distinct bodies of water meet, provide food-rich habitat for large pelagic predators, such as tuna. The biotic components of habitat consist of living or dead organisms. Some biotic components are of plant origin, such as salt marsh grasses, seagrasses, and kelp beds. Others are of animal origin, such as oyster bars and coral reefs. Some marine species can opportunistically occupy man-made habitats, including pier pilings and bridges, that attract encrusting invertebrates and fish. Sometimes old ships and other debris are deliberately sunk to provide artificial fish habitat and increased opportunities for successful fishing trips.

Richard B. Mieremet, NOAA

Aerial view of a coral atoll in the western Pacific Ocean showing the barrier reef (with terrestrial vegetation) separating the open ocean, to the outside, from the shallow lagoon on the inside.

It is intuitively obvious that organisms require habitat, so one would expect that population sizes would be affected by habitat availability. This is often true, but the role of habitat in determining population size and distribution varies widely, and continues to be an active area of research. In some cases, there is a close relationship. For example, the blockage of access to upstream spawning habitat by dams has led to declines in many anadromous species such as salmon and shad. However, even in these cases, many other variables, such as reduced water flow, contaminants, and disease, also affect population sizes. Changing environmental conditions can also affect open-ocean habitats and result in population changes. For example, oceanographic regime shifts in the Pacific, which influence patterns of currents, water temperature, and primary productivity, can influence ocean survival of many species, such as Pacific salmon, and resultant popu-

> "One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats."
>
> *—Excerpt from the Sustainable Fisheries Act (1996 SFA Pub. L. No.104–297, Title I, §101)*

lation sizes. Often, abundance–habitat relationships are difficult to clarify because other factors, such as variation in recruitment, abundance of prey or predators, environmental changes, pathogens, or fishing may also influence population size.

Habitat requirements can vary by species, life stage, and life-cycle activity such as spawning, breeding, feeding, or growth to maturity. Salmon, for example, require freshwater habitats to spawn, utilize estuarine habitats to varying degrees during their seaward movement, migrate to the ocean to grow, and eventually return to fresh water to complete their life cycle. Other organisms, like shrimp in the Gulf of Mexico, use tidal estuaries as nursery areas and oceanic habitats for spawning. Some species, at least at some life stages, are generalists, and can successfully exploit many different types of habitats. For example, while juvenile Atlantic cod are highly dependent on specific types of seafloor substrate as essential habitat, adult Atlantic cod typically occur over a wide range of bottom types.


NOAA

An Atlantic cod in protective bottom habitat.

In contrast, some species are obligate habitat specialists. For example, several species of damselfish occur only in association with tropical coral reefs, so that any change in availability of coral-reef cover would result in a change in damselfish populations.

Habitat and habitat function can be impacted by naturally occurring stresses. Relatively short-term (and in some cases infrequent) events, such as storms, submarine landslides, and tsunamis, can damage or destroy habitat. Often the impacts last only a few years and rarely reach the deep seafloor. However, in some areas such as on barrier islands or in estuaries, relatively permanent changes can take place. For example, tropical or winter storms can scour out or cover seagrass beds with sand, carve a new inlet, or plug an old one. Submarine landslides are thought to play a major role in structuring habitat in sloping areas, such as along the edges of shelves and banks. Landslides on the slope off Oregon tremendously alter habitat, and some might equate this to destruction. However, at the same time these slides can create very large and structurally complex terrain that can be beneficial habitat for certain species of marine animals post-disturbance. Some naturally occurring cycles of climate variability, such as the El Niño–Southern Oscillation or the Pacific Decadal Oscillation, occur on time scales of a few years and also affect the distribution and condition of habitat. Other climate cycles, such as those associated with the ice ages and the advance and retreat of glaciers, last many thousands of years and can have global impacts on the distribution of habitat.

Habitat and habitat function also can be impacted by anthropogenic, or human-caused, stresses. Many are the obvious result of societal activities, such as the construction of dams that block access to spawning streams used by anadromous species, filling of salt marshes that serve as nursery areas for estuarine-dependent species such as some shrimp and flounder, or destruction of coral reefs that support a wide variety of organisms. Other habitat effects may be less direct and obvious but just as significant. For example, runoff from urban and agricultural areas or other sources can produce excessive input of nutrients, degrade water quality, and potentially result in a phytoplankton (algal) bloom. Depending on the extent and intensity of a phytoplankton bloom, bacterial decomposition of the excess phytoplankton can deplete dissolved

Page Valentine, USGS

Substrate at Northeast Peak in Georges Bank.

Left: Heavily disturbed gravel habitat that continues to be impacted by mobile fishing gear. Note that the gravel is clean, and that sand shows between the pebbles.

Middle: Recovering seafloor community. Note that there is some cover by epifauna, primarily sponges. The area had been closed 2.5 years.

Right: Undisturbed gravel habitat on the Canadian side of Georges Bank in an area characterized by scattered cobbles and boulders, which prevent access by mobile fishing gear. Note the nearly full cover provided by attached fauna.

oxygen so much that a fish kill occurs. For coral reefs, excess nutrients can act as fertilizers, stimulating vigorous growth of algae documented in many instances to have negative impacts on the slower growing corals. Sedimentation can also threaten sedentary marine organisms. For example, excess sediment can slow coral growth rates and weaken, or even kill, corals, depending on the quantity (Burke et al. 2011; Rogers, 1990). Additional examples of anthropogenic threats to habitat (e.g. marine debris, offshore energy development) will be discussed in greater detail in the National Summary chapter.

One notable anthropogenic threat to habitat addressed by NMFS is the impact of fishing on habitat and associated fish populations. Scientific theory and empirical evidence suggest that the impact is related to habitat type, fishing gear, and the frequency and intensity of both fishing activities and naturally occurring disturbances. Negative effects have been documented where fishing damages long-lived, slow-growing habitat structures on which certain species depend. For example, deep-sea coral that is damaged by trawling has an estimated recovery time of more than 30 years (Rooper et al., 2011). As shown in the above images, substantial bottom gear impacts to benthic substrate in the northwest Atlantic have been observed as a result of historical trawling activities. The northern edge of Georges Bank is, in a large part, covered by gravel of glacial origin where fishing activity is a major source of disturbance. As a result, unfished areas retain complex habitat characterized by abundant bushy epifaunal taxa, while disturbed areas have patchy or no epifauna, and expanses of bare substrate. Another example is the loss of the three-dimensional structure of oyster reefs, caused by the continual reworking of these reefs by dredges and tongs in Atlantic Coast estuaries. Oyster growth and survival are highest on the tops of these reefs, yet fishing has reduced many oyster reefs to thin veneers on the seafloor. In contrast, research in sandy areas lacking fragile, structure-forming biota, and characterized by frequent disturbance by waves or swift currents, has not identified a clear impact of fishing on seafloor habitats. Indirect impacts to habitat through trophic interactions as a result of reducing biomass of fishery species can also occur. For example, fishing for herbivorous species on coral reefs reduces grazing pressure on the reefs, which in turn can result in algal overgrowth and reduction of suitable settlement substrate for new corals.

Claire Fackler, NOAA, Natioal Marine Sanctuaries

A kelp rockfish taking shelter in the water column of a kelp forest in the Channel Islands National Marine Sanctuary. Many fish species rely on the shelter provided by kelp.

SUMMARY OF NMFS' RESPONSIBILITIES FOR HABITAT

Three major laws define NMFS' responsibilities: the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA). All three contain provisions relevant to habitat. See Appendix 2 for a detailed list of the habitat-related laws for which NMFS is responsible.

Magnuson-Stevens Fishery Conservation and Management Act

Originally enacted as the Fishery Conservation and Management Act in 1976, the MSA is the primary legislation governing marine fisheries in the United States. The Act established eight regional fishery management councils to manage fisheries in the EEZ under fishery management plans (FMPs). FMPs may include one or several species, and are designed to achieve specified management goals for a fishery.

Essential fish habitat (EFH) provisions were added to the MSA through the 1996 Sustainable Fisheries Act (see text box on page 27). As stated in the Act: "One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States."[2] The legislation mandates that NMFS and the fishery management councils implement a process for conserving and protecting EFH. Three key features of this process are to 1) describe and identify EFH; 2) minimize adverse effects of fishing on EFH; and 3) consult on impacts of other activities on EFH.

Describe and Identify EFH—NMFS and the fishery management councils are required to describe and identify EFH for each life stage of the species included in their FMPs.[3] NMFS regulations also recommend that councils identify specific rare, sensitive, or ecologically important habitat types, called Habitat Areas of Particular Concern (HAPC). HAPCs are subsets of EFH that are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area.

Minimize to the Extent Practicable the Adverse Effects of Fishing on EFH—Councils must assess fishing impacts to EFH and minimize, to the extent practicable, the impacts of fishing on EFH. This may lead to fishing gear restrictions and time/area closures. In addition councils must identify other actions to encourage the conservation and management of EFH.

Consult on Impacts to EFH—Federal agencies are required to consult with NMFS when a proposed non-fishing activity may have adverse effects on EFH. In this consultation process NMFS provides recommendations to the other agencies. States are not mandated to consult with NMFS on purely state actions. However, many state actions also include federal actions, such as funding or the issuance of a federal permit. In such situations, NMFS would have to provide EFH conservation recommendations to the state that might include

[2]1996 SFA Pub. L. No. 104–297, Title I, §101.

[3]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.

Essential Fish Habitat (EFH)

What is EFH?

EFH is defined as "… those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" [MSA, 16 U.S.C. 1802(10)]. This terminology, broken down, refers to the following:

"Waters" refers to aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish, where appropriate.

"Substrate" refers to sediment, hard bottom, structures underlying the waters, and associated biological communities.

"Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem.

"Spawning, breeding, feeding, or growth to maturity" refers to the stages representing a species' full life cycle.

EFH Levels

The EFH Final Rule issued on 17 January 2002 (NMFS, 2002) categorized the information available to support EFH designation into 4 levels that are summarized as follows:

Level 1: Distribution data are available for some or all portions of the geographic range. At this level, only distribution data (i.e. presence/absence) are available to describe the geographic range of a species (or life stage).

Level 2: Habitat-related densities are available. At this level, quantitative data (i.e. density or relative abundance) are available for the habitats occupied by a species or life stage.

Level 3: Growth, reproduction, or survival rates within habitats are available. At this level, quantitative data are available on habitat-related growth, reproduction, and/or survival by life stage.

Level 4: Production rates by habitat are available. At this level, data are available that directly relate the production rates of a species or life stage to habitat type, quantity, quality, and location.

NOAA

North Atlantic right whales interacting in ocean habitat.

suggested actions to avoid, minimize, mitigate, or offset impacts to EFH. Like states, private entities are not required to consult with NMFS unless a proposed project may adversely affect EFH and is funded, permitted, or authorized by a federal agency.

Additional Habitat-Related Provisions—The MSA was reauthorized through the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA), which was signed into law in January 2007. The MSRA did not make any major changes to existing EFH legislation, but did contain some key provisions related to habitat. It authorized the creation of the Community-based Restoration Program for Fishery and Coastal Habitats to implement and support the restoration of fishery and coastal habitats. The program actively engages communities in on-the-ground restoration activities and emphasizes partnerships and collaborative strategies built around restoring NOAA trust resources and improving the environmental quality of local communities. The MSRA also established the Deep Sea Coral Research and Technology Program. To encourage EFH conservation and enhancement, the MSRA provided discretionary authority for FMPs to include designated zones to protect deep-sea corals from damage or loss due to fishery gear interactions. FMPs may also include conservation measures to protect non-target species and habitats.

Endangered Species Act and Marine Mammal Protection Act

The ESA and the MMPA define the protected-species mandates of NMFS. Under the ESA, NMFS is responsible for protecting marine species that are threatened with, or in danger of, extinction. Certain fish, invertebrates, sea turtles (when in the marine environment), marine mammals (cetaceans [whales, dolphins, and porpoises] and pinnipeds [seals and sea lions]), and marine plants are listed under the ESA. Listed seabirds, shorebirds, sea otters, walruses, manatees, and polar bears are managed separately by the U.S. Fish and Wildlife Service (USFWS) under the same or similar laws. NMFS and the USFWS share jurisdiction for conservation and recovery of sea turtles and anadromous species such as salmon. For these two groups, NMFS' jurisdiction is in the marine environment but extends into the riverine environment for salmon on the West Coast. USFWS' jurisdiction is in the riverine environment for salmon on the East Coast and on the nesting beaches of sea turtles on all U.S. coasts. Critical habitat must, to the maximum extent prudent and determinable, be designated for every species listed under the ESA (with the exception of some species that were on the original ESA list). As part of the ESA Section 7 consultation process,[4] NMFS issues Biological Opinions for federal actions that may adversely affect the critical habitat of ESA-listed species.

Under the MMPA, NMFS is responsible for protecting all species of cetaceans and pinnipeds (except walrus), regardless of their status under the ESA. This includes conducting studies

[4]Under Section 7 of the ESA, federal agencies must consult with NMFS or USFWS when an action the agency carries out, funds, or authorizes may affect a listed endangered or threatened species or its critical habitat.

of abundance, distribution, status, trends, and human-related impacts, and reviewing (and where necessary, revising) Marine Mammal Stock Assessment Reports every one to three years. When human-related impacts are identified that may cause declines or impede recovery of marine mammal stocks, NMFS is responsible for developing and implementing measures to alleviate these impacts on rookeries, mating grounds, feeding grounds, migratory routes, or in other ecologically significant areas.

NOAA's Habitat Blueprint

As evident from the mandates previously discussed, Congress has charged NOAA with managing the Nation's fish, threatened and endangered species, marine mammals, and other natural resources within the coastal zone. Recognizing that these mandates share a common thread, NOAA developed the Habitat Blueprint.[5] The Blueprint is a framework to think and act strategically across NOAA programs—to create healthy habitats that sustain resilient and thriving marine resources, help recover protected species, and protect coastal communities from storm damage. The Habitat Blueprint has a three-pronged approach that includes 1) establishing Habitat Focus Areas in each NOAA region where collaboration among NOAA's management and science programs and external partners can address multiple habitat-dependent objectives; 2) implementing a systematic and strategic approach to conducting habitat science that ultimately guides effective decision-making; and 3) strengthening policy and legislation at the national level to achieve meaningful habitat conservation results. The Blueprint will help guide NOAA's habitat strategy and actions going forward. Additional details on the Habitat Blueprint are provided in the National Summary chapter.

Other Mandates Related to Habitat

Several federal agencies and state and local governments participate in decisions involving conservation and protection of aquatic habitats. Whether explicitly focusing on conservation, issuing construction permits, conducting land-use planning, or undertaking infrastructure maintenance and development projects, many people with different objectives and values are involved in decisions that directly affect these habitats. Other major federal agencies outside of NOAA that deal with aquatic habitat-related conservation, restoration, and research include the Department of Defense (DOD), Department of Homeland Security (DHS), Department of the Interior (DOI), Environmental Protection Agency (EPA), Federal Energy Regulatory Commission, and the U.S. Department of Agriculture (USDA).

Recognition of the importance of habitat has led to many legal mandates to conserve and protect habitat (see Appendix 2 for a complete listing). When the actions of other federal agencies may impact the habitats of living marine resources, these agencies are often required to consult with NMFS and/or undertake other actions, depending on the applicable mandate. NMFS annually reviews several permit applications from the DOD's U.S. Army Corps of Engineers and other federal agencies that propose projects that may impact oceanic, coastal, estuarine, or riverine habitats vital to living marine resources. NMFS is involved in other consultation roles, such as those relating to power plant licensing (water quality, entrainment, and entrapment) and coastal-zone consistency reviews. These actions are subject to a number of procedural requirements.

Biogeography Team, CCMA, NOS, NOAA

A diver conducts ecosystem research in the Caribbean Sea.

[5]See http://www.habitat.noaa.gov/habitatblueprint/ (accessed March 2015).

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Harbor seals hauled out and resting on rocks in Puget Sound, Washington.

In addition to the laws discussed above, which are under the jurisdiction of NMFS, there are three other notable U.S. habitat protection laws. The Clean Water Act aims to prevent destruction of aquatic ecosystems, including wetlands, by authorizing water quality and pollution research, providing grants for sewage treatment facilities, setting pollution discharge and water quality standards, addressing oil and hazardous substance liability, and establishing permit programs for water quality, point source pollutant discharges, ocean pollution discharges, and dredging or filling of wetlands. The National Environmental Policy Act requires federal agencies to analyze the potential effects of any proposed federal action on the human environment. Under the Federal Power Act, which regulates dams, NMFS can issue mandatory fish-passage prescriptions and recommend hydropower license conditions to protect, mitigate damages to, and enhance anadromous fish populations, including related spawning grounds and habitat. Other natural resource-related laws, such as the Fish and Wildlife Coordination Act, also contain sections pertaining to the protection of habitats. Please see Appendix 2 for an expanded listing of mandates that apply to habitat.

HOW MUCH HABITAT IS ENOUGH?

As habitat is lost due to development, pollution, fishing activities, etc., the number of fish and other marine species that the environment can support is reduced. Enough habitat must be maintained to support every life stage of a species at levels sufficient to maintain populations at the management target, be it maximum sustainable yield[6] or some other index. Determining how much habitat is needed to maintain a species or stock at a specific target level requires knowledge about a number of factors, including abundance; quantity, quality, and accessibility of available habitat and how stock dynamics are affected by these factors; fishing and other sources of mortality; impacts of climate change; etc. Moreover, this information is needed for all life stages.

Information on the amount of each habitat type needed for all the life stages of each species remains an ongoing challenge to quantify. At one end of the spectrum are species like Atlantic salmon that have been greatly reduced in abundance, in large part because of the loss of spawning habitat. In

[6]The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.

Benefits of Coastal Habitat for Community Resilience

Nationwide, there is strong societal and economic reliance on coastal resources such as wetlands, beaches, and estuaries. Effective management and restoration of these coastal resources is as critical to local economies as it is to ecosystem health.

The following are among the naturally protective benefits of coastal habitats and shorelines:

- Healthy wetlands protect communities from storm surges, filter runoff before it enters rivers and estuaries, provide food and nursery grounds for commercially important species of fish, and increase the value of the homes located nearby because of their scenic beauty. Coastal wetlands in the United States are estimated to provide $23.2 billion per year in storm protection services by serving as self-maintaining “horizontal levees” for storm protection (Costanza et al., 2008).

- Oyster reefs stabilize bottom sediments, reduce wave energy, and prevent erosion, which fortifies wetlands as a protective barrier (Stokes et al., 2012).

- Coral reefs also serve as natural barriers to storm surges that can cause great destruction to coastlines and communities. By one estimate, coastal protection accounts for $9.0 billion of the total $29.8 billion global net benefit of coral reefs (Cesar et al., 2003; Conservation International, 2008).

- Coastal barrier islands and dunes are natural lines of defense and an integral part of efforts to reduce risk from floods and storm surge (Grzegorzewski et al., 2011).

In the wake of recent coastal storm events such as Hurricane Irene and Superstorm Sandy, many coastal decisionmakers are looking toward practical, cost effective approaches to better incorporate the natural protective capacity of “green” (natural) infrastructure solutions in their communities. Incorporating these green infrastructure approaches can include promoting land conservation, wetland and dune restoration, living shorelines, and directing development away from naturally protective features and vulnerable areas.


OAR/NURP

Spotted moray eel in coral habitat, Florida Keys.

this case it could be relatively straightforward to estimate how much more spawning habitat would need to be accessible to reach a target abundance, assuming other factors, such as downstream passage or climate change would not become limiting. However, for other species with low abundance, the relative contribution of habitat problems to the population decline is much less clear. At the other end of the spectrum are species that support large, healthy fisheries such as Atlantic sea scallops that have had minimal habitat loss. In this case, habitat is not likely to be limiting. Between these examples are many species that have been subject to heavy fishing (e.g. red drum) or incidental-take pressure (e.g. sea turtles), while also losing significant amounts of habitat to coastal development. While many factors can affect the abundance of living marine resources, a precautionary approach with respect to habitat protection can help sustain healthy stocks.

Research will yield better information and lead to answers to the "how much is enough" question, enabling coastal and other managers to make informed decisions about tradeoffs between conservation of habitats for living marine resources and the development or maintenance of human infrastructure. There are many competing but legitimate demands on the habitats used by fish and protected species, such as coastal development, shipping, homeland security, agriculture, and waste disposal. Optimizing the use of habitat for any one purpose often reduces the options for other uses. Thus, effective management will require a comprehensive understanding of the effects of potential trade-offs.

CURRENT STATUS OF THE SCIENCE UNDERLYING HABITAT ASSESSMENT, AND THE RELATIONSHIPS AMONG SPECIES, HABITATS, AND ECOSYSTEMS

Fulfilling the habitat mandates for managing living marine resources must be based on the scientific understanding of how species use habitat and how marine communities depend on the amount and condition of available habitat. As the scientific paradigm for living marine resource management shifts toward an ecosystem-based approach, habitat research will continue to be a vital component of this endeavor. To help guide development of a habitat science program for fishery species and other living marine resources, NMFS developed the Marine Fisheries Habitat Assessment Improvement Plan (NMFS, 2010). If fully implemented, this plan will help: 1) develop the habitat science necessary to meet the mandates of the Magnuson-Stevens Act and the economic, social, and environmental needs of the Nation; 2) improve NMFS' ability to identify essential fish habitat and habitat areas of particular concern and assess the impacts to these areas; 3) contribute to assessments of ecosystem services; and 4) contribute to ecosystem-based fishery management, integrated ecosystem assessments, and coastal and marine spatial planning. Although habitat science for protected species is not a focus of the Plan, much of the information that would be generated on fish habitat (e.g. maps) would also be relevant to protected species. NMFS may consider developing a habitat-science plan for protected species in the future.

From the perspective of sustainable management of living marine resources, habitat research may be distilled into a series of fundamental questions. The following five sections address these questions.

How Do Species Use Habitat?

Most marine species undergo complex life cycles, so their use of habitat can vary widely over the course of their lives. Thus, quantity and quality of habitat for every life stage can potentially affect species abundances and distributions. Accordingly, research to determine habitat use requires sampling appropriate for every life stage. For example, the typical fish life begins with an egg, which may be as small as 1 millimeter (0.04 in). Depending on the species, the egg may develop internally within the parent, externally in a free-floating form, or attached to a substrate. Research to determine habitat use by eggs would require sampling the water for plankton, or identifying and sampling the specific substrate. After days to months, the egg hatches, releasing a larva that is usually free swimming, often drifting with the currents and tides. Most fish larvae are on the order of millimeters to centimeters in size. Research to document habitat use by this stage would also require plankton sampling. However, many larvae are active swimmers capable of avoid-

Santa Cruz Laboratory, NMFS

Santa Cruz Laboratory, NMFS

Left: A laser line scanner integrated with a tow body is deployed off Big Sur Coast, California, to image seafloor organisms and habitats.

Right: A scan image of fishes around a 4 m (13 ft) high rock outcrop with white sea anemones off Big Sur Coast, at a 60 m (200 ft) depth, taken by the scanner in the left photograph.

ing some plankton samplers. The larva undergoes metamorphosis into a juvenile, which may live in the water column for several months to years, or become associated with the seafloor. Conducting research on habitat use by juveniles may require larger gear, such as trawls, traps, or imaging systems such as video cameras. As the juvenile grows and matures, it may migrate to different geographic regions, depths, and bottom types for feeding, predator avoidance, or spawning. As with the other life stages, research must be tailored to the appropriate habitat types and geographic scales.

Our knowledge of how the various species use habitat during each of their life stages is most refined for species of relatively high economic value that have been studied for many decades. For many other species, we know only whether they are present or absent from a given area, and we may not even know that for all life stages.

What is the Quantity of Usable Habitat?

Understanding the impacts of habitat on populations, communities, and ecosystems requires knowledge of how much habitat exists, how much of that habitat is in a condition that will support a particular species of interest, and how that habitat persists through time. These three components are related, but have distinct information requirements.

Habitat quantity and distribution are determined by a variety of survey methods that can vary depending on the types and locations of the habitats, and on the scale of the information required. Surveys employing hand sampling may be appropriate for marshes and wetlands, while small boats or divers may be needed for estuaries and shallow areas close to shore. In the open ocean, modern research ships, and sometimes aircraft, with oceanographic instrumentation are required. Many high-tech, remote-sensing technologies, including satellites, are available for economical and accurate large-scale surveys, or surveys of inaccessible or deep areas. These include acoustic methods such as multibeam and sidescan sonar, and optical methods such as aerial photography, multispectral and laser-line scan imagery, and video. All of these methods provide data that can be used in scientific analyses and management decision-making.

NMFS is taking many steps, including publishing this report, to determine the distribution and amount of fisheries habitat and how it is used by various species. However, only a small percentage of the U.S. EEZ seafloor has been characterized, and

Coastal and Marine Ecological Classification Standard (CMECS): Using Common Terminology for Describing Ecosystems

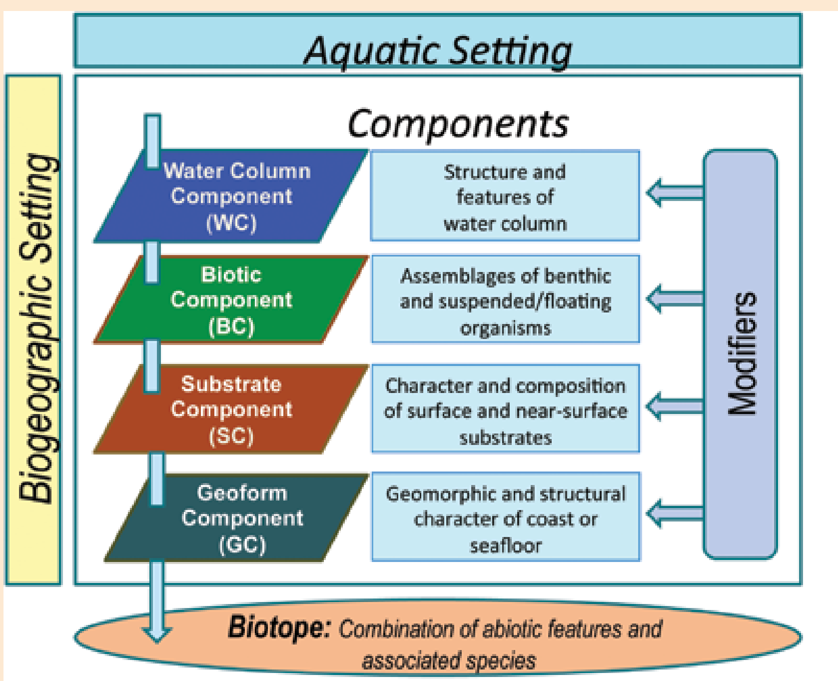
NOAA has been a leader in interagency efforts to develop and gain Federal Geographic Data Committee (FGDC) endorsement for CMECS—the first-ever comprehensive federal standard for classifying and describing coastal and marine ecosystems. CMECS provides a simple, standard framework and common terminology for describing and organizing information about coasts and oceans and their living systems.

CMECS Benefits

- applies regardless of collection methods and instruments—sensor independent;
- applies across spatial scales—e.g. from benthic grabs to satellite imagery;
- accommodates biological, geological, chemical and physical data;
- includes water column features and habitats; and
- revises readily to accommodate new information.

CMECS Status

NOAA is working to implement CMECS within the agency, across other elements of the Federal Government, and with state, regional, and local governments, nongovernmental organizations (NGOs), industry, and academia. For more information, see http://www.csc.noaa.gov/digitalcoast/publications/cmecs (accessed May 2015).



our understanding of dynamic pelagic (open water) habitats is similarly limited. Nevertheless, the amount of scientific information available on the dynamic oceanographic and biological processes that characterize open-water habitats continues to grow, particularly in a few well-studied areas such as the Gulf Stream, California Current System, Shelikof Strait, and Georges Bank.

Most marine organisms have some level of habitat specificity. Most species require a suite of conditions in terms of suitable food, living space, protection, and reproduction. Even within a range of what appears to be suitable habitat, many portions often are not usable due to microscale factors affecting the seafloor; water characteristics such as flow, temperature, and salinity; or other factors that may not be known. The only way to determine whether or not a habitat is suitable, and how often it is being used, is to conduct sampling at appropriate spatial and temporal scales to quantify the distribution and abundance of the organisms and the associated habitat variables.

A system of classifying, or defining and naming, habitat types is a prerequisite for quantifying habitat. In 2012, the Federal Geographic Data Committee endorsed the Coastal and Marine Ecological Classification Standard (CMECS) as the first comprehensive federal standard for classifying and describing coastal and marine ecosystems (USGS, 2012; see the CMECS website for further information[7]) CMECS offers a simple, standard framework and common terminology for describing natural and human-influenced ecosystems from the upper tidal reaches of estuaries to the deepest portions of the ocean. The unifying framework is organized into two settings, biogeographic and aquatic, and four components: water column, geoform, substrate, and biotic. Each describes a separate aspect of the environment and biota. Settings and components can be used in combination or independently to describe ecosystem features. The CMECS system is hierarchical, so that it can be used to quantify habitat at different levels of detail and to develop habitat characterizations over a range of spatial and temporal scales (see the CMECS text box on the next page for additional information).

[7]http://www.csc.noaa.gov/digitalcoast/publications/cmecs (accessed March 2015).

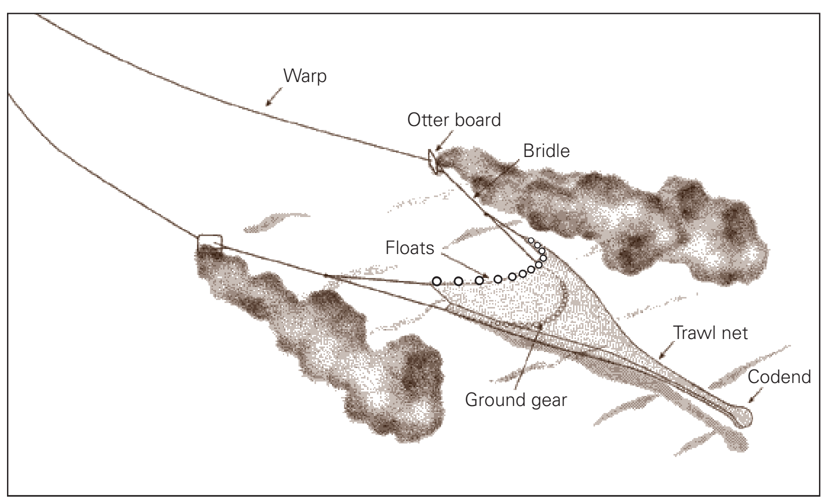
What Factors Affect the Quantity and Quality of Available Habitat?

The widespread fragmentation, loss, and degradation of habitats have been caused by a variety of anthropogenic and natural factors. Anthropogenic factors that can affect habitat quality or quantity include agriculture, coastal development, dams, fishing, grazing, invasive species, water withdrawals, logging, mining, pollution, urbanization, and vessel traffic, among other activities. These activities impact aquatic environments through habitat alteration such as a change in water flow that restricts organism movement, or by actual habitat removal or destruction. For example, fishing methods such as bottom trawling can cause long-term damage to some types of seafloor habitat, especially those dependent on fragile and/or slow-growing biogenic structures such as deep-sea corals. Natural factors such as climate variability may also impact habitats. For example, winter storms can cause significant

In the photographs below, both from the Gulf of Alaska, the left image shows how an intact sponge provides fish habitat and protection; the right image shows how these fragile structures can be damaged by mobile fishing gear, such as trawls or dredges.

The illustration below (adapted from FOOCG, 2001) shows a bottom trawl during fishing operations. The metal otter boards (doors) and floats on the headrope spread the trawl open horizontally and vertically, respectively. The doors, bridles (sweeps), and groundgear contact with the seabed.

Auke Bay Laboratory, NMFS



Dan Howard, NOS

A nutrient-rich mud flat at California's Tomales Bay.

seasonal disturbance to kelp bed habitats. El Niño and La Niña events can alter environmental factors, such as precipitation and ocean currents, and cause major changes in habitats throughout Pacific ecosystems. This results in major changes in the abundance and distribution of both predators and prey, as well as shelter sites. Additionally, sea level rise continues to impact coastal marshes and wetlands, particularly in areas subject to land subsidence. More details are provided on these factors in the National Summary and in the regional chapters.

Efforts to improve coastal and river water quality have had significant success through reductions in raw sewage inflows and improved land-management practices that reduce erosion and sediment loads, among other factors. Still, there are persistent and increasing problems. Among them are excess nutrients, residual contamination from now-prohibited activities, loss of coastal wetlands, and continued coastal development. Research is directed at determining and monitoring the status of habitats to determine any changes in habitat quality or quantity over time and to find methods to reduce and repair damaged areas. Such research efforts will be discussed in more detail later in the report. In addition, actions by NMFS and the fishery management councils to address gear impacts to benthic habitats have the potential to significantly decrease the future loss of certain habitats due to fishing impacts. Examples can be found throughout the United States, ranging from the West Coast where bottom trawling was prohibited in designated waters to help safeguard the habitat of groundfish, to the Southeast Region where five Habitat Areas of Particular Concern were recently established for deep-sea coral protection and include prohibitions on the use of most types of fishing gear that contact the seafloor.

How are Species Abundances Affected by the Quantity and Quality of Habitat?

The linkage between habitat and fisheries productivity has long been reported and is an ongoing area of research. Such information, if available, can support and improve fisheries management. Numerous confounding factors, as described above, can make it difficult to understand the direct role of habitat in affecting species abundances. Further, some organisms require specific types of habitat, while others can utilize or adapt to a wide range of environments. Various habitats, disturbed or pristine, may have different values to certain species. What degrades a particular habitat for one suite of species may improve habitat for different suites of species. An additional complication is that habitat function can vary geographically or under changing environmental conditions, such as different climactic, salinity, or tidal regimes.

Nonetheless research has identified many direct linkages between habitat and fisheries productivity. Many studies examining the role of wetlands as nurseries have concluded that seagrass beds, salt marshes, and mangrove forests provide important support for juvenile fish and invertebrates (e.g. Beck et al., 2003). Other studies have shown that oyster reefs support a high density, biomass, and richness of estuarine fish species in comparison to other habitat types (e.g. Stunz et al., 2010). Additional research has demonstrated that productivity of blue crabs and brown and white shrimp in marsh habitats is considerably higher than in open water habitats (Minello et al., 2008), further showing the value of salt marshes in supporting the productivity of these commercially important species.

Several literature reviews also provide further insights. Heck et al. (2003) summarized the results of over 200 papers dealing with the importance of seagrass meadows. Their results indicated that seagrass is more productive than unvegetated habitat, producing numbers, growth, and survival of im-

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Habitat areas that are important as fish nurseries: upper left, salt marsh; upper right, seagrass; lower left, oyster cobbles; lower right, kelp bed.

portant species similar to those produced by other structurally complex ecosystems, such as oyster or cobble reefs and kelp beds. Another review (Minello et al., 2003) found that, based on fish density, the value of ecosystems as nurseries could be ranked from first to last in the following order: seagrass, vegetated marsh edge, non-vegetated marsh, open water, macroalgae (seaweed), oyster reefs, and vegetated inner marsh. Another review (Sheridan and Hays, 2003) concluded that intertidal mangroves can be as important in supporting high fish and invertebrate densities as other structured habitats such as seagrasses or salt marshes. These reviews yield valuable insight to resource managers and to scientists, greatly furthering our understanding of the importance of different habitat types. Additional research that can identify linkages between habitat and species productivity, as well as longer-term data sets that track the productivity of a habitat over time, will further help managers understand critical connections between species abundances and habitat quantity and quality.

How Can the Structure and Function of Degraded Habitat Be Restored?

As habitat loss remains a growing problem for coastal and estuarine areas of the United States, restoration has become an important conservation practice. From restoring fish habitat such as salt marsh and coral reefs to building oyster reefs and planting mangroves to protect the coast from erosion and flooding, the science behind restoration is as diverse as the habitats themselves.

NOAA collaborates with partners and provides technical assistance on engineering, site evaluation, restoration planning, monitoring, and environmental compliance to ensure effective design and implementation of restoration projects (see the NOAA Restoration Center's website for more details[8]). Some of NOAA's restoration efforts depend on volunteers, such as NOAA's Community-based Restoration Program. There are several examples

[8]http://www.habitat.noaa.gov/restoration/ (accessed March 2015).

What is Restoration?

"The return of an ecosystem to a close approximation of its condition prior to disturbance . . . . Both the structure and functions of the ecosystem are recreated. Merely recreating a form without the functions in an artificial configuration bearing little resemblance to a natural form does not constitute restoration. The goal is to emulate a natural, self-regulating system that is integrated ecologically with the landscape in which it occurs."

—Definition of restoration from the National Research Council report "Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy" (NRC, 1992).

of NOAA-supported restoration efforts. NOAA recently participated in the Elwha River Floodplain Restoration Project to help restore habitat of protected salmon species in the Pacific Northwest. Restoration activities began soon after the removal of the first of two obsolete hydroelectric dams slated for deconstruction on the Elwha River, which began in 2011, and included the removal of dikes and invasive species and the planting of native species. NOAA also helped restore shoreline and critical barrier island habitat in Louisiana's Barataria Bay to help prevent shoreline breaching and to protect and create dune, swale, and intertidal marsh habitats. By restoring barrier islands, wetlands, and other habitats that buffer impacts of floods and storms, NOAA also helps to build hazard-resilient coastal communities.

Restoration, however, is not simply the physical construction of a particular habitat type in a specific location. The fundamental goal of aquatic ecosystem restoration is to return disturbed habitat to a condition that resembles its natural pre-disturbed state. Achievement of this goal entails restoration of the target ecosystem's structure and function, both locally and within its broader landscape or watershed context. To measure the degree of success in achieving restoration goals, physical, chemical, and biological data are necessary to verify that a restored habitat is functioning as intended. To achieve long-term success, aquatic ecosystem restoration should address the causes and not just the symptoms of ecological disturbance. In some situations a restoration plan must consider what is acceptable under existing social, political, economic, and engineering constraints.

ORGANIZATION OF THIS REPORT

This report summarizes the available information, as well as the gaps in this information, on the relationships between the productivity of living marine resources and habitat. The purpose is to educate scientists, managers, and the interested public, and to help improve and support fishery management and conservation efforts. Inadequate scientific information can make it difficult to identify the habitats most critical to the growth, reproduction, and survival of federally managed species, and therefore to designate EFH and critical habitat. As a consequence, areas may be inadequately defined because of uncertainty regarding the types and range of habitats necessary to sustain marine species. Thus, identifying information gaps is also an important contribution to improving management and conservation.

The next section, the National Summary, presents an overview of status and trends in habitat use and information quality for federally managed and protected living marine resources, and highlights national habitat issues, trends, and research needs.

Following the National Summary, the report is divided into five regional chapters: Northeast, Southeast, Pacific Coast, Alaska, and Pacific Islands (Figure 1, Table 1). These regions are based on geography and are generally similar to the NMFS regional structure. All the report's regions extend from the upper reaches of watersheds utilized by anadromous fishes to the U.S. EEZ boundary, which is either an international boundary (e.g. with Canada or Mexico), or 370 km (200 nmi) off the U.S. coast. It should be noted, however, that most

Table 1 Characteristics of geographic regions used in the *Our Living Oceans: Habitat* report.

Region in OLO Habitat report	Geographic extent	NMFS fisheries science centers	Fishery management councils
Northeast	From the U.S.–Canada border (Maine–New Brunswick) to Cape Hatteras, North Carolina	Northeast Fisheries Science Center, Woods Hole, Massachusetts	New England FMC Mid-Atlantic FMC
Southeast	From Cape Hatteras, North Carolina, to the U.S.–Mexico border (Texas–Tamaulipas); also Puerto Rico and U.S. Virgin Islands	Southeast Fisheries Science Center, Miami, Florida	South Atlantic FMC Gulf of Mexico FMC Caribbean FMC
Pacific Coast	From the U.S.–Canada border (Washington–British Columbia) to the U.S.–Mexico border (California–Baja California)	Northwest Fisheries Science Center, Seattle, Washington Southwest Fisheries Science Center, La Jolla, California	Pacific FMC
Alaska	Alaska	Alaska Fisheries Science Center, Seattle, Washington	North Pacific FMC
Pacific Islands	Hawaii, Northwest Hawaiian Islands, and several small island territories extending nearly as far west as Japan and to nearly 20 degrees south of the Equator	Pacific Islands Fisheries Science Center, Honolulu, Hawaii	Western Pacific FMC

states have jurisdiction over waters from the mean lower low water line at the coast out to 5.6 km (3 nmi). The exceptions are Texas, Puerto Rico, and the Gulf Coast of Florida, which have jurisdiction out to 16.7 km (9 nmi) from the coastline. The distributions of some highly migratory fish and marine mammals extend into the territorial seas of other countries and/or into the international waters of the open ocean.

Four primary habitat categories are used in this report. They are defined in Table 2: freshwater, estuarine, shallow marine, and oceanic habitat. These broad habitat categories incorporate more specific habitat types such as seagrass beds, rocky intertidal zones, coral reefs, mangrove forests, kelp forests, mud flats, marshes, hard shell and sandy bottoms, the open water column, and numerous others.

Each regional chapter includes descriptions of the region's geographic areas, an in-depth look at the four habitat categories, descriptions of habitat use by federally managed fishery and protected species and key examples of state-managed species, a summary of habitat trends, and an overview of the research needs for that region. Descriptions of habitat use by federally harvested marine species are organized by fishery management plans. At the time this report was developed, there was a combined total of 46 fishery management plans and fishery ecosystem plans (See Appendix 3 for a full listing). Descriptions of habitat use by protected species are grouped by cetaceans (whales, dolphins, and porpoises), pinnipeds (seals and sea lions), sea turtles, or other categories as appropriate. Please see Appendix 5 for a full listing of fishery and protected species included in the report.

Examples of the four habitat categories: upper left, freshwater habitat (Alaskan stream); upper right, estuarine habitat (Grand Bay, Mississippi); lower left, shallow marine habitat (Point Dume, California); lower right, oceanic habitat (Atlantic Ocean).

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Table 2 Definition of the habitat categories used in the *Our Living Oceans: Habitat* report.

Category	Definition	Examples
Freshwater habitat	Habitats located between headwater and head-of-tide, with negligible salinity. (Headwater is the inland source from which a river originates; head-of-tide is the inland limit of water affected by tides.)	Columbia River, Penobscot River, Togus Stream, Bond Brook (latter two are Kennebec River tributaries)
Estuarine habitat	Habitats located in a semi-enclosed coastal body of water extending from head-of-tide to a free connection with the open sea, within which sea water is mixed with fresh water.	Chesapeake Bay, Puget Sound
Shallow marine habitat	Habitats 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. EEZ, which is usually 370 km (200 nmi) from shore. This includes the seafloor and open water column over areas shallower than 200 m.	Continental Shelf habitats, fringe and barrier reefs, atolls (e.g. Johnston Atoll), Gulf of the Farallones, Heceta Bank
Oceanic habitat	Habitats 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.	Continental Slope habitats, Bear Seamount, Hudson Canyon, Gulf of Maine basins, Monterey Canyon, abyssal plains

Habitat—What is it worth?

It is easy to understand why healthy coastal and marine habitat is important for fish and wildlife, but what value do we place on these habitats for ourselves? Though we often take it for granted, nature plays a significant role in our lives, whether we are eating seafood from a nearby estuary or vacationing at our favorite beach—two examples of benefits we receive from healthy coastal and marine ecosystems. Today, you might hear these benefits referred to as ecosystem services.

We conserve habitat to make sure these ecosystem services are available for healthy coastal communities and future generations. The work of conserving habitat makes a positive contribution to our economy by generating "green" jobs and making sure coastal resources are available for industries such as fishing and tourism.

What is our role?

With healthy habitat under threat nationwide, we can no longer take ecosystem services for granted. Our goal is to enhance coastal resource management decisions by demonstrating the social and economic contributions of healthy habitat with respect to the following factors:

- coastal and marine resources;
- commercial, recreational, and non-market economic activities;
- the health and safety of the Nation's citizens; and
- protecting property and communities.

Local communities find value in restoring the Elwha River

An example of research on the value of restoring ecosystem services is developing in Washington State. The Elwha River will be restored to its natural state following the removal of two large dams that began in 2011 and was completed in 2014. During this time 33.2 hectares (82 acres) of riparian zone (non-wetland) habitat were restored. NOAA's Elwha River and Floodplain Restoration Project includes three discrete project areas: 1) restoration of floodplain habitat in the lower Elwha River; 2) native plantings and control of invasive plants that support dam removal actions; and 3) initiation of long-term monitoring of adult fish populations in the Elwha River. With funding from the Estuary Restoration Act, NOAA is conducting an ecosystem services valuation survey to estimate recreational and passive-use values for the restored river and flood plain. The study will provide answers to the following three questions:

1. What is the effect on the public's welfare from dam removal and flood plain restoration?
2. What is the value of preserving key endangered or threatened species?
3. What are the potential changes in recreational use from river restoration?

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Part 3
National Summary

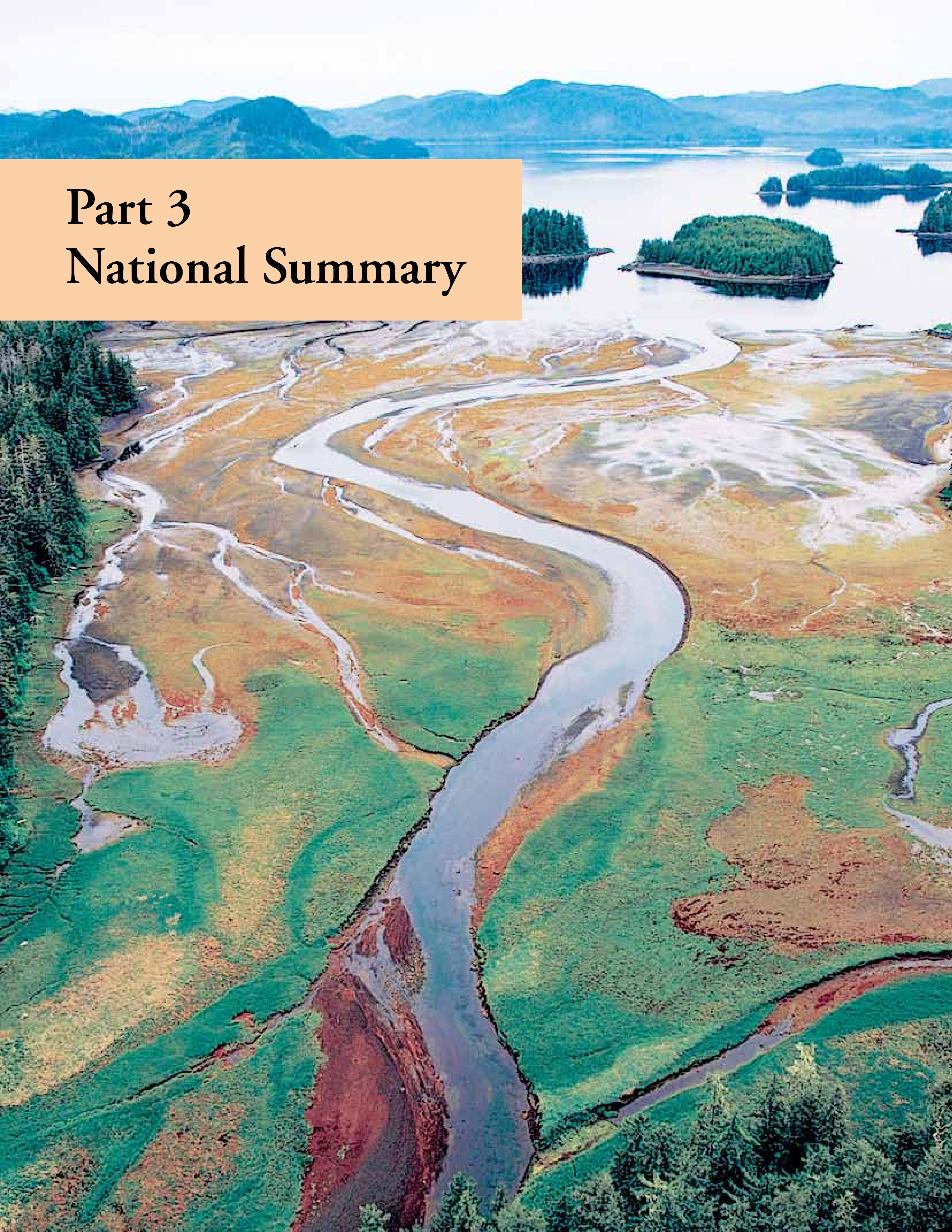

Photo on previous page: A Southeast Alaska wetland and estuary. Photo credit: Mandy Lindeberg, NMFS.

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-

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.

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.

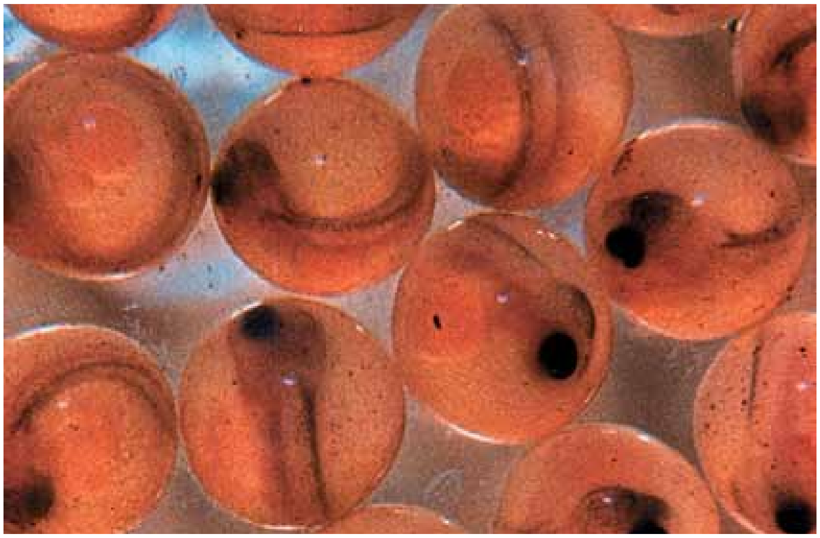
For federally managed marine species in all regions, shallow marine and oceanic habitats are the most commonly used, while freshwater habitats are the least used (Table 3). Anadromous species, namely salmon, are the primary FMP/FEP species that utilize freshwater habitats. FMP/FEP species make extensive 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.

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

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.



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.

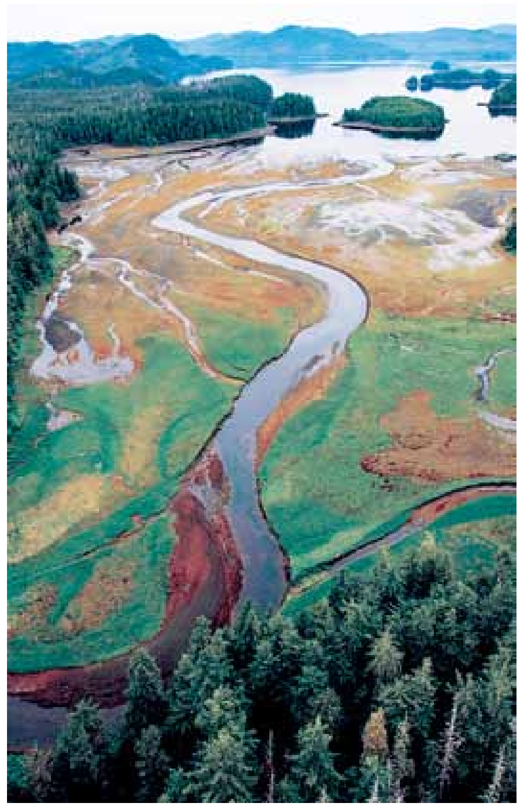
HABITAT STATUS AND TRENDS

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.



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

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

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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).

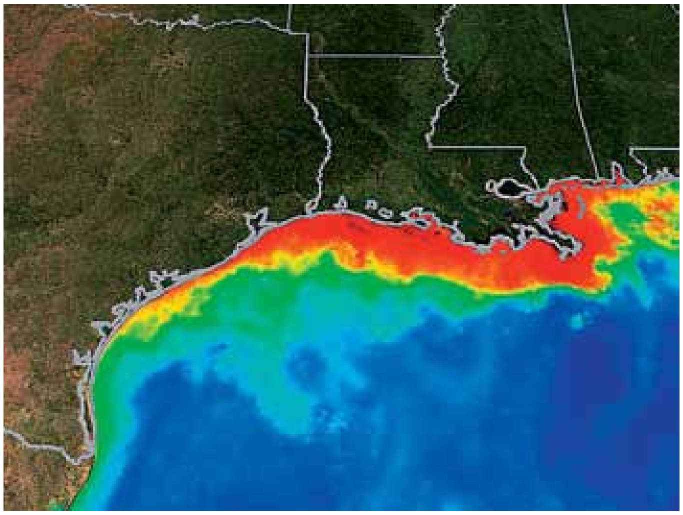
NASA

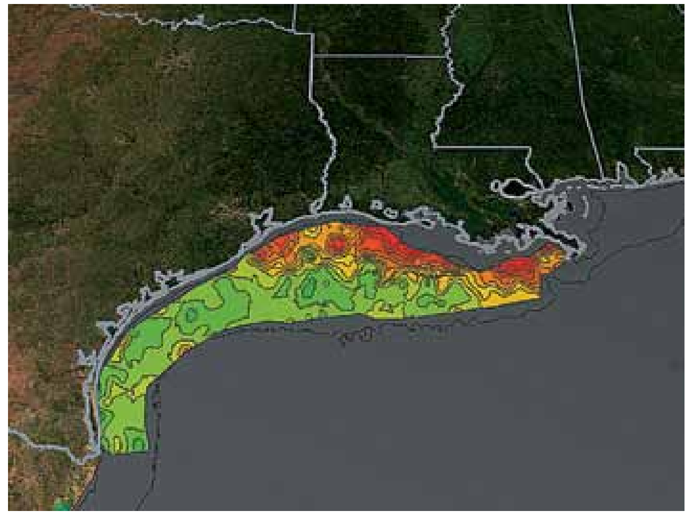
Satellite photo of the southwest part of Lake Erie in 2011 showing a harmful algal bloom (HAB).

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

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."

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*.

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

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://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.

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

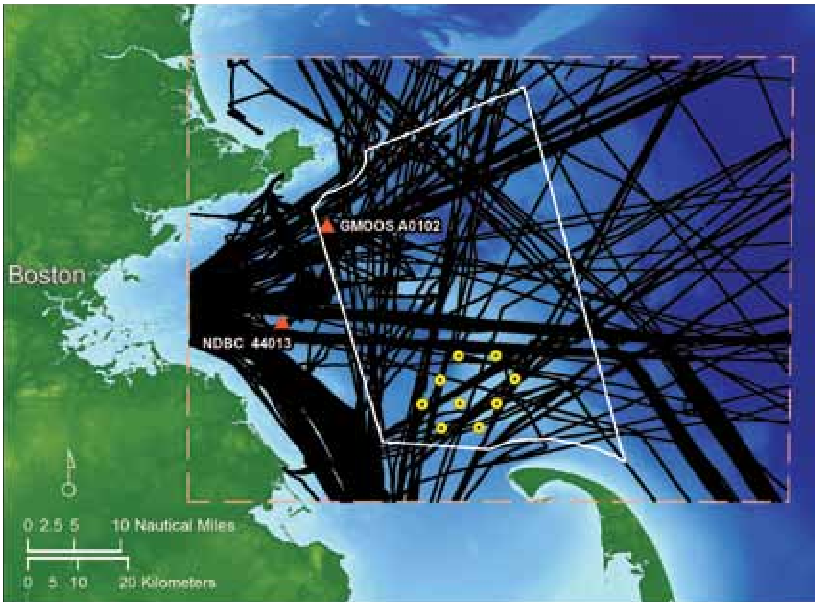
N. Iadanza, NMFS

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



NOAA

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.

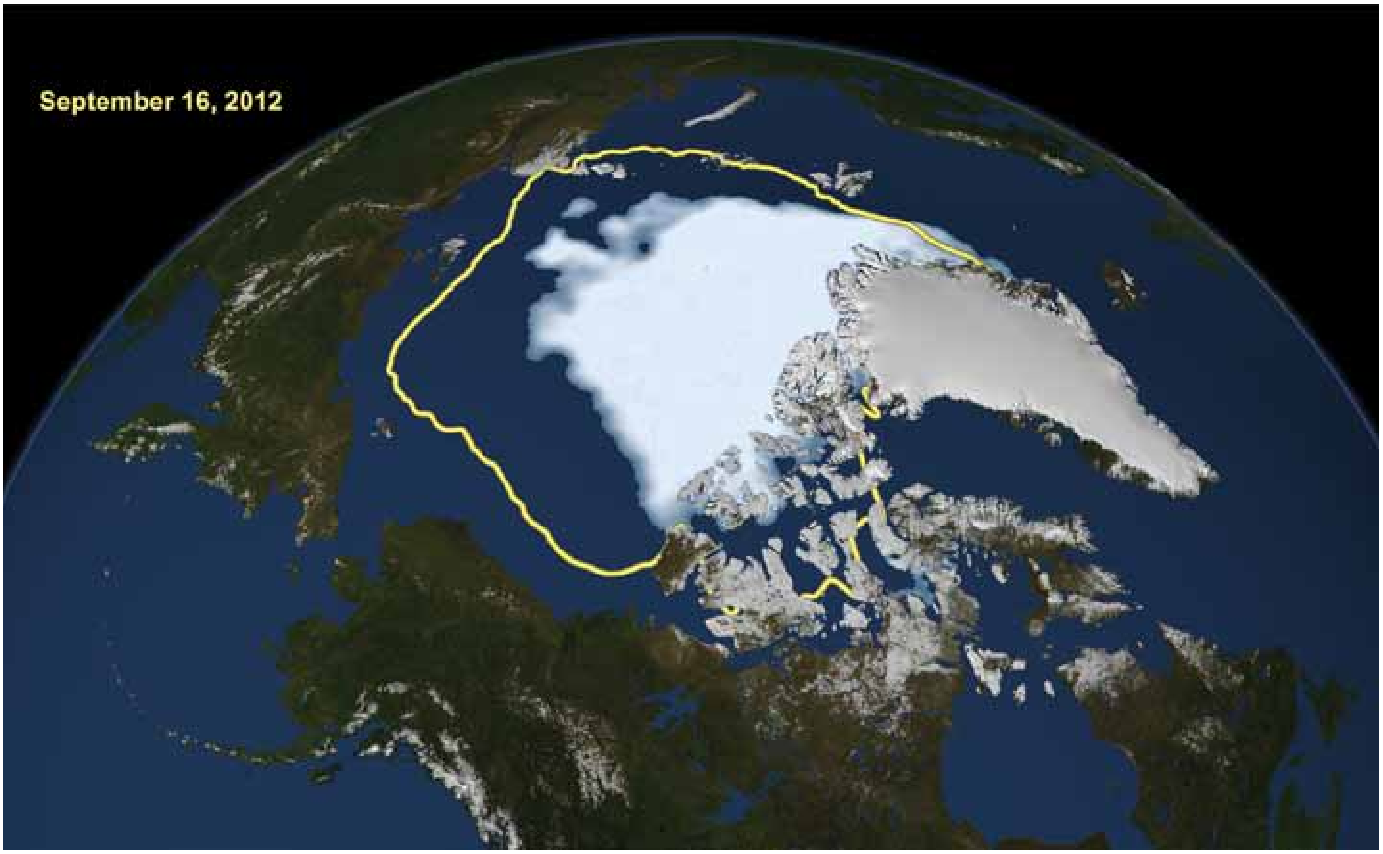
Noise—Noise is fast becoming a pervasive pollutant in some marine habitats. Anthropogenic noise from vessel traffic, geophysical exploration, active sonar, construction activities, and other sources may have various adverse effects on marine life, ranging from relatively benign to severe. Noise from 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.

Map showing the five Sentinel Site Cooperatives.

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

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.

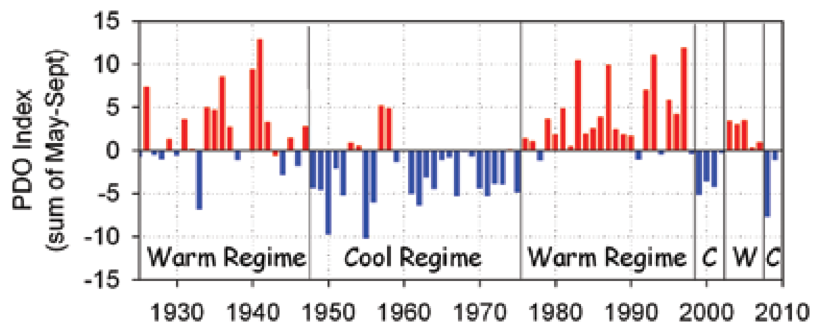
es are impacted by such natural climate variability, species are evolutionarily adapted to these natural cycles and often rebound when favorable conditions return.

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 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.

Todd Marsee, Michigan Sea Grant

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

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


NOAA

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.

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.

U.S. Fish and Wildlife Service

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

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.

NOS

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

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

[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).

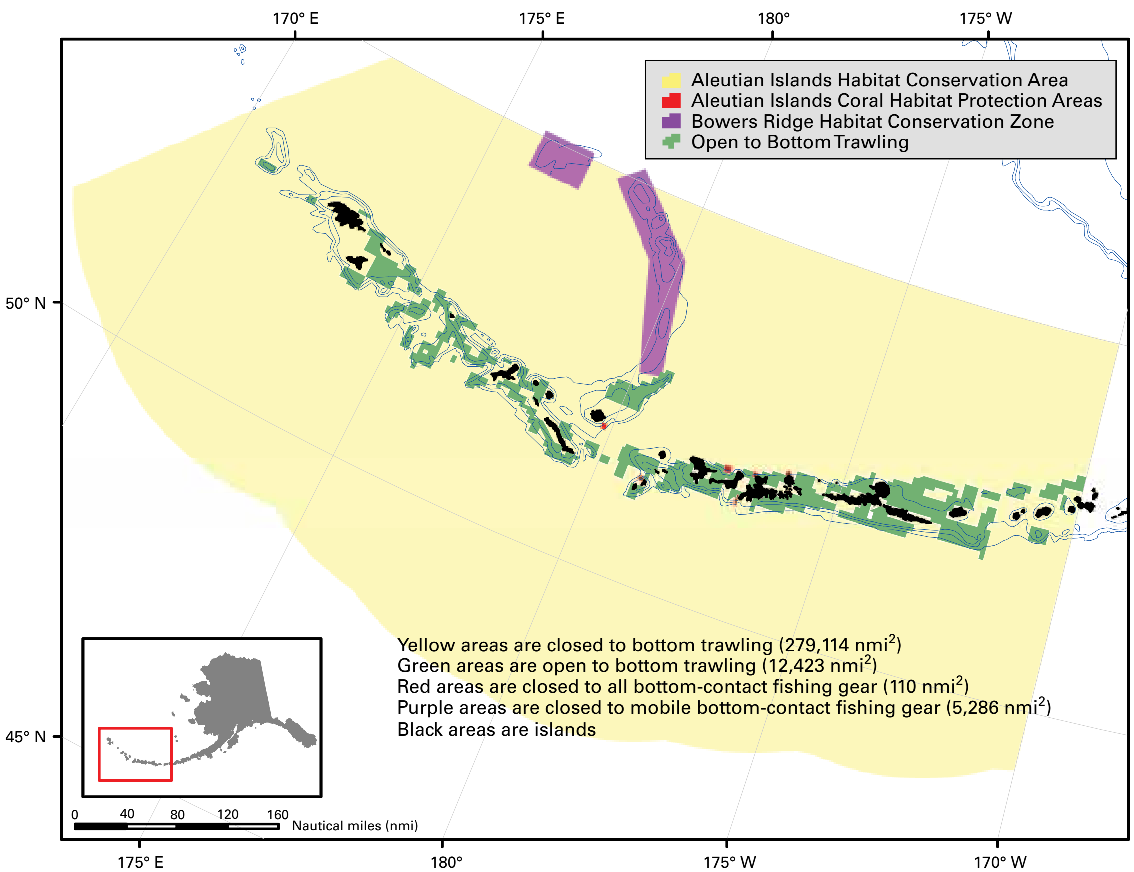
[19]This definition is taken from Marine Protected Areas Executive Order 13158.

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.

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.

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 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:

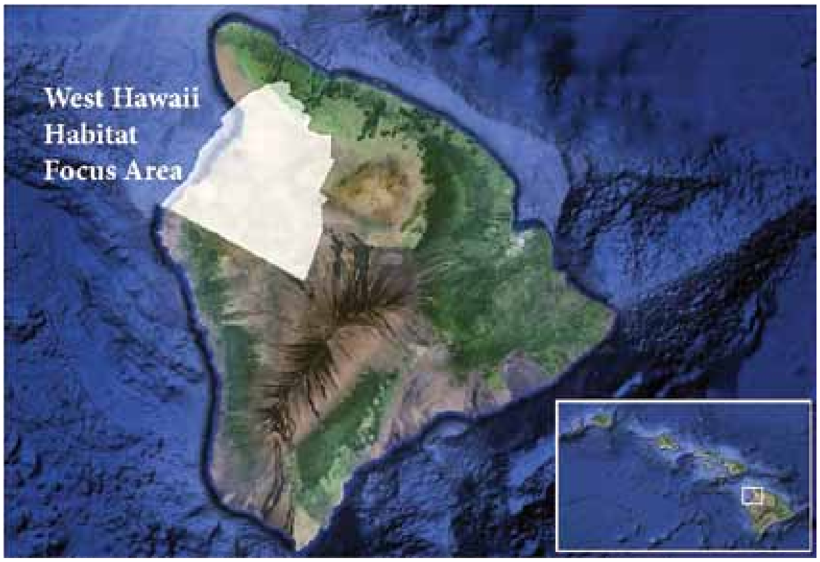
- harvested federally managed fish species for which increased habitat availability and/or improved conditions will increase harvest levels and remove limiting factors for rebuilding stocks;
- protected species for which increased habitat and/or improved condition is a limiting factor for recovery or 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.

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


NOS

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.

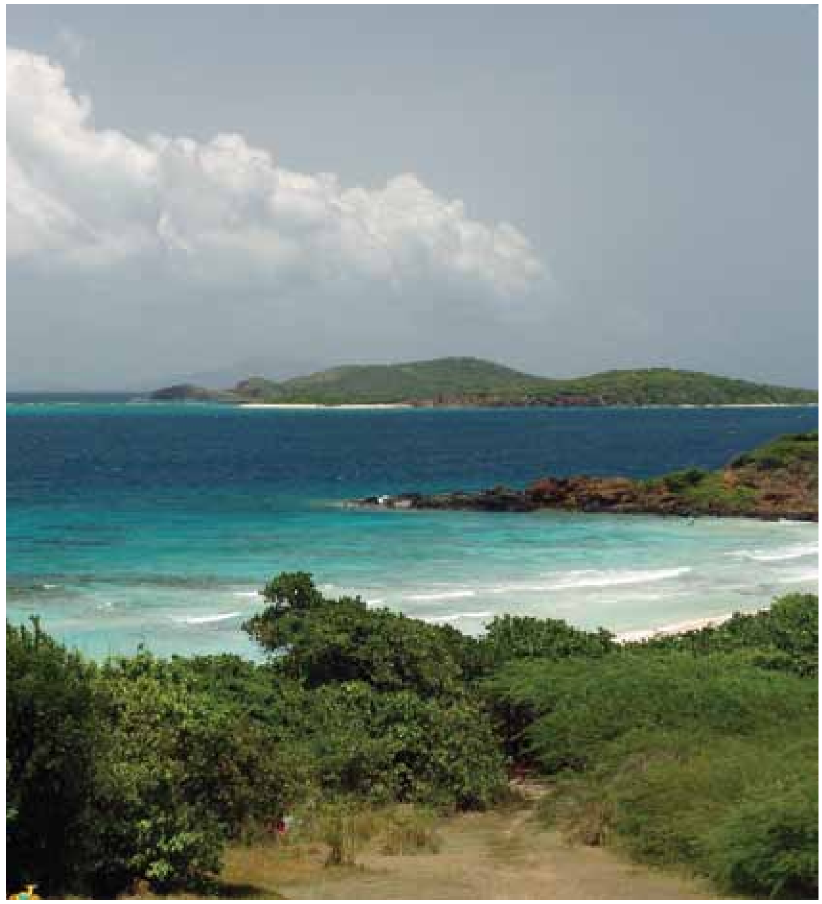
  Although Kachemak Bay has amazing marine resources, the region has experienced significant declines in shrimp and crab that have not recovered despite fisheries closures. The ecological richness is vulnerable to impacts from development activities in Cook Inlet and to changes in ocean acidity and hydrodynamics 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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Part 4
Regional Summaries

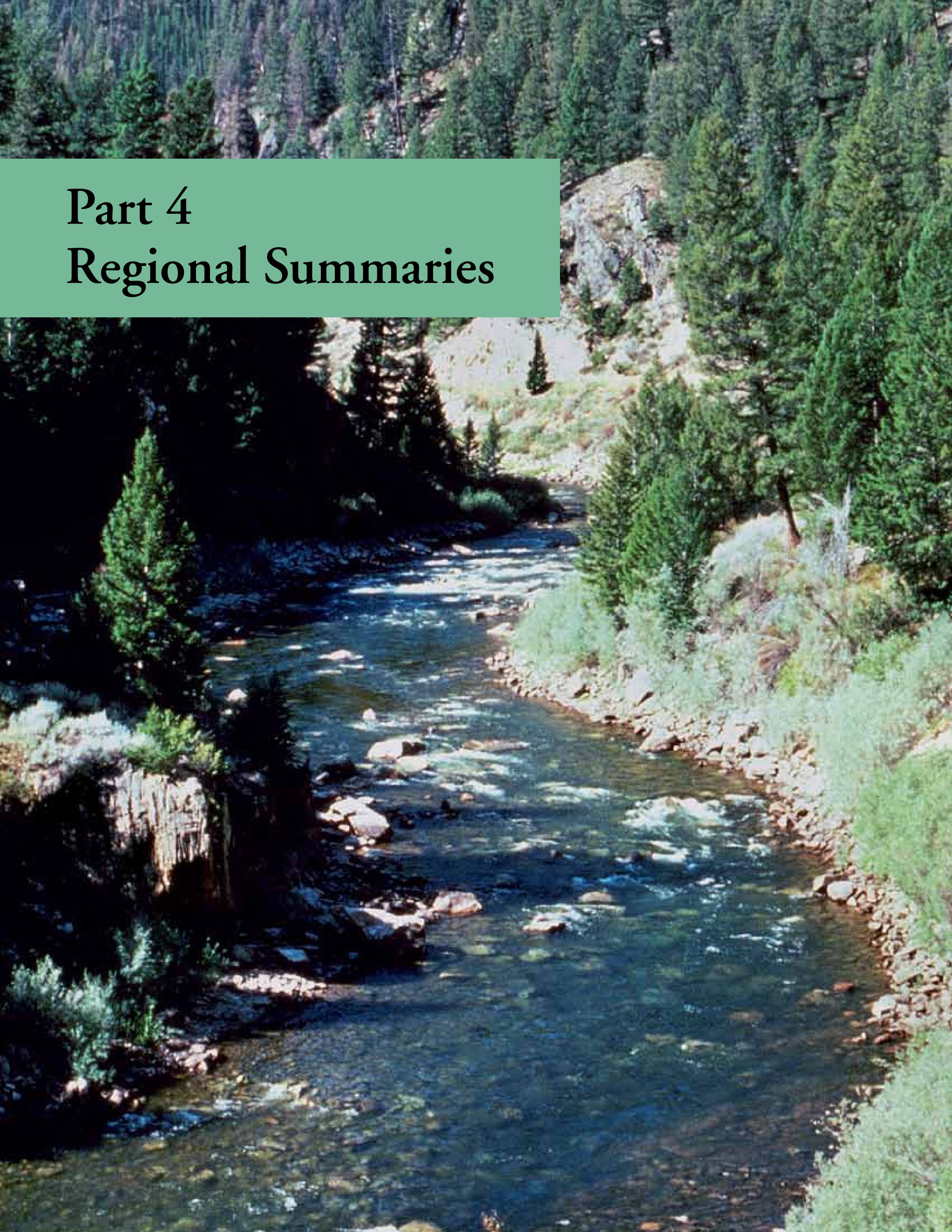


Photo on previous page: The Salmon River, in Idaho, is part of the spawning and migration system for sockeye salmon. Photo credit: © Robin Waples.

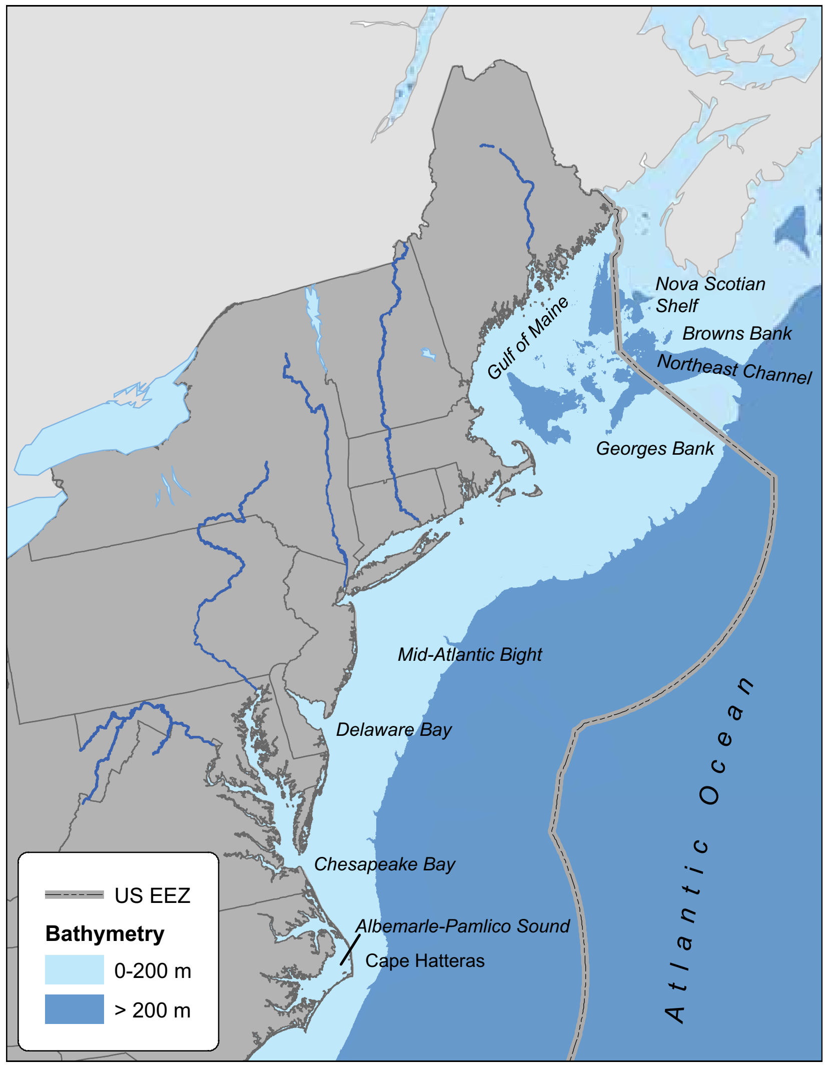
Northeast Region

HABITAT AREAS

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

Gulf of Maine

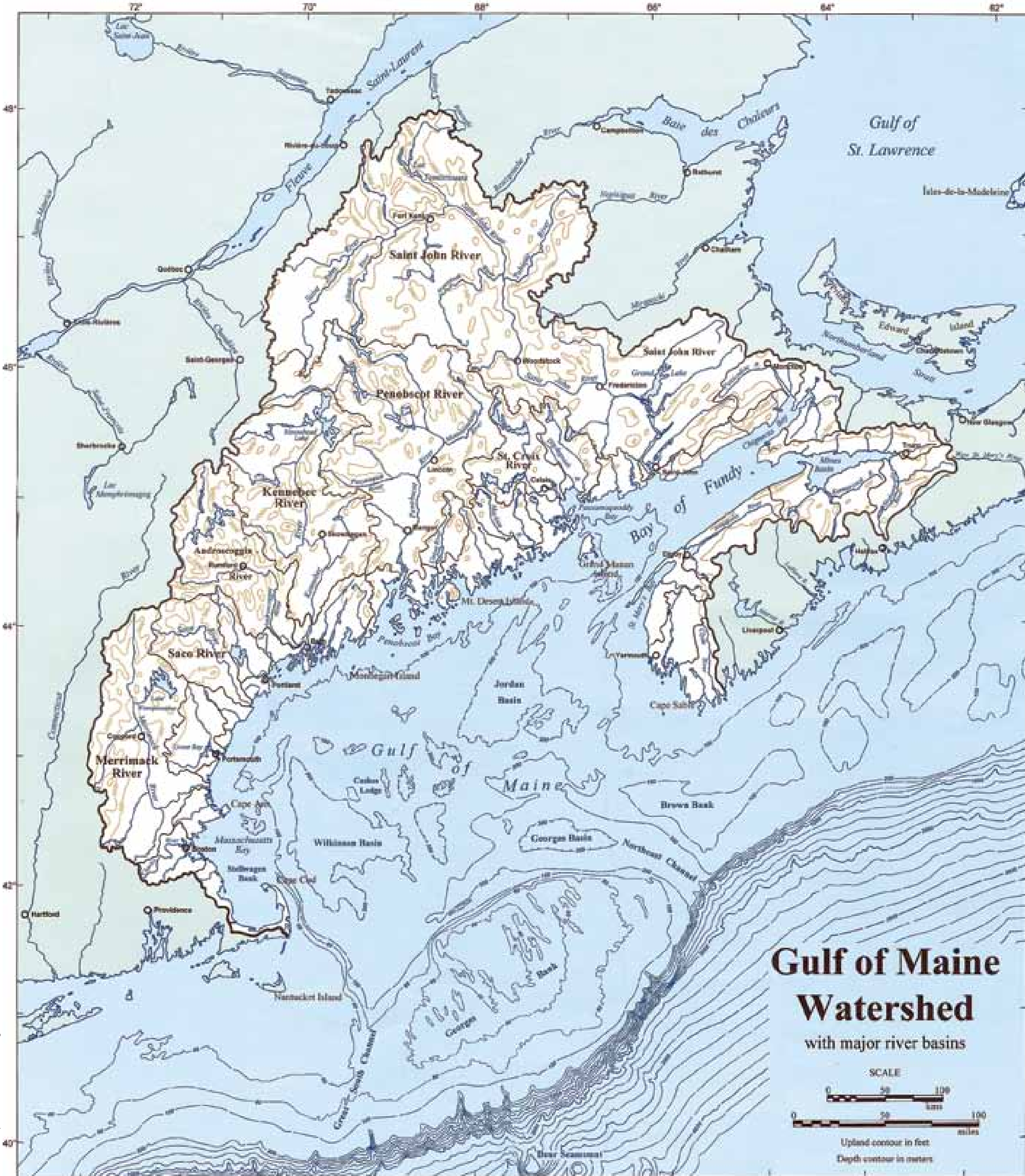
The Gulf of Maine is bordered by Maine, New Hampshire, and Massachusetts. It covers an area of 90,700 km^2 (35,000 mi^2) on the Continental Shelf, extending north to the Nova Scotian Shelf, east to Browns Bank, and south to Cape Cod and Georges Bank. It is characterized by a system of 21 deep basins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



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

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

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.



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

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

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

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

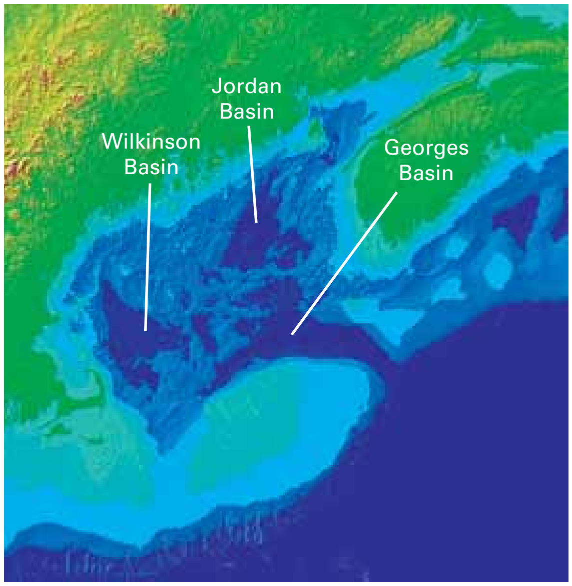
Estuarine Habitats—The Gulf includes more than 59,570 km^2 (23,000 mi^2) of estuarine drainage areas, and the long Maine coast supports the largest number of estuaries. Important examples (listed alphabetically) include Blue Hill Bay, Casco Bay, Cobscook Bay, Englishman Bay, Frenchman Bay, Machias Bay,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

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

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

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

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



USGS

The three basins in the Gulf of Maine.

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

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

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

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

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

Georges Bank

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

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

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

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

Mid-Atlantic Bight/Southern New England

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


NASA

Satellite map of Chesapeake Bay and surrounding area.

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


NOAA

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

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

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

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

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

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

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

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

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

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

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

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

M. Hollinger, NOAA

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

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

Deep-Sea Coral Habitats

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

Peter Auster, NOAA

Barbara Hecker, NOAA

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

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

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

HABITAT USE

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

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

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

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

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

[b] Atlantic salmon are managed as both FMP and protected species, but are listed only once in the table, under the FMP.

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

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

Habitat Use by FMP Species

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

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

Dann Blackwood, USGS

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

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

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

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

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

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

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

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

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


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


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

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

A golden tilefish over sandy bottom habitat.

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

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

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

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

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

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

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

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

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


NOAA

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

Habitat Use by Protected Species

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

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

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

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

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

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

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

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

Habitat Use by State-Managed and Non-FMP Species

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

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

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

Louise and Tom Kane, NOAA Restoration Center

A young lobster perched on the fingertip of a scientist.

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

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

NY State Department of Environmental Conservation

An eastern oyster.

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

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

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

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

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

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

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

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

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

HABITAT TRENDS

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

USGS

An American eel captured for research purposes.

Freshwater Trends

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

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

NOAA Community-based Restoration Program

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

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

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

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

Estuarine and Coastal Habitat Loss and Fragmentation

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

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

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

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

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

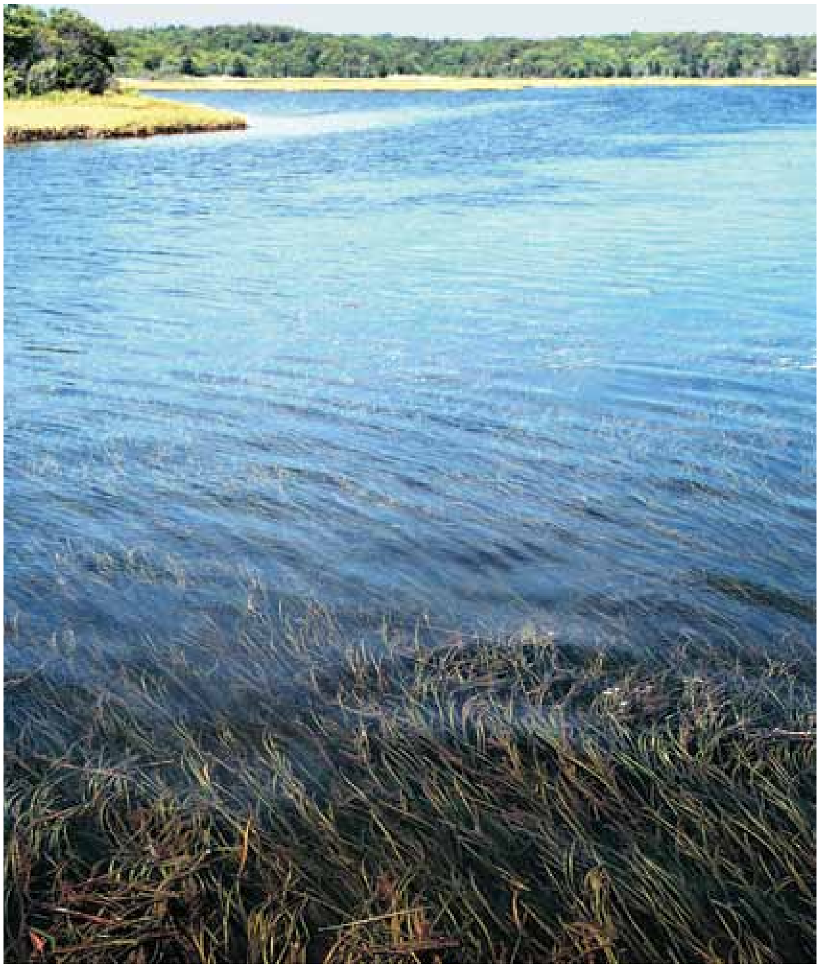
1959. Losses in overall island low-marsh vegetation averaged 38% since 1974, though smaller islands lost up to 78% of their vegetation (Hartig et. al, 2002). From 1989 to 2003, the average rate of loss was 13 hectares (33 acres) per year, compared to a fairly consistent rate of approximately 7 hectares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

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

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


NOAA National Estuarine Research Reserve Collection

Wetlands in the North Carolina National Estuarine Research Reserve.



R. Crawford, NOAA National Estuarine Research Reserve Collection

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

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

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

Effects of Fishing Gear

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

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

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

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

RESEARCH NEEDS

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

Atlantic Salmon Ecology

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

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

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

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

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

Deep-Sea Corals

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

Effects of Fishing Gear on Benthic Ecosystems

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

Habitat Mapping

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

Invasive Species

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

D. Blackwood, USGS

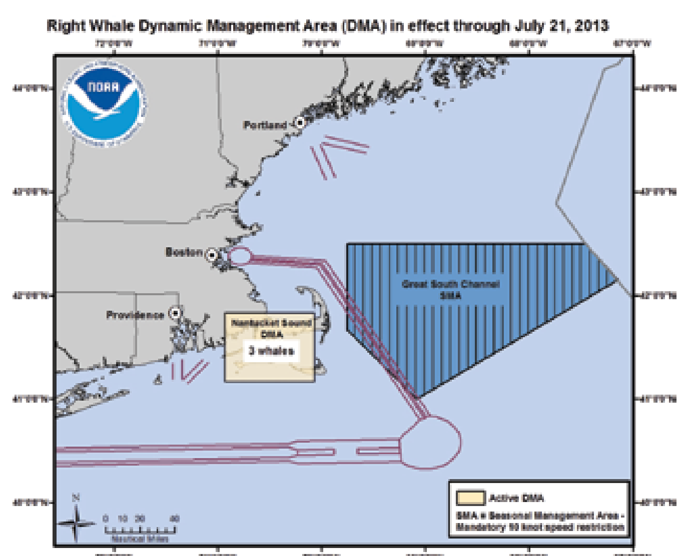
This invasive tunicate *Didemnum* sp. covers scallops as well as parts of the sea floor on Georges Bank in New England.

Oyster Disease Control and Habitat Restoration

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

Reducing Ship Collisions with North Atlantic Right Whales

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



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

Research goals for oyster restoration include the following activities:

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

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

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

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

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Southeast Region

HABITAT AREAS

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

Freshwater Habitats

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

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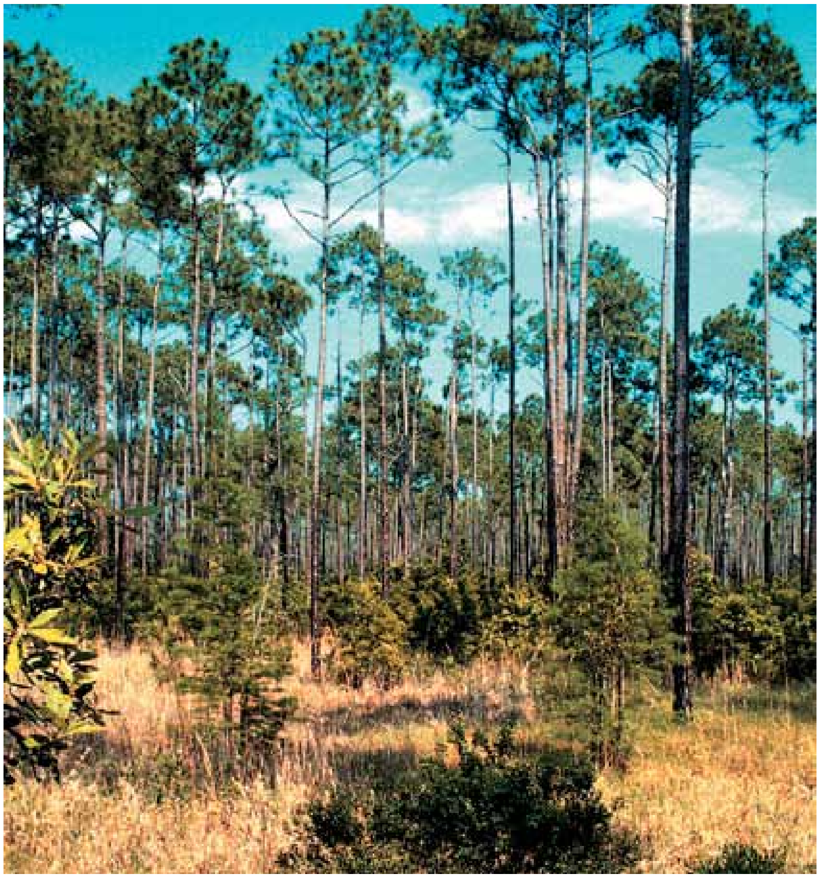

Maritime slash pine savannah on the state line between Mississippi and Alabama.

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

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

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

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

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

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

Alabama, Arkansas, Florida, Georgia, Ken-

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

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

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

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

Estuarine Habitats

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

NPS

NMFS

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

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

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

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

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

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

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

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

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

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

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

P.R. Hoar, NOAA/NESDIS/NCDDC

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

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

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

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

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

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

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

Shallow Marine Habitats

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

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

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

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

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

Joyce and Frank Burek, NOAA Sanctuary Collection

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

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

Barrier islands off the Louisiana and Mississippi coastline.

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

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

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

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

Not all reefs are naturally occurring. For ex-

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

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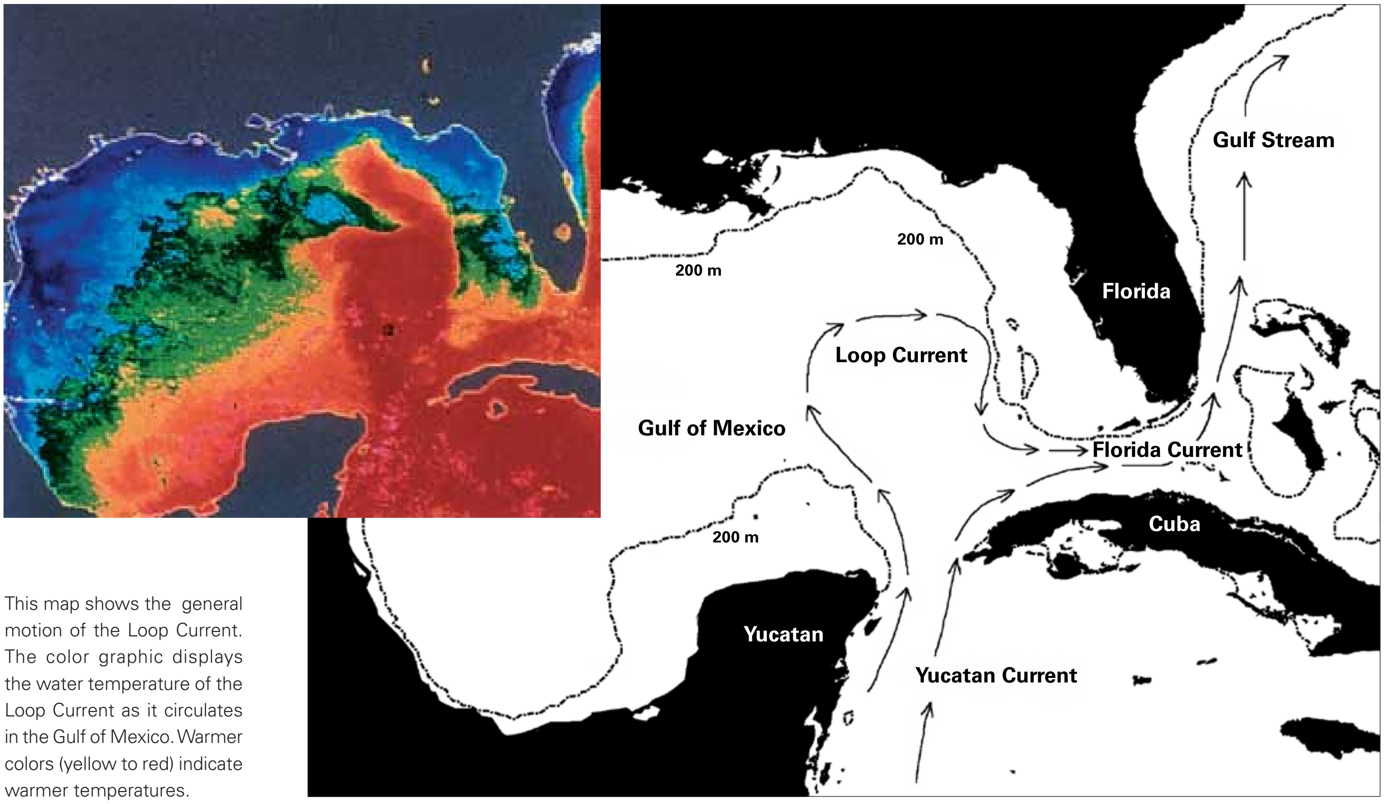


NOAA

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

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

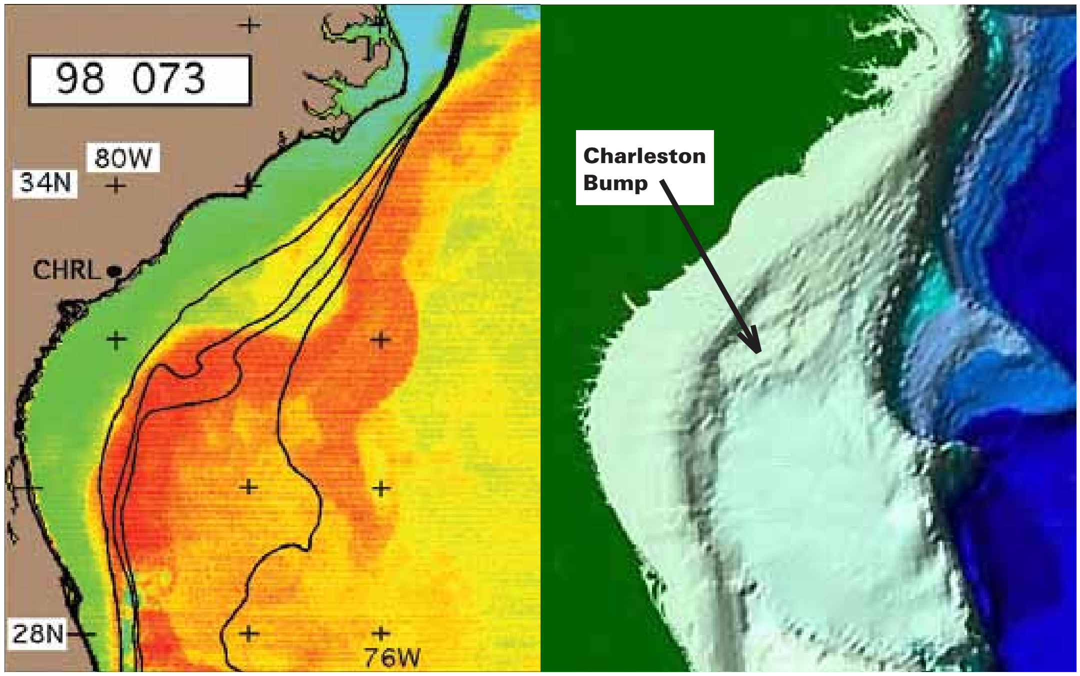
Limited coastal plains, narrow shelves, constant temperature gradients, oligotrophic waters, and sparse zones of upwelling characterize many shallow marine habitats of the U.S. Caribbean Islands and Navassa Island. Among these, St. Croix in the U.S. Virgin Islands and Mona Island in Puerto Rico, both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

Oceanic Habitats

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

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

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



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

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

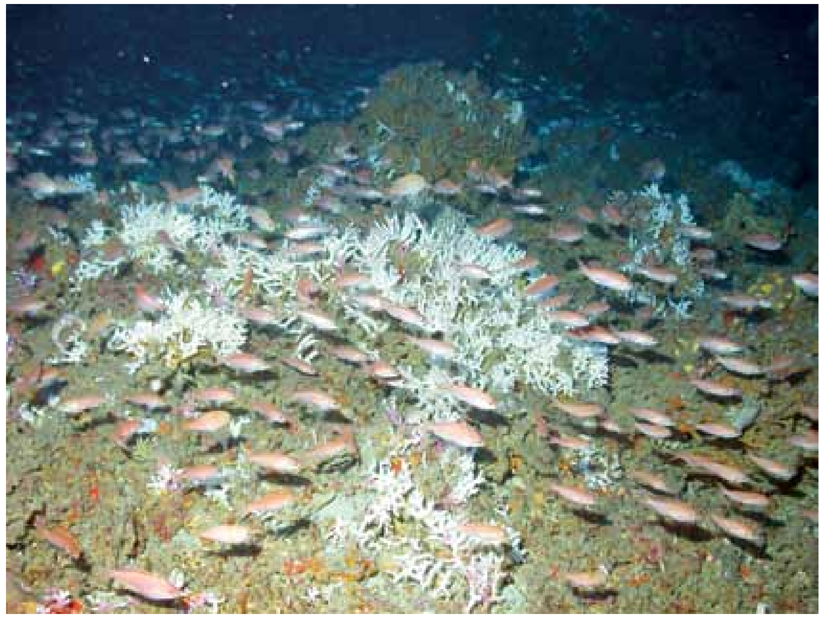
When the Loop Current is north of latitude 27° N, it occasionally bifurcates to produce large eddies measuring 300 km (186 mi) or more in diameter. These rings of high-salinity water break off from the main current and drift westward of the Mississippi River Delta along the northern and western Continental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

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

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

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

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



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South Atlantic Fishery Management Council

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

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U.S. Coast Guard

HABITAT IMPACTS OF THE *DEEPWATER HORIZON* OIL SPILL

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

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

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

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

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

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

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

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

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

HABITAT USE

This section contains a qualitative description of habitat use for Southeast Region species grouped by fishery management plan (FMP) and by protected species. Several state and non-FMP species are also included. Appendix 5 contains a full listing of all species discussed. The Consolidated Atlantic Highly Migratory Species FMP is included in the Southeast Region, although these species can occur in the Northeast at least during warmer months. Table 9 provides a summary of typical habitat use patterns in the Southeast Region, organized by FMP and the protected-species groups covered in this report (cetaceans, pinnipeds, and sea turtles). There are 18 total FMPs in the Southeast, though the table does not include the Aquaculture FMP, so 17 FMPs are summarized.

The table shows patterns of typical use for one or more species within each group. However, it is important to recognize that these groups include many species, all of which have unique habitat requirements by life stage. Habitat information is lacking for many Southeast species, particularly in the earlier life stages, and such critical information gaps are not captured in this table.

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

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

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

(table continued on next page)

Table 9
(continued)

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

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

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

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

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

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

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

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

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


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A loggerhead sea turtle swimming near Panama City, Florida.


NOAA

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

Habitat Use by FMP Species

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

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

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

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

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

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

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

- **Sharks**

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

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

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

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

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

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

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

Adult dolphinfish from the NMFS longline observer program.

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

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

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

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

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

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

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

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

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

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

Queen Conch—Queen conch generally occur on expanses of shelf habitat in tropical or subtropical waters, from the shoreline to depths of about 76 m (250 ft). Adult queen conch commonly inhabit sandy bottoms that support the growth of seagrasses, primarily turtle grass, manatee grass, shoal grass, and epiphytic algae, upon which they feed. They also occur on gravel, coral rubble, smooth hard coral or beach rock bottoms, and sandy algal beds. Since queen conch are herbivorous gastropods, they are generally restricted to waters where light can penetrate to a depth sufficient for plant growth. Queen conch are often found in sandy spurs that cut into offshore reefs. Larvae require certain substrate conditions to metamorphose and settle to the bottom. Habitat condition at the larval stage seems critical, although the requirements are largely unknown.

Heather Dine, Florida Keys National Marine Sanctuary

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

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

Jim Raymont, Florida Keys NMS

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

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

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

- **Shallow-Water Reef Fishes**

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

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

- **Deepwater Reef Fishes**

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

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

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

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

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

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


Andrew David, NMFS; Lance Horn, UNCW/NURC

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

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

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

A Caribbean spiny lobster.

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

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

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

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

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

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

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

Habitat Use by Protected Species

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

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

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

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

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

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

M. Herko, NURP Collection, NOAA

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

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

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

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

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

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

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

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

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

Smalltooth sawfish (endangered) inhabit shal-

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

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

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

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

Habitat Use by State-Managed and Non-FMP Species

States manage many of the species that primarily inhabit estuaries or nearshore areas, coordinating their activities through the Atlantic States and the Gulf of Mexico Marine Fisheries Commissions and the appropriate fishery management councils. Many key examples of these species are discussed by category (crustaceans, mollusks, and fish).

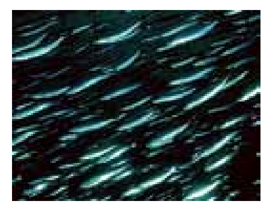
Crustaceans—The blue crab is widely distributed in estuaries along the coast of the Southeast Region. Distribution within estuaries and their associated tributaries varies with the age and gender of the crabs and with season. Smaller blue crabs generally occur in shallow estuarine waters with bottoms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

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

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

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


W. F. Hettler, NMFS

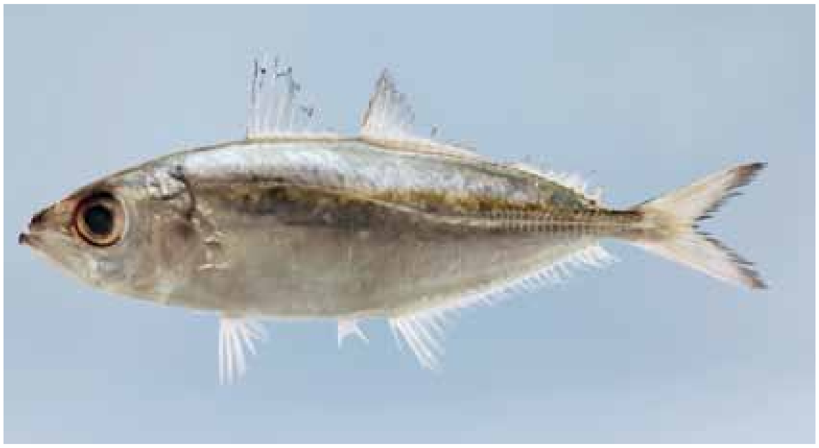

NMFS


USGS

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

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

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



A bigeye scad.

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

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

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

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

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


U.S. FWS

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

HABITAT TRENDS

Freshwater Quality and Quantity

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

Diversion of Freshwater Flow

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

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

Wetland Loss

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

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

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

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

Kathryn Smith, USGS

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

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

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

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

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

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

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

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

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

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

Coastal Development

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

Flood Control

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

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

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

Jacinta Quesada, FEMA

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

Coral Reefs

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

Coral Bleaching

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

Andy Bruckner, NMFS

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

Weeks Bay NERRS

Josh Harper, Texas Department of Parks and Wildlife

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

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

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

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

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

Eutrophication and Hypoxia

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

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

RESEARCH NEEDS

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

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

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

Estuarine Habitat Condition

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

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

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

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

Coral Reef Ecology

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

Habitat Mapping

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

NOAA / GTMNERR

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

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

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

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

Karen Roeder, Gray's Reef National Marine Sanctuary

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

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

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

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

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

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

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

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

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

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


NOAA

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

Habitat Restoration

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

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

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

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

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

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

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

Transboundary Biological and Oceanographic Linkages

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

Effects of Underwater Sound

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

Additional Research Needs

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

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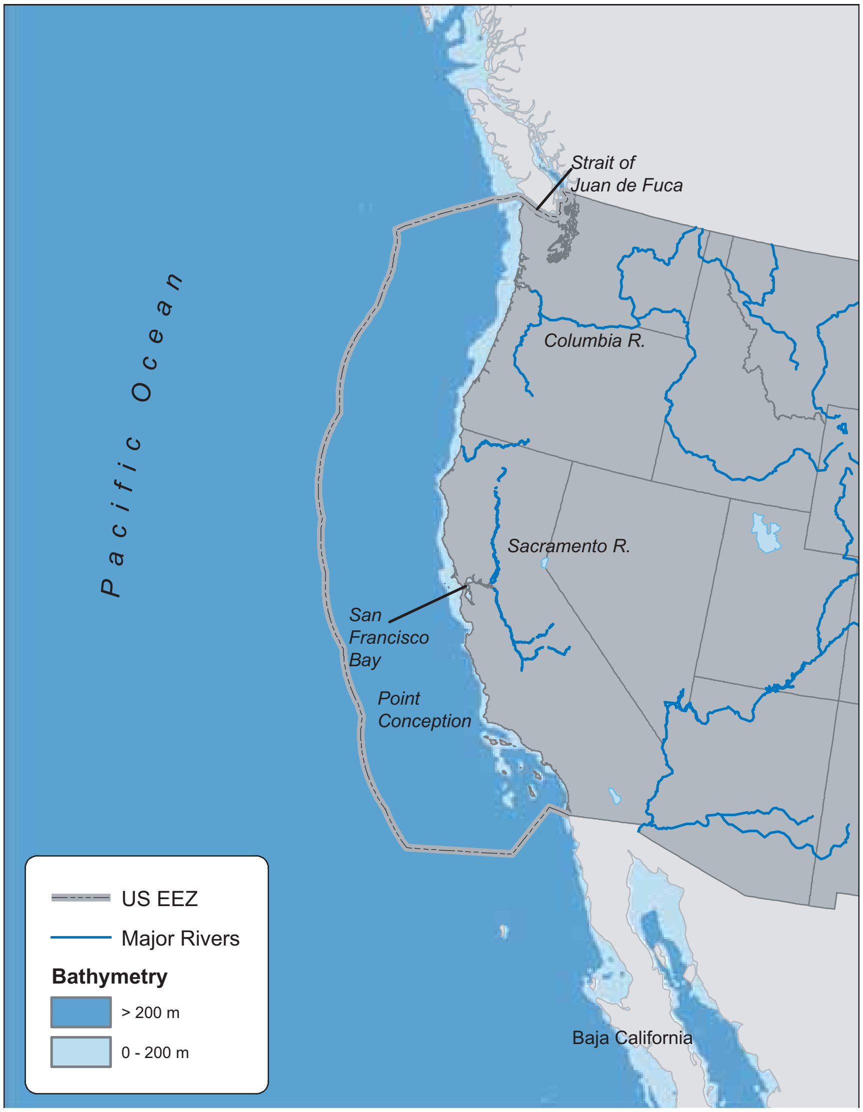
Pacific Coast Region

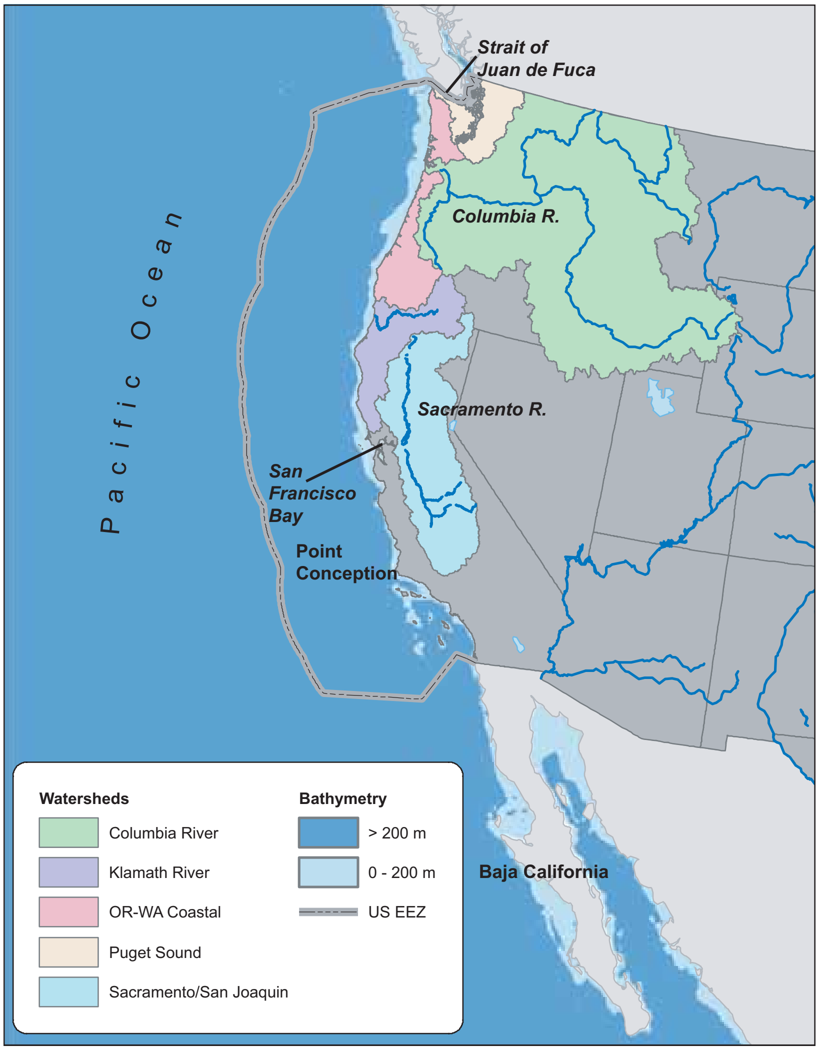


HABITAT AREAS

The Pacific Coast Region[1] lies adjacent to California, Oregon, and Washington, and encompasses about 7% (812,000 km^2 [237,000 nmi^2]) of the total area of the U.S. Exclusive Economic Zone (EEZ). There are five principal habitat categories in the Region: 1) freshwater streams and rivers, which include most watersheds in California, Oregon, Washington, and Idaho; 2) bays and estuaries; 3) the coastal Continental Shelf system extending

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

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.



Five major U.S. watersheds draining to the Pacific Coast. Note their distance from the sea.

from the intertidal zone to the 200 m (656 ft) depth contour, which is typically 8–60 km (5–36 mi) offshore in this region; 4) benthic habitats of the offshore Continental Slope extending from about 200 m (656 ft) to over 1,000 m (3,281 ft) depths at the seaward edge of the EEZ; and 5) the oceanic system, comprising pelagic habitats, divided into three broad depth zones—the epipelagic (0–200 m [0–656 ft]), mesopelagic (200–600 m [656–1,969 ft]), and bathypelagic (600 m [1,969 ft] to near the seafloor). Of these five principal habitat categories, the first three correspond directly to the freshwater, estuarine, and shallow marine habitat categories, respectively, used elsewhere in this report. The fourth and fifth principal habitat categories correspond to the oceanic habitat category used elsewhere in this report.

There are two distinct zoogeographic provinces within the Pacific Coast Region, as described by McGowan (1971) and Allen and Smith (1988). The Oregonian Province lies within the Boreal (cold-temperate) Eastern Pacific and is bounded by the Strait of Juan de Fuca, Washington, to the north and Point Conception, California, to the south. The San Diego Province, within the warm-temperate California region, extends from Point Conception, California, south to Magdalena Bay, Baja California Sur, Mexico.

Oregonian Province (Strait of Juan de Fuca, Washington, to Point Conception, California)

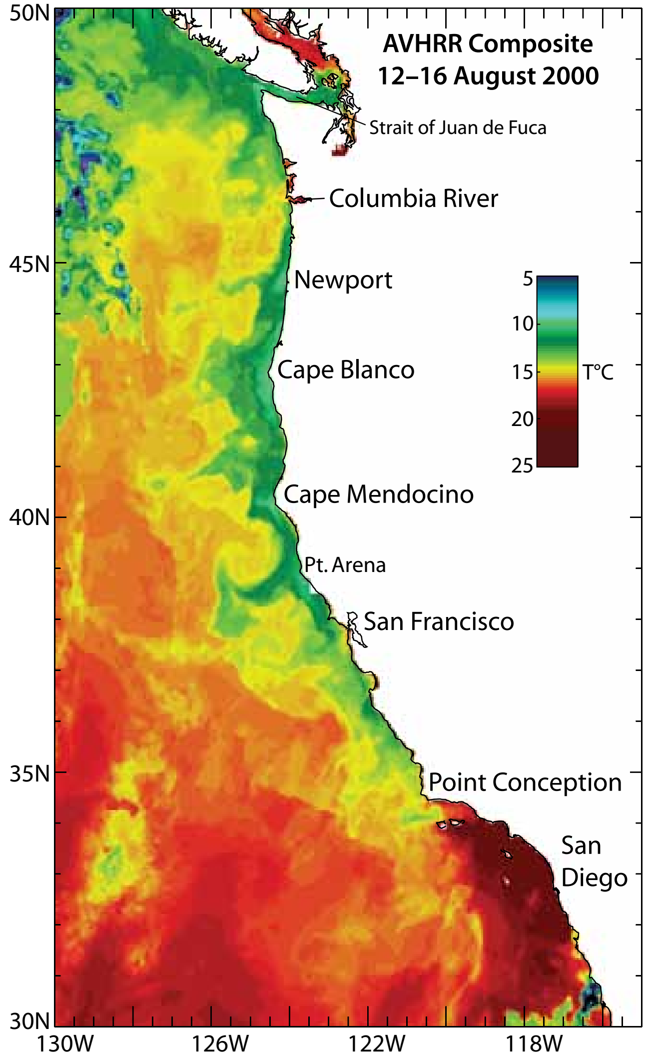
Watersheds in the Oregonian Province drain a diverse geographic area that includes rain forests on the northwest Washington coast, desert and high desert in the interior, and, in some cases, mountains of the interior west. These watersheds contain small (<5 m [<16 ft] wide) tributaries that drain coastal mountains, as well as larger streams. Rivers such as the Sacramento, Klamath, Umpqua, and Columbia drain coastal and interior areas and slopes of the Sierra Nevada (Sacramento River) and Cascade and Rocky Mountains (Columbia River). Thus, the habitats and associated organisms in these freshwater streams and rivers are impacted by natural phenomena and human activities that span much of the Pacific Coast Region.

Three major estuaries and embayments—San Francisco Bay, the Columbia River, and Puget Sound—and several smaller ones (including Gray's Harbor and Willipa Bay, Washington; Yaquina Bay, Oregon; Humboldt Bay, Elkhorn Slough, and Morro Bay, California; and others) are part of this province. Estuarine habitats include mudflats, freshwater and brackish marshes, seagrass beds, and shallow and deep channels. San Francisco Bay is fed by the Sacramento and San Joaquin Rivers, and contains more than half of all wetlands in the Pacific Coast Region. The Columbia River is the largest river on the Pacific Coast and, together with its tributaries, drains 670,000 km^2 (258,688 mi^2). Most estuarine habitats have been significantly altered from historical diking, filling, and dredging, as well as from adjacent farming and other development activities.

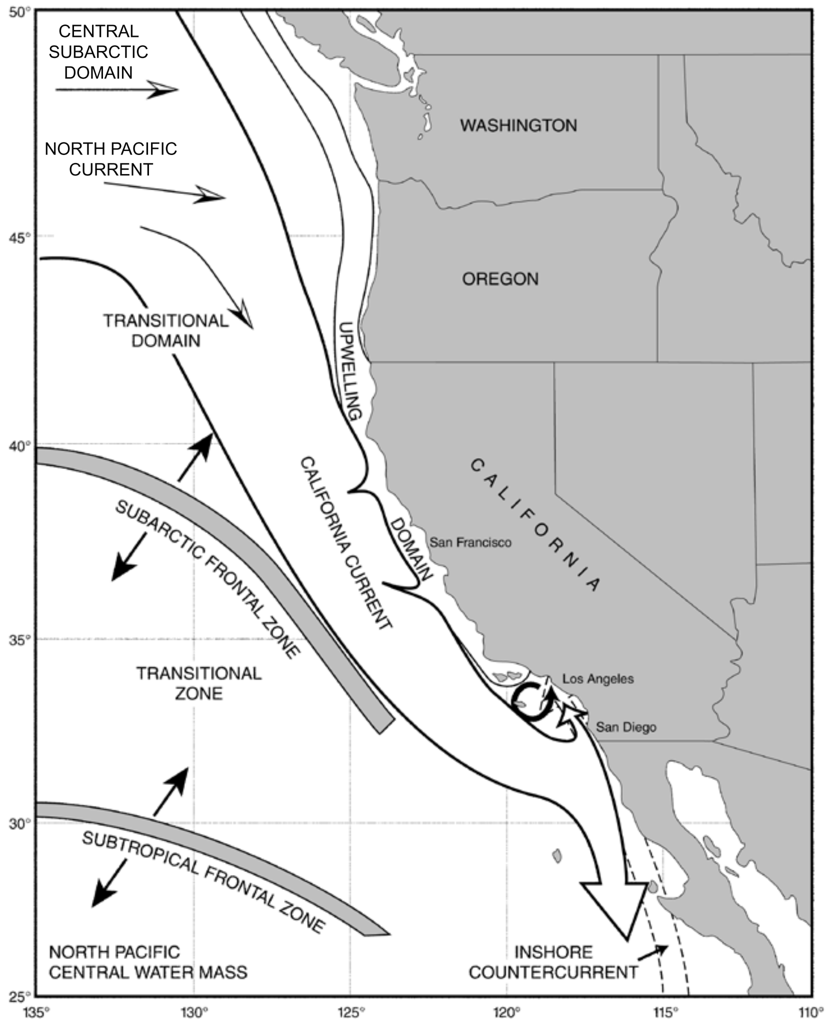
The Continental Margin includes a variety of benthic habitats. Nearshore habitats (intertidal to about 3 km [1.86 mi] offshore) comprise rocky shores and sandy beaches, subtidal rock outcrops, boulders, low-relief sand, gravel and cobble fields, seagrasses, prominent kelp forests, and a few offshore islands. Rocky areas in depths less than 40 m (131 ft) often are covered by extensive kelp beds (giant kelp off southern and central California; bull kelp along the northern California, Oregon, and Washington coasts). Kelp beds and other marine algae in rocky areas provide structural habitat for many species and life stages occurring from the seafloor to the sea surface. Such rock-kelp areas are greatly affected by strong currents, storm waves, and freshwater runoff and thus can undergo dramatic seasonal and interannual changes. Surfgrass is another structure-forming habitat that occurs on rocky substrates. Flowering seagrasses use dense rhizomes to attach to rocks in high-energy intertidal and subtidal zones. Threats to this habitat, which often is slow to recover from disturbance, include shoreline armoring (physical structures that protect the shoreline from coastal erosion), dredging, and disposal of dredge material. The nearshore area continues to be the focus of increased human activities for energy development, sand management operations, commercial and recreational harvest of fish and shellfish, water quality and runoff problems, recreational boating and diving, and research and educational programs.

Seaward of 3 km [1.86 mi] from shore, Continental Shelf habitats include patchy distributions of rock outcrops, pinnacles, and boulder fields surrounded by low-relief sand, mud, and cobbles. Other than a few notable offshore rocky banks (e.g. Heceta Bank, Cordell Bank, Farallon Islands), however, the vast majority of bottom on the Continental Shelf is composed of sand and sandy mud sediments. All of these Continental Shelf habitats have long been targeted by large commercial and recreational fisheries. The offshore Continental Slope habitat is largely expanses of muddy sediment interspersed with hills and gullies, and rock outcrops with scattered boulders. Several submarine canyons (e.g. Astoria Canyon and Monterey Canyon) and large banks (e.g. Heceta Bank and Cordell Bank) are part of the shelf and slope systems. Submarine slumps and landslides continually modify the morphology of the slope. Certain segments of the margin are characterized by venting of fluids, and in some cases include extensive deposits of gas hydrates. These "cold seep" areas harbor unique chemosynthetic biological communities. All of these benthic habitats on the Continental Margin include an important biogenic component comprising many structure-forming macroinvertebrates such as corals, sponges, and brittle stars, among others.

Seaward of the slope are the expansive areas that underlie the oceanic habitat of the California Current, and include complex deepwater habitats at depths of 2,500–4,000 m (8,202–13,123 ft) and beyond: plains, channels, hills, sedimentary fans, volcanically active ridges, and seamounts. The most conspicuous bathymetric features are seamounts, escarpments, and ridges. There are at least six seamounts and seamount groups within the EEZ, with



Satellite sea-surface temperature of the California Current System, August 2000 (modified from Checkley and Barth, 2009).



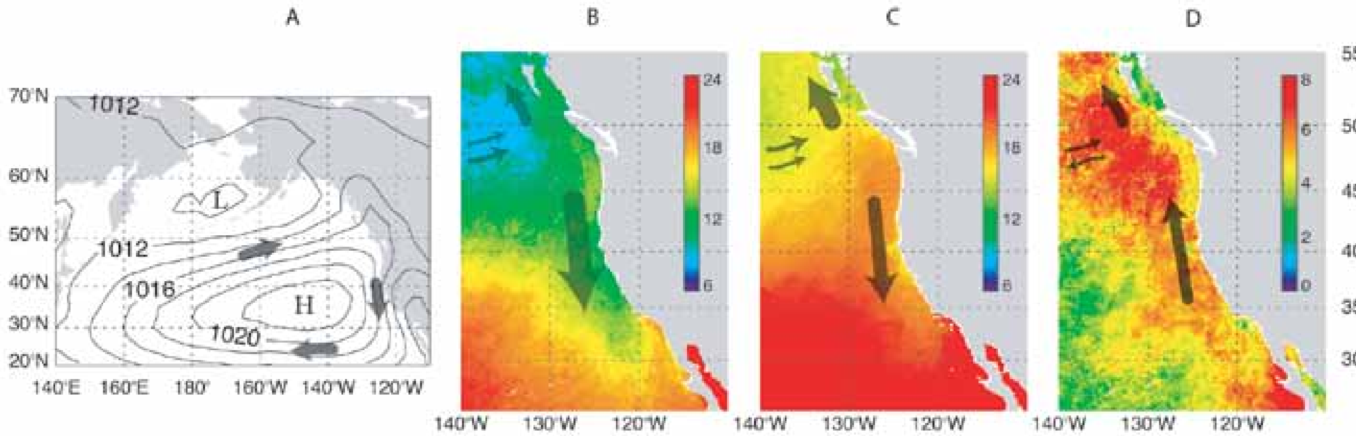
A schematic of the primary ocean currents off the Pacific Coast (modified from PFMC, 2003).

depth of summits ranging from 770 m (2,526 ft) for Pioneer Seamount off San Francisco to 2,229 m (7,313 ft) for Tanney Seamount off Monterey Bay, California. There are an additional seven seamounts located just outside the EEZ of the Oregonian Province boundary. The Gorda and Juan de Fuca Ridges, extending from northern California to Washington, also are significant physiographic features of the Oregonian Province. These two ridges are seafloor-spreading centers—sites where submarine volcanism brings hot magma to the surface of the seafloor and where hydrothermal vents (hot springs) are common. The hydrothermal fluids support unique biological communities that derive chemical energy independent of sunlight.

Oceanic habitat in the Oregonian Province includes coastal and offshore waters that are dominated by the eastern boundary current complex known as the California Current System. Oceanic habitat of the Oregonian Province also includes one of the major coastal upwelling areas of the world, where waters brought up from the bottom by wind-driven currents provide a relatively nutrient-rich environment and high densities of forage for marine species. This area is influenced by various currents and water masses, the shifting nature of which affects the occurrence and distribution of species at particular times of the year and from year to year. Diverse bathymetric features such as headlands, submerged pinnacles, submarine canyons, seamounts, and coastal islands also influence current patterns and concentrations of economically valuable species and their prey.

Large-scale currents within this area include the surface-flowing California Current and inshore countercurrent (Davidson Current), and the subsurface California undercurrent. Water masses within this oceanic system generally include three types: Pacific Subarctic, North Pacific Central, and Southern (or Subtropical Equatorial). Pacific Subarctic water, characterized by low salinity and temperature and high oxygen and nutrients, is advected equatorward along the coast by the California Current. North Pacific Central water, characterized by high salinity and temperature and relatively low oxygen and nutrients, enters the system from the west. Southern water, characterized by high salinity, temperature, and nutrients, and low oxygen, enters the system from the south. The California Current forms the eastern limb of a large clockwise circulation pattern in the North Pacific Ocean. The cold, low-salinity water of the California Current dominates much of the EEZ. Its position and intensity change seasonally and from year to year, with shifts in the southeastern extension of the Subarctic Frontal Zone (California Front). Shoreward it mixes with plumes of cold, more saline upwelled water in the north, or warm countercurrent and gyre water of the Southern California Bight in the south.

Further offshore, the California Current mixes with the oceanic waters of the Transition Zone. The Transition Zone lies between the Subarctic and Subtropical Fronts, separating the Subarctic Water Mass and North Pacific Central Water Mass. During the winter and spring, westerlies in the northern portion of the Transition Zone and



Schematic of California Current atmospheric forcing and ocean circulation during normal and El Niño conditions: A) mean summer North Pacific atmospheric pressure, dominated by the North Pacific High and Aleutian Low, and surface wind forcing; B) typical sea surface temperatures (SST) and ocean transport patterns; C) SST and transport during El Niño periods; D) the anomaly in SST and transport, showing the impacts of El Niño. Figure adapted from Strub and James (2002).

trade winds to the south create convergent fronts where colder, denser water from the north meets warmer, less dense water from the south.

Physical oceanographic features of the Oregonian Province change seasonally, as well as during interannual oceanographic and atmospheric El Niño and La Niña events and during periods of large scale, interdecadal climate regime shifts. The California Current generally flows southward year round, with strongest flows in spring and summer. Inshore, these flows may be reversed by the seasonal appearance in fall and winter of the surface, poleward-flowing Inshore Countercurrent, and locally by spatial gradients in wind-stress forcing and coastal topographic effects. The California Undercurrent intensifies, primarily in late spring and summer, as a narrow ribbon of northward flow, which presses against the Continental Slope at depths of 150–300 m (493–984 ft) beneath the upper layers that flow equatorward. Beneath the undercurrent and extending to depths >1,000 m (>3,281 ft), there occurs a layer where oxygen concentrations are naturally and consistently low. This feature is called the oxygen minimum zone (OMZ), where oxygen concentrations are less than 22 μmol/kg (0.5 mL/L). Every few years, this oxygen-depleted water mass is advected up and onto the Continental Shelf, creating "dead zones" that kill those organisms unable to move to more-oxygenated waters. Coastal upwelling of cold, salty, and nutrient-rich water to the surface occurs primarily in spring and summer in California and into early fall off Oregon, driven by prevailing seasonal winds. Upwelling often is most intense near promontories such as Cape Mendocino and Point Conception. During most El Niño events, ocean and atmosphere forcing, linked to tropical conditions, leads to an anomalously weak California Current transport and an anomalously strong California Undercurrent, which combine to produce a reduced southward transport (northward anomaly). These factors also generally result in weaker than normal upwelling and an upper water column that is anomalously warm and low in nutrients, and relatively unproductive. Climate variability also exhibits considerable multidecadal variability in the system, with alternating periods of warm and cool ocean temperature (Parrish et al., 2000; Peterson and Schwing, 2003). The cooler climate regimes are associated with higher biological production.

The coastline in the northern part of the Pacific Coast Region is relatively unprotected from the force of the sea and prevailing northwest winds, and rugged water and sea state conditions are common. During much of the year, the coastal waters off central Oregon are under the influence of the eastern portion of the eastward-flowing North Pacific Current or West Wind Drift. This current has a moderating influence on coastal temperatures during the summer, when sea surface temperatures may be several degrees warmer off northern Oregon and central Washington than to the north, off British Columbia. Sea surface temperatures during summer are colder off northern and central California because upwelling-favorable winds are stronger in that area. Year-to-year differences in the trajectory and strength of the North Pacific Current, due to global climate variability, create substantial shifts in ocean temperature and nutrient concentrations along portions of the coast (Parrish

The Southern California Bight extends from Point Conception to San Diego, California.

et al., 2000). In this region, the Columbia River's freshwater plume also has a considerable effect on oceanographic features along the northwest coast. The plume flows poleward over the shelf and slope in fall and winter, and equatorward as much as 300–400 km (186–249 mi) offshore of the shelf in spring and summer, extending its influence as far south as Cape Mendocino, California. In late summer, the Columbia River contributes 90% of the fresh water entering the sea between the Strait of Juan de Fuca and San Francisco Bay.

San Diego Province (Point Conception, California, to Baja California Sur, Mexico)

Although the coastline is relatively straight between the Strait of Juan de Fuca, Washington, and Baja California, Mexico, a large bend occurs from Point Conception to San Diego. This bathymetrically complex region is known as the borderland of the Southern California Bight, and differs dramatically from areas to the north and south. The Continental Shelf generally is very narrow, but widens in some areas of the Bight and includes several offshore islands (e.g. the Channel Islands). A series of undersea ridges and deep basins (e.g. Catalina Basin, 1,326 m [4,350 ft] deep; San Nicholas Basin, 1,795 m [5,889 ft] deep) also defines the bathymetry of the Bight. Dissolved oxygen concentrations are reduced in the deep basins; in one case (the Santa Barbara Basin, 613 m [2,011 ft] deep), anoxic conditions persist for extended periods, interrupted by flushing events during periods of intense upwelling.

A portion of the California Current turns in a counterclockwise gyre south of Point Conception. This feature is called the Southern California Countercurrent during years when the northward flow rounds Point Conception, or the Southern California Eddy when the flow recirculates within the Southern California Bight. The ocean generally is warmer and more protected here than in areas to the north, especially inshore of a line roughly drawn from San Miguel Island to San Clemente Island.

Compared to the large river-dominated systems to the north, there is little continuous freshwater input in the southern part of the Pacific Coast Region. Only a few relatively small bays, lagoons, and estuaries occur in this southern area, with the exception of San Diego Bay, which is the third largest California bay after San Francisco Bay and Humboldt Bay. Estuarine habitats are thus limited in area, but include mudflats, freshwater and brackish marshes, seagrass beds, and shallow and deep channels. Eelgrass, found in shallow coastal environments along the entire West Coast, provides a variety of habitat functions. Eelgrass is an important structural component of this environment, serving as refuge from predation and as nursery habitat for a variety of commercially and recreationally valuable finfish and shellfish. Eelgrass also contributes primary and secondary production to the ecosystem, and improves water clarity, nutrient cycling, and sediment stabilization (which can reduce erosion). Approximately 50% of the eelgrass resources in Southern California are located within San Diego Bay.

The coastal shelf system includes a variety of inshore benthic habitats, including rocky shores and sandy beaches, subtidal rock outcrops, pinnacles, boulders, low-relief sand and cobble fields, prominent kelp forests, seagrasses, and many

R.V. Schwemmer, NOAA Channel Islands NMS

Anacapa Island, a member of the Southern California Bight's Channel Islands archipelago, provides a diverse range of habitats for both terrestrial and marine plants and animals.

offshore islands. Offshore benthic habitats largely consist of expansive mud fields interspersed with rock outcrops and scattered boulders. Several submarine canyons, large banks, and seamounts are part of the shelf and slope systems in this part of the Pacific Coast Region. Structure-forming macroinvertebrates represent an important biogenic component of all benthic habitats of the San Diego Province, just as they do in the Oregonian Province.

In addition to the natural habitats in this area, there are numerous artificial reefs on the shallow sand shelf, and 26 oil and gas platforms located in water depths from 11 to 363 m (36 to 1,191 ft) (Love et al., 2003). Such anthropogenic structures represent complex habitats with relatively high vertical relief, support a diverse assemblage of fishes and macroinvertebrates, and contribute to local (and perhaps regional) fish production. Some of these platforms and artificial reefs could serve as de facto marine protected areas, depending on the degree to which fishing is restricted around these structures. Additionally, high densities of young rockfishes are associated with some of these structures, indicating that they function as nurseries for some species. However, there also has been some concern that oil platforms and other artificial structures may concentrate fish at the expense of populations on natural reefs.

HABITAT USE

This section describes habitat use by those species found in the Pacific Coast Region that are managed by NOAA's National Marine Fisheries Service (NMFS) under fishery management plans (FMPs) or as protected species under the Marine Mammal Protection Act (MMPA) and/or the Endangered Species Act (ESA) in cooperation with state authority or by international commission.

There are four FMPs within the Pacific Coast Region: 1) Pacific Coast Salmon (some salmon, including steelhead trout, also are protected under the ESA or managed by the states); 2) Coastal Pelagic Species (krill, market squid, Pacific sardine, Pacific or chub mackerel, northern anchovy, and jack mackerel); 3) Highly Migratory Species (tunas, sharks, billfish, and dolphinfish); and 4) Pacific

Table 11
Typical use of the four major habitat categories in the Pacific Coast Region, summarized by FMP and protected-species groups of cetaceans, pinnipeds, and sea turtles.

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

Fishery management plans [a]	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
1. West Coast Salmon [b]	F	F	F	F
2. Coastal Pelagic Species	N	O	F	F
3. West Coast Highly Migratory Species	N	O	F	F
4. Pacific Coast Groundfish [b]	N	F	F	F
Total percentage of all Pacific Coast FMPs with one or more species that use each habitat type	25%	100%	100%	100%
Protected species groups [a]				
Cetaceans	N	O	F	F
Pinnipeds	O	F	F	F
Sea Turtles	N	F	F	F
Total percentage of all Pacific Coast cetacean, pinniped, and sea turtle groups that use each habitat type	33%	100%	100%	100%

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

[b] Some of these species are managed as protected species as well as under an FMP.

Coast Groundfish (rockfishes, flatfishes, sablefish, hake, lingcod, some sharks, and others). These FMPs are the responsibility of the Pacific Fishery Management Council (PFMC) acting on behalf of the Federal Government (NMFS) in managing fishery resources within the U.S. EEZ.

NMFS manages most of the Region's marine mammals (cetaceans and pinnipeds), all of which are covered by the MMPA and some of which are listed under the ESA. The U.S. Fish and Wildlife Service manages the southern sea otter, which is not discussed in this report. Sea turtles, white and black abalone, green sturgeon, steelhead trout, Pacific eulachon, and bocaccio, yelloweye, and canary rockfishes in Puget Sound and Georgia Basin are managed in this Region by NMFS under the ESA. Nearshore species occur in estuarine and/or marine coastal habitats, typically from the intertidal zone to the 5.6 km (3 nautical mile [nmi]) boundary of state waters. Some nearshore species are not managed as part of federal FMPs or as protected species, but rather are the responsibility of the coastal states, with cooperation from NMFS. Pacific halibut are managed by the International Pacific Halibut Commission (IPHC).

Table 11 provides a summary of typical habitat-use patterns in the Pacific Coast Region, organized by FMP and protected-species groups of cetaceans, pinnipeds, and sea turtles (managed by NMFS). The table shows patterns of typical use for one or more species within each group. However, it is important to recognize that these groups include many species, all of which have unique habitat requirements by life stage. Habitat information is lacking for many Pacific Coast species, particularly in the earlier life stages, and such critical information gaps are not captured in this table.

Out of the Pacific Coast's federally managed and protected species, only salmon, and occasionally some pinnipeds (harbor seals), use freshwater habitats. Estuarine, shallow marine, and/or oceanic habitats are all frequently used by at least some species within each of the four FMP groups and by some cetaceans, pinnipeds, and sea turtles. Specific patterns of habitat use depend on species and life stage. Information on habitat-specific productivity is not available for even the most common federally managed and protected species. Habitat-specific growth, reproduction, or survival rates for even one of the habitat categories are available for only a few species and life stages. This lack of detailed information on habitat use is a major source of uncertainty in terms of understanding species-habitat relationships.

Habitat Use by FMP Species

Pacific Salmon—Pacific salmon are managed by several entities. The federal FMP focuses mainly on Chinook salmon, coho salmon, and the Puget


Todd Bennett, NMFS

Spawning pink salmon holding in a pool in Bacon Creek, Washington. Note the clean gravel in the riverbed that is clear of mud and silt. This is a requirement of habitat suitable for egg laying.

Sound stock of pink salmon. State and tribal governments, the Pacific States Marine Fisheries Commission, and NMFS work together to help manage and protect stocks of Pacific salmon (e.g. chum salmon, sockeye salmon) and steelhead trout listed under the ESA. Given the general similarity in habitat use among different species and stocks of Pacific salmon and steelhead trout, their habitat-use patterns will be discussed together.

Pacific salmon are anadromous, spawning in fresh water and migrating to sea, where they live from 6 months to 5 years before returning to their natal (home) streams to spawn. Pacific salmon spawn in streams from near tidewater to more than 3,200 km (2,000 mi) inland and have developed diverse life history traits within and among species to exploit various freshwater habitats. Salmon historically inhabited three-fourths of the streams of Washington and Oregon, much of Idaho, and almost all coastal watersheds in California. Their range encompasses ecosystems from sparsely vegetated deserts and semi-arid lands in the interior Columbia watershed, Sacramento–San Joaquin Valley, and southern California to the rainforests of the coastal Pacific Northwest. Hydrology in these streams is highly variable, ranging from rain-dominated systems on the coast to those dominated by snow melt in the interior and mountainous regions. Ocean migrations of some Pacific salmon are very extensive, ranging from estuarine and coastal waters to the eastern Pacific and Bering Sea.

Pacific salmon use a variety of streams, wetlands, lakes, and other freshwater habitats for spawning and rearing. The various species of Pacific salmon have different patterns of habitat use. For example, species such as steelhead trout and Chinook salmon may spawn hundreds of kilometers inland in mountain streams, while chum salmon and pink salmon typically spawn in low-gradient stream reaches near tidewater. Salmon build nests (called redds) and deposit their eggs in clean gravel and cool water with high levels of dissolved oxygen. Juvenile salmon migrate downstream to the marine environment after spending a few weeks to several years in fresh water.

Use of estuarine habitat by Pacific salmon also varies dramatically within and among species. For example, Chinook salmon, cutthroat trout, and chum salmon may spend from just a few weeks to several months in the estuary, while juvenile steelhead trout, sockeye salmon, and pink salmon spend little time in estuaries. While some salmonids spend only a short time in the estuaries, it may be a critical time in their life cycle. Juveniles and adults depend on estuaries for migration and physiological transition between fresh water and salt water. Juveniles also use the estuary for foraging and growth and as a refuge from predators.

The distribution of juvenile Pacific salmon is predominantly within the U.S. EEZ. Juvenile Chinook salmon and coho salmon, in particular, are found in highest abundance within coastal waters along the Continental Shelf, but some portions of these populations migrate into the Gulf of Alaska where they mature. Sockeye salmon, pink salmon, and chum salmon migrate northward through coastal waters, but spend much of their time after their first summer beyond the EEZ in the open ocean of the North Pacific, Gulf of Alaska, or even the Bering Sea. In contrast, juvenile steelhead trout generally migrate directly to the open ocean and do not follow the coastal route as the other salmonids do. Less is known about the offshore habitats of adult salmon, especially in the winter, but they inhabit a large part of the Subarctic North Pacific. Areas of increased upwelling, such as the Continental Shelf, offshore islands, banks, and submarine canyons, can be particularly productive regions and important feeding areas for salmon.

NMFS

NMFS SWFSC

Top photo: krill are small crustaceans closely resembling shrimp. Lower photo: jack mackerel in a tight school.

Coastal Pelagic Species—The Coastal Pelagics FMP includes species such as krill, market squid, Pacific sardine, Pacific mackerel, northern anchovy, and jack mackerel. In addition to being important as harvestable species, many of the small coastal pelagics represent an important forage base for other federally managed fishes, protected species (e.g. cetaceans), and seabirds. Only very general descriptions of Essential Fish Habitat (EFH), such as temperature ranges, have been compiled for small pelagics. Krill (euphausiids), shrimp-like crustaceans approximately 2.5 cm (1 in) in length, are a good example of such a forage species, and they have only recently been included in the Coastal Pelagic Species FMP. Krill graze on microscopic plants and animals and form a critical trophic link in marine food chains throughout the world's oceans. Two species of krill, *Euphausia pacifica* and *Thysanoessa spinifera*, are most common in the diets of higher trophic level predators. *Euphausia pacifica* are distributed in Continental Slope waters around the Pacific Rim, from central Baja California north to Alaska, across the Pacific and south to the Yellow Sea (between Korea and China). They are also found in oceanic waters across the North Pacific Ocean, north of approximately latitude 40° N. *Thysanoessa spinifera* are found only in Continental Shelf and Slope waters of the eastern North Pacific, from central Baja California to the Gulf of Alaska. There are an additional 25 less-common krill species that occur in the eastern North Pacific off the U.S. West Coast. The distribution of each krill species is strongly influenced by a combination of factors that include oceanographic features and conditions, food availability, and seafloor topography. Some species show affinities for cold oceanic or shelf waters, while others are associated with warmer subtropical waters, the latter being more available during warm-water El Niño years. A number of krill species exhibit daily vertical migrations from daytime depths of 180–400 m (600–1,300 ft) to the surface at night (Brinton and Townsend, 2003; PFMC, 2006).

Market squid range from Baja California to southeastern Alaska. The habitat of market squid extends from the shoreline to 160 km (100 mi) offshore. Market squid is an unusual coastal pelagic species, because it spawns on the seafloor and lives less than 1 year. Mature squid form large spawning aggregations in nearshore waters. Female squid deposit capsules containing 200–400 eggs on clay and silt sediments at 10–70 m (33–230 ft) depths. Squid spawn only once in their lifetime, dying soon after spawning. The eggs incubate for 4–6 weeks, depending on temperature. After hatching, paralarvae rise into the water column and remain entrained within the nearshore water mass, where currents are dominated by tidal flow. After 2–3 months, the squid begin to form schools and disperse into more offshore waters. Paralarvae, juveniles, and adults use the neritic zone (water overlying the Continental Shelf) to forage for prey.

The Pacific sardine is found in two distinct habitats of the Pacific Coast Region. The nearshore habitat from Baja California, Mexico, to Central California is occupied by spawning adults in the summer as well as by young-of-the-year during most of the year. The other habitat, offshore in the California Current along the entire coast of North America, is occupied by sardines at spawning time in April, and also while this species migrates to a northern boreal feeding zone that ranges from

Oregon to Alaska. Most life stages of sardine occur in coastal state waters over the Continental Shelf and Slope as well as beyond the EEZ. Habitat data range from information on species distribution, to species density or abundance estimates by habitat, to information on growth, reproduction, and survival rates within habitats. The latter is restricted to the Southern California Bight, where California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys have been conducted since 1985.

The Pacific mackerel mainly occurs nearshore, but also is found outside the EEZ within the California Current. Pacific mackerel spawn in the warmer waters of Baja and southern California and migrate to British Columbia and southern Alaska (54.5° N) to feed. Habitat-specific distribution (presence/absence) data is the primary type of information available for this species.

The Northern anchovy commonly is found in the inshore waters of the California Current system over the Continental Shelf and Slope. Most anchovies inhabit southern and central California waters and are not found beyond the EEZ. Information on habitat-specific growth, reproduction, and survival rates of northern anchovy is available for the period 1979–85, and absolute instantaneous spawning biomass of this species has been estimated. Currently, anchovy biomass is only crudely estimated as larval and egg indices, with no population assessments conducted systematically. Other anchovy populations occur in the nearshore of the Pacific Northwest as far as latitude 51° N, and off southern Baja California, Mexico.

The principal biomass of jack mackerel occurs in the open ocean outside the EEZ, from Guadalupe Island, Mexico, to the base of the Aleutian Island chain in Alaska. They are found seasonally in the south, and spawn and migrate to the north through the spring and summer. The young are found in nearshore shoal waters of rocky coastlines, and the pre-recruits school with anchovy, sardines, and Pacific mackerel of similar swimming ability. After rapid growth nearshore, they reinhabit and spawn in the offshore areas of the entire North American coast. Habitat-specific distribution (presence/absence) data are the primary type of information available on this species.

Highly Migratory Species (HMS)—Most tunas, swordfish, marlin, and pelagic sharks in the Pacific Coast Region occur in offshore, oceanic island, and bank habitats, although some species, like young common thresher sharks, also may use habitat in nearshore and estuarine waters, where there is an abundance of schooling prey. Most HMS occur predominantly in epipelagic (near the surface) waters, with occasional, infrequent forays into the deeper mesopelagic zone. Bigeye tuna and bigeye thresher[2] are exceptions, spending significant amounts of time in the mesopelagic zone. Temperate-water species such as albacore, swordfish, common thresher shark and, to some extent, northern bluefin tuna, occur regularly within the region on a seasonal basis. Many HMS associate with the northerly portion of the Transition Zone that extends across the Pacific, where a front is located at the boundary between the low-chlorophyll subtropical gyres and the high-chlorophyll subarctic gyres. Areas of convergence along this chlorophyll front concentrate phytoplankton and other organisms (shrimp, squid, and other fishes), which serve as forage for higher trophic level predators such as albacore, bluefin tuna, swordfish, marlin, and shortfin mako and blue sharks. Some of the more tropical species, such as the skipjack and yellowfin tunas, pelagic thresher shark, dolphinfish and striped marlin, use habitat in the Pacific Coast Region mostly during warm-water El Niño events. The quality of habitat information ranges from distribution (presence/absence) to habitat-specific density data, though

Mark Conlin / NMFS

A mako shark that has just been tagged near the Channel Islands off the California Coast.

[2]Note that bigeye thresher and pelagic thresher sharks are no longer managed in the HMS FMP, and have been reclassified by the PFMC as ecosystem component species.

many data gaps in habitat-use information exist for various life stages of these species.

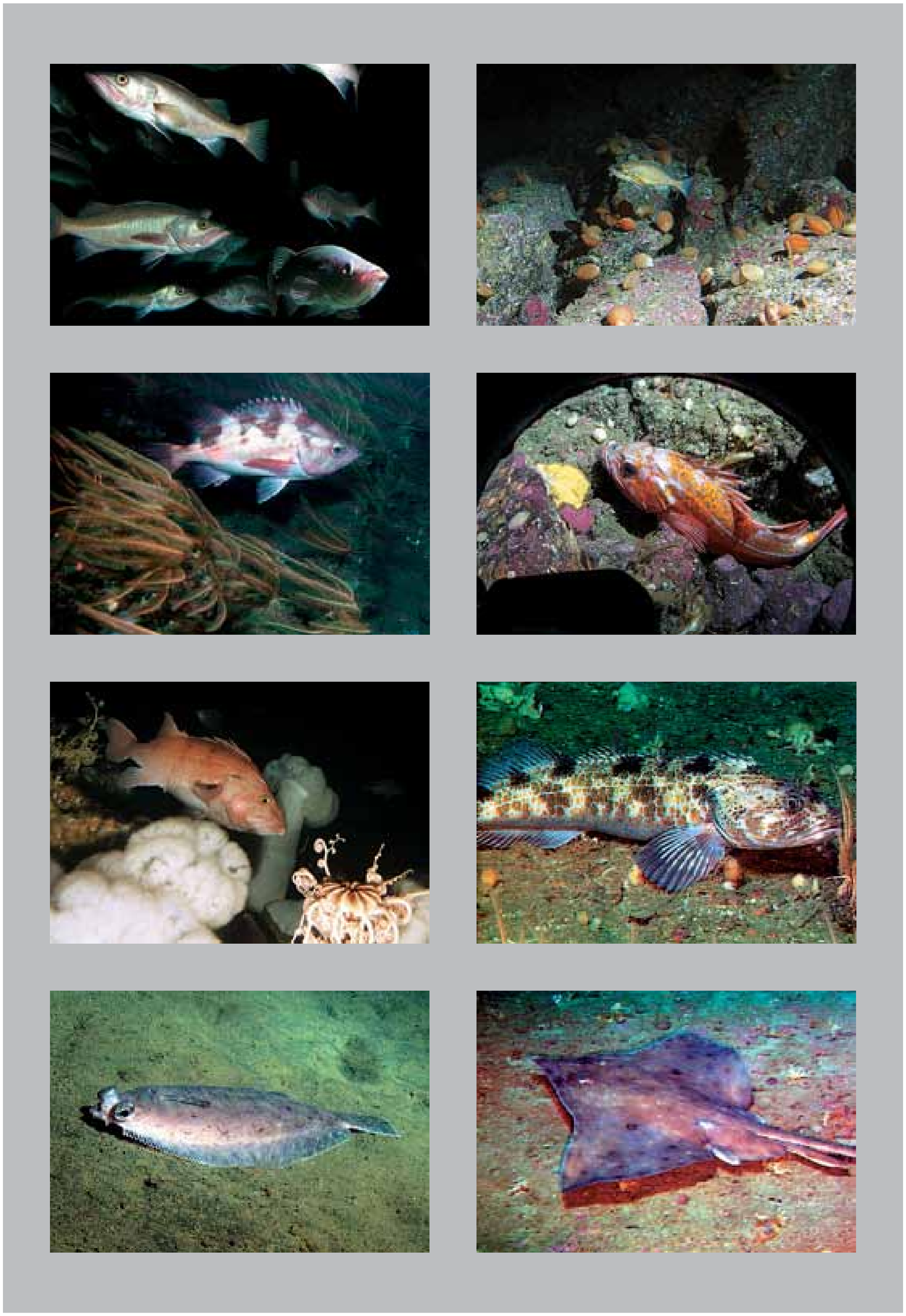
Pacific Coast Groundfish—The PFMC's FMP currently covers 91 species of commercially important groundfishes, including 64 species of rockfishes, 12 species of flatfishes, 7 elasmobranch species of sharks, skates, and chimaeras, and 8 species of various other groundfishes. Groundfish species occupy diverse habitats during all stages in their life histories. In general, species diversity is greatest off southern California, and diminishes to the north and south. Species diversity also is greatest in complex rock habitat and in deep (>30 m [>100 ft]) water on the shelf, but diversity diminishes with increasing depth down the Continental Slope.

Many of these species, particularly some of the rockfishes, can dominate coastal benthic habitats from subtidal kelp forests, to rock outcrops in submarine canyons at depths >200 m (>656 ft), to low-relief mud fields on the shelf and slope in depths >2,800 m (>9,186 ft). Eggs, larvae, and young juveniles of many of the groundfish species are epipelagic and may disperse widely in coastal waters. Settlement of juveniles for many of these species occurs in relatively shallow water, with movement to deeper habitats as the fish develop. A few groundfish species use bays and estuaries as nursery and spawning grounds. The adults of most species of rockfishes are associated with complex (e.g. rock ledges, crevices, cobble and boulder fields, shell debris) or vertical (e.g. rock pinnacles, kelp, macroinvertebrates, or artificial structures) habitats. Flatfishes and adult sablefish primarily are associated with low-relief sand and mud habitats. Hake and some rockfish species are considered to be semi-pelagic, and aggregate in large numbers. Hake are the most migratory groundfish species. They spawn in late winter off southern California and then disperse along the shelf and upper slope from San Francisco to the Queen Charlotte Islands in British Columbia, Canada. Older hake move the furthest north and the extent of northern movement is greatest during El Niño events. Several species of groundfish (e.g. sablefish, shortspine thornyhead, and Dover sole) inhabit the Continental Shelf and shelf break as juveniles and young adults, and make protracted migrations to the upper slope (600–1,200 m [1,969–3,937 ft]) and deeper into the oxygen minimum zone as they age.

Until recently, surveys of benthic marine habitats and associated groundfishes largely were limited to subtidal (<30 m [<100 ft] water depth) observations, and yet most of these species and their fisheries occur in deeper water. Assessing habitat attributes on scales pertinent to groundfish distributions and ecological issues is especially difficult in deepwater marine environments because of restricted access to this system. For two decades, NMFS researchers have been developing new tools, technologies, and partnerships to characterize deepwater fishes and habitats in the Pacific Coast Region. Coupling geophysical techniques of mapping the seafloor with observations made from a variety of underwater vehicles now has made the assessment of fish and their habitats in deep water more feasible nationwide. This approach addresses goals to describe and conserve EFH, identify areas in need of additional protection, improve assessments of groundfish populations, and evaluate ecological effects of fishing.

Currently there are several efforts underway to create comprehensive and easily accessible maps of seafloor habitats for the Pacific Coast Region. These maps are facilitated by the development of a unifying seafloor classification system for benthic habitats (Greene et al., 1999, 2007). Maps and underlying georeferenced databases are critical elements in the identification of EFH for West Coast groundfishes, in comparative risk assessments of anthropogenic impacts (e.g. fishing gear, pollution, dredging, etc.) to these habitats, and in designing and monitoring effective marine protected areas.

These maps are a first step in describing, quantifying, and understanding benthic habitats throughout the entire range of groundfish species in the Pacific Coast Region. These databases and maps comprise varying levels of data quality and verification, and it is absolutely imperative that they be revised as new information is collected. Currently, detailed mapping of groundfish habitat has been accomplished in a few important areas, such as state waters (100% coverage for California, and 50% for Oregon), some offshore banks of the Southern California Bight, and Heceta Bank, Oregon, and is slowly being extended to other areas of the Pacific Coast Region. Habitat data for the diverse groundfish group range from distribution (presence/absence) to habitat-specific densities for some commercial species.



Mary Yoklavich and Waldo Wakefield, NMFS

Representation of habitats for groundfishes off the U.S. West Coast of California and Oregon. Clockwise from the upper left corner, the fish species are bocaccio, squarespot rockfish, vermilion rockfish, lingcod, longnose skate, Dover sole, cowcod, and darkblotched rockfish. The images were collected from ROPOS, a remotely operated vehicle (ROV), and from the *Delta* submersible.

A pair of large blue whales, each nearly 30 m (100 feet) in length, pause at the surface before diving at the Cordell Bank National Marine Sanctuary.

Habitat Use by Protected Species

Marine Mammals—The Pacific Coast Region supports a wide variety of temperate and subtropical marine mammal species that are managed by NMFS, including about 30 species belonging to the order Cetacea (whales, dolphins, and porpoises) and six species of the order Carnivora (pinnipeds, more commonly known as seals and sea lions). Several large whale species, including blue, fin, sei, humpback, sperm, and North Pacific right whales, are listed as endangered under the ESA because of historical over-exploitation by whaling operations in the North Pacific. One very small population, the southern resident killer whale, is listed as endangered. Although pinnipeds were exploited heavily in historic times and many populations were reduced to very low levels, most populations have rebounded and presently are either increasing or stable. Under the MMPA, a marine mammal stock can be further categorized as "strategic" if human-caused mortality exceeds the potential biological removal level, if the stock is listed as endangered or threatened under the ESA, if the stock is declining and likely to be listed as threatened under the ESA, or if the stock is designated as depleted. In the Pacific Coast Region, several marine mammal stocks have been determined to be strategic, including beaked whales, short-finned pilot whales, and larger whales (including blue, humpback, and sperm whales); however, measures to reduce human-caused mortality have successfully been implemented in most of these cases.

- **Cetaceans**

  About 30 cetacean species are known to regularly inhabit the Pacific Coast Region. They comprise a diverse taxonomic group, including dolphins (nine species), porpoises (two species), sperm whales (three species), beaked whales (eight species), and baleen whales (eight species). Cetaceans of the Pacific Coast Region are known to forage widely on fish and invertebrates in coastal, offshore, and bank habitats. Some species, such as bottlenose dolphins, are occasionally found in estuarine habitats, but cetaceans are almost never found in freshwater systems along this coast. Their habitat-specific distribution and abundance vary by season and year as oceanographic conditions change. Several species undergo long migrations (hundreds to thousands of kilometers), and use available habitats for seasonal foraging or migrations. Many cetaceans in this Region can be divided into temperate species (e.g. Dall's porpoise, northern right whale dolphin) or subtropical species (e.g. short-beaked and long-beaked common dolphins, Risso's dolphin). Some species inhabit waters over the Continental Shelf and Slope (e.g. humpback whales, harbor porpoise), whereas others are primarily found in deeper, offshore waters (e.g. beaked whales, sperm whales). With the exception of the sperm whale, which shows latitudinal differences in the distribution of males and females with offspring, cetaceans are not known to exhibit different distributions by life stage or gender. Their habitat use largely is influenced by dynamic oceanographic and biological processes, which in turn determine the abundance of prey resources. Although a few species (e.g. blue whale) are specialists and exploit patches of their primary prey wherever they can locate large concentrations, many other species (e.g. Pacific white-sided dolphin and common dolphins) are opportunistic and will feed on a wide variety of species in several habitats.

- **Pinnipeds**

  Six species of pinnipeds inhabit the Pacific Coast of California, Oregon, and Washington. They use island and mainland habitats for breeding and molting, and they forage widely in freshwater, estuarine, coastal, offshore, and bank habitats. Unlike cetaceans, pinnipeds exhibit different habitat-use patterns by gender and age. Adults of both genders come together at the breeding rookeries on coastal islands and some mainland sites, whereas males of several species forage more widely than juveniles and females. Sea lions primarily forage in coastal and offshore habitats, but will also feed opportunistically in estuarine and freshwater systems. Elephant seals and two species of fur seals, the northern fur seal and the Guadalupe fur seal, forage widely throughout offshore areas of the North Pacific, including some bank habitats. Harbor seals represent the most coastal pinniped species in the Region, foraging and breeding exclusively in coastal, estuarine, and some freshwater habitats.

Offshore islands such as Año Nuevo on the central California coast offer relatively predator-free habitat for many breeding pinniped species.

Sea Turtles—Four species of sea turtles, the loggerhead, olive ridley, green, and leatherback, are found in the Pacific Coast Region. Sea turtles migrate from tropical nesting beaches in other regions of the Pacific to forage in offshore or coastal waters of the Pacific Coast Region. Loggerheads, olive ridleys, and green turtles are limited to warm water and rarely occur north of Pt. Conception, California. Loggerheads are pelagic in the Region and often associated with pelagic red crabs. Green turtles occur year round in San Diego Bay, which they use as foraging (on seagrasses and algae) and developmental habitat. The leatherback has the largest geographic range of any reptile, occurring from latitude 60° N to at least latitude 42° S in the Pacific Ocean. Shelf and slope waters off California, Oregon, and Washington have been designated as critical foraging habitat for leatherback sea turtles that nest in the western Pacific. Leatherbacks migrate extensively throughout offshore habitats. Their habitat use is influenced by dynamic oceanographic and biological processes, which determine the abundance of prey resources. The presence of leatherback turtles in summer and fall correlates with a seasonal increase in sea surface temperature >15 °C (>59 °F) and the development of large blooms of jellyfish (Scyphomedusae). Leatherback turtles are specialists and exploit large concentrations of their gelatinous prey.

Jim Harvey, Moss Landing Marine Laboratories

Sea lions and elephant seals on Año Nuevo Island, off the central California coast. Offshore islands such as this provide habitat for breeding pinnipeds that is relatively free of predators.

ESA-listed Salmonids—Pacific Coast salmonids have declined dramatically in abundance during the past several decades as a result of human-induced and natural factors. There are 28 distinct population segments (DPS) and evolutionarily significant units (ESUs)[3] of chum salmon, coho salmon, sockeye salmon, and Chinook salmon and steelhead trout that are listed as threatened (23) or endangered (5) under the ESA as of November 2012. These anadromous fishes hatch in fresh water, migrate to the ocean to grow into adults, and then return to fresh water to spawn. Even within species they differ in many aspects of life history: when they migrate to sea; how long they spend in fresh water prior to emigration; how long they stay in the ocean, and where; whether they stay in, and

[3]The ESA provides for listing species, subspecies, or DPS of vertebrate species. A DPS represents a vertebrate population or group of populations considered to be discrete from other populations of the species, and significant in relation to the entire species. An ESU is essentially a DPS specific to Pacific salmon. It is a population or group of populations reproductively isolated from other populations of the same species, and represents an important component of the evolutionary legacy of the species.

The canary rockfish, a species listed by the ESA as threatened in Washington State's Puget Sound and the nearby Georgia Basin.

how they use, the open ocean and coastal waters; and when they return to their natal streams or rivers. Salmonids are discussed in more depth in the FMP section on page 196.

Non-salmonid Marine Fishes—Five non-salmonid fish species have now been listed by NMFS under the ESA. In 2010, the southern DPS of green sturgeon, which spawns in the Sacramento River Basin, was listed as threatened. Green sturgeon are long-lived, slow-growing, anadromous fish, and the most marine-oriented species of the sturgeon family. This migratory species uses bays and estuaries along the Pacific coast from Alaska to Mexico. Recent telemetry studies have demonstrated an annual fall migration of green sturgeon from the United States (central California) to Canada (central British Columbia) with a return migration in the spring (Lindley et al., 2008). Historical and current spawning locations are not well established, because green sturgeon make non-spawning movements into coastal lagoons and bays in the late summer to fall, and because their original spawning distribution may have been reduced due to harvest and other anthropogenic effects. Presently green sturgeon spawn in the Rogue River, Klamath River Basin, and the Sacramento River. Juveniles spend 1–4 years in fresh and estuarine waters before dispersing to salt water. Green sturgeon have a relatively narrow depth range in marine habitats, from 20 to 70 m (66–230 ft). The principal threat to green sturgeon in the southern DPS is the reduction of available spawning habitat due to barriers constructed along the Sacramento and Feather Rivers. Other threats include insufficient river flow, increased water temperatures, water diversion, non-native species interactions, pesticide and heavy metal contamination, and local fishing and poaching. The migration pattern of green sturgeon may make this species vulnerable to bycatch in bottom trawl fisheries.

The southern DPS for Pacific eulachon (also called Pacific smelt) was listed as threatened in 2010 under the ESA. Eulachon are endemic to the eastern North Pacific Ocean, ranging from the Eastern Bering Sea (Alaska) to Point Conception (central California). Eulachon typically spend 3–5 years in salt water, generally occurring over the Continental Shelf in 20–150 m (66–492 ft) depths, before returning to fresh water to spawn from late winter through mid spring. South of the U.S.–Canada border, most eulachon production originates in the Columbia River Basin, but this species also has been documented elsewhere in California (e.g. Mad River, Redwood Creek, Klamath River), Oregon (e.g. Umpqua River), and infrequently in coastal rivers of Washington. Eulachon populations are at or near historically low numbers and have all but disappeared from several locations. Threats to eulachon include effects of climate change on freshwater and marine habitats, bycatch in the pink shrimp fishery, water management and habitat changes in the Klamath and Columbia Basins, and predation by marine mammals and birds, especially in the Fraser and other rivers of British Columbia.

The DPSs of three species of rockfishes in Puget Sound, Washington, and the Georgia Basin were listed as endangered (bocaccio) and threatened (canary and yelloweye rockfishes) under the ESA in 2010. Bocaccio range from the western Gulf of Alaska to Punta Blanca (Baja California) but are most common between northern California and northern Baja California. In Puget Sound most bocaccio are found south of Tacoma Narrows. Canary rockfish range from the western Gulf of Alaska to Punta Colonet (northern Baja California), and are most common off central Oregon. Juveniles and subadults of bocaccio and canary rockfish are associated with rocky outcrops, kelp canopies, and artificial structures such as piers. Adults move into deeper water with age and are often associated with complex rock substrates in depths of about 95–225 m (312–738 ft). Yelloweye rockfish occur from the Aleutian Islands (Alaska) to Ensenada (northern Baja California), and are common from the Gulf of Alaska to central California. Juvenile and sub-adult yelloweye rockfish can be found in high-relief, rocky, nearshore areas in about 40–50 m (120–150 ft) depths. Adults are closely associated with high-relief rock outcrops and boulder fields, most often in about 90–200 m (300–590 ft). All three rockfish species have been harvested at high levels for many decades along the Pacific Coast. Like most other rockfish species, these bottom dwellers are long-lived and slow to mature and reproduce, which makes them especially vulnerable to overfishing. Threats to these three species include destruction of habitat by active and derelict fishing gear on the seafloor, chemical contaminants, and low levels of dissolved oxygen.

Marine Invertebrates—The white abalone is currently listed as endangered under the ESA. It is an herbivorous marine gastropod that feeds on attached or drift algae. It occurs in relatively deep water (20–60 m; 66–197 ft) from Point Conception, California, southward to Baja California Sur, Mexico. This species lives on complex hard benthic substrates such as rock pinnacles, low-relief boulders, and banks. Once occurring in densities as high as 1 per m^2 (11 ft^2) of suitable habitat, they now are found only occasionally. Surveys throughout the Southern California Bight found white abalone densities ranging from 1.5 to 13 per hectare (2.5 acres) (Butler et al., 2006). Recent surveys on one offshore bank (Stierhoff et al., 2012) suggest that a 78% decline in the total white abalone population has occurred since 2002.

White abalone off the California coast.

The white abalone is a broadcast spawner. If fertilized, the eggs hatch after only one day, but high concentrations of sperm are required for an egg to be fertilized, necessitating aggregations of adults for successful fertilization. Recent studies suggest that this species has likely suffered reproductive failure resulting from severe overfishing. Because of the white abalone's sedentary lifestyle, repopulating depleted areas via migration is difficult.

Black abalones also were listed as endangered under the ESA in January of 2009. Like white abalones, they are herbivorous marine gastropods and broadcast spawners. Black abalones are most commonly distributed from Point Arena in northern California down to Bahia Tortugas and Isla Guadalupe, Mexico. They are found in rocky intertidal and subtidal habitats down to a depth of 6 m (20 ft), often within the high-energy surf zone wedged into rock crevices, cracks, and holes. They can sustain extreme variation in temperature and salinity. Declines in black abalone abundance are attributed largely to overfishing and a disease known as withering syndrome. For example, the population south of

A pair of black abalone.

San Francisco declined 90–99% due to withering syndrome. Habitat destruction, illegal harvest, and ecological factors such as competition and predation have also contributed to population declines. Conservation efforts include a system of California marine protected areas and fishery closures, both commercial and recreational. There has been recent recruitment and some recovery of black abalone at San Nicholas Island (southern California) and at sites within the Monterey Bay National Marine Sanctuary, and the population north of San Francisco has not declined.

Habitat Use by Non-FMP, State-, and Internationally Managed Species

Nearshore invertebrate and fish resources comprise a diverse array of commercial and recreational species including shrimps, crabs, abalones, clams, squids (also managed under the Coastal Pelagic FMP), sea urchins, sea cucumbers, and both cartilaginous and bony fishes that are not federally protected or included in an FMP (e.g. the Pacific halibut, which is managed by the IPHC). Many nearshore species are managed by West Coast states, which, in the case of some species, coordinate their activities through the Pacific States Marine Fisheries Commission and the PFMC. The ranges of many nearshore species overlap state and federal waters, and associated fisheries may be managed separately in those areas. For example, the Pacific Coast salmon fishery in federal waters is managed by the PFMC, but the states manage salmon fisheries in their waters. There is cooperation between the PFMC and the states on setting quotas, etc., but the fisheries are managed separately.

It is beyond the scope of this report to present a comprehensive review of habitats used by all nearshore species. Rather, this section highlights habitat use by some significant commercial and recreational species and groups. Many FMP and protected species use nearshore habitat during all or part of their life cycle; the rockfishes are one example, with about 20 species inhabiting nearshore areas during at least one life stage. Comprehensive reports on nearshore living marine resources have been compiled by Leet et al. (2001) for California and by the Oregon Department of Fish and Wildlife (ODFW, 2000, 2005) for Oregon. The ecology of marine fishes off California and northern Baja California has been thoroughly reviewed and interpreted by Allen et al. (2006).

California and Pacific Halibut—Two types of halibut occur in Pacific Coast waters, the California and the Pacific halibut. California halibut are state-managed and common in nearshore, sandy environments. They generally occur at depths to 30 m (100 ft) and occasionally to 91 m (300 ft) and use bays and estuaries as nursery grounds. Their broad range is from Baja California to Washington, although they tend to be more abundant farther south (Domeier and Chun, 1995). Pacific halibut are managed by the International Pacific Halibut Commission. The Commission was established by a convention between the United States and Canada in 1923 to implement management of and research on Pacific halibut stocks in waters over the Continental Shelf from northern California to the Aleutian Islands and throughout the Bering Sea. Pacific halibut live on or near the seafloor from Punta Chamala, Baja California, Mexico, to the Bering and Chukchi Seas, at depths from 6 to 1100 m (20–3,600 ft). However, they are commonly found in water depths from 27 to 274 m (90–900 ft) and temperatures of 3–8 °C (37–46 °F), and are uncommon south of Cape Mendocino, California. Between November and March, mature halibut congregate at spawning areas near the edge of the Continental Shelf at depths from 183 to 457 m

(600–1,500 ft) in the Bering Sea, Gulf of Alaska, and British Columbia. Halibut eggs and larvae drift passively in deep ocean currents, moving closer to the ocean's surface with development. Counterclockwise currents transport these early life stages sometimes thousands of miles westward of spawning grounds. Upon leaving the planktonic stage, young halibut settle to the bottom of bays and inlets near central and western Alaska and the inner shelf of the Bering Sea, where they occur on mud, sand, and gravel. Halibut move farther offshore as they develop, with fourth-year halibut typically found off southeast Alaska and British Columbia. Pacific halibut, one of the largest fish species in the world, grow to approximately 2.5 m (over 8 ft) and 227 kg (500 lbs), and both males and females live to 55 years (IPHC, 1998).

Dungeness Crab—Dungeness or market crab is the most important species of crab harvested commercially and recreationally along the West Coast. This species ranges from the Aleutian Islands of Alaska to near Point Conception, California. The distribution of Dungeness crab is primarily determined by water temperature, with the 3–18 °C (37.4–64.4 °F) surface isotherms considered to be the limits of the adult range. However, temperature tolerance (10–14 °C; 50–57 °F) of the larvae may be a stronger determinate of geographic range. The benthic life stages of Dungeness crab inhabit sand and sand/mud sediments on the Continental Shelf and in lower reaches of estuaries, from the intertidal zone to a depth of at least 230 m (755 ft); it is less abundant beyond 90 m (295 ft) depths. Juveniles often are found in estuarine areas of soft sediment containing eelgrass and bivalve shells. Adults move onshore in the summer and offshore in the winter. Their populations are determined as much (or more) by environmental conditions than by fisheries.

Rock Crabs—Three species of "rock crab" are harvested along the West Coast: brown rock crab, yellow rock crab, and red rock crab. Of these, yellow rock crabs have a more southern distribution, occurring on soft sediments from northern California to Baja California, Mexico. Brown and red rock crabs occur over rocky substratum as far north as Washington State and Kodiak Island, Alaska, respectively.

NOAA

A small Dungeness crab in eelgrass at the Padilla Bay National Estuarine Research Reserve.

Sheep Crab—Sheep crabs are commercially important in southern California. They are distributed from northern California to Baja California, Mexico, and inhabit a range of habitats from sandy to rocky substrates at depths of 6–125 m (20–410 ft). Sheep crabs also occur on artificial subtrates such as pilings and jetties.

Shrimps—Eleven species of shrimp are harvested commercially throughout the Pacific Coast Region, including Pacific ocean shrimp (also called pink or smooth pink shrimp), spot prawn, coonstriped shrimp (three species), red rock shrimp, ridgeback prawn, and bay/mud shrimp (a complex of four species). The Pacific ocean shrimp and spot prawn range from Alaska to southern California, the former occurring on mud and sand/mud sediments primarily in 73–229 m (240–751 ft) depths, and the latter primarily in 46–488 m (151–1,601 ft) depths on steep soft sediment slopes and on offshore rocky outcrops. Coonstriped shrimp range from Alaska to San Diego, California, in waters of 18–183 m (59–600 ft) depth, primarily in areas of sand or gravel and strong tidal current. Red rock shrimp is a southern species that is distributed from Santa Barbara, California, to Bahia Sebastián Vizcaíno, Baja California, Mexico. They inhabit rocky and algal substrates from the low intertidal to a depth greater than 55 m (180 ft). Ridgeback prawns occur from central California to Baja California at depths of 44–160 m (144–525 ft) on

A California spiny lobster. Primarily nocturnal, this species relies on rocky habitat for shelter as it hides during the day.

sand, shell, and mud. Bay shrimps inhabit estuaries from Alaska to southern California in areas of mud or sand, but also occur on rocks and in the rocky intertidal zone. They tolerate a wide range of salinity and temperature.

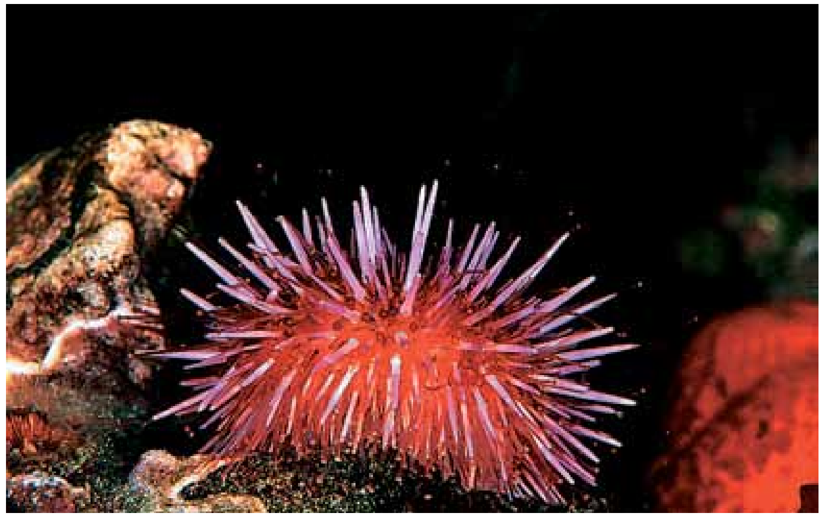
California Spiny Lobster—The California spiny lobster ranges from Monterey Bay, California, to Manzanillo, Mexico, and supports valuable recreational and commercial fisheries in southern California. The population is concentrated from the Southern California Bight to Magdalena Bay, Baja California, with an isolated population at the northwestern end of the Gulf of California. Adults generally inhabit rocky areas from the intertidal zone to depths of at least 73 m (240 ft), where they aggregate in cracks, crevices, and cave-like features, especially during daylight. Adult spiny lobsters move seasonally between shallow water (<9 m [<30 ft]) during warmer months and deep water (>15 m [>49 ft]) during colder months. After a long pelagic period, juvenile lobsters spend their first 2 years in surfgrass habitats. Sub-adults also are found in shallow rocky crevices and mussel beds.

Clams—Pacific Coast clams inhabit estuaries, bays, and open coast sandy beaches, and include razor clams; seven species of littleneck clams, including the introduced Manila or Japanese clam; Washington clams; butter clams; Pismo clams; two species of gaper clams; geoduck; the softshell clam; and others. The Pacific razor clam is generally found on flat or gently sloping sandy beaches with moderate to heavy surf. Littleneck clams of the genus *Chione* are distributed from southern California to Baja California, Mexico (and in one species, to Peru), and occur on intertidal mud and sand flats of sloughs, bays, and coves (with some subtidal occurrences to 50 m [164 ft] depths). Littleneck clams of the genus *Protothaca* have latitudinal distributions extending further to the north than *Chione*, and occur intertidally and in shallow subtidal areas of sand and muddy sand. The Manila clam is found from the intertidal zone to about 9 m (30 ft) depths in gravel, sand, mud, and shell substrates of protected inlets and bays. The Washington clam ranges from northern California south to San Quentin Bay, Baja California, and inhabits intertidal and shallow subtidal sandy mud or sand in estuaries. Butter clams range from Sitka, Alaska, to San Francisco Bay, and are found in habitat similar to that of the Washington clam. The historical range of the Pismo clam is from Half Moon Bay in central California to Socorro Island, Baja California. This intertidal species occurs on sandy beaches of the open coast and at entrances of estuaries and bays. In central California, Pismo clam populations are low, thought to be a result of predation by sea otters. Gaper clams range from Alaska to Baja California and live in fine sand or firm sand-mud in bays, estuaries, and protected areas of the outer coast from the intertidal zone to a depth of at least 46 m (151 ft), tolerating a wide salinity range. The geoduck has a broad latitudinal range from southeastern Alaska to Baja California, including the Gulf of California, although it is not as common south of Washington, and in Oregon it is known only from Netarts Bay, where it was transplanted. One of the largest burrowing clams in the world, the geoduck occurs from the lower intertidal zone to a depth of 110 m (361 ft) in bays, estuaries, and sloughs on mud, sand, and gravel. The softshell clam has expanded its range from San Francisco Bay, California, and now occurs from southeastern Alaska to Elkhorn Slough, California. Softshell clams are found buried 25 cm (10 in) or more in muddy and sandy sediments in the low to middle intertidal zone of the low-salinity reaches of estuaries.

Mussels—There are three species of commercially important mussels within the Pacific Coast Region:

the California (sea) mussel and two so-called "edulis-like" mussels, the Pacific Northwest mussel and the non-indigenous Mediterranean mussel. Mussels attach to hard substrates by secreting byssal threads from the base of their foot. Mussel beds represent a complex structural habitat for a diverse community of intertidal organisms. The California mussel is distributed from the Aleutian Islands of Alaska to Baja California, Mexico, where it forms extensive beds in the surf-exposed rocky intertidal zone and on artificial substrates such as pier pilings and jetties. This species also occurs subtidally in isolated patches to a depth of at least 30 m (100 ft). The Pacific Northwest mussel is found in protected estuaries and bays of the northwestern United States, and along open coasts in the high intertidal zone above beds of the California mussel. It also colonizes exposed rock where physical disturbance has removed the California mussel. The invasive Mediterranean mussel occurs south of the Monterey Peninsula (California), where it has been known to hybridize with the Pacific Northwest mussel.

Abalones—Habitat use for black and white abalone species was discussed in the protected species section, and habitat use for other abalone species is covered in this section. In addition to black and white abalones, Pacific Coast abalone species include red, green, pink, flat, and pinto abalones. An eighth species, the threaded abalone, is now thought to be a southern subspecies of the pinto abalone. Red abalones occur from Oregon to Baja California in association with rocky kelp habitat. In central and northern regions, they are found from intertidal to shallow subtidal depths, whereas in southern regions they are exclusively subtidal and restricted to upwelling locations along California's mainland and the northwestern Channel Islands. Pink, green, and pinto (threaded) abalones occur in warmer waters south from Point Conception, California, to central Baja California and the southeastern Channel Islands. Green abalones are centered at shallower depths in open coast habitat that is shallow and rocky; pink abalones extend from the lower intertidal zone to 61 m (200 ft) depths, but mainly between 6 and 24 m (20 and 80 ft) depths. Flat abalones are found in the cool waters north of Point Conception.



Laura Francis, Channel Islands National Marine Sanctuary

A purple sea urchin in California's Channel Islands National Marine Sanctuary.

Sea Urchins—Red sea urchins and purple sea urchins occur along the Pacific Coast from Alaska to Isla Cedros, Baja California (red sea urchins also occur in the western Pacific). Red sea urchins inhabit lower intertidal and subtidal rocky substrates to a depth of at least 91 m (300 ft). These are locally abundant subtidal herbivores that are important in structuring kelp-forest communities. The tests and spines of red sea urchins provide biogenic habitat for other benthic invertebrates including juvenile sea urchins. Purple sea urchins have a life history similar to that of red sea urchins, but occur in high-energy intertidal and subtidal areas. A third species, the green sea urchin, is common in the rocky intertidal of Puget Sound, Washington, and the outer coasts of Washington and British Columbia, Canada. Aside from these shallow-water urchins, there are several other species of urchins that live in deep sand habitats on the Continental Shelf and Slope.

Sea Cucumbers—The California, or giant red, sea cucumber is distributed from Alaska to Baja California from the low intertidal zone to 244 m (800 ft) depths. At the southern end of their range, California sea cucumbers are replaced in shallow water by the warty sea cucumber. The warty sea cucumber is found from Monterey Bay, California, to Baja California, from the lower intertidal zone to 27 m (90 ft) depths. Sea cucumbers occur over a range of substrates from mud to rock, but are most abundant on sand, gravel, and shell debris.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Leopard sharks commonly inhabit coastal and bay habitats from northern Mexico to northern California.

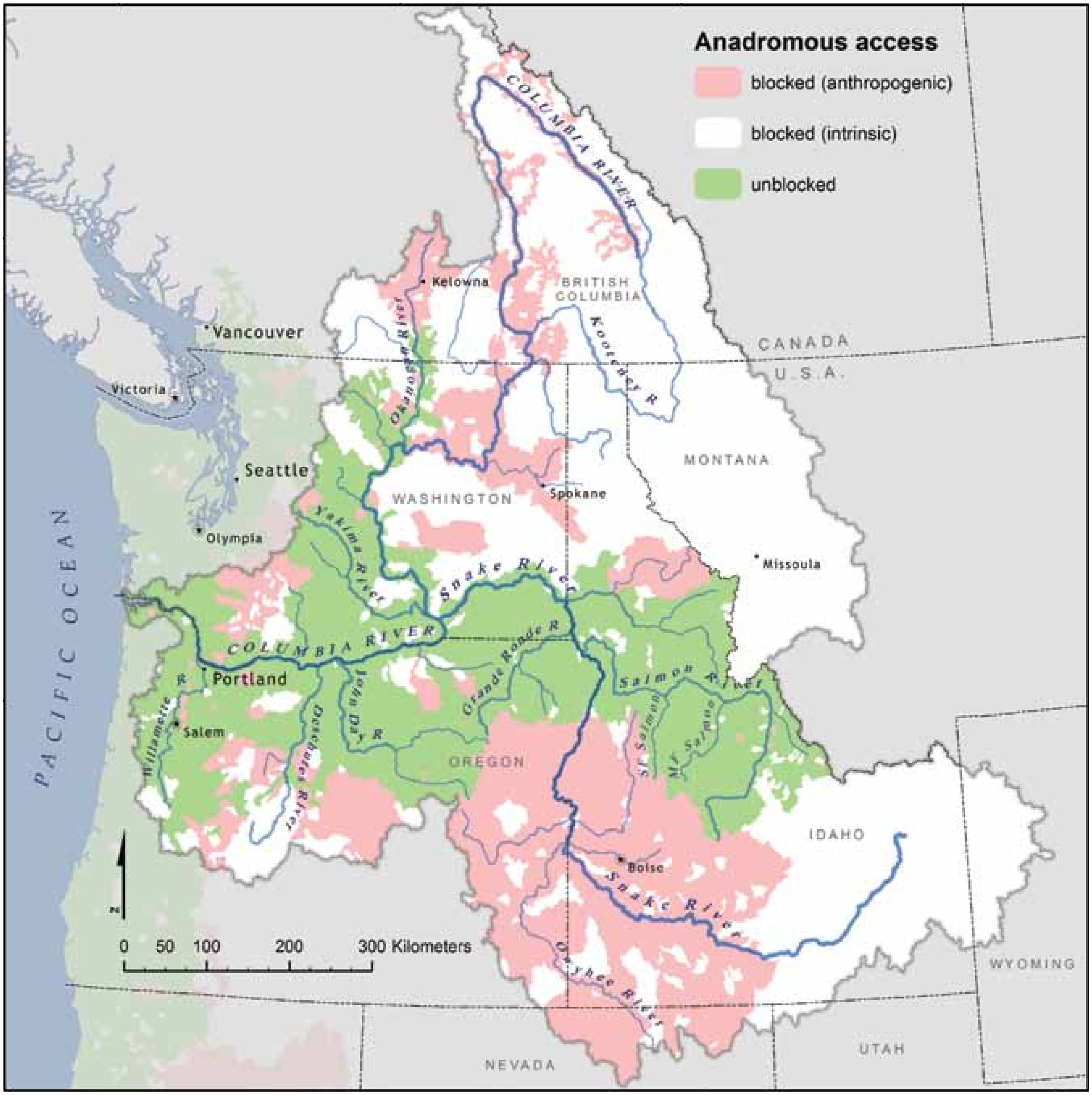
Cartilaginous Fishes—Cartilaginous species include sharks, rays, skates, and ratfishes. Some have been considered in the previous sections on highly migratory and groundfish species. A number of these species use nearshore habitats for all or part of their life cycle. Sharks occurring in the nearshore area of the Pacific Coast Region and targeted by commercial and recreational fisheries include the common thresher, shortfin mako, basking, white, salmon, blue, soupfin, leopard, sixgill, sevengill, spiny dogfish, and others. These species range widely throughout the eastern Pacific, and water temperature is an important determinant of their seasonal distribution. Inshore coastal waters, embayments, and estuaries commonly serve as pupping and nursery grounds.

Skates and rays occur in all marine habitats, from protected bays and estuaries to the outer coast. Two common species are the big skate and the longnose skate, both ranging from the Bering Sea to Baja California, from shallow waters to depths greater than 610 m (2,000 ft). Most stingrays, such as the common round stingray and bat ray, are bottom dwellers, occurring in shallow inshore waters, bays, estuaries, and sloughs, although some also are found in deeper waters.

Bony Fishes—Habitat use by many of the bony fishes has been discussed in earlier sections on FMPs and protected species. In general, these fishes have varying affinities to nearshore ecosystem habitats. Many move between bays and estuaries and the open ocean. Some of these movements are ontogenetic, representing a change in habitat association over the course of development. Many movements are related to spawning events, when fishes congregate at specific habitats. The short duration of the spawning period and rough ocean conditions have made it difficult to accurately define spawning times and locations for most nearshore fishes. Fishes such as the yellowtail, California (Pacific) barracuda, and Pacific bonito are open-water coastal migratory species. Croakers are represented by eight species, which occur primarily off southern California and Mexico, and inhabit shallow water in or near the surf zone along beaches and bays over sand or mud. Rockfishes represent one of the more diverse groups of nearshore fishes, with over 20 species inhabiting rocky areas in waters less than 30 m (100 ft) deep. Smelt are distributed widely throughout the coastal zone, and six species inhabit estuarine or open-coast habitats at one or more life stages. The white sturgeon, like the green sturgeon discussed earlier, is anadromous, ranging from Alaska to Mexico, and inhabits marine, estuarine, and riverine waters over a wide range of sediments. Both species migrate into freshwater streams to spawn in areas containing large cobble and boulders. The Pacific herring is a pelagic species occurring in coastal and offshore waters throughout the Pacific Rim from Japan to northern Baja California and into the Arctic Ocean. Herring spawn in bays and estuaries in both intertidal and subtidal zones, where they lay adhesive eggs on a variety of substrates including aquatic vegetation, rocks, and artificial structures such as pilings and jetties. There are 17 species of viviparous (live-bearing) surfperches in the Pacific Coast Region. Surfperches are distributed from Baja California to Alaska, but many of the species occur primarily off California and Baja California. Although surfperches occur over a broad depth range from the intertidal to 230 m (750 ft), they primarily inhabit estuaries, bays, and nearshore areas in association with a variety of substrates including sand, rock, vegetation, and also artificial structures such as pier pilings.

HABITAT TRENDS

Many Pacific Coast Region habitats have been dramatically reduced from their original pristine state. Major habitat trends include continued reductions in freshwater flows and habitat access



Accessible and blocked anadromous fish habitat in the Columbia River Basin. On the Columbia River and its main tributaries, over 250 reservoirs and 150 hydroelectric projects reduce access and use of a majority of the 647,500 km^2 (250,000 mi^2) drainage basin (PSMFC, 2006; McClure et al., 2008).

due to dams, estuarine habitat loss, and increased loading of coastal waters with toxic contaminants including metals, pesticides and chemicals of emerging concern, like pharmaceuticals, from agricultural and urban runoff. Trends in habitat quantity and quality also are significantly impacted by continued damage to seafloor habitats during fishing, and climate variability such as El Niño events.

The loss and degradation of freshwater habitat in the Pacific Coast Region has been well documented. For example, in the Columbia River Basin more than half of the streams historically used by salmon are no longer accessible due to large dams. In the last 10 years, there have been many notable examples of dam removal projects that have restored historical access to many miles of river habitat in the Pacific Northwest. In particular, the

Olympic National Park

The Glines Canyon Dam, in Washington State, in the early stages of being dismantled.

removal of the Elwha Dam (completed in 2012) and Glines Canyon Dam (completed in 2014) represent the largest dam removals in U.S. history. These removals will help restore the Elwha River to its natural state and allow Chinook salmon, whose populations prior to removal were a fraction of their historical abundance, return to their native spawning grounds. Still, many river sections, such as those above Grand Coulee Dam, will remain inaccessible to Pacific salmon (see map at top of page 209). Additionally, there has been a minimum estimated loss of 48% of historical stream mileage formerly accessible to Chinook salmon in California's Central Valley watershed. Because steelhead trout penetrate much farther than Chinook salmon into this watershed, aggregate losses summed across all anadromous species are likely to be substantially higher. Remaining accessible freshwater habitats have been greatly simplified and degraded by land-use practices such as logging, grazing, agriculture, urbanization, dredging, diking and filling wetlands, and others. Diversion of fresh water can significantly modify reproductive patterns and success for Pacific salmon, as well as reduce water flow and flushing in bays and estuaries.

Estuarine habitat in the Pacific Coast Region has been dramatically impacted by human activities. More than 70% of the estuarine habitat, both in the Pacific Northwest and along California, has been lost or degraded due to diking, filling, polluting, and other human activities. At least 90% of wetlands, including bays, estuaries, and salt marshes, were lost in California alone from the time of European settlement to the 1980s (Dahl, 1990; Zedler et al., 2001). Much of this change occurred more than 50 years ago, but a recent joint report by NOAA and the U.S. Fish and Wildlife Service found that the coastal watersheds of California, Washington, and Oregon are still losing wetlands—over 2,100 hectares (5,200 acres) between 2004 and 2009 (Dahl and Stedman, 2013). Efforts now are underway to protect and restore these habitats in many areas. In fact, a substantial amount of aquatic habitat has been, or is being, restored and made accessible to fishes and other aquatic organisms along the Pacific Coast via the removal or relocation of dikes and levees. Another clear trend in the status of nearshore coastal habitats is the decline in mainland habitat for breeding pinnipeds, although nearshore rocks and islands continue to support relatively large rookeries.

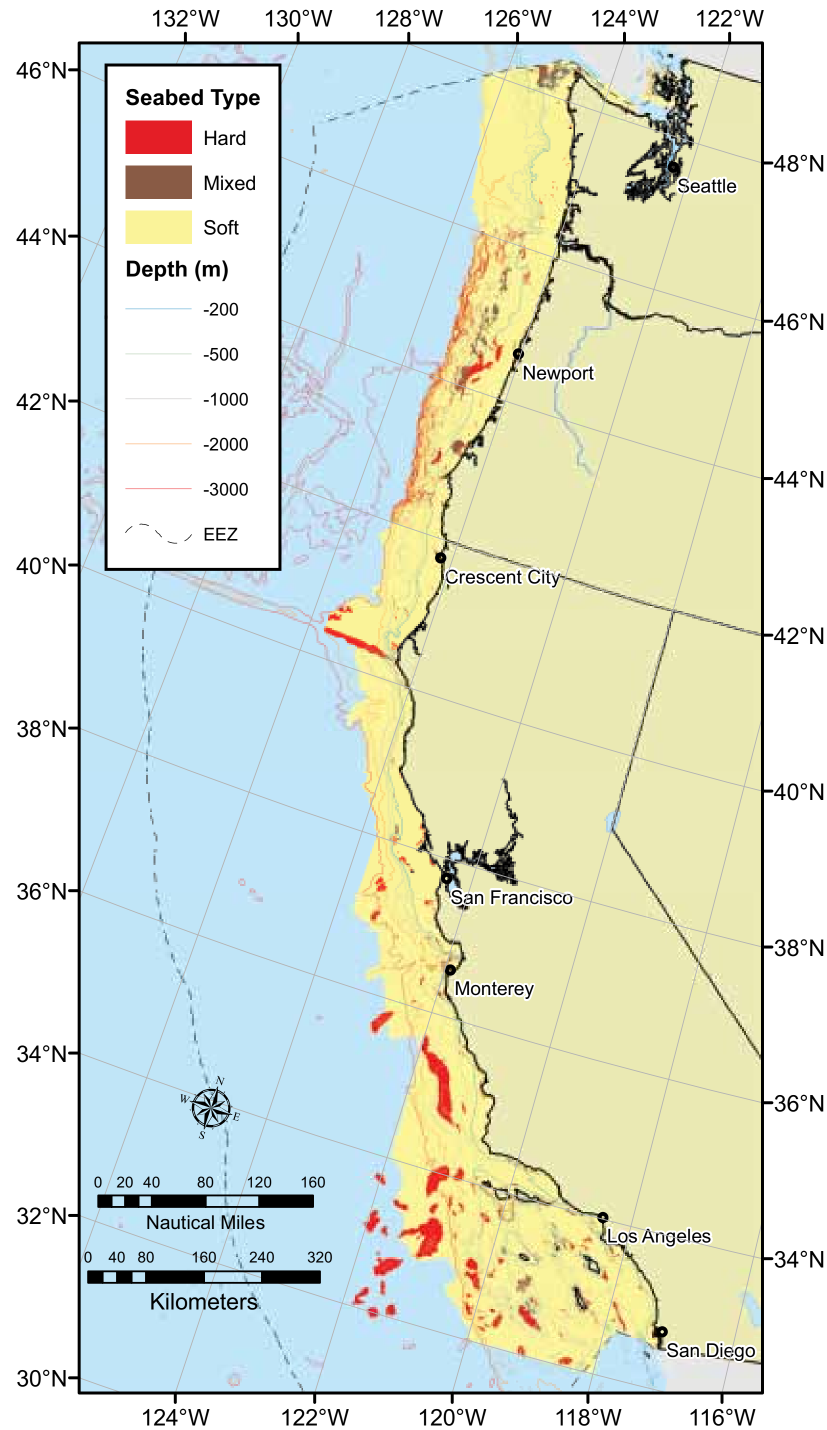
In much of the Pacific Coast Region, the populations of many groundfish species are at historically low levels. Overfishing by both recreational and commercial fishermen and unfavorable oceanographic conditions are significant contributing factors to the severe declines in some populations. Alteration and destruction of habitats could also play a role in diminishing populations of some species, although baseline information on the condition of seafloor habitats prior to commercial fishing is not available. Fishing gear, particularly certain types of bottom trawls, has contributed to the destruction of seafloor habitats, which could in turn diminish the survival of both young and adult groundfish species. We know little about historical or recent impacts of benthic disturbances, and specifically the impact of fishing gear, to groundfish habitats on the West Coast.

The habitat occupied by most highly migratory species of fishes, turtles, and marine mammals within the Region represents a very small portion of their total range. Thus, these species may be further impacted by other factors such as fishing activities and changing environmental conditions outside of the Region. Habitat for these species primarily is located in the upper water column, and thus not affected directly by disturbance to the seafloor by bottom fishing gear.

Large changes in upwelling and ocean temperatures associated with climatic changes, such as the El Niño Southern Oscillation (ENSO) or the Pacific Decadal Oscillation, have dramatic effects on primary and secondary production and subsequently on all levels of predators in the Pacific Coast Region. These large climatic shifts have been correlated with changes in distribution, abundance, reproduction, and survival for many of the managed species and their forage base (e.g. krill) in the Region. While these fluctuations can occur naturally, the potential effects of long-term anthropogenic climate change on these fluctuations are still being studied. However, there has been a trend of decreasing dissolved oxygen in the California Current oxygen minimum zone (OMZ), accompanied by a shoaling of the upper boundary of the OMZ. This hypoxic water has impacted the chemical and biological oceanography and living marine resources on the Continental Shelf. For example, over the past decade, dissolved oxygen off Oregon and Washington has reached hypoxic levels that can be detrimental to fishes and invertebrates (Chan et al., 2008). Effects of long-term climate change may increase or decrease suitable habitat, but definitive answers are presently unavailable for many species.

RESEARCH NEEDS

Habitat-oriented research needs are considered for specific groups of species, although much of this information is needed for all groups. In general, information that relates species' densities, growth, survival, reproduction, and production rates directly to particular habitats is lacking for most species and life stages. These higher levels of information are critical for understanding the relative importance and availability of suitable habitat in affecting the abundance of marine species of the Pacific Coast Region. Table 12 presents an overview of habitat-specific research needs for the Pacific Coast Region, with more detailed information provided in the text that follows.



Map of seabed types in the Pacific Coast Region, produced by C. Romsos (Oregon State University) and J. Bizzarro (University of Washington) for the Pacific Coast Groundfish 5-year Review of Essential Fish Habitat (PFMC, 2012). Map and data sets available at http://efh-catalog.coas.oregonstate.edu/overview/ (accessed May 2015).

Pacific Salmon

Although Pacific salmon have been the subject of intensive study for many years, there are many key research needs related to fish-habitat linkages that largely remain unaddressed. These include seasonal habitat use in both freshwater and marine environments, relationships between habitat alteration and fish survival and production through all life stages, lethal and sublethal effects of many pollutants on salmon and their prey, the relationships between viability of wild populations and ocean and freshwater conditions, potential effects of climate change on freshwater and marine habitats, and effectiveness of restoration techniques, especially watershed-scale restoration. In addition, research is needed on the response of freshwater habitats and salmon populations to dam removal, linkages between habitat diversity and population resistance and resilience to disturbances, and interactions between hatchery-raised and wild fish, in both fresh water and the ocean.

Coastal Pelagic Fishes

The increasing demands of fishery management for information, and the costs and demands for sea-going research vessels, require new approaches to gather and analyze biomass and ocean habitat data for coastal pelagic species. Continued modernization of satellite oceanography, autonomous underwater vehicles, and acoustic surveys of the epipelagic zone are necessary for effective management of pelagic resources. For example, considerable predictive ability in assessing the Pacific sardine population could be achieved by assembling habitat data that relate to the eddy structure, from the mesoscale to the megascale, of the circulation of the North Pacific subtropical anticyclonic eddy. Mechanisms for developing a functional explanation of the biophysics of sardine reproductive success could be established from juvenile surveys of growth and survival rates. Presently there is no adequate and timely detection of change in biomass of northern anchovy and Pacific jack mackerels that occurs due to environmental forcing. Research needs for the market squid include identification and description of spawning habitats throughout the species range in both unfished as well as fished areas, particularly during El Niño events. Although there is a considerable body of information on the biology of some krill species for subregions of the California Currrent System, a comprehensive coast-wide delineation of primary krill habitats for each life stage under different oceanographic conditions and regimes is lacking. Such delineation can be accomplished with planned acoustic surveys of the entire West Coast.

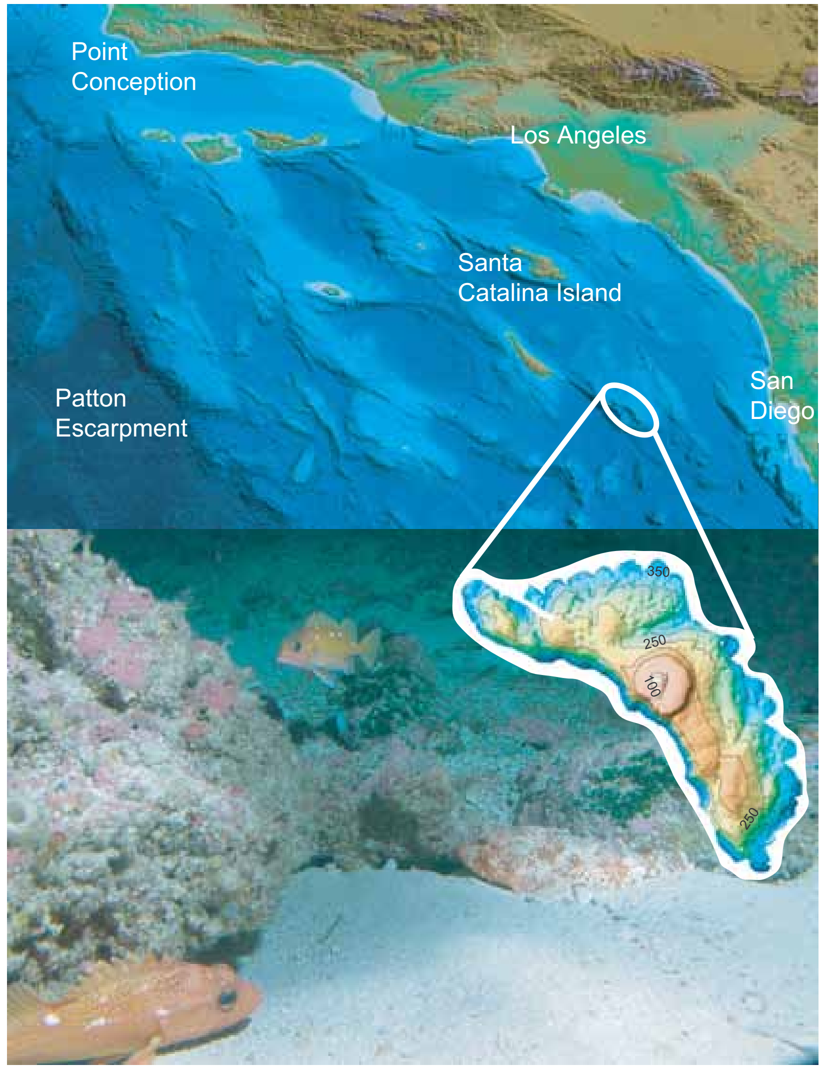
Highly Migratory Species

Research needs for highly migratory species include identification of pupping grounds and core nursery areas of the common thresher shark and shortfin mako shark. These areas, where pregnant females congregate, may be sensitive to perturbation that make aggregated females and pups vulnerable to fishing and other adverse effects. There also is a need to determine seasonal and age-specific use of habitat by deep-dwelling adult albacore, bigeye tuna, and other HMS species in the North Pacific. For other HMS not targeted by fisheries, very little is known about the habitat of various life stages.

Groundfish

There is a critical need for comprehensive, detailed information on benthic habitats and associated groundfish assemblages on spatial scales relevant to fishery management and habitat protection. Development of more efficient and effective visual and acoustic methods to survey deepwater benthic habitats and fishes is necessary, especially in complex, diverse habitats that are difficult to assess with conventional survey tools such as trawl and longline gear. About 120,000 km^2 (46,332 mi^2) of the seafloor still needs mapping to a depth of 1,300 m (4,265 ft) off Washington, Oregon, and California.

Identification and protection of core spawning and nursery grounds also are important, especially in coastal habitats. Priorities for research on groundfish habitat also include improvement of our understanding of the ecological effects of fishing on the biodiversity and trophodynamics of the ecosystems on which these species depend; evaluation of gear impacts to marine benthic habitats on the Continental Shelf and Slope; and the development of ways to reduce adverse impacts, including monitoring marine protected areas, modifying fishing gear, and collecting bycatch information. There also is a critical need to evaluate the role of deep-sea coral communities as groundfish EFH in Continental Shelf and Slope ecosystems. Because large invertebrates, such as sponges and corals, enhance the diversity and structural component of fish habitat and are vulnerable to impacts by at least some fisheries, it may be appropriate to identify them as Habitat Areas of Particular Concern. Fi-



J. Chaytor and C. Goldfinger, Oregon State University

Mary Nishimoto, UC Santa Barbara

An example of benthic habitats at various spatial scales of resolution. A color-shaded map of southern California's ridge–basin topography (top), extending shoreward from the Patton Escarpment (1,000–3,000 m [3,281–9,842 ft] depth). New and archived acoustic sonar data were compiled from Oregon State University, Scripps Institute of Oceanography, NOAA, USGS, and NASA. A high-resolution bathymetric map of one offshore bank is superimposed over typical microscale habitats and associated groundfish species (bottom) surveyed by NMFS from an occupied submersible at a depth of 80 m (262 ft).

Jim Harvey, Moss Landing Marine Laboratories

Researchers on the NOAA ship *David Star Jordan* track a tagged leatherback sea turtle during a survey of the species' use of oceanic habitat.

nally, understanding the relationship between large climate events and abundance, growth, spawning success, and survival of groundfish species is a productive focus of future research.

Pinnipeds

Current understanding of habitat use by pinnipeds has been based largely on tracking studies and food-habit investigations near rookeries. Such studies will continue to improve habitat knowledge for pinnipeds. However, further study of the nature and magnitude of competitive interactions between humans and pinnipeds also is necessary. Such interactions may occur where fisheries are removing prey species that are important to pinnipeds, and when pinnipeds may impact the recovery of commercially valuable, threatened, or endangered fish species. Furthermore, additional research on the impacts of natural habitat variability and toxic algal blooms on pinnipeds is important, as these impacts are known, but not well understood.

Cetaceans

A primary research need is to characterize habitats for cetaceans in the Pacific Coast Region, and to further study movement patterns and local abundances. During the last decade, significant efforts have been made by NMFS to conduct comprehensive abundance and distribution studies for cetaceans in the Pacific Coast Region. These studies generally collect oceanographic data, and habitat-based models of cetacean distribution and abundance have been developed recently for many species. However, this diverse group of species will require more detailed studies to gain a better understanding of important habitats. Continuing studies of human-related impacts, such as fisheries, harmful algal blooms, and pollution, also are important for management and conservation of cetaceans throughout the Pacific Coast Region.

Sea Turtles

There are several research priorities for endangered or threatened sea turtles. Habitat use of turtles during migration and foraging has been characterized recently, but finer-scale studies are needed to examine the spatial and temporal coincidence of leatherbacks and the commercial swordfish fishery. This will allow mitigation of commercial fishery impacts in these habitats. It also is known that jellyfish are important predators of commercially valuable coastal fish and crab species, and the potential role of leatherback turtles in regulating jellyfish predation on these species represents an intriguing research topic with implications for an ecosystem-based approach to management.

A scuba diver photographing kelp forests in the Channel Islands off the California coast. Kelp is a food source for abalone and other invertebrates, as well as important habitat for many marine species.

Protected Marine Invertebrates

Research needs include quantification of white and black abalone habitat, population assessment and monitoring of these species, estimation of the density of cryptic animals (i.e. animals that hide or are difficult to see), evaluation of mobility and aggregation during the spawning season, and determination of threshold distances for successful fertilization.

Additional Research Needs

The Pacific Fishery Management Council also has identified research and data needs specific to the Pacific Coast Region and produces a summary document of these research needs that is updated every few years. Additional research needs to support the Pacific Coast Region FMP species and their habitats can be found at the Council's website on research and data needs.[4]

[4]http://www.pcouncil.org/resources/research-and-data-needs/ (accessed July 2013).

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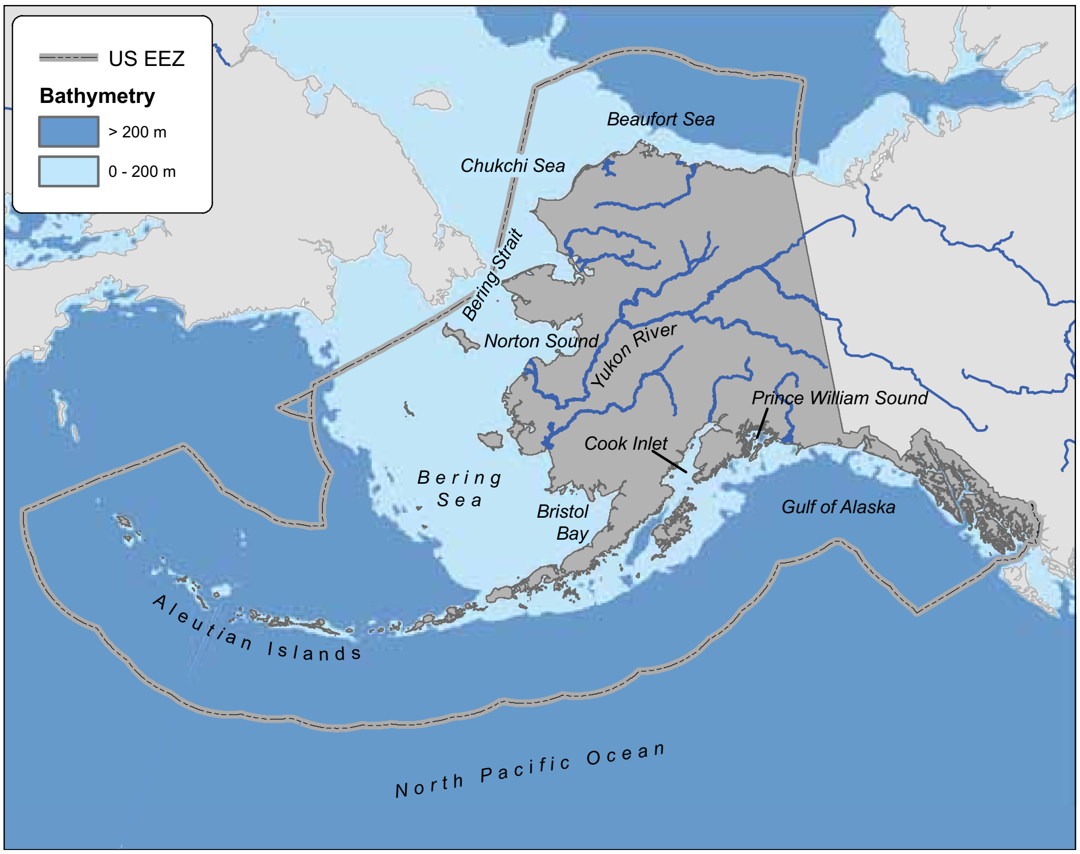
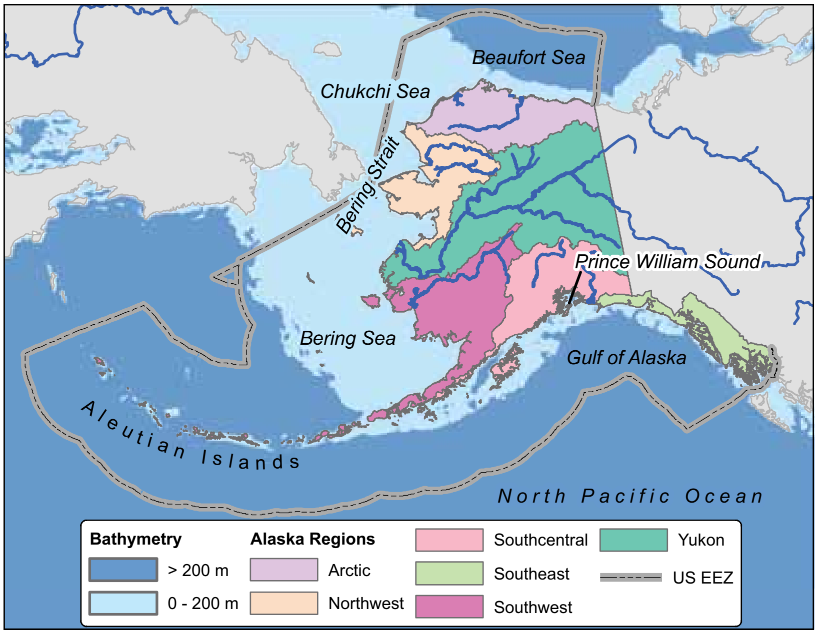
Alaska Region



HABITAT AREAS

Alaska is the largest state in the United States, with a total area of nearly 1.7 million km^2 (663,267 mi^2), including 44,659 km^2 (17,243 mi^2) of inland water, 70,057 km^2 (27,049 mi^2) of coastal water over which the state has jurisdiction, and about 690,000 km^2 (266,410 mi^2) of wetlands (Dahl, 1990). Alaska's productive marine waters include the North Pacific Ocean, the Bering Sea, the Chukchi Sea, and the Arctic Ocean. These extensive marine waters of the U.S. Exclusive Economic Zone (EEZ) off the coast of Alaska total about 3.258 million km^2 (950,000 nmi^2) and encompass more than 70% of the total area of the U.S. Continental Shelf (NMFS, 2004). The breakdown of the Region has 1,800 named islands, coastal plains, mountains, rain forests, interior rivers and lakes, and fjords, and at least 70,000 km (44,000 mi) of tidal shoreline (Graydon, 2001; Johnson et al., 2012) that includes a diversity of mostly pristine freshwater, estuarine, and marine habitats. The distribution and extent of many habitat types important for spawning, rearing, or feeding of commercially important marine resources are mostly unknown. Most wetland and nearshore marine habitats (e.g. palustrine, lacustrine, riverine, estuarine, and ma-

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.



The watersheds of Alaska extend far into the interior of the state.

rine) are being inventoried by the U.S. Fish and Wildlife Service (Glass, 1996). Only about 43% of Alaska, however, has been mapped to determine acreage of these nearshore habitat types.[1] In addition, through partnerships with federal, state, and non-profit organizations, Alaska's shoreline is being imaged and mapped using the ShoreZone coastal habitat mapping system. ShoreZone uses low-altitude, oblique video and high-resolution still imagery to map coastal biology and geomorphology using a standardized classification system. The end product is posted online as a searchable, web-enabled GIS database. Imagery of Alaska's coastline can be viewed while navigating virtually through a map, and users can view or create their own habitat maps. This online tool serves a wide audience of researchers, managers, educators, and the public.[2]

Freshwater and nearshore marine habitats include lakes, rivers, wetlands, estuaries, and tidal shorelines. These habitat types are some of the most productive in Alaska and the most threatened by human disturbance. Alaska has more than 3 million lakes and tens of thousands of rivers, streams, and creeks (Glass, 1996; Graydon, 2001). About 17,000 lakes, rivers, or streams around the state have been identified as being important for anadromous fish. An estimated additional 20,000 or more water bodies used by anadromous fish have not been catalogued (ADFG, 2010). Regional watersheds of Alaska extend from the interior of the state, including Yukon areas, to the Arctic, northwest, and southern coasts.

The Alaska Department of Fish and Game maintains a detailed description of Alaska's wetland types and scientific literature resources (ADFG, 2006). Overall, wetlands account for over 43% of the state's terrestrial area (ADFG, 2006). Of these, contiguous wetlands, those that have direct hydrological connections to marine waters, are essential habitats for anadromous fish stocks. Estuarine wetlands, important nursery and forage areas for many marine species, cover more than 8,500 km^2 (3,282 mi^2), while marine intertidal wetlands, which border the open sea, cover about 195 km^2 (75 mi^2) of Alaska (Hall et al., 1994).

Coastal and offshore habitats include soft bottoms of sand and silt, pinnacles, banks, gullies, slopes, seamounts, and coral gardens. Recently discovered coral gardens provide bottom structure and support high biological diversity. There are six major taxonomic groups and at least 141 species of coral found off the coast of Alaska (Lumsden et al., 2007). Diversity and abundance of corals is highest in the Aleutian Islands (Heifetz, 2002). Seamounts are submerged volcanic features that can be isolated or lineally aligned in a chain. In the North Pacific, the age of seamounts slowly increases in a northwesterly direction along tectonic plate convergences. In 2002 and 2004, NOAA explored and mapped, using 3-D multibeam imagery, Alaskan seamounts in the Gulf of Alaska.[3] Detailed imagery depicts a range of rough and smooth formations. NOAA research has documented rich, diverse living habitat structures (corals and sponges) on some seamounts, while others are laden with softer sediments, remnants of earlier higher-relief habitats. Seamounts are thought to provide island-type habitats within the larger

[1]Julie Michaelson. U.S. Fish and Wildlife Service, National Wetlands Inventory Staff, 1011 E. Tudor Rd., Anchorage, AK, 99503. Personal communication, September 2013.

[2]See http://alaskafisheries.noaa.gov/shorezone (accessed August 2013).

[3]See http://oceanexplorer.noaa.gov/explorations/04alaska/background/volcanic/volcanic.html (accessed August 2013) and http://oceanexplorer.noaa.gov/explorations/04alaska/welcome.html (accessed August 2013).

open-ocean abyssal area. Crab, sablefish, rockfish, and Pacific salmon are associated with seamount features and are thought to be attracted by large diurnal prey movements.

Detailed seafloor habitat mapping and modeling has occurred in the Bering Sea (Yeung and McConnaughey, 2007). Hydrographic survey backscatter data were used to assess habitats and their use by fish. Elsewhere, site-specific research in the Aleutian Islands details multidimensional, layered living habitat structure (Heifetz et al., 2005). These areas may contain species not yet discovered by science and may serve as refugia for many commercial fish. Overall, region-wide coastal and seafloor habitat mapping is hampered by cost and harsh ocean conditions that span the enormous Alaska Region.

Other habitat types or characteristics that are unique to Alaska include numerous glacially carved fjords and sea ice. Coastal fjords are long narrow inlets that lie between tall, steep cliffs. Most fjords are usually deep and strongly influenced by wide fluctuations in tides and salinity from freshwater runoff. The second greatest tide range (12 m [39 ft]) in North America is in upper Cook Inlet near Anchorage (Graydon, 2001). Fjords are common in Prince William Sound, Kenai Peninsula, and southeastern Alaska. Extremely low temperatures in Alaska can affect habitat availability seasonally. For example, pack ice covers portions of the Bering Sea during winter and spring.

Bering Sea and Aleutian Islands

The Bering Sea is a semi-enclosed high-latitude sea; 44% is over the Continental Shelf, 13% is over the Continental Slope, and 43% is over deep-water basin (Mac et al., 1998). Seasonal ice cover in the Bering Sea begins in November and grows to greater than 80% coverage of the Continental Shelf during its maximum extent in March. The Bering Sea is separated from the North Pacific Ocean by the Aleutian Island arc, which forms a porous boundary through which warm, relatively fresh surface and subsurface water is transferred. The majority of this water comes from the Alaska Stream, which flows westward along the Aleutian Islands and forms the northern boundary of the Northeast Pacific Subarctic Gyre. Circulation within the Bering Sea Basin is cyclonic (i.e. counterclockwise). It is bounded on the west by the southward-flowing Kamchatka Current, and on the east by the northward-flowing Bering Slope Current. Water flows out of the Bering Sea via Kamchatka Strait into the North Pacific, and via Bering Strait to the Arctic Ocean (Stabeno et al., 1994).

Anne Morekill, USFWS

Hall Island, near St. Matthew Island, in the Bering Sea.

Numerous rivers and streams enter the Bering Sea from western Alaska and the Alaska Peninsula. The largest embayments in the Bering Sea are the Gulf of Anadyr (Russia), Norton Sound, and Bristol Bay; within these embayments many small estuaries exist. The Anadyr River enters the Bering Sea from the west, and the Yukon River enters from the east. The Yukon River is the longest river in Alaska and is the third longest in the United States (USGS, 1990; Brabets et al., 2000). The Yukon River drains a watershed of more than 855,000 km^2 (330,117 mi^2) and flows for more than 3,000 km (1,864 mi) from its headwaters in Canada to the sea. The Yukon–Kuskokwim Delta is one of the largest in the world and supports more than 40,469 km^2 (15,625 mi^2) of wetlands (Glass, 1996). Izembek Lagoon, near the tip of the Alaska Peninsula, contains the largest eelgrass bed (160 km^2 [62 mi^2]) along the Pacific Coast of North America and the largest known single stand of eelgrass in the world (Ward et al., 1997).

Allen Shimada, NMFS

The Alaskan pollock fishery lands more fish by weight than any other fishery in the United States (NMFS, 2008).

Patti Haase, NOAA

The wide coastal region of the Bering Sea, except for part of the Seward Peninsula, is mostly shallow with offshore bars and lagoons. Sand and silt are the primary components over most of the seafloor of the Bering Sea, with sand predominating in waters at a depth of less than 60 m (197 ft) (NMFS, 2004). Dense coral gardens have been discovered on high-relief rocky areas in the vicinity of the Aleutian Islands (Stone, 2006)

The Bering Sea is one of the most productive and biologically diverse marine ecosystems in the world. Over 500 vertebrate species are found in the Bering Sea; this includes 418 fish, 102 bird, and 29 marine mammal species (Greenwald, 2006). More than 15 whale and other cetacean species use the Bering Sea as a summer and fall feeding area or as wintering area for several months each year.

The Bering Sea supports one of the largest commercial fisheries in the world. Major commercial species in the Bering Sea are walleye pollock, Pacific cod, flatfish, Atka mackerel, sablefish, rockfish, and crab. Walleye pollock produce the largest catch of any single species in the Alaskan EEZ; walleye pollock made up 62% of the average groundfish catch off Alaska in 2011 (AFSC, 2013).

North Pacific Ocean (Gulf of Alaska)

The Gulf of Alaska (GOA) lies off the southern coast of Alaska and the western coast of Canada. The GOA has about 160,000 km^2 (61,776 mi^2) of Continental Shelf, which is less than 25% of the amount of shelf under the eastern Bering Sea (Mac et al., 1998). In the GOA, between Canada and Cape Spencer, the Continental Shelf is narrow and rough. As the shelf curves westerly from Cape Spencer toward Kodiak Island, however, it extends some 80 km (50 mi) seaward, making it the most extensive shelf area south of the Bering Sea (NPFMC, 2002a). Offshore circulation in the GOA is driven by the Northeast Pacific Subarctic Gyre (also called the Alaska Gyre), which flows counterclockwise (Musgrave et al., 1992). The southern boundary of this gyre is composed of the eastward-flowing Subarctic (Aleutian) Current and the North Pacific Current. These currents divide at the North American coast into the southward-flowing California Current and the Alaska Current, which flows northwest up the Alaska coast. As it reaches the top of the Gulf, the Alaska Current turns west and deepens, becoming the Alaska Stream and the northern boundary of the Alaska Gyre. The Alaska Stream flows offshore along the shelf break. Inshore of the Alaska Current/Alaska Stream is the Alaska Coastal Current (ACC), which is driven by extensive freshwater runoff and winds. The ACC joins the Alaska Stream flowing westward along the Aleutian Islands (Mundy, 2005). The seasonality and strength of these currents, as well as the water exchange between them, are important factors in determining productivity on the Gulf of Alaska portion of the Continental Shelf.

Thousands of rivers and streams enter the GOA from south-central to southeastern Alaska. Prince William Sound, site of the 1989 *Exxon Valdez* oil spill, lies at the northeast end of the GOA. The eastern GOA is bounded by the Alexander Archipelago, a group of over 1,100 islands. Both Prince William Sound and southeastern Alaska are characterized by thousands of miles of rugged shoreline, temperate rain forests, mountains, and glaciers. Tremendous freshwater input and mixing with salt water in Prince William Sound and southeastern Alaska make these areas some of the most biologically productive in the world. Prince

William Sound is classified as a fjord-estuary (Holleman, 2003), and thousands of mostly small estuaries exist in southeastern Alaska.

A variety of habitat types is present in nearshore and offshore waters in the GOA. Nearshore areas of Prince William Sound and southeastern Alaska are characterized by sheltered and exposed rocky shores, sand and gravel beaches, boulders, exposed bedrock walls, tidal flats, kelp forests, and marshes. Eelgrass meadows are common in many protected bays and inlets. Offshore habitats include deep basins and rocky pinnacles. There are two parallel seamount chains in the GOA, extending several hundred kilometers. Seamounts rise from depths as great as 4,200 m (13,780 ft) to as shallow as 170 m (558 ft) (Alaska Marine Conservation Council, 2003). Compared to the Bering Sea, the GOA has relatively weaker currents and tidal action near the seafloor, and therefore contains a variety of substrate types such as sand, silt, gravel, and areas of bedrock (NMFS, 2004). Coral gardens, sponges, and anemones have been identified in the GOA (Krieger and Wing 2002; Heifetz, 2002).

The GOA supports a diverse ecosystem that includes several commercially important species such as walleye pollock, Pacific cod, salmon, sablefish, rockfish, and halibut. Diversity of commercial groundfish species in the GOA is intermediate between the Bering Sea, where fewer species occur, and the Pacific Coast region, where more species are present (NPFMC, 2002a).

High-latitude ecosystems such as the GOA and the Bering Sea are dynamic, with strong seasonal environmental changes that determine the foraging and reproductive patterns of many species. Strong environmental forcing can lead to changes in biological populations between years, which can be exacerbated by climatic regime shifts. Cyclic patterns in weather and biology are often evident, although the linkage is sometimes complex. A wealth of evidence suggests that a major climatic event caused a biological regime shift in the North Pacific Ocean after 1976 (Mantua, 2002). Changes in ocean circulation, upwelling, and temperature resulted in declines of some species and increases in others (NPFMC, 2002b). For example, in the early 1970s NOAA's National Marine Fisheries Service (NMFS) trawl surveys in the GOA had catches that were dominated by crustaceans such as shrimp; whereas in the late 1970s through the late 1990s, catches were dominated by flatfish, cod, and pollock (Anderson and Piatt 1999; Mantua, 2002). Similarly, harvests of Alaska salmon in the 1990s rebounded to near all-time peak levels compared to record low catches in the 1970s (Heard and Andersen, 1999). Steller sea lion and some sea bird populations have declining trends that may also be related to the regime shift. In addition to long-term changes, there is considerable annual variability in ocean conditions (e.g. ice cover, storms), which in turn affects the survival of fish larvae.

NMFS

Sampling fish with a beach seine in an eelgrass meadow near Sitka, Alaska.

Arctic Ocean

Alaska's Arctic region is bounded by the Beaufort Sea to the north, the Chukchi Sea to the west, and the crest of the Brooks Range to the south. Surface waters of the Pacific Ocean mix with those of the Arctic Ocean through the Bering Strait. In winter, a permanent cap of sea ice covers almost all of the Arctic Ocean. In summer, the ice shrinks and exposes narrow bands of relatively open water along the coast of Alaska. In the last decade sea ice has been less in extent and thickness. Recently, the summer extent of Arctic sea ice has been 15–20% below the 1979–2000 average (NOAA, 2011a). The Arctic region is crossed by many northward-flowing streams, the largest of

NMFS

A small stream entering the Chukchi Sea near Barrow, Alaska.

which is the Colville River. The region is not currently glaciated, although evidence suggests that an ice cap 1 km (0.62 mi) or thicker covered the Arctic Ocean during the Pleistocene glaciations (Polyak et al., 2001). The Arctic region contains continuous permafrost, tundra, and numerous small lakes and ponds. Numerous estuaries exist where freshwater streams enter the Beaufort and Chukchi Seas. These areas are often bordered with barrier islands, creating vast brackish-water lagoons. For example, Kasegaluk Lagoon, in the Chukchi Sea, is over 190 km (120 mi) long and its width spans 8 km (5 mi). The Colville River Delta, near Prudhoe Bay, spans over 40 km (25 mi) in width, and its shallow waters (less than 3 m (10 ft) deep) extend 16 km (10 mi) or more offshore. Shallow waters persist across the entire southern Beaufort Sea, roughly 645 km (400 mi), and along the eastern edge of the Chukchi Sea.

The coastline of the Beaufort Sea and Chukchi Sea is similar to the Bering Sea, harboring extensive barrier islands with lagoon habitats. The Chukchi Sea also has sections of sea cliffs, particularly southwest of Barrow. Approximately one-third of the Arctic Ocean is underlain by the Continental Shelf, including a narrow shelf along North America. The average depth of the Arctic Ocean is only 1,300 m (4,265 ft) due to its vast shallow expanses over the Continental Shelf (NPFMC, 2009a,b).

Arctic fisheries provide important contributions, mostly as subsistence food for Alaskan Natives. Important species in the nearshore Beaufort Sea include Arctic cisco, broad whitefish, least cisco, and Dolly Varden char (Thorsteinson and Wilson, 1995).

HABITAT USE

This section contains a qualitative description of habitat use for regional species grouped by fishery management plan (FMP), protected species, and state-managed and non-FMP species. Table 13 provides a summary of typical habitat use patterns in the Alaska Region organized by FMP and protected-species groups of cetaceans, pinnipeds, and sea turtles (managed by NMFS). The table shows patterns of typical use for one or more species within each group. However, it is important to recognize that these groups include many species, all of which have unique habitat requirements by life stage. Habitat information is lacking for many Alaska species, particularly in the earlier life stages, and such critical information gaps are not captured in this table.

As Table 13 shows, in the Alaska Region salmon are the primary FMP species to utilize freshwater habitats. Estuarine, shallow marine, and oceanic habitats are all important for FMP species in the Alaska Region, with the extent of the importance depending upon the species, population, and life stage.

The NMFS Habitat Assessment Reports are major sources of information on the habitat associations, characteristics, and predator–prey relationships of FMP species; these reports compile species information by life stage (NMFS 2005). Most Alaska FMP species are lacking more detailed habitat information beyond distribution (presence/absence). Information on habitat-specific densities, growth, reproduction or survival rates, and production rates is usually not available. The Alaska salmon FMP has the most complete information on salmon distribution across all habitat categories in Alaska. Most species groups at some time during their life history utilize estuarine and nearshore habitats, but little information is available to characterize the relationships. Additional information and site-specific research

Table 13
Typical use of the four major habitat categories in the Alaska Region, summarized by FMP and protected-species groups of cetaceans, pinnipeds, and sea turtles.

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

Fishery management plans [a]	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
1. Alaska Salmon	F	F	F	F
2. Alaska Scallops	N	O	F	O
3. Bering Sea/Aleutian Islands Groundfish	N	F	F	F
4. Bering Sea/Aleutian Islands King and Tanner Crabs	N	F	F	F
5. Gulf of Alaska Groundfish	N	F	F	F
6. Arctic Management Area (Cod Species and Crab)	N	O	F	F
Total percentage of all Alaska FMPs with one or more species that typically use each habitat type	17%	100%	100%	100%
Protected species groups [a]				
Cetaceans	O [b]	F	F	F
Pinnipeds	O [b]	F	F	F
Sea Turtles	N	N	O	O
Total percentage of all Alaska cetacean, pinniped, and sea turtle groups that use each habitat type	67%	67%	100%	100%

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

[b] Alaska cetaceans occasionally found in freshwater habitats are beluga whales and harbor seals; however, there are a few documented exceptions that display more frequent use of freshwater habitats. The Bristol Bay stock of beluga whales regularly uses the Kvichak River each spring to feed on salmon and rainbow smelt. Additionally, there is a population of harbor seals that resides year-round in Lake Iliamna, located in southwestern Alaska.

on habitat use by nearshore fishes can be accessed online in the Nearshore Fish Atlas of Alaska.[4]

NMFS has developed a new approach to refine overly-broad information on Pacific salmon marine distributions (Echave et al., 2012). Oceanic variables, such as sea surface salinity, temperature, and depth, were analyzed to assess "preferred" habitats for each species by life history stage. These modeled areas were then correlated with data from NOAA surveys, commercial catches, international fish studies, and historic accounts. Results depict concentration areas unique to each species and life stage. This approach could be used to refine the distributional information on other widely distributed marine species through analysis of associated oceanographic variables.

Alaska's cetaceans and pinnipeds use a wide range of habitats including estuarine, shallow marine, and oceanic habitat types, though use depends on species, stock, and life stage. Some pinniped species (e.g. harbor seals) and cetacean species (e.g. beluga whales) and populations occasionally use freshwater habitats. There are some harbor seals that reside year-round in Lake Iliamna, a freshwater environment. Sea turtles are rare in the Alaska Region and tend to occur only under certain environmental conditions. As in other regions, habitat-specific productivity information is scant for most cetaceans, pinnipeds, and sea turtles, while distribution (presence/absence) information is most common.

[4]See http://alaskafisheries.noaa.gov/habitat/fishatlas/ (accessed August 2013).

Habitat Use by FMP Species

Habitat use information is limited for most species included in the six FMPs for Alaska. The six FMPs are for groundfish in the Bering Sea and Aleutian Islands (BSAI); groundfish in the GOA; king and Tanner crab in the BSAI; scallops; salmon; and the Arctic.

BSAI and GOA Groundfish FMPs—More than 60 groundfish species with different life history strategies and habitat requirements are managed in the BSAI and the GOA. These include walleye pollock, Pacific cod, rock sole, yellowfin sole, flathead sole, Pacific ocean perch, northern rockfish, Atka mackerel, and sablefish (NPFMC, 2012a,b).


Victoria O'Connell, ADFG

Pacific cod and rockfish in the Gulf of Alaska

Many of the species occur over broad ranges in the North Pacific Ocean, although species that occur in both the BSAI and GOA are believed to consist of different stocks in the two areas. There is a wide diversity of habitat types ranging from extensive soft-bottom areas of the Bering Sea Shelf to complex high-relief habitats of the Aleutian Islands and portions of the GOA. Depending on species and life stage, habitats used in the BSAI and the GOA include intertidal beaches, bays and estuaries, the Continental Shelf (<200 m [<656 ft]) and Slope (>200 m), and deepwater basins (>3,000 m [>9,843 ft]) (NPFMC, 1998, 2002a; AFSC, 2013). Information on distribution and habitat use is limited for many of the above species, especially for early life stages. Several forage fish species are included in the BSAI and the GOA FMPs. These species are usually not targeted by commercial fisheries but are significant components of the ecosystem. Forage fish are extremely important in the diet of other fish, sea birds, and marine mammals. Important forage species include Pacific sand lance, capelin, and eulachon. Pacific herring, another important forage species, is managed by the State of Alaska and is not a federal FMP species.

For two of the most abundant target species in the BSAI and the GOA, walleye pollock and Pacific cod, larvae are pelagic, occurring in the upper 45 m (148 ft) of the water column in the outer- to mid-shelf region of the BSAI and throughout the Continental Shelf in the GOA. Juveniles of both species occur over the inner, middle, and outer areas of the Continental Shelf—Pacific cod are associated with mud, clay, silt, and gravel substrates, whereas the benthic habitat preference of pollock juveniles is unknown. In some areas of the North Pacific Ocean, juvenile pollock and Pacific cod occupy nearshore habitats of eelgrass and kelp (Dean et al., 2000; Johnson et al., 2003, 2012; Thedinga et al., 2011).

In the BSAI, few adult pollock occur in waters shallower than 70 m (230 ft); some pollock occur pelagically in the Aleutian Basin. Pacific cod generally occur from the shoreline to 500 m (1,640 ft) depth. Generally, both pollock and Pacific cod move inshore during summer and offshore for winter, occupying greater depths during the cold months.

The most diverse species group in the GOA is the rockfishes (genus *Sebastes*), of which 30 species have been identified. Habitats commonly used by rockfish are complex bottoms of cobble and boulder, vertical bedrock walls, gullies, and offshore banks. Most flatfishes in the BSAI and the GOA are associated with soft bottoms of mud, silt, and sand. Juvenile flatfish and rockfish are frequently found in nearshore waters.

BSAI King and Tanner Crab FMP—The BSAI king and Tanner crab FMP includes red king crab, blue king crab, golden king crab, Aleutian Islands scarlet king crab, Tanner crab, Bering Sea snow crab, grooved Tanner crab, and triangle Tanner crab (NPFMC, 2011). Habitat use and information levels vary by species and stock (NPFMC, 1998). In general, larvae tend to be found in estuarine or nearshore areas. Blue king crab larvae are typically found at depths from 40 to 60 m (131–197 ft). Tanner crab larvae are typically found in the BSAI water column at depths from 0 to 100 m (0–328 ft) in early summer.

Early-stage juveniles also tend to be found in nearshore areas. Many species use bottoms with high relief provided by living substrates (e.g. anemones, sea star arms, sponges, barnacle assemblages) and non-living substrates (e.g. cobble, shell hash[5]). Red king crab early-stage juveniles tend to be found at depths less than 50 m (164 ft) and

[5]Shell hash: a mixture of sand or mud with gravel and unconsolidated broken shells of clams, oysters, or other shellfish.

use high-relief bottom habitat of coarse substrate consisting of boulders, cobble, shell hash, and living substrates like bryozoans or stalked ascidians (Pirtle et al., 2012). Blue king crab early-stage juveniles use substrate consisting of gravel and cobble overlaid with shell hash, sponge, hydroid, and barnacle assemblages. Tanner crab early-stage juveniles are found on mud bottoms at depths between 10 and 20 m (33–66 ft) in summer.

Late-stage juveniles prefer both nearshore and offshore habitats, depending on species. Blue king crab and Bering Sea snow crab late-stage juveniles utilize nearshore habitats, and golden king crab utilizes offshore habitats. Adults also prefer a range of habitats; for example, blue king crab adults tend to be found in nearshore areas, whereas golden king crab adults can be found at all depths. Many species migrate to shallow, nearshore waters for mating and molting. In addition, steep and rocky outcrops and slopes as well as strong currents are associated with species such as golden king crab and Aleutian Islands scarlet king crab.

Arctic FMP—The Arctic FMP was added in 2009 in response to a changing marine ecosystem due to warming ocean temperatures and loss of sea ice. These new environmental conditions could lead to commercial fisheries opening in the U.S. EEZ of the Beaufort and Chukchi seas. Currently there is not enough information to conduct stock assessments and identify essential fish habitat for these areas. Compounding this data gap are significant protected resources and subsistence activities in the Arctic's marine ecosystem. Until sufficient information is available for an implementable fisheries management plan, all federal waters in the Arctic, an area of 515,144 km^2 (150,000 square nautical miles [nmi^2] are closed to commercial fishing (NPFMC, 2009a). The Arctic FMP, however, does not regulate subsistence or recreational fishing or State of Alaska-managed fisheries in the Arctic.

Target species for the Arctic FMP are Arctic cod, saffron cod, and snow crab. These species were determined to have the most biomass in Arctic marine waters; all three species are more abundant in the Chukchi Sea (NPFMC, 2009b). These target species tend to be smaller in length compared to populations in the Bering Sea or Gulf of Alaska. Detailed life-history descriptions of these species are not available, and how they utilize Arctic habitats is unknown. A 30–40 year gap exists between comparable bottom trawl surveys in the Arctic. The earliest surveys in the Chukchi Sea were conducted during 1959 and 1976 by the University of Alaska (Barber et al., 1994), and the more recent surveys were conducted by the NMFS Alaska Fisheries Science Center (AFSC) in 2008 and 2012 (Rand and Logerwell, 2011).

Arctic cod, although small in size, is considered a keystone species in the Arctic ecosystem. Studies have shown that Arctic cod are an important prey species consumed by belugas, ringed seals, and marine birds (Frost and Lowry, 1984). In turn, Arctic cod rely on the highly variable secondary producers, such as copepods, euphausiids, and pelagic amphipods, for forage. Scientists know very little, however, about Arctic cod spawning areas, reproductive success, larval and juvenile stages, and growth or survival rates. Saffron cod are not considered a keystone species but are a major species in the Arctic ecosystem, and basic information on their life history is scarce (Johnson et al., 2009). How important is the Arctic nearshore to these species, and how do they utilize ice habitat? These are critical questions that need to be answered to manage any potential fisheries in the future.

The habitat use of snow crab in the Arctic is likely similar to that of populations in the Bering Sea, and their management will focus on harvestable males of a certain carapace size. The sizes of

NMFS

A Tanner crab with sonic tag attached to monitor movement and habitat use of this commercially valuable species.

Elizabeth Calvert Siddon, NOAA, UAF

NOAA

Top: Arctic cod swimming among ice floes at Canadian Basin, north of Barrow, Alaska. Below: a close-up view of young cod.

Beaufort and Chukchi sea snow crabs currently average below the Bering Sea harvestable size. A 2008 Beaufort Sea survey revealed snow crab carapace widths ranging from 55 to 119 mm (2–5 in), and this species was the second most abundant invertebrate captured (Rand and Logerwell, 2011). From limited survey data, it appears snow crab populations in the Arctic are often immature females and sublegal males, but they can mature at a small size, unlike populations found in more southerly latitudes.

Component species of the Arctic FMP are a mix of common fish species and marine invertebrates, many of which are associated with benthic habitats. Some of these species have been placed in general groupings like “eelpouts” or “snailfishes,” due to their high diversity and unresolved species identifications (see Appendix 5). In general, benthic habitats in the Beaufort and Chukchi Seas have a high ratio of invertebrates to fish, with invertebrates accounting for more than 90% of the total identified biomass in bottom trawl hauls (Frost and Lowry, 1984). Brittle stars, sea stars, crinoids, sea cucumbers, and crustaceans dominate trawl catches.

Alaska Scallop FMP—The Alaska Scallop FMP includes all scallop stocks in federally managed waters of Alaska. Since weathervane scallops are the primary stock harvested commercially, their habitat use is the primary focus of this section. Weathervane scallops use coastal and offshore habitats (NPFMC, 1998). Gametes and larvae use demersal and pelagic waters of the inner, middle, and outer areas of the Continental Shelf of the GOA and, to a lesser extent, the BSAI. Larvae drift with tides and currents, and after 2–3 weeks, settle to the bottom. Within 2 months of settling, juveniles develop the ability to swim. Juveniles and adults are generally found on substrates of clay, mud, sand, and gravel at depths from 2 to 185 m (6–607 ft). Weathervane scallops are also likely to be found in areas where red king crab, Tanner crab, shrimp, octopi, flatfish, Pacific cod, and other benthic marine organisms are present (NPFMC, 2006).

Other species listed as ecosystem components in the FMP include pink (or reddish) scallops, spiny scallops, and rock scallops. Pink scallops are distributed between California and the Pribilof Islands and are found at depths up to 200 m

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Left: A salmon spawning stream in the southeastern part of Alaska.

Upper right: Several sockeye salmon in spawning coloration.

Lower right: Newly hatched salmon in the alevin stage.

(660 ft). They prefer soft sediment and spawn January through March. Spiny scallops are distributed from California to the Gulf of Alaska and are found at depths up to 150 m (495 ft). They prefer areas with hard sediment and strong currents, and they spawn August through October. Rock scallops are distributed from Mexico to Unalaska Island and are found in shallower waters down to a depth of 80 m (264 ft). They attach to rocks, prefer areas with strong currents, and spawn during October through January and March through August (NPFMC, 2006).

Alaska Salmon FMP—The Alaska Salmon FMP includes pink salmon, chum salmon, sockeye salmon, Chinook salmon, and coho salmon (NPFMC, 1990). Alaska salmon have a generalized life history that includes initial rearing of juveniles in fresh water, migration to oceanic habitats for extended periods of feeding and growth, and return to natal waters for completion of maturation, spawning, and death. Alaska salmon, including all their different life stages, use freshwater, estuarine, nearshore, offshore, and oceanic island and bank habitats. Habitat preference and duration of use varies by life stage and species (Groot and Margolis, 1991; North Pacific Fishery Management Council, 1998; Echave et al., 2011).

Eggs and larvae are found in freshwater habitats, which include rivers, streams, sloughs, lakes, ponds, streambeds, and sometimes, intertidal areas. Some factors that influence site selection for eggs and larvae are sediment type, water depth, current velocity, temperature, and dissolved oxygen. Preferences among freshwater habitats and water conditions vary by species. Length of freshwater residence ranges from only a few weeks for pink and chum salmon to 4 years for sockeye salmon rearing in lakes.

Species with extended freshwater rearing, such as coho salmon, prefer still water (e.g. pools, beaver dams)—these habitats are often formed by large woody debris and provide protection from fast currents and predators. Juvenile salmon also utilize stream areas with overhanging vegetation as cover and to provide advantageous positions for feeding on terrestrial insects that fall into the water.

During seaward migration, juvenile salmon utilize freshwater or estuarine habitats depending upon species and stock. Unobstructed passage and suitable water depth, water velocity, water quality, and cover are important elements for migration habitat of all species. Further into migration, all


Alaska ShoreZone Program, NMFS

Complex tidal channels in a salt marsh in Southeast Alaska are important habitat for juvenile salmon as they migrate to the sea.

species utilize estuarine waters to complete the physiological transition needed to live in oceanic environments. In estuarine waters, some species use kelp, eelgrass, and other submerged aquatic vegetation for feeding and cover (Johnson et al., 2003, 2005).

Once salmon reach the ocean, adults and juveniles can be found in nearshore, offshore, and oceanic island and bank habitats, although usage and duration varies by species and stock. Time at sea ranges from 18 months for pink salmon to 5 years for Chinook salmon and chum salmon. In nearshore areas, salmon can be found in the intertidal zone, in bays, and throughout the Continental Shelf. In offshore areas, salmon may be found in upper and lower slope habitats ranging from 200 to 3,000 m (656–9,843 ft) in depth and in basins greater than 3,000 m depth. Salmon may also be found in island passes in areas of high current. Salmon occupy the upper water column, generally from the surface down to a depth of about 50 m (164 ft). Chinook salmon and chum salmon, however, use deeper waters, generally to about 300 m (985 ft), but on occasion to 500 m (1,640 ft). Upon returning from the ocean to freshwater habitats for life cycle completion, estuarine and freshwater habitats as described earlier are once again used.

In Alaska, Chinook salmon fisheries in western Alaska and Cook Inlet started failing in 2010, and were declared a fishery resource disaster for 2012. The exact cause of these failures is undetermined, but changing ocean conditions, loss of habitat, and inadequate management are likely factors (Mundy and Evenson, 2011).

Habitat Use by Protected Species

Marine Mammals—NMFS has management authority for 45 stocks of cetaceans and pinnipeds that occur within the Alaska Region. Sixteen of these stocks are designated as strategic stocks. This means that either human-caused mortality exceeds the potential biological removal level, the stock is listed as endangered or threatened under the Endangered Species Act (ESA), the stock is declining and likely to be listed as threatened under the ESA, and/or the stock is designated as depleted. Alaskan strategic stocks include the Alaskan bearded seal; the Cook Inlet beluga whale; larger whales, including bowhead, fin, humpback, right, and sperm whales; harbor porpoises, and steller sea lions. Polar bears, sea otters, and walrus fall under the jurisdiction of the U.S. Fish and Wildlife Service and are not discussed in this report. Alaska's cetaceans and pinnipeds use a wide variety of habitats that include all four habitat types (freshwater, estuarine, shallow marine, and oceanic) discussed in this report, although habitat use patterns vary by species and stock.

- **Cetaceans**
  Harbor porpoises, Dall's porpoises, humpback whales, killer whales, and gray whales are commonly found in the nearshore waters of Alaska. Fin whales and blue whales are also found in Alaska's waters, but generally occur in the open ocean rather than near the coast. Many cetaceans bear their young in Alaskan waters, although gray and humpback whales traverse long distances to lower latitudes to bear their young but then return to Alaska for foraging—the rich and abundant prey base in Alaska is often critical to their life history. Apart from gray

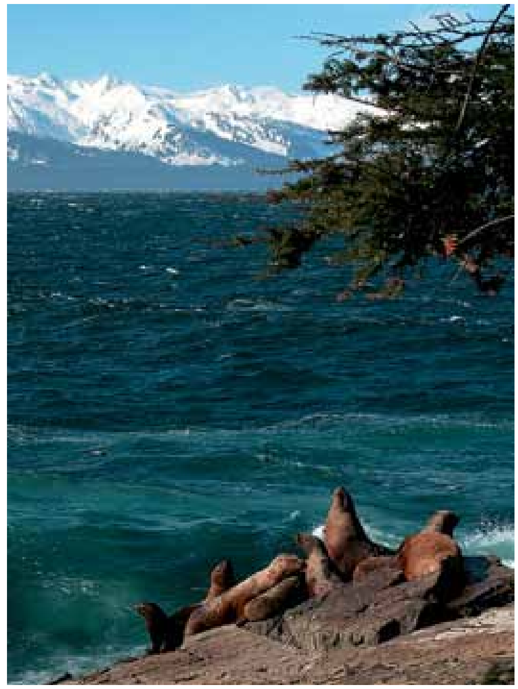
whales, which were delisted under the ESA, all large whales occurring in Alaskan waters are listed as endangered due to over-exploitation by commercial whaling operations. Among the large whales that occur in Alaskan waters, the North Pacific right whale is the only cetacean for which critical habitat has been designated: it is situated in a broad area of the North Pacific Ocean.

Beluga whales can occur in estuarine, coastal, offshore, and even freshwater habitats. Concentrations of beluga whales can be found in Cook Inlet, Bristol Bay, Norton Sound, Kasegaluk Lagoon, and the Mackenzie Delta (NMFS, 1999a). The Cook Inlet beluga whale population is currently listed as endangered under the ESA. The Bristol Bay stock regularly uses the Kvichak River each spring to feed on salmon and rainbow smelt. Seasonal distribution of beluga whales is affected by ice cover, tides, food availability, temperature, and human activity. During winter, beluga whales occur in offshore waters associated with pack ice; in spring, they migrate to warmer coastal estuaries, bays, and rivers for mating and calving (NMFS, 1999a).

- **Pinnipeds**

Steller sea lions, harbor seals, and northern fur seals need habitat to rest, avoid predation, and bear their young. Rocky shores, reefs, sand and gravel beaches, sand and mud bars, and glacial and sea ice are commonly used haul-out and rookery sites. These sites are very specific to each species and are used every year. Some species, such as harbor seals, make extensive use of river deltas and estuaries for feeding. There is even a population of harbor seals that resides year round in Lake Iliamna, a freshwater environment located in southwestern Alaska.

The abundance of western Steller sea lions is increasing overall in Alaska, but there are regional differences in trends. In the central and western Gulf of Alaska and through the eastern Aleutian Islands, the population is increasing; while through part of the central and all of the western Aleutian Islands, numbers are declining. Reasons for the decline in part of their range are unknown, but likely include decreased prey availability, lower diet diversity, environmental change, increased predation by killer whales,


NMFS

Steller sea lions hauled out on Benjamin Island near Juneau, Alaska.

disease, contaminants, and anthropogenic effects (Allen and Angliss, 2012). Steller sea lion populations west of Kayak Island in the Gulf of Alaska are listed as endangered.

Ringed, bearded, ribbon, and spotted seals, commonly referred to as “ice seals,” can be found on Alaska’s sea ice. Throughout different parts of the year, these seals rely on sea ice for pupping, mating, foraging, and resting. Each ice seal species has unique habitat needs and relies on the ice in different ways. For example, ringed seals rear their pups in snow caves on the ice, and bearded seals need ice close to shallow-water habitats for foraging. The extent of sea ice in the Arctic and sub-Arctic has been declining in recent years due to climate change, which is reducing the amount of habitat for ice seals. Because this trend is predicted to continue or even increase, ice seal populations are likely to be under increasing pressure in the future.

Sea Turtles—All six species of sea turtles found in the United States are listed as endangered or threatened under the ESA (NMFS, 1999b). In Alaska there are no nesting beaches, and observations of sea turtles in open waters are rare. Documented sea turtle occurrences in Alaska since 1960

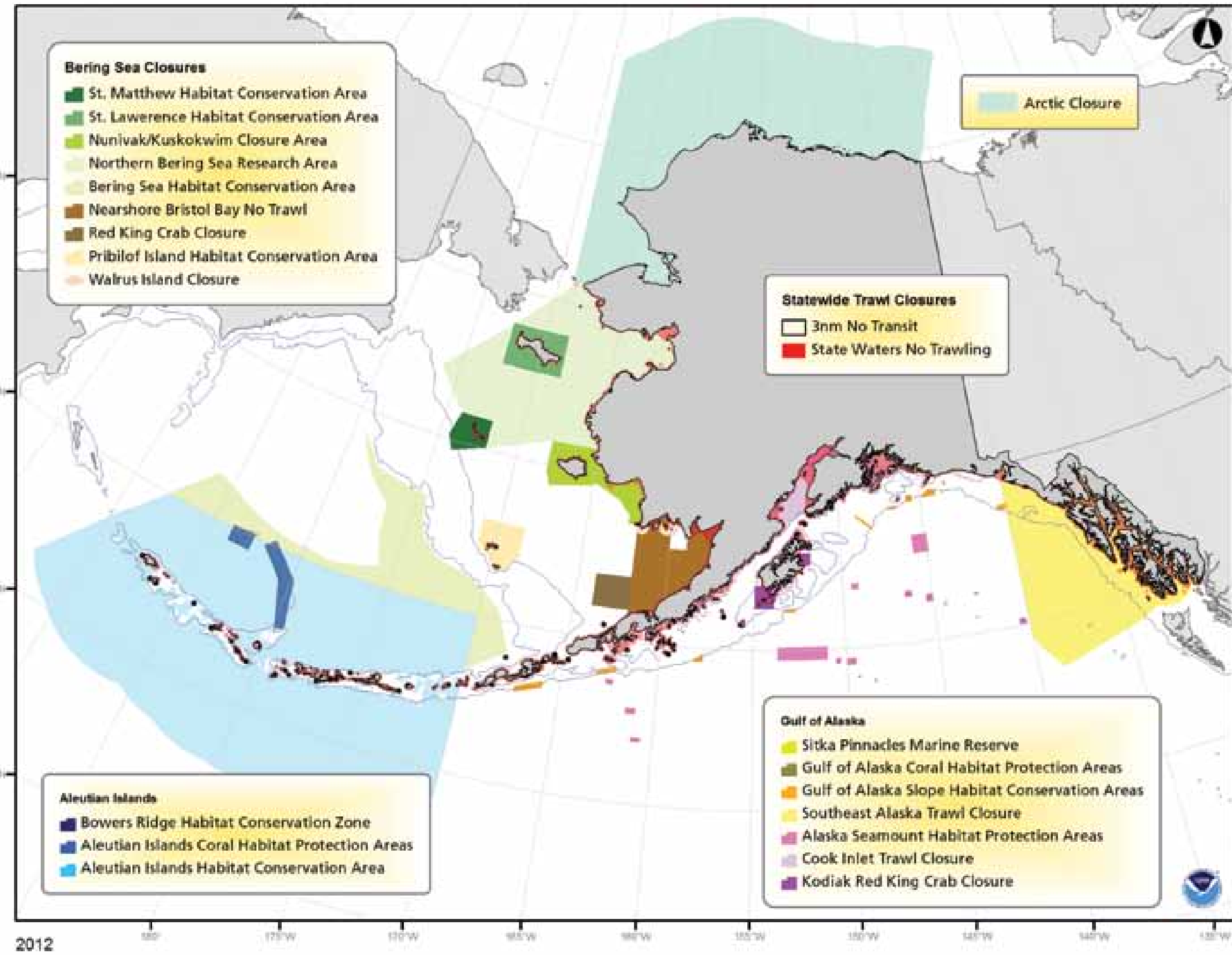


Figure 2
Alaska habitat conservation areas as of 2012.

include 19 leatherback, 9 green, 2 olive ridley, 2 loggerhead, and 2 unidentified hard-shell turtles (Hodge and Wing, 2000). Rare turtle observations mainly occur when warmer ocean currents trend northward into the North Pacific, such as during El Niño events.

Deep-Sea Corals—While the protected species habitat use section primarily addresses species included under the ESA and MMPA, some species and habitats are protected as the result of fishery management actions, rather than under the ESA or MMPA. In the Alaska Region, these protected areas include sensitive deep-sea coral habitat for fishery species and are some of the largest protected areas in the U.S. See Figure 2 that shows a map of Alaska's habitat-protected (conservation) areas for 2012. Sixteen seamounts (with a total area of over 18,200 km^2 [7,027 mi^2]) are identified as Habitat Areas of Particular Concern (HAPC) and are conservation areas where fishing activities are prohibited or restricted from contacting the seafloor (NOAA, 2006). As deep corals are found within these seamounts, they have been protected to prevent destruction of the associated fragile corals.

Deep-sea corals are widespread throughout Alaskan waters, including the Continental Shelf and upper slope of the Gulf of Alaska, Aleutian Islands, and the eastern Bering Sea, and extending as far north as the Beaufort Sea. Coral distribution, abundance, and species assemblages differ among geographic regions (Stone and Shotwell, 2007). Gorgonians and black corals are most common in the Gulf of Alaska, while gorgonians and hydrocorals are the most common corals in the Aleutian Islands. True soft corals are common on Bering Sea Shelf habitats (Stone, 2006).

Overall, the Aleutian Islands have the highest diversity of deep-sea corals in Alaska, and possibly in the North Pacific Ocean, including representatives of six major taxonomic groups and at least 50 species or subspecies of deep-sea corals that may be endemic to that region. In the Aleutian Islands, corals form high-density "coral gardens" that are similar in structural complexity to shallow tropical reefs and are characterized by a rigid framework, high topographic relief, and high taxonomic diversity (Stone and Shotwell, 2007). Although the Aleutian Islands support the highest diversity and abundance of corals in Alaska waters, other subregions, such as the Gulf of Alaska and Bering Sea, support important single-species assemblages of gorgonians, pennatulaceans, and true soft corals.

Many of the commercial fish and crab species currently harvested in Alaska spend all or part of their life cycle in deep-water habitats where corals are potentially found. Their fisheries have caused disturbance and moderate damage to some of these habitats (Heifetz et al., 2009). The Coral Reef Conservation Program helps provide support to reduce harm to and restore the health of corals (including deep-sea corals), and the Magnuson-Stevens Reauthorization Act (MSRA) mandates continued research, mapping, and protection of deep-sea coral communities. As part of NOAA's Deep Sea Coral Research and Technology Program (established by MSRA), NMFS initiated a 3-year research program in 2012 to address questions about deep-sea corals in Alaska and help provide basic information on their biology, distribution, and species-specific responses to stressors.

Habitat Use by State-Managed, Non-FMP, and Internationally Managed Species

Species of commercial and subsistence value, primarily managed by the State of Alaska or other authorities, include Pacific salmon, Pacific halibut (managed by the International Pacific Halibut Commission), Pacific herring, lingcod, Dungeness crab, pink shrimp, coonstriped shrimp, humpy shrimp, sidestriped shrimp, spot shrimp, butter clam, cockles, softshell clam, truncated softshell clam, geoduck clam, razor clam, Pacific littleneck clam, pinto abalone, California sea cucumber, and green sea urchin. These species occupy a wide range of depths and habitat types (ADFG, 2003). Pacific halibut spawn in deep waters (365–550 m [1,200–1,800 ft]) off the edge of the Continental Shelf. The eggs and larvae can be transported several hundred kilometers, and juveniles eventually settle and rear in shallow, nearshore areas. Pacific herring spawn in nearshore areas, often on kelp or eelgrass. Lingcod typically inhabit nearshore rocky reefs at depths from 10 to 100 m (33–328 ft); juveniles can be found in eelgrass meadows. Dungeness crab prefer sandy or muddy bottoms at depths of less than 90 m (295 ft), but can be found at depths down to 185 m (607 ft). Spot and coonstriped shrimp are generally associated with rock piles and corals; whereas pink, sidestriped, and humpy shrimp typically occur over muddy bottoms. Depending on the species, shrimp can be found at depths from 3 to 1,500 m (10–4,921 ft). Most clam species occupy intertidal and shallow subtidal areas with soft bottoms. Pinto abalone use nearshore rocky areas with ocean swell, often in thick kelp beds. California sea cucumbers occupy either hard or soft bottoms from shallow, nearshore waters down to depths of 250 m (820 ft). Finally, green sea urchins occur on rocky shores near kelp beds but can be found to depths of 130 m (427 ft).


NOAA

A deep-sea coral community showing delicate structures.

An intertidal reef with sand and gravel on its crest, near Craig, Alaska.

HABITAT TRENDS

Alaska's freshwater and marine ecosystems remain healthy and are some of the most productive in the world. Habitats in some regions, however, have been affected by human activities, but historical information on habitat gains and losses is limited. Habitat losses are occurring in wetland or coastal habitats from construction of boat harbors, log transfer facilities (LTFs), residential areas, industrial complexes, roads, and airports. Coastal wetlands provide habitat for many life stages of commercial species. Similarly, habitat has been lost or impaired in some estuaries and anadromous fish streams, mostly near population centers or larger developments associated with natural resource extraction (e.g. mining, logging, oil and gas field development).

Riparian vegetation provides woody debris to streams for anadromous fish habitat, maintains water quality, and moderates stream temperature, siltation, and erosion. Harvested logs are sometimes stored in protected estuaries for later transport to mills. Bark and other debris lost at LTFs and storage sites can accumulate on the seafloor and smother or alter benthic habitat important for crabs and other organisms.

Approximately 2,080 km (1,300 mi) of shoreline in Prince William Sound, Alaska, was impacted by oil from the *Exxon Valdez* spill in 1989 (Peterson et al., 2003). The largest deposits of oil covered 320 km (200 mi) of shoreline, especially in the upper and middle intertidal zones on sheltered rocky shores. Some of the species affected by the spill include sea otters, harbor seals, killer whales, Pacific herring, and salmon. Many of the marine resources affected by the spill have recovered or are well on their way to recovery. Decades later, residual oil remains in some habitats and continues to be a problem for species that spawn or forage in these areas (Short et al., 2006, 2007). This persistence of oil may delay for many years the complete recovery of some habitats or species (Peterson et al., 2003).

Future demands for urban space from population growth and increased production of domestic oil, gas, and fish products will continue to affect the quantity and quality of fish habitat. For example, oil production in Alaska is declining, but national policies may change, increasing exploration in wetland and coastal areas. Alaska has known reserves of oil and gas that remain undeveloped. Commercial timber harvest has also declined in Alaska, but less-protected areas can still be developed, particularly in urban neighborhoods. Fishing activity continues in the BSAI and the GOA, and stocks are considered healthy and sustainably fished.

Human influences on habitat quantity and quality are obvious, when there are direct impacts on fish stocks or on critical habitats. Possibly more profound effects on the productive habitats of Alaska are the indirect effects caused by climate change, which may cause changes in species distributions and the extent of some habitat types (e.g. sea ice) (Orensanz, 2004; Mueter and Litzow, 2008). Likewise, increases in persistent organic pollutants (e.g. PCBs, pesticides) and heavy metals in fishes of northern latitudes (Jewett and Duffy, 2007) may have profound effects on apex predators such as marine mammals in the North Pacific.

RESEARCH NEEDS

The vast size, remoteness, and diversity of habitats in Alaska require comprehensive research and management plans to better understand the importance of habitat and ecological processes. These plans must also be flexible and adapt over time as environments change.

Recently, priorities for research needs in Alaska have been identified at all levels of government: Presidential Executive Orders[6] and a new NOAA Arctic Strategy (NOAA, 2011b); a NMFS Marine Fisheries Habitat Assessment Improvement Plan (NMFS, 2010) and the Habitat Blueprint Initiative;[7] and the AFSC Science Plan and Essential Fish Habitat (EFH) Research Plan (AFSC, 2010; Sigler et al., 2012). All of these plans echo the general need for research in EFH, loss of sea ice, oil and gas development, ocean acidification, and an ecosystem-based approach to management. Table 14 provides a summary of habitat-related research priorities identified in these key planning documents.

Table 15 presents an overview of habitat-specific research needs for the Alaska Region by habitat type. As Table 15 shows, basic life history information is needed as well as an improved understanding of the quantity and quality of habitats needed for all life stages of both FMP and protected species. Habitat mapping is another important research need for both FMP and protected species in all (relevant) habitat types and will help further support an ecosystem-based approach to management. Going forward, it will also be important to understand the effects of many commercial activities on the various habitat types, particularly oil

[6]See this website for examples: http://alaskafisheries.noaa.gov/analyses/ (accessed August 2013).
[7]See this website for more information: http://www.habitat.noaa.gov/habitatblueprint/ (accessed August 2013).

Table 14.
Habitat-related research priorities for the Alaska Region identified in key planning documents, as summarized by Sigler et al. (2012).

2006 EFH Research Plan (AFSC, 2006)
1. Characterize habitat utilization and productivity.
2. Assess sensitivity, impact, and recovery of disturbed benthic habitat.
3. Improve the habitat impacts model.
4. Map the seafloor.
5. Assess coastal areas facing development.
5-year EFH review (NPFMC, 2010)
Immediate Concerns:
1. Assess whether Bering Sea canyons are habitats of particular concern.
2. Assess Bering Sea skate nursery areas and evaluate the need for designation of new Habitat Areas of Particular Concern.
3. Assess baseline conditions in the northern Bering Sea and Arctic.
Ongoing Needs:
4. Improve habitat maps (especially, benthic habitats).
5. Begin to develop a GIS relational database for habitat including spatial intensity of commercial fisheries.
6. Assess the extent of the distribution of *Primnoa* spp. corals in the GOA.
7. Evaluate importance of habitat-forming living substrates to commercially important species, including juveniles.
8. Develop a time series of the impact of fishing on Gulf of Alaska, Aleutian Island, and Bering Sea habitats.
9. Evaluate effects of fishing closures on benthic habitats and fish production.
10. Develop new analytical approaches and/or models to refine EFH descriptions at higher levels.
Habitat Assessment Improvement Plan (NMFS, 2010)
Meet Magnuson-Stevens Act mandates:
1. Improve identification and impact assessments of EFH.
2. Reduce habitat-related uncertainty in stock assessments and facilitate a greater number of advanced stock assessments.
2010 AFSC Science Plan (AFSC, 2010)
Describe and assess the role of habitats in supporting healthy marine ecosystems and populations of fish, crab, and marine mammals:
1. Assess and evaluate the importance of specific habitat types for fish, crab, and marine mammal populations.
2. Evaluate and forecast ecosystem impacts of fishing, and develop mitigation tools.
3. Evaluate and forecast impacts of human activities (other than fishing) on fish, crab, and marine mammals and their habitats.
NOAA Habitat Blueprint
1. Preserve or improve the habitat condition within a defined geographic area and on a scale greater than an individual restoration project.
2. The science component should contribute to the initiative through integration of information, modeling, decision support, and/or monitoring.

and gas development, as well as their impact on the marine species that use these habitats. Climate change is another critical research area, particularly in Alaska. Understanding the direct and indirect effects of climate change with respect to ocean acidification and loss of sea ice on fishery species, deep-sea corals, and marine mammals will be essential for managing and protecting these living marine resources. Improved and increased habitat monitoring and restoration will also provide essential support for the Alaska Region's fishery and protected species.

Essential Fish Habitat

Alaska has more than 60 commercial fish species occupying a diverse range of marine, estuarine, and freshwater habitats. Alaska contains over 50% of the U.S. coastline and leads the Nation in fish habitat area and value of fish harvested; however, large gaps exist in our knowledge of EFH. A range of habitat information is needed, from baseline habitat conditions to investigating the ecological significance of habitats important to all life stages of FMP species. Habitats that need to be surveyed and mapped with new or existing technologies include coastal shorelines, estuaries, salt marsh wetlands, anadromous streams, riparian zones, submerged aquatic vegetation (e.g. eelgrass), deep-sea corals, pinnacles, seamounts, and fishing grounds on the Continental Shelf and Slope.

The NMFS AFSC and Alaska Regional Office (AKRO) identified several priority research areas for EFH that are highlighted in Table 14. These include improved capabilities to do the following: 1) characterize habitat utilization and productivity, increase the level of information available to describe and identify EFH, and apply information from EFH studies at regional scales; 2) assess sensitivity, impact, and recovery of disturbed benthic habitat; 3) validate and improve the habitat-impacts model and begin to develop geographic-based databases for offshore habitat data; 4) map the seafloor; and 5) assess coastal and marine habitats facing development (Sigler et al., 2012). These priorities are based on a review of the 2006 Alaska EFH research plan (AFSC, 2006) and several recent documents: 1) the NMFS Habitat Assessment Improvement Plan, which identified approaches for improving habitat science (NMFS, 2010); 2) the AFSC Science Plan, which identified habitat research priorities (AFSC, 2010); 3) the North Pacific Fishery

Management Council and NMFS Alaska Region 5-year EFH review, which identified habitat research priorities and also summarized recent EFH research (NPFMC, 2010); and 4) the proceedings of the 1st National Habitat Assessment Workshop (Blackhart, 2010).

In 2010, the AKRO and AFSC completed an EFH 5-Year Review (NPFMC, 2010). This review is a status report of EFH knowledge and management measures and is based on published scientific literature, unpublished scientific reports, information solicited from interested parties, and previously unavailable or inaccessible data. It evaluates ten different components ranging from activities that may adversely affect EFH to research and information. As a result of the 2010 EFH 5-Year Review, several actions were taken, including the development of FMP amendments,[8] drafting of new and updated EFH descriptions, revision of FMP Habitat Assessment Reports, and an assessment of the effects of fishing on EFH. Also, a thorough review of non-fishing activities that may adversely affect EFH was completed (NMFS, 2011a).

Loss of Sea Ice

According to the National Snow and Ice Data Center, the extent of sea ice in the Northern Hemisphere in 2012 was the smallest on record, 48.7% below average (NOAA, 2012). Marine ecosystems adapted to cold temperatures and seasonal sea ice will presumably shift northward as ocean temperatures warm and sea ice retreats poleward. Research programs are needed to observe such potential shifts in living marine resources to higher latitudes. Addressing shifts of ecosystems and the habitats within them is critical for managing fisheries and marine mammals. Bering Sea commercial fisheries (which account for >40% of the U.S. catch) are located primarily within the southeastern Bering Sea, and at least 30 Alaska Native communities depend on marine mammals for subsistence. Research needs related to loss of sea ice in the Bering Sea include understanding: 1) changes in species distribution and abundance; 2) linkages between sea ice and availability of living marine resources; and 3) economic and sociological impacts of a changing ecosystem on human communities. Targeted research will enhance forecast model capabilities and enable scientists to develop a comprehensive understanding of the response of living marine resources to loss of sea ice. The AFSC's Habitat and Ecological Processes Research (HEPR) Program serves as a cross-divisional, science-based program to assess possible changes from the loss of sea ice.

John Jansen, NMFS

A bearded seal resting on a small ice floe off the Alaskan coast.

Oil and Gas Development

Energy demand is driving the exploration of new oil fields and expansion of existing oil fields. Oil and gas development is an emerging issue because of the exploration and potential development of new geographic areas (e.g. Chukchi Sea, Beaufort Sea, Bristol Bay). Changing conditions in the Arctic are providing access to areas that were once inaccessible. NOAA must use the best available science to evaluate permit requests for oil and gas development while protecting living marine resources. Major research needs include: 1) determining the impacts of exploration and production-related sound (seismic testing) on marine animals, especially marine mammals; and 2) collecting baseline fishery and marine mammal information (abundance, distribution, resilience to disturbance) in preparation for response to environmental impacts, including oil spills or other disasters.

[8]See the following website for more information: http://www.fakr.noaa.gov/frules/77fr66564a.pdf (accessed August 2013).

Pteropods, which have shells formed of calcium carbonate, are important food souces for juvenile salmon, mackerel, herring, and cod.

Ocean Acidification

Global climate-change studies have revealed that the rate of increase in atmospheric carbon dioxide (CO_2) concentration has increased substantially since the industrial revolution (mid-1700s). The global oceans have absorbed approximately 30% of the anthropogenic carbon emissions released during that time frame (NOAA Ocean Acidification Steering Committee, 2010). When CO_2 is absorbed by seawater, chemical reactions occur that increase acidity and reduce the concentration of calcium carbonate, a mineral important in shell formation, in a process known as "ocean acidification." If CO_2 emission rates continue to increase at the current rate, ocean acidity could increase by approximately 150% relative to the beginning of the industrial era by 2100 (Orr et al., 2005; NOAA, 2010). The resulting reduction in the saturation of calcium carbonate will make it more difficult for some calcifying organisms to sequester calcium carbonate needed to build shells. Marine organisms in Alaska are particularly at risk of effects associated with ocean acidification, because the calcium carbonate saturation levels in the North Pacific Ocean are naturally low. Some Alaska species, such as deep-sea corals and golden king crab, already inhabit undersaturated environments, and understanding how they thrive in this low calcium carbonate environment will help scientists investigate the effects of ocean acidification on Alaska species.

Scientists at the AFSC have worked locally, nationally, and internationally since 2007 to address the potential impacts of ocean acidification on scales from individual organisms to ecosystems. In 2008, AFSC scientists developed a research plan to investigate how increased ocean acidity, and the resultant reduced availability of calcium carbonate, would impact growth, survival, and reproduction of calcareous plankton, commercially important fish and shellfish, ecologically important prey species, and deep-sea corals. Because species-specific physiological responses to ocean acidification are not well understood, a broad research effort was considered for several taxa. Prioritization was given to investigating the larval and juvenile stages of marine organisms, which are thought to be more vulnerable to ocean acidification. Calcareous invertebrates such as shellfish (e.g. clams), pteropods, and euphausiids are likely to suffer direct effects of reduced calcium carbonate availability, and because they are important prey items, this could have impacts on commercially important fish species and marine mammals. In addition, deep-sea corals that provide habitat for commercially important species such as rockfish are sensitive to ocean carbonate chemistry. Additional research will be needed to fully understand the impacts of increased ocean acidity on Alaska's living marine resources.

Ecosystem-Based Approach to Management

As fishery management organizations make progress in incorporating ecosystem-based thinking into management, there is a need to more clearly define the ecosystem-oriented management goals of the organization and the tools available to managers to attain those goals. Parallel to this must be an expansion of the scientific advice provided to management beyond traditional single-species stock assessment advice. In 2007, an ecosystem-based, fishery management strategic planning document was drafted by a team comprising ecosystem, stock assessment, and fishery management experts. The Aleutian Islands Fishery Ecosystem Plan (NPFMC, 2007) is a pilot plan to provide a means (or example) of how a fishery management plan that incorporates the ecosystem approach could be developed. This plan does not supersede or replace any management plan within the current BSAI.

The Resource Ecology and Ecosystem Management group at the AFSC provides the most up-to-date ecosystem information and assessments in the annual Ecosystem Considerations Report (Zador, 2012). This report contains compiled and summarized information about the Alaska marine ecosystem for the North Pacific Fisheries Management Council, the scientific community, and the public. The report includes an ecosystem assessment, updated status and trend indices, and ecosystem-based management indices and information for the Bering Sea, Aleutian Islands, and the Gulf of Alaska ecosystems. This document accompanies the groundfish stock assessment reports presented to the North Pacific Fishery Management Council each fall.

There is a broad spectrum of ecosystem research currently being conducted by the AFSC and elsewhere that can provide useful advice to managers. This work includes habitat and trophic interactions research, long-term monitoring of non-commercial species, and multispecies and ecosystem modeling. Although the ultimate goal is to have quantitative predictions from this research to guide management, these efforts already provide indicators of ecosystem status and trends. These indicators can provide an early warning system for managers, signaling human- or climate-induced changes that may affect stocks and warrant management action. They can also serve to track the success of previous ecosystem-oriented management efforts.

Quantitative indicators are also being developed by the Fisheries and the Environment (FATE) Program, a NOAA program that supports the agency's mission to ensure the sustainable use of U.S. fishery resources under a changing climate.[9] The focus of FATE is on the development and evaluation of leading ecological and performance indicators, their application to practical fishery management problems, and the continuing responsibility to regularly update the indicators, thereby providing current information to fishery stock analysts and the public.

Ivone Ortiz, NMFS

An Atka mackerel tagged for research purposes.

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[9]For more information on the FATE program, see http://www.st.nmfs.noaa.gov/fate/ (accessed March 2015).

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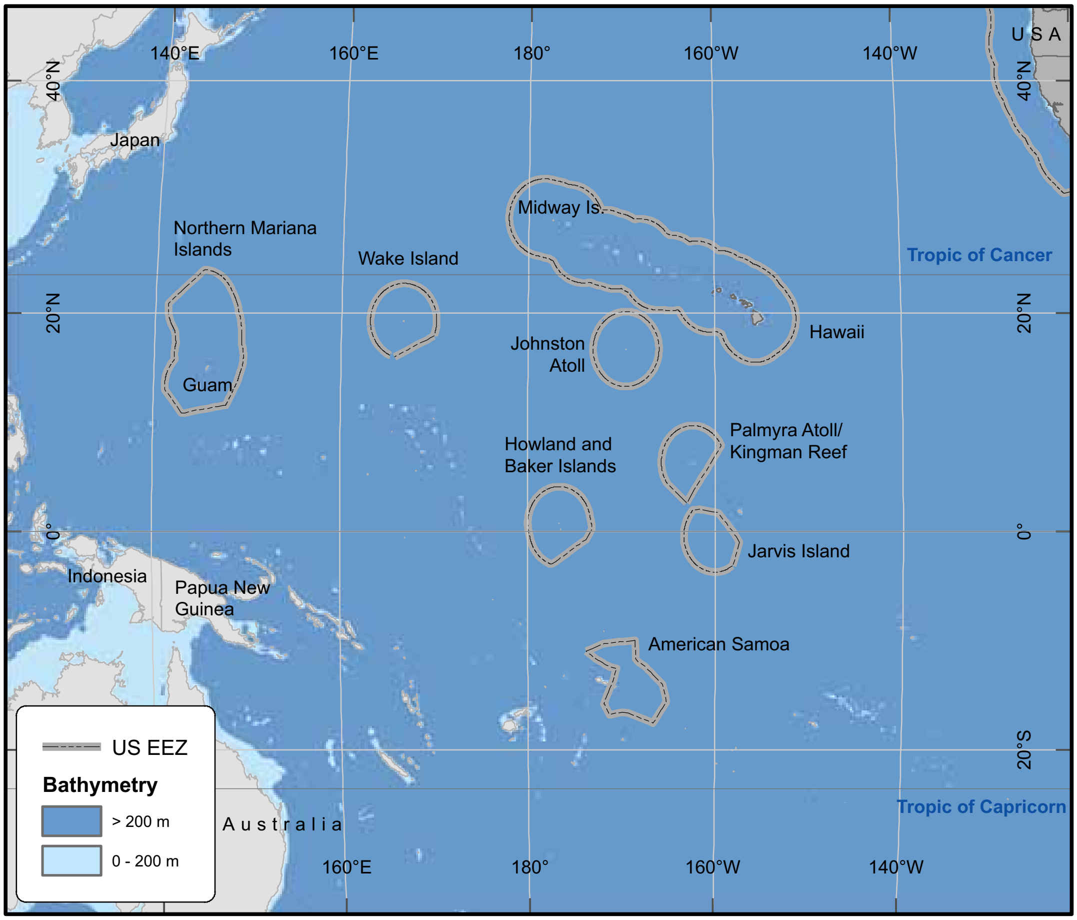
Pacific Islands Region

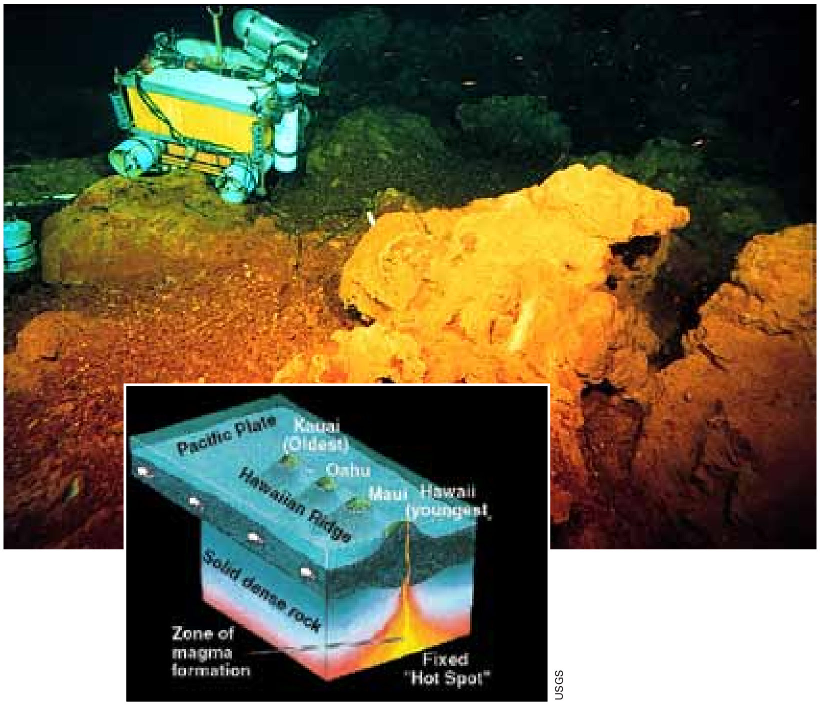


HABITAT AREAS

The United States has jurisdiction over about 50 Pacific Ocean islands, including two archipelagos (Hawaiian and Marianas), part of another archipelago (Samoan), and eight isolated atolls or low-lying islands (Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland Island, Baker Island, Swains Island, and Wake Atoll).[1] Created by volcanoes erupting from the seafloor, these islands are the summits of pinnacles that rise steeply from ocean depths of 4–7 km (2.5–4.35 mi). Although the land area (about 1,900 km^2; 734 mi^2) of the U.S. Pacific Islands Region is small when compared to North America, the total area of U.S. Exclusive Economic Zone (EEZ) waters included in the Pacific Islands Region is 5.751 million km^2 (1.677 million nmi^2), or almost 50% of the entire U.S. EEZ. This combination of geographically wide-spread holdings with small land areas and large marine EEZs creates a large region of predominantly marine biological resources. The indigenous societies of this region, Micronesian in the west and Polynesian in the center, relied on marine resources for food and cultural needs, creating the most maritime of civilizations, and this

[1]Kingman Reef, Palmyra Atoll, Jarvis Island are also part of an island chain known as the Line Islands.

Note: This report has the correct year of publication in the header. The year in the file posted online in July 2015 was incorrect.



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Inset image: Illustration of magma rising to the surface and forming the Hawaiian Islands, and showing the relative age of each island in the chain.

Background image: Underwater equipment monitors Loihi, a volcano that is still underwater in the Hawaiian chain.

reliance continues today. Thus, the islands' marine resources often have a greater per capita value than those of industrialized fisheries, despite the lesser monetary value of island harvests.

The geomorphology of the islands varies and includes some of the youngest and oldest islands in the world. Mountainous "high" islands are found in areas of active volcanism, such as the Marianas and the southeastern end of the Main Hawaiian Islands (MHI), where the next island, called Loihi, which is still roughly 1,000 m (3,280 ft) underwater, is currently being formed. Atolls, or "low" islands, are the much older coral-encrusted remnants of high islands that have eroded to sea level with the passing millennia. The Line Islands (south of Hawaii, crossing the Equator) are estimated to be one of the oldest archipelagos. The Hawaiian Archipelago is an excellent example of the transition of young high islands to old low islands. Islands successively created as the Pacific Plate drifts northwest over a stationary hot spot erode from their initial state as high mountainous islands (e.g. Maui and Hawaii) to become low coral atolls at the opposite end of the chain (e.g. Midway, Kure). Finally, plate drift, subsidence, and sea level rise have drowned many of these low features, creating numerous submerged banks and seamounts.

The oceanography of the Pacific Islands Region is equally varied, with notable differences in effects from ocean currents. Many species at varying trophic levels, and particularly plankton (both holoplankton, which are plankton their entire life cycle, and meroplankton, which are plankton during only part of their life cycle, such as larval fish), are sometimes restricted to single water masses or currents; the endemism of these species indicates the limits of single biogeographic regions. Within the Pacific, these regions are the northern and southern central gyres,[2] the northern and southern currents that border the gyres (in regions called "transition zones"), the equatorial currents, and a fringe area referred to as the eastern tropical Pacific. Because of the pelagic environment's fluidity, the boundaries of these regions overlap, particularly in the western Pacific. As a consequence of this overlap, the environment's fluidity, and the biota's dispersal capability, most pelagic species have ranges that encompass two or more of these ecosystems. U.S. Pacific holdings lie within the following pelagic ecosystems: Midway, Kure, and the northern Hawaiian seamounts are in the north central gyre/northern transition zone ecotone (transitional area);[3] Hawaii and Wake are in the North Pacific central gyre; Johnston is in the central gyre/eastern tropical Pacific ecotone; Kingman and Palmyra are in the equatorial/eastern Pacific ecotone; Jarvis, Howland, and Baker are in the equatorial ecosystem; American Samoa is in the south central Pacific ecosystem; and the Mariana Islands are in an ocean complex with elements from the north central gyre, transition zone origin, and equatorial ecosystems.

Biological resources in the oceanic Pacific differ remarkably from those off the coast of North America. U.S. islands span the east–west extent of the tropical Pacific with its rich warm-water biota, and Hawaii extends from the subtropics northward into the south-temperate climes. An eastern Pacific expanse devoid of land separates the islands from the Americas, while archipelagos within less than 1,000 km (621 mi) of each other connect to the Pacific's western edge. The earth's highest marine biodiversity exists at the juncture of

[2]Gyres are large-scale circular features made up of ocean currents that travel clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

[3]An ecotone is a transition area between habitats or environments.

the Indian and Pacific Oceans; the Pacific Islands Region connects most closely with this area, sharing many species with it. U.S. possessions, dispersed across a realm of great biological richness, therefore contain more marine species than all other U.S. marine regions. These biodiversity patterns in the oceanic Pacific have been shaped primarily by volcanism, tectonic plate movement, sea level change, island subsidence, ocean currents, and human-caused extinctions and species introductions. High and low islands have large ecological differences. Substantial human populations often live on high islands in urban centers that low atolls cannot support. High islands often have substantial rainfall, allowing forests, freshwater streams, and estuaries to exist. Most atolls are dry, lacking dense vegetation and estuaries. High islands have a greater diversity of aquatic habitats, including freshwater and estuarine areas necessary for the life histories of some species that are absent from low islands.

The Pacific Islands Region contains many diverse habitats including high islands, atolls, submerged banks, seamounts, and offshore oceanic habitat. Nearshore habitats with beaches are important terrestrial nesting sites critical to the survival of seabirds and sea turtles and as haul-out sites for Hawaiian monk seals. Shallow nearshore habitats include algal beds, seagrass beds, sand flats, rocky reefs, and rubble-covered bottom, but the most productive habitat of these Pacific islands is the coral reef.

Coral reef ecosystems are among the most diverse and biologically complex ecosystems found on earth, harboring a richness of algae, corals, reef invertebrates, fish, and a variety of other flora and fauna. They are found in the warm, clear, shallow waters of tropical oceans worldwide. Coral reefs and their associated habitats provide economic and environmental services such as shoreline protection, areas of natural beauty and recreation, and sources of food, chemicals, pharmaceuticals, jobs, and revenue. In addition, reef habitats play an important cultural role within the U.S. Pacific Islands Region, where community-based conservation, subsistence fisheries, and managed areas have been successfully implemented for generations. Coral reef ecosystems are deteriorating worldwide at alarming rates due to multiple stressors including climate change, coral bleaching, over-exploitation, coastal development, pollution, marine debris, habitat destruction, boat groundings, diseases, and invasive species. Some of the most serious threats posing extinction risk to corals are considered to be ocean warming, disease, and ocean acidification (Brainard et al., 2011). The rapid degradation of these diverse marine ecosystems is causing significant social, economic, and environmental damage to the Pacific Islands Region and around the world.

PIFSC, NMFS

A Pacific coral reef showing a wide diversity of coral and fishes.

The formation of a coral reef is a long and complex process. Generally, hard corals build coral reefs through the secretion of calcium carbonate by their polyps. Through their symbiosis with unicellular algae (zooxanthellae), reef-building hard corals are the source of primary production in reef communities. Wave action, boring organisms (e.g. sponges, worms, bivalves), and grazers (e.g. parrotfish, sea urchins) break down the coral skeletons into sediment that settles into the interstitial spaces in the reef. Coralline algae, encrusting bryozoans, and minerals then cement the eroded material and stabilize the reef structure. The prevailing theory of coral reef formation, first developed by Charles Darwin, recognizes three types of reefs: the fringing reef, the barrier reef, and the atoll.[4] Fringing reefs border the shorelines of continents and islands in tropical seas, and are commonly found in the South

[4]For more information on atolls, different types of reefs, and their formation, see http://oceanservice.noaa.gov/education/kits/corals/coral04_reefs.html (accessed March 2015).


NOAA

Yellow tangs swimming in coral reef habitat.

Pacific, Hawaiian Islands, and in some parts of the Caribbean. The barrier reef occurs farther offshore, forming when an associated land mass sinks, and fringing reefs become separated from shorelines by wide channels. Barrier reefs are common in the Caribbean and Indo-Pacific, with the Great Barrier Reef off the northeastern coast of Australia recognized as the largest barrier reef in the world, stretching more than 2,000 km (1,240 mi). If the land mass is a small island, it may eventually disappear below the ocean surface, and the reef then becomes an atoll. The result is usually several low coral islands that surround a central lagoon. Atolls commonly occur in the Indo-Pacific, and there are several in the Northwestern Hawaiian Islands (NWHI). The world's largest atoll, Kwajalein, is located 3,900 km (2,423 mi) southwest of Honolulu, Hawaii, and is part of the Republic of the Marshall Islands. Kwajalein Atoll surrounds a lagoon over 97 km (60 mi) long.

Reef-building corals, which thrive above depths of 50 m (164 ft), become rare below 150 m (492 ft), but many animals usually associated with reef habitat may be found to depths of 200–300 m (656–984 ft).

Reef habitats at central Pacific U.S. possessions encompass 15,852 km^2 (6,120 mi^2) divided among 50 islands from four distinct biogeographic regions and have more species than any other single island habitat type. Fishery Ecosystem Plans (FEP) for the Mariana Archipelago, American Samoa, Hawaii, and the Pacific Remote Island Areas list hundreds of currently harvested coral reef species and includes many more potentially harvestable species for a total of more than 2,000 species. But even this number does not adequately represent the high level of biodiversity present in many Pacific reef habitats.

Algal beds are another important habitat in the Pacific Islands Region. These beds are a nearshore habitat used by various organisms for food, shelter, and nursery grounds. Calcareous algae are a major source of sand, which in turn forms habitat for many other species. Subadult and adult green sea turtles, for example, forage primarily on algae and seagrasses.

Freshwater Habitat

There are few enclosed freshwater bodies in the Pacific Islands Region, and they tend to be small and vary widely in their morphology (Maciolek, 1969; Mink and Bauer, 1998). In Hawaii, where they are best described, they include man-made reservoirs, mountain ponds, and water-filled volcanic craters. All of these are isolated from the ocean. Most freshwater habitat in the Pacific Islands Region occurs in the form of streams that are exclusively found on the high islands. Some of these streams are ephemeral in nature, and others flow year-round. In Hawaii, more than 500 streams have been documented. Streams in the least-developed areas are the healthiest, because they have been subjected to fewer introduced species and less channelization. On islands with recent lava flows, fresh water travels underground through the porous crust to mix with salt water on the coast and form anchialine ponds, a unique habitat niche with its own community of animals. On the islands comprising American Samoa, Tutulia has at least 30 streams.

Generally, there is little information available regarding freshwater biodiversity and habitat use in this region (Ellison, 2009). The watershed of the Marianas has had some preliminary study of the fauna, but a complete inventory is needed, particularly in the remote Northern Islands (Concepcion and Nelson, 1999; Donaldson and Myers, 2002). Pacific streams and coastal ponds are habitat for species of freshwater fish, mollusks, and crustaceans that are a conservation concern (Englund, 1999, 2002; Yamamoto and Tagawa, 2000; Cook, 2004). A number of these species have a poorly understood oceanic larval component to their life history.

Estuarine Habitat

Estuaries are semi-enclosed bodies of water that are open at some location to the sea and have a freshwater inflow aside from rainfall. Estuaries and lagoons of Pacific tropical islands are usually small, in contrast to North American estuaries. All estuaries are found on the high islands. The estuaries range from large bays that are primarily salt water, to the mouths of rivers, which vary from salt to fresh water depending on the river flow and tidal phase. Estuaries are composed of mud bottoms, mangrove swamps, brackish marshes, man-made canals, and coral reefs. The Hawaiian Archipelago has 18 estuaries; American Samoa has 14; and the Marianas have 10. The species assemblage varies with each type of estuary. Only a few species are known to complete their entire life histories within certain types of estuaries. Many reef species are known to use brackish habitats as nursery grounds. Estuaries emptying into large saltwater embayments can support sizable adult reef fish communities. The importance of estuarine habitats is largely unknown for species under the jurisdiction of NOAA's National Marine Fisheries Service (NMFS), but indications are that, while some species may opportunistically use estuarine habitats, none of the NMFS species exclusively depend on estuaries for any portion of their life history (e.g. Smith and Parrish, 2002). However, estuarine habitats have been identified as a source of energy (e.g. detritus, meroplankton) that enhances adjacent offshore nursery grounds of deepwater snappers (Parrish et al., 1997).

Shallow Marine Habitat

Lacking a continental shelf, the shallow marine habitats of the Pacific Islands Region can be hard to delineate. This is further complicated by a long history of sea level change, which has created a series of guyots[5]—some connected to islands and reefs, and some located far from any coastal influence other than supporting a shallow (30 m [100 ft]) euphotic demersal[6] community. For the purposes of this description, we will define shallow marine habitats as those benthic habitats connected to the coast. Independent guyots, seamounts, and deep slope habitats will be addressed in the oceanic habitat category. Coastal shallow marine habitats in the Pacific Islands Region can be divided broadly into fringing reefs and atolls.

In Hawaii there are over a dozen fringing reef systems, half of which surround the high islands, and the other half of which skirt the small emergent basalt pinnacles dispersed in the lower half of the archipelago. Samoa supports five fringing reefs, and Guam and the Marianas have six. Fringing reefs are distinguished by their considerable exposure to storm conditions in the form of wave energy and runoff from the adjacent land. As a consequence, these reefs are primarily encrusting forms that can handle the stress of storms. In Hawaii, some of the main islands (Maui, Molokai, and Lanai) are interconnected by submerged land bridges that were drowned as the sea level rose. Currents race over these submerged platforms, providing excellent conditions for the largest known black coral bed in the Pacific Islands Region. In one area the platform extends 40 km (25 mi) seaward, forming a habitat feature referred to as Penguin Bank. In the NWHI, seven of the islands are bordered

NOAA Photo Library

An example of estuarine habitat in the Waimanu Valley on the Island of Hawaii.

[5]Guyots (also referred to as tablemounts) are submarine seamounts with flat tops.

[6]Demersal species are those that live on or near the seafloor.

Pelagic armorhead swim near soft coral habitat on Hancock Seamount, near Midway Island.

by extensive shelves radiating out at 30–40 m (100–130 ft) depths. Cumulatively, this shelf area represents nearly 4,000 km^2 (1,544 mi^2) of area, and its habitat and faunal assemblages are the same as oceanic tablemounts described in the oceanic section (Parrish and Boland, 2004).

Ten atolls in total are found within the U.S. Pacific Islands Region. Four, including the world's most northern atoll, are in the NWHI (Maragos and Gulko, 2002). Two atolls are in Samoa, two are in the Line Islands, and the last two are Johnston and Wake Atolls. Atolls are typically reefs that enclose a lagoon. The protected water conditions of the lagoon provide areas for recruitment of fragile branching corals and settling points for particulates. Features in lagoons can include extensive coral structure, rubble patches, mud plains, algal meadows, and sand. Biological activity largely depends on the degree of oceanic flushing. Residence time of lagoon waters can be many months, and the speed at which the water is replaced can shape the habitat and the faunal assemblage.

Oceanic Habitat

Because the islands in the Region rise abruptly from the ocean floor, most of the offshore area in the EEZ surrounding the islands is oceanic habitat. Traveling less than 5 km (3 mi) offshore from many of these islands usually places one over water deeper than 2,000 m (6,563 ft). Consequently, oceanic habitat can be divided into pelagic and benthic types. The pelagic habitat can be described in terms of its vertical structure and geographic boundaries. The benthic habitat includes an array of oceanic guyots and seamounts that are diverse in morphology but are all independent from coastal habitats. For this reason, this discussion refers to them all as seamounts.

The offshore oceanic waters typically have a vertical structure consisting of a homogeneous, photic, warm upper surface mixed layer of low nutrients above cold, nutrient-rich waters. The warm upper and cold lower waters are separated by a permanent thermocline that limits vertical enrichment of the euphotic zone throughout the year. The offshore oceanic habitat is often influenced by high-gradient dynamic features such as frontal meanders, eddies, and jets on spatial scales of 10–100 km (6–62 mi) (Pickard and Emery, 1990). These mesoscale features give rise to localized regions of higher productivity leading to aggregation of food items and development of a forage base, while physical gradients provide cues for pelagic predators to locate prey. Pelagic larvae and organisms may reside in surface waters, at depth, or migrate vertically to use both habitats. The magnitude and influence of these features are subject to variability in climate and short- and long-term cycles associated with the natural variability of the Pacific water masses within which the several groups of U.S. Pacific islands reside. Regionally important climate and oceanographic factors include wave strength, rainfall, surface winds, hurricanes, surface currents including eddy and meander formation, El Niño events, and climate regime shifts.

Seamounts, particularly those that rise to within a few hundred meters of the surface, can have a strong influence on adjacent open-ocean habitat in a variety of ways. Waters over-lying seamounts are often characterized by high standing stocks of plankton, and at some locations they concentrate and transfer energy not only within the pelagic community, but also to the demersal community below (Uchida et al., 1986; Rogers, 1994). The Hawaiian Archipelago is known to contain more than 40 seamounts. They range from pinnacles with peaked summits at subphotic depths (>300 m [>984 ft]) to those with extensive tabletops at 40 m (131 ft) depths, comprising more than 800 km^2 (309 mi^2) of habitat. Eleven seamounts are found near American Samoa, 8 near Guam, and 34 in the Marianas. The habitat and faunal assemblages of these seamounts vary with their summit depth (Chave and Malahoff, 1998). The flat tops of the tablemounts support extensive algal meadows and impoverished reef fish communities. Deeper slopes support larger-bodied fish, including many commercially important species. At subphotic depths the habitat is carbonate, manganese/basalt, or sand. Patches of deep-sea corals, often called "beds," are found at sites with bottoms subject to high waterflow. The ecological role of these deep-sea corals is not well understood.

HABITAT USE

Until 2010, the Western Pacific Regional Fishery Management Council (WPRFMC) utilized five fishery management plans (FMPs). These included the Pelagics FMP, Bottomfish FMP, Crustaceans FMP, Precious Corals FMP, and Coral Reef Ecosystems FMP. Beginning in 2010, the WPRFMC adopted five new Fishery Ecosystem Plans (FEPs). The FEPs (Pelagics FEP, American Samoa FEP, Marianas FEP, Hawaii FEP, Pacific Islands Remote Area FEP) shifted management focus from species-based to place-based, and began the implementation of ecosystem-based approaches to fisheries management in the Pacific Islands. The adoption of these FEPs created the organizational structure to incorporate additional information, community input, and local knowledge into development of fishery ecosystem management (WPRFMC, 2009). Recent amendments to the FEPs have established fishery regulations, including annual catch limit procedures, and gear requirements for the American Samoa longline fishery to reduce sea turtle interactions. Additionally, longline area closures have been established in the Commonwealth of the Northern Mariana Islands, and fishing regulations have been created for the Pacific marine national monuments.

As such, the habitat relationships depicted in Table 16, which are listed by Management Unit Species (MUS) in each FEP, including crustaceans, bottomfishes, coral reef ecosystem species, pelagics, and precious corals, are still valid.

This section contains qualitative descriptions of habitat use for Pacific Islands FEP MUS and protected species groups (cetaceans, pinnipeds, and sea turtles) and to a smaller extent, state-managed and non-MUS species. Habitat use is only described once for each MUS group, but the

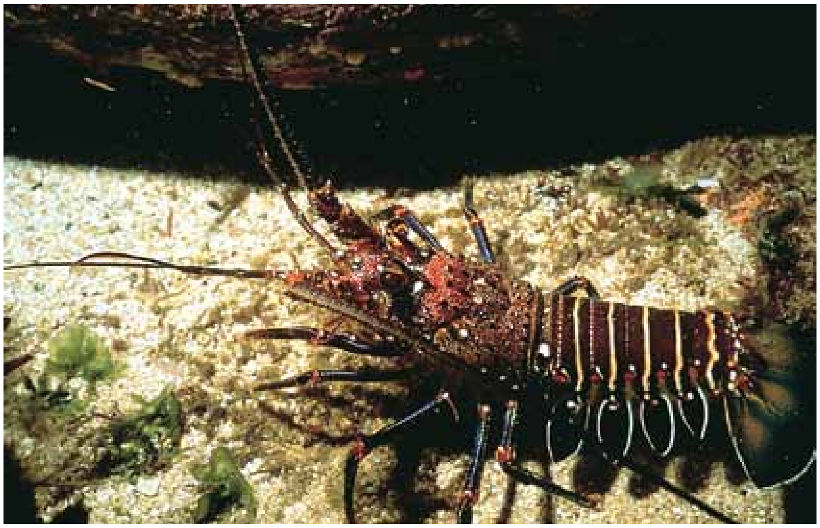
FEP management unit species [a]	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
1. Bottomfishes	N	N	F	F
2. Coral Reef Ecosystem Species	N	O	F	F
3. Crustaceans	N	N	F	F
4. Pelagics	N	N	F	F
5. Precious Corals	N	N	F	F [b]
Total percentage of all Pacific Islands FEP management unit species that have one or more species that use each habitat type	0%	20%	100%	100%
Protected species groups [a]				
Cetaceans	N	N	F	F
Pinnipeds (monk seals)	N	N	F	F
Sea Turtles	O	O	F	F
Total percentage of all Pacific Islands cetacean, pinniped, and sea turtle groups that use each habitat type	33%	0%	100%	100%

[a] Appendix 3 lists official FEP titles. Appendix 5 lists the species.

[b] Note that pink and gold precious corals are typically found at depths greater than 200 m (656 ft) and on slopes or ridges associated with volcanic islands, atolls, and seamounts.

Table 16
Typical use of the four major habitat categories in the Pacific Islands Region, summarized by FEP and protected-species groups of cetaceans, pinnipeds, and sea turtles.

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



Bruce Mundy, NMFS

A Hawaiian spiny lobster, Oahu, Hawaii.

information applies to each of the location-based FEPs. For example, the crustacean habitat-use description below applies to the crustacean MUS in the American Samoa, Marianas, Hawaii, and Pacific Islands Remote Area FEPs.

Table 16 provides a summary of typical habitat-use patterns in the Pacific Islands Region organized by FEP MUS and protected-species groups of cetaceans, pinnipeds, and sea turtles (managed by NMFS). The table shows typical patterns of use for one or more species within each group. However, it is important to recognize that these groups include many species, all of which have unique habitat requirements by life stage. Habitat information is lacking for many Pacific Islands species, particularly for the earlier life stages, and such critical information gaps are not captured in this table.

As the table shows, MUS in the Region do not typically use freshwater habitats, and most MUS do not use estuarine habitats. This may be due in part to the relative rarity of these types of habitats in the Pacific Islands, compared to their much greater availability on mainland North America. Shallow marine and oceanic areas are used by one or more species in all MUS groups. In regard to cetaceans, pinnipeds, and sea turtles in the Pacific Islands, one or more species in all three groups use shallow marine and oceanic habitats. Sea turtles are also known to use estuarine habitats occasionally for foraging and resting. Although freshwater habitat is not commonly used, some sea turtle species, like green turtles, travel up rivers in Hawaii and elsewhere.[7] Distribution (presence/absence) data is the most prevalent type of habitat information available for all harvested and protected marine species, while habitat-specific productivity information is not available for most harvested or protected species in any habitat.

Habitat Use by MUS Groups Within the FEPs

Crustaceans—The Crustacean MUS group involves several species of spiny and slipper lobsters, which have a pelagic larval stage ranging from 3 to 12 months. They use offshore oceanic habitat from the surface to 150 m (492 ft) depths in the water column during their larval period, and afterwards settle on benthic habitats. Adults inhabit reef or rubble habitat from the surge zone to 100 m (328 ft) depths or deeper, and they also inhabit offshore seamounts and banks. Habitats of new postlarval and early juvenile stages are not well known.

Bottomfishes—The Bottomfish MUS group includes a multispecies complex of snappers and groupers, which all have a pelagic larval stage that uses the water column of offshore oceanic habitat. After their larval period, most juveniles and adults use island and bank benthic habitats in 0–400 m (0–1,312 ft) depths. For most species the juvenile habitat is shallower than that for adults. Bottomfish habitat preferences vary by species and life stage. Some species, for example, show an affinity for rocky slopes (e.g. Ehu and Gindai), while other species prefer sandy bottoms (e.g. juvenile opakapaka) or areas with a diversity of features (e.g. adult opakapaka).

Coral Reef Ecosystem Species—The Coral Reef Ecosystem MUS group encompasses coral and all the species associated with coral reef habitat. By definition, the habitats most essential to the coral reef ecosystem species (over 2,000) have corals as part of the substrates, including not only coral reefs themselves, but also lagoons, surge zones, and deep-slope terraces. Benthic species are usually restricted to coral or rocky reefs as adults, but adults of many mobile reef-associated species can be found in all other demersal habitats.

[7]Kyle Van Houtan. NMFS, PIFSC, 1845 Wasp Blvd., Honolulu, HI 96818. Personal communication, January 2015.

Most reef organisms have pelagic larvae or eggs that drift in the mixed layer and upper water column, although there are numerous exceptions in all taxonomic groups. Behaviors of some larvae keep them very close to reefs, but other larvae, including those of some of the most visible reef fishes, drift great distances from their natal and settlement habitats. Juveniles of demersal reef species settle to reefs or immediately adjacent substrates, but what little information is available suggests that many of the more mobile species settle to transitional sediment, sand, rock, or rubble habitats. A few reef species, such as some jacks and barracudas, use mangroves and estuaries as juvenile habitat, and a very few, such as some mullets and flagtails, occur in freshwater directly connected to tidal water. For these reasons, important habitat for coral reef management species includes all waters from the shorelines to the offshore boundaries of the U.S. 370 km (200 nautical mile [nmi]) EEZs, from the surface to 90 m (300 ft).

Pelagics—The Pelagic MUS group is a multispecies complex that comprises tunas, billfishes, sharks, and associated pelagic species. The eggs and larvae of these species occur in the water column from the surface to 200 m (656 ft) depths, while juveniles and adults use shallow marine and oceanic habitat from the surface to 1,000 m (3,281 ft) depths and from the shoreline to the outer limit of the EEZ and beyond. All stages are often found associated with submerged banks and seamounts, and with oceanic features including eddies and fronts.

Precious Corals—The three primary targets of the precious coral fishery are black coral, pink coral, and gold coral. Each of these coral types occurs in patches that are referred to as beds. Their fixed attachment to the substrates and the vertical relief they create make these corals a significant component of habitat in regions where they occur. The locations and sizes of coral beds are poorly known, so the description of habitat uses and trends will be limited to the few known beds that have been identified in Hawaii. Black coral grows on current-swept bottom in the MHI between depths of 30 and 100 m (100–328 ft). Pink and gold corals are found on current-swept bottom depths of 300–500 m (984–1,640 ft). Black coral occurs primarily in the main islands (three significant beds) of the Hawaiian Archipelago, with none identified in the NWHI. Beds of pink and gold coral have been documented throughout the main islands at Cross Seamount and halfway up the Hawaiian Islands chain.

NOAA Hawaiian Undersea Research Lab

Black coral in the waters of the Hawaiian Islands. The species is named for the black color of its skeleton, visible in this photograph where the specimen attaches to the sea floor; the living tissue is brightly colored, like this orange specimen.

Habitat Use by Protected Species

Cetaceans—The Pacific Islands Region supports at least 24 species of cetaceans including sperm whales (3 species), beaked whales (3 species), baleen whales (6 species), and delphinids (12 species). The delphinids, which include dolphins and small species of toothed whales (such as melon-headed whales and false killer whales), include tropical and subtropical species that forage near islands (e.g. spinner dolphins, bottlenose dolphins) or in deeper offshore waters (e.g. spotted dolphins, pygmy killer whales). They forage on a variety of fish and invertebrates, such as squid. Most of the large whale species found within the Pacific Islands Region are migratory, ranging northward as far as Alaska. The central North Pacific stock of humpback whales, consisting of just over 10,000 animals, breeds in the Hawaiian Islands during winter and forages in Alaska waters during summer. Several large whale species, including blue, fin, humpback, and sperm whales, are listed as endangered under the Endangered Species Act (ESA)


Bruce Eilerts, USFWS

A Hawaiian monk seal hauled out on the beach and resting.

owing to historical over-exploitation by whaling operations in the North Pacific. Additionally, one species of dolphin, the Hawaiian Islands false killer whale, is listed under the ESA as a result of its low population abundance estimate, but the cause of its decline remains uncertain. Under the Marine Mammal Protection Act (MMPA), as amended in 1994, marine mammal stocks are further categorized as "strategic" stocks if either human-caused mortality exceeds the potential biological removal level, the stock is listed as endangered or threatened under the ESA, the stock is declining and likely to be listed as threatened under the ESA, and/or the stock is designated as depleted. In the Pacific Islands Region, all ESA-listed species are considered strategic, and the Hawaii pelagic stock of false killer whales is considered strategic due to interactions with longline fisheries in Hawaiian waters.

Pinnipeds—The Hawaiian monk seal is the only pinniped in the Pacific Islands Region. Monk seal colonies are found primarily around the atolls of the NWHI, where beaches and adjacent shallows are used for bearing and weaning pups. The seals' foraging activities are poorly known, but telemetry instruments carried by the seals suggest that they routinely travel between banks to forage, ranging more than 160 km (100 mi) from their colony. The bulk of feeding occurs between 30 and 200 m (100–656 ft) depths at the atolls and on the summits of neighboring banks. A small percentage of feeding effort has been documented at depths greater than 500 m (1,640 ft). Telemetry and scatological analysis indicate that all prey species are bottom-dwelling.

Sea Turtles—Green sea turtles within the EEZ of the Pacific Islands Region use a variety of habitats, including beaches for nesting, algal beds from the shoreline to 100 m (328 ft) depths for foraging, and underwater caves for resting. Other species of sea turtles including olive ridleys, leatherbacks, hawksbills, and loggerheads also migrate through the Region and forage largely at oceanic fronts and eddies or subsurface at the deep scattering layer. Hawksbill turtles are also known to nest and forage in coral reef habitats.

Habitat Use by State-Managed and Non-FMP Species

Most of the nearshore species managed under state jurisdictions also occur in federally managed habitat. The summits of shallow seamounts and habitat that extends outside the 5.5 km (3 nmi) state boundaries support reef communities that are addressed under the Coral Reef Ecosystem Species group.

HABITAT TRENDS

In most cases, a lack of habitat information for the Pacific Islands Region makes it difficult to detect trends. Little is known about natural changes in the habitat associated with prolonged cycles in temperature regimes (e.g. annual differences in foliation of algal beds on bank summits) or prevailing weather patterns (e.g. interannual differences in the erosion of sand islets). Prior studies have identified the ecological importance of various habitats, whereas future work should evaluate their natural dynamics and look for possible anthropogenic impacts. While a majority of the habitats are not near populated coastal areas, and thus are somewhat insulated from many of the typical anthropogenic stressors (runoff, pollution, etc.), valuable habitats such as fringing reefs are directly adjacent to populated islands and exposed to these stressors. Impacts from fishing, invasive species, and contaminants are anthropogenic stressors to marine habitats in the region, which require further study.

The Papahānaumokuākea Marine National Monument was created in June 2006, designating over 360,000 km^2 (140,000 mi^2) of islands, atolls, and ocean along the Northern Hawaiian Islands chain as a protected national monument. This is one of the largest protected marine areas in the world, and encompasses over 13,200 km^2 (5,100 mi^2) of coral reef habitat. The monument is home to approximately 80% of the Hawaiian monk seals and contains the breeding grounds for about 95% of the green sea turtles of the Hawaiian Islands. Conservation efforts in the monument include prohibiting unauthorized ship passage, unauthorized activities of a recreational or commercial nature, dumping waste, and extracting coral, wildlife, minerals, and other resources. Commercial fishing activities were phased out over a 5-year period. In addition, in January 2009 under the Antiquities Act President George W. Bush established three new national monuments (Marianas Trench, Pacific Remote Islands and Rose Atoll) in the tropical western Pacific, with a total area of over 490,000 km^2 (190,000 mi^2) (White House, 2009). Additionally, in September 2014 under the Antiquities Act President Obama designated expansion of the Pacific Remote Islands Marine Monument to 1,056,720 km^2 (408,000 mi^2) (White House, 2014). 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. The largely uninhabited areas contain pristine coral reefs, volcanic ecosystems, and the Mariana Trench, which at approximately 11,000 m (36,000 ft) depth, is the deepest region of the oceans. Protections for these areas include designated bans on fishing and shipping.

Invasive Species

Species of fishes, crustaceans, invertebrates, and algae have been introduced to varying extents throughout the Pacific Islands Region, both intentionally and accidentally. Some of the intentional introductions were made in the 1950s as part of fishery enhancement efforts. Notable examples of this include the introduction of the blue-striped snapper, the blue-spotted grouper, the mud crab, and the algae *Kappaphycus striatum* in Hawaii. Species such as the algae *Hypnea musciformis* were intentionally introduced for aquaculture. Other species were introduced accidentally by transport on the hulls of ships or in their ballast water (e.g. snowflake coral and the algae *Gracilaria salicornia*). Some introduced fish species have been documented to spread from their point of introduction at the southern end of the Hawaiian Island chain up to the remote northwest end of the archipelago. Some algae known to ride on ship hulls have been identified in the remote NWHI. Another source of introduction has been through marine debris. Large pieces of debris from the 2011 Tohoku tsunami reached the continental U.S. western coast and Hawaiian Islands in 2012, some of them carrying non-native species of algae and invertebrates.

Of the introduced species, algae may have the greatest impacts to the habitat ecology. In Hawaii many have spread to become the dominant bottom cover in reef and coastal areas. Tons of algae are routinely removed from Hawaii's beaches, making invasive algae a public health and economic issue. Introduced species are poorly documented in American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI), but, given the history of military and other vessel traffic, these regions are also likely to have impacts from invasive species.

The invasive algae *Cladophora* has overgrown and smothered the coral in this area off Maui, Hawaii.

NMFS

Removing marine debris (derelict fishing nets) in the NWHI.

Trends in MUS Species Habitat

Trends in Crustacean Habitat—Trends in habitat are unknown for many crustaceans in the Pacific Islands. Lobster habitats were inspected in the NWHI by diver and remote camera surveys in the early 1990s with some follow-up survey work in recent years, and algae was identified as the primary bottom cover. More information is still needed on the seasonal and interannual changes in the foliation of algal beds of bank summits and the associated ecological implications for lobsters and other species.

Trends in Bottomfish Habitat—Trends in bottomfish habitat are unknown. Juvenile habitats have been identified at shallower depths, including algal beds and sand terraces. These shallower habitats may be more subject to change than adult habitats, which are considerably deeper and thought to be more static environments. This is because the shallower areas are more likely to experience a higher flux in primary productivity and greater vulnerability to natural and anthropogenic disturbances.

Trends in Coral Reef Ecosystem Species Habitats—Data on U.S. Pacific Island coral reef ecosystem habitats is collected on a biennial basis to help determine the status of these vital areas and identify any trends. Three factors that can adversely impact these habitats and that are watched closely include marine debris, shoreline construction, and point and nonpoint source pollution.

- **Status of Baseline Data**

  The state of coral reef habitats in the U.S.-affiliated islands of the Pacific is being monitored on an annual basis (or on a triennial basis in different parts of the Pacific) with support from the NOAA Coral Reef Conservation Program. Coral reef monitoring and habitat mapping are routinely conducted on NOAA research cruises throughout the Hawaiian Archipelago; the Mariana Archipelago (including Guam); American Samoa; Johnston, Wake, and Palmyra Atolls; Howland, Baker, and Jarvis Islands; and Kingman Reef. These cruises are staffed by fish, coral, invertebrate, and algal taxonomists, and specialists in coral disease and water quality, as well as oceanographers and mapping specialists. Results show these habitats are generally in good condition, with some notable exceptions in areas where human impacts are concentrated, such as population centers or shipwreck sites.

- **Marine Debris**

  NMFS has been actively involved in marine debris removal from the NWHI since 1996. Over 750 metric tons (1.65 million lbs) of derelict fishing gear have been removed as part of a multiagency partnership supported by the NOAA Coral Reef Conservation Program, NOAA Marine Debris Program, Papahānaumokuākea Marine National Monument, and the NOAA Damage Assessment Remediation and Restoration Program. A 5-year (2001–05) intensive effort resulted in the removal of much of the historical debris on the coral reefs of the NWHI. NOAA removed over 16 metric tons (35,000 lbs) in 2006, the first year of the maintenance-level effort, which was aimed at keeping pace with new accumulation. However, a 2007 NMFS study estimated the accumulation rate to be approximately 52 metric tons (115,000 lbs) annually, which was higher than expected (Dameron et al., 2007). NMFS is also working with the NOAA Marine Debris Program, Office of National Marine Sanctuaries, and NOAA

Unmanned Aircraft Systems Program in looking at remote sensing technologies and their application for marine debris at sea. The goal is to detect and remove debris at sea before it damages reef ecosystems and impacts protected species in the nearshore area. The 11 March 2011 tsunami that struck Japan 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, some of which reached the continental U.S. western coast and Hawaii in 2012. Based on ocean current models, more is expected in the coming years, but the magnitude, timing and impact of this debris are uncertain.

- **Shoreline Construction and Other Habitat Alteration**
  Shoreline construction and other habitat alteration have impacted reef habitats in the MHI, Guam, and to a lesser extent Tutuila, for over a century. Such alterations have resulted in loss of marine habitat, conversion of coral reefs to lesser-value habitat, and increased sedimentation rates along many of the Region's coastlines.

- **Point and Nonpoint Source Pollution**
  Awareness of environmental problems in populated areas of Hawaii, Guam, and Samoa has resulted in amelioration of point source and nonpoint source pollution degradation since the 1970s and 80s. Most notable in this regard are Oahu's Kaneohe Bay and American Samoa's Pago Pago Harbor. The more remote islands are still relatively pristine.

Trends in Pelagic Habitat—The oceanic central North Pacific region, including the Hawaiian Archipelago, exhibits a low-frequency oscillation between cooler and warmer phases, approximately on decadal time scales. This oscillation generally coheres with climate indices such as the Pacific Decadal Oscillation (PDO) index and sea level height data (Polovina and Howell, 2005). For example, during 1999 to 2002 there was an elevation in sea level height in the central North Pacific, resulting in increased vertical stratification and a decline in winter surface chlorophyll at the northern end of the Hawaiian Archipelago. In the pelagic environment, a better understanding of the impact of climate variability on key oceanic habitats (e.g. fronts, frontal systems) is still required. For example, variations in fronts and frontal systems (e.g. latitudinal position, degree of meandering), intensification of current flow fields, and coupled biological responses to the environment associated with changing regimes need to be addressed.


NMFS

Spinner dolphins resting in a sheltered, shallow water area.

Trends in Precious Corals Habitat—Over the last 30 years the biomass of the Auau Channel black coral population has decreased by 25% or more. Data collected during submersible dives also show a decline in recruitment. This decrease may be related to an increase in the abundance of snowflake coral, an alien hydroid, which has been identified as a risk to the black coral stocks. Black coral trees too deep for harvest by divers were thought to serve as a reserve to the fishery until recent surveys determined that deep colonies were fully encrusted with the hydroid (WPRFMC, 2008). Refining knowledge of the growth rate of gold coral and determining the importance of these corals as fish habitat are also the current foci of study. Recent research results indicate that gold corals (*Gerardia* sp.) are much older and have much slower growth rates than previously believed (Parrish and Roark, 2009).

NOAA Ship McArthur II

Low, flat beaches, such as this Pacific atoll, are vital habitat for sea turtles and monk seals and would be affected greatly by sea level rise.

Trends in Protected Species Habitat

Trends in Cetacean Habitat—Pelagic cetacean habitat is affected by natural oceanographic variation that occurs over seasonal, interannual, and decadal time scales. These processes can change the distribution and intensity of marine productivity, which in turn may lead to variations in the amount of suitable habitat available for different cetacean species. In general, however, cetaceans have life-history traits that enable them to adapt to these natural variations. Anthropogenic impacts to cetacean habitats have also been documented in both nearshore and offshore areas. Near the shore, habitat quality may be affected by vessel traffic and an increased risk of vessel collisions with cetaceans. Disturbance of cetaceans by whale-watching boats and swim-with-dolphin programs is an increasing habitat concern in some areas, particularly for Hawaiian spinner dolphins, which come into shallow bays to rest during the daytime. Nearshore fisheries may also injure or kill marine mammals incidentally. In oceanic habitats, the primary threats to cetaceans and their habitats involve fisheries and anthropogenic underwater noise. Longlines and marine debris are known to cause incidental mortality and injury of cetaceans in many areas of the U.S. Pacific Islands region. Some interactions with cetaceans and gillnets have also have been observed as a result of small-scale nearshore fishing activities. In addition, a significant increase in the volume and extent of noise in the world's oceans has become a subject of increasing concern. High-intensity underwater sound production from a wide range of anthropogenic sources (e.g. industrial or military activities) can reach intensities of over 235 dB (as intense as an underwater earthquake) and may particularly affect susceptible cetacean species.

Trends in Hawaiian Monk Seal Habitat—Considerable loss of haul-out area due to current-swept beach erosion has impacted the reproductive success of ESA-listed Hawaiian monk seals at some locations in the NWHI (Antonelis et al., 2006). This phenomenon may be related to climate change, sea level rise, or changes in current patterns; and if this erosion continues at a rapid rate, it could represent a bottleneck in the population's recovery. Habitats important for seals' foraging and at-sea resting are only now being identified. In the MHI, monk seal sightings and observations have been steadily increasing, including at beaches utilized regularly in populated areas.

Trends in Sea Turtle Habitat—Sea level rise is a threat to critical sea turtle habitats. Nearly 95% of Hawaiian green sea turtle nesting occurs at French Frigate Shoals in the NWHI (Kittinger et al., 2013), and a recent study found that hawksbill sea turtles inhabit the NWHI and may have done so historically in greater numbers (Van Houtan et al., 2012). These low-lying islands are particularly vulnerable to sea level rise, putting protected species that rely on them at even further risk. Atolls, such as French Frigate Shoals, are less than 2 m (6.6 ft) above sea level, and topographic models predict that rising waters could significantly decrease available nesting habitat (Baker et al., 2006). Whale-Skate Island, located in the French Frigate Shoals, was once an important nesting site, but now is completely submerged.

The impacts of introduced algal species are also a concern in the Pacific Islands. Research has found that Hawaiian green sea turtles have expanded their foraging as introductions occur and three non-native species are now common in their diet (Russell and Balazs, 2009). There is compelling evidence that foraging on macroalgae in nutrient-elevated coastal areas in the MHI is promoting the tumor disease fibropapillomatosis in green turtles. Non-native, invasive species of macroalgae contain an amino acid that is known to promote tumor growth, making the spread of invasive algae an even greater concern (Van Houtan et al., 2010). Uninhabitated areas, such as the NWHI, are not impacted by nitrogen-rich agricultural runoff and sewage wastewaters known to elevate nutrient levels, but macroalgal communities should be continually monitored for the presence of invasive species that may promote this disease.

RESEARCH NEEDS

In order to provide guidance to resource managers and officials charged with protecting habitat, information is needed on how species use habitat, where it exists, its condition, the best practices to conserve it, and how marine communities and, ultimately, sustainable fishery yields and conservation of protected species depend on the amount and condition of available habitat. Because the Pacific Islands Region is so vast and widely dispersed, there are large gaps in the basic knowledge of the fishery and protected species in the Region, the quantity and quality of available habitat, and how these species use the habitats.

The Pacific Islands Region is a research frontier, where leading-edge research conducted by NOAA scientists continues to advance the knowledge needed for resource management in a set of complex, interconnected marine systems. As a part of Coral Reef Conservation Program-sponsored research cruises to all of the islands in the Region, almost complete baseline bathymetric maps in water depths of 20–1,000 m (66–3,281 ft) are now available for CNMI, Guam, American Samoa, the Pacific Remote Island Areas, and the MHI. In the NWHI, where there are extensive submerged bank-top areas that provide habitat for many ecologically and commercially important species, as of 2012 only about 30% of these bank-top areas had been mapped within the top 100 fathoms (183 m).[8] Although bathymetric data are now readily accessible, considerable effort is still needed to analyze, interpret, and correlate the physical and biological data and produce benthic habitat maps for species of interest. Estuarine, shallow marine, and oceanic habitats all require extensive research, ranging from ecological assessment and life history studies to population dynamics and fishery impacts. Freshwater habitats, though rare, support a number of native and endemic species that rely on freshwater streams and marshes, including some endangered bird species. The geographic area of research requires expansion as well. Historically, most research has occurred in and around the Hawaiian Archipelago. Current NOAA efforts under the Coral Reef Initiative are doing a better job of conducting research at these remote locations. Table 17 presents an overview of habitat-specific research needs for the Pacific Islands Region, with more detailed information provided in the text that follows.

[8]J. Rooney, NMFS, PIFSC, 1845 Wasp Blvd., Honolulu, HI 96818. Personal communication, January 2013.

Jean Kenyon, NMFS

Coral and green algae in Rose Atoll, American Samoa.

Fishery Species

All Fishes—Life history research is needed for many fish species, particularly on the habitat needs for early life stages of species such as juvenile tunas. There is also a great need to develop time-series observations on fish habitats of all types in the Pacific Islands Region to address emerging questions about the effects upon marine resources of such things as pollution at the urbanized islands, extraction of marine resources, introduced species impacts, and climate variability. Almost all research in the Pacific Islands Region has been directed at specific problems for short durations. The pri-

Table 17 Overview of research needs for Pacific Islands Region fishery and protected species.

Research Needs	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
Collect life history information on fishery and protected species as related to habitat needs, particularly for the early life stages.[a]		x	x	x
Complete baseline descriptions of habitats for fishery and protected species and monitor these habitats over the long-term.	x	x	x	x
Delineate and map important fishery and protected species' habitats and complete high-resolution mapping of bottom topography, bathymetry, currents, algal beds, substrate types, and habitat relief.		x	x	x
Define cetacean spatial and temporal pelagic habitat use.			x	x
Characterize juvenile monk seal foraging habitat in the Hawaiian Archipelago.			x	x
Evaluate habitat loss at turtle nesting and monk seal pupping sites.			x	
Identify sea turtle nesting and foraging sites.			x	
Evaluate the ecological impact of invasive species colonizing native habitat.	x	x	x	x
Determine effects of natural and anthropogenic stresses to habitats.			x	x
Determine which islands and banks are sources or sinks for larvae and how widely separated island populations are connected by larval mixing and dispersal.		x	x	x
Initiate assessment and monitoring surveys following storm events to measure habitat impacts and recovery rates.			x	x
Monitor impacts of fisheries and marine debris and levels of anthropogenic sound.			x	x
Quantify habitat-related densities and growth, reproduction, and survival rates within habitats for all life-history stages of fishery species.[b]			x	x

[a] This includes information on species distribution, the environmental and biological features that determine suitable habitats, identification of foraging and spawning habitats, and understanding species metapopulation dynamics.

[b] This includes establishing baseline catch per unit effort for many coral reef ecosystem species.

mary exception at present is the NMFS Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystems Division's monitoring program, which began time-series observations in 2000 at coral reef habitats at 0–30 m (0–100 ft) depths in the U.S. Pacific islands. Even this effort has acquired just over a decade of data at 1- to 3-year intervals for each major island group in the Region (i.e. the Hawaiian Islands; the Mariana Islands; and American Samoa; plus Johnston Atoll, Wake Atoll, the U.S. Line Islands, and the U.S. Phoenix Islands). Research programs establishing time-series observations in the other NMFS regions have been crucial to establishing an understanding of the role of habitat change in driving marine resource population fluctuations (Roemmich and McGowan, 1995; Brodeur et al., 2003). The California Cooperative Oceanic Fisheries Investigation,[9] in which the NMFS Southwest Fisheries Science Center (SWFSC) is a partner, is a well-known example of this type of program. Critical needs for similar habitat research in the Pacific Islands Region include, but are not limited to, obtaining time-series data by collecting micronekton and plankton at major oceanographic fronts and current boundaries in the Region in order to relate satellite observations of oceanography to real biological changes in pelagic habitats at trophic levels above primary production; conducting repeated multiyear observations of deepwater bottomfish and invertebrate habitats to track changes in benthic habitats below 30 m (100 ft) depth; and continuing the shallow-water coral reef and precious coral fishery species surveys. Habitat research is needed for all Pacific Island regional fishery species, including demersal and pelagic fishes, and deepwater bottomfishes.

- **Reef Fishes**

  The habitat requirements of most reef-associated fishes of the U.S. Pacific Islands Region are, in general, poorly known. Baseline catch per unit effort (CPUE)[10] data are needed for many species.

[9] For more information see http://www.calcofi.org (accessed March 2015).

[10] CPUE data is a measure of the density or population size of a species targeted by fishing.

The habitat relationships of fish species typically found in shallow (< 30 m [100 ft] depth) coral reefs (Friedlander and Parrish, 1998; DeMartini, 2004) are only marginally better documented than those of deep-slope bottomfishes (Kelley et al., 2006). Research priority should be given to documenting the essential fish habitat (EFH) requirements of functionally dominant piscivores and herbivores (keystone species) and other ecologically important species, as well as economically important reef fishes. These data are essential to effectively evaluate habitat when siting and designing the no-take Marine Protected Areas needed to manage and conserve fish stocks in the MHI and elsewhere. Special consideration should be given to factors that complicate species-level classifications; studies should focus on habitat areas of particular concern (HAPC), such as juvenile nursery and adult spawning habitats.

- **Aquaculture**

Research on the environmental interactions and mitigation of potential impacts of coastal and offshore cage aquaculture on island habitats are emerging study areas. While much information exists for temperate aquaculture, including best management practices designed to minimize impacts, less is understood for tropical environments. Impacts of finfish cage-culture and other aquaculture facilities upon marine resource habitats include direct physical modification of habitats from the facility structures; effects of nutrient discharges on surrounding marine habitats; pathogen and parasite transmittal to, from, and among cultured organisms; and the potential genetic effects on wild stocks of accidental escapes of aquaculture species (Stickney et al., 2006). Siting aquaculture facilities in locations that minimize the potential for adverse impacts, and monitoring for any environmental effects, such as checking for changes in nearby benthic communities, can help mitigate potential impacts of aquaculture operations. Over the past couple of decades, technologies have been developed to raise finfish and shellfish in offshore waters. Hawaii presently has one existing offshore commercial cage operation that has been the location of initial research on habitat effects from open ocean aquaculture.

Marie Hill / NMFS

A false killer whale leaping in the waters off Rota, in the Northern Mariana Islands.

Crustaceans—An important research need is to define early life-stage habitats for species of concern, particularly the settlement habitats of slipper and spiny lobsters. In addition, the seasonal and interannual changes in the foliation of algal beds of the bank summits and their ecological implications to lobster and other taxa should be a focus of future investigations.

Protected Species

Cetaceans—Relatively little is known about temporal and spatial habitat use of most cetacean species occurring in the Pacific Islands Region. Specifically, research is needed into the habitat used by the three stocks of false killer whales to refine knowledge of stock ranges and better understand the environmental factors that maintain separation of the existing stocks. Such information is critical for determining population impacts and the level of mitigation needed to reduce harmful fishing gear interactions. Characterization of nearshore, shallow marine habitat use by spinner dolphins is essential for defining the feeding and resting areas requiring protection from human interactions (e.g. swim-with-dolphin activities). Similarly, improved resolution of humpback whale habitat use is needed to address the increasing ship strikes on humpbacks, particularly calves, and to address the potential dangers of future high-speed ferry use in the MHI. Finally, increasing anthropogenic sound in the ocean environment is of concern. Additional research is needed on where and when such sounds occur and the degree to which they may impact various cetacean species in the Region.

Dwayne Meadows, NMFS

A green sea turtle swimming near coral in the NWHI.

Hawaiian Monk Seals and Sea Turtles—Over 50% of the major Hawaiian monk seal pupping sites at French Frigate Shoals have been lost due to erosion over the last 40 years (Antonelis et al., 2006), and additional loss of habitat there and at other breeding sites in the NWHI will occur if sea level rise continues as predicted (Baker et al., 2006). Research is needed to better understand this problem throughout the NWHI, to assess the potential threats to the recovery of this ESA-listed species, and to evaluate possible methods of mitigation. Studies are also needed to more accurately define the foraging habitat of juvenile monk seals. Poor juvenile survival is the primary reason for the monk seal decline; therefore, foraging habitat is an essential factor that must be considered when identifying and protecting the prey resources on which they depend.

While much is known about the habitat use and population of the Hawaiian green sea turtle in the Hawaiian Archipelago, relatively little is known about the spatial and temporal use of habitat by green sea turtles in the rest of the Pacific Islands Region. Hence, more research is needed to obtain a better understanding of their nesting and foraging habitats throughout the Region. Similar studies are also needed for hawksbill sea turtles occurring in the Region. Research is needed to characterize the problem of loss of green sea turtle nesting habitat due to beach erosion, especially at French Frigate Shoals, and to determine the feasibility of mitigation. Additional research is needed to better understand the pelagic habitat needs of juvenile sea turtle species during the time between hatching and movement to coastal habitats for feeding and reproducing.

The issue of future sea level rise and its impacts to beach habitat used by Hawaiian monk seals, green sea turtles, and sea birds is an emerging research issue. An initial estimate of the impact of sea level rise on the islands in the NWHI concluded that, based on a median sea level rise scenario of 48 cm (19 in) by the year 2100, terrestrial habitat loss for nesting seabirds, sea turtles, and for monk seal pupping could be 3 to 65%, depending on factors such as each island's shore-slope angle and the percentage of land covered by low coastal fringes, etc. (Baker et al., 2006). However, further research is needed to monitor and understand beach habitat dynamics in the Insular Pacific.

Corals—The abundance and distribution of the major reef-building corals have been relatively well studied on shallow reefs of the NWHI. However, the recent listing of 15 Indo-Pacific coral species as threatened under the ESA will necessitate additional monitoring and research on coral recovery. In addition to these research needs, range extensions of known corals as well as probable new species have been discovered within the past few years, indicating that additional efforts aimed towards coral biodiversity studies may be warranted. The occurrence of two mass coral bleaching events since 2002 (Kenyon and Brainard, 2006) and the documentation of 10 coral diseases throughout the NWHI (Aeby, 2006) indicate that the health condition of reefs throughout the NWHI should be monitored on a regular basis and studied to prevent further declines in coral abundance, and especially those species listed under the ESA. Additionally, PIFSC Reef Assessment and Monitoring Program (RAMP) activities in all islands of the Pacific should be continued to provide on-going multidisciplinary information on the coral reef ecosystem.

Invasive Species

The habitat and ecological impacts of the invasive octocoral called snowflake coral is another research issue. Snowflake coral is a zooxanthellate, shade-loving, shallow water species (Bayer, 1961) that was introduced to the Island of Oahu in the mid-1960s. In the decades since, it has spread throughout the MHI, fouling the shaded areas under piers and reef ledges. Its most notable impact has been on the black coral community that lives in the dim depths below 70 m (230 ft; Grigg, 2003). Snowflake coral preferentially colonizes black coral trees, smothering the colonies completely. Surveys of the largest black coral bed located in the channel waters off Maui found 50% of the black coral colonies below 70 m (230 ft) were encrusted with snowflake coral (Kahng and Grigg, 2005). This finding prompted a reevaluation of the management strategy for the Hawaii black coral fishery (Grigg, 2004). However, the impacts of snowflake coral on other habitats and ecosystems are not well known.

Invasive algae are a major problem for habitat integrity of the coral reefs of the MHI (Smith et al., 2002), although they are not an issue in many of the other U.S. Pacific island groups. Even though much research has been completed on invasive algae in Hawaii, much more needs to be done to obtain an understanding of habitat impacts. For example, the impact that invasive algae have on fish communities is largely unexplored in Hawaii. The following are examples of the many questions that still need investigation: How do invasive algal species affect fish grazing behavior? Are the problems caused by invasive algae due to herbivorous fish not eating them? Do invasive algae overgrow preferred food sources of herbivorous fish, and if so, does this habitat alteration affect fish distributions or production? Does local fishing pressure and its effects on herbivore density affect the ability of invasive algae to compete with native coral species? What management efforts will be effective in restoring habitats damaged by invasive algae if those algae are removed? Are all reef habitats equally susceptible to algal invasions, and if not, why? What attributes of habitats and algal species promote algal invasions in reef habitats? What are the short-, medium-, and long-term impacts of large-scale algae removal efforts?

Invasive snowflake coral covering metal structures on a sunken ship off Oahu in the MHI.

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Part 5
Appendices

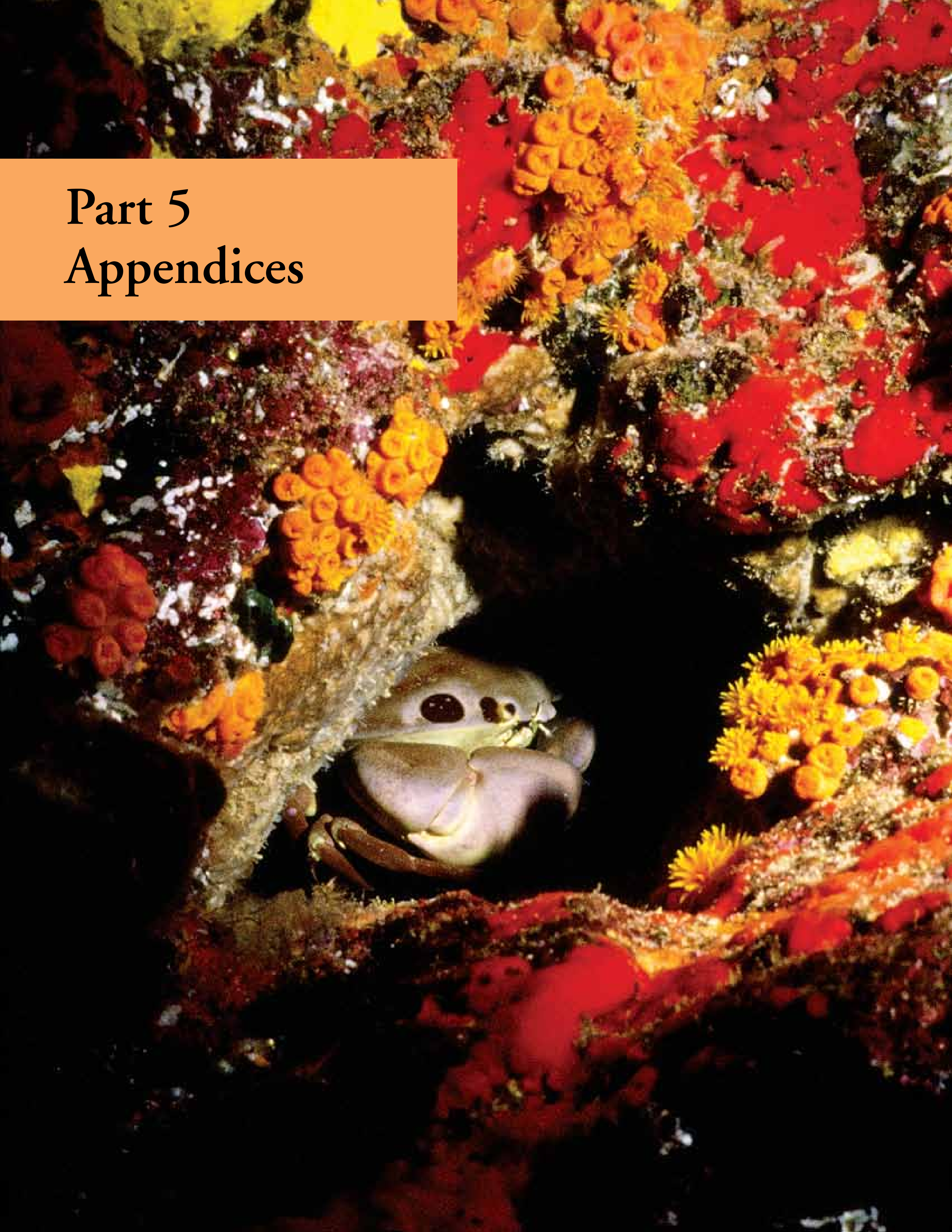

Photo on previous page: A "7-11 crab" ("ala kumee" in the Hawaiian language) hides within a pocket in a rocky reef with sponges and coral off Oahu, Hawaii. Photo credit: Bruce Mundy, NMFS.

Appendix 1
Acknowledgments

As is appropriate for a national report on the habitats of living marine resources, the time, effort, and expertise of many individuals were required to develop the underlying concepts and to write the *Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources* report. Dr. William W. Fox, Jr., while Director of the NMFS Office of Science and Technology, conceived the project and provided critical guidance as the project began. Dr. Ned Cyr, current Director of the NMFS Office of Science and Technology, provided critical support in order to complete the project. The editors, authors, and other contributors are listed below. (Affiliations as listed were accurate at the time of contribution. Some affiliations have changed since then.)

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Appendix 2
Legislative Mandates for Habitat

There are several legislative mandates that apply to habitat. This list emphasizes those mandates that apply to the National Oceanic and Atmospheric Administration (NOAA) and summarizes the specific aspects that apply to habitat. In many or most cases, the laws cited do considerably more than just deal specifically with habitat. The agencies within NOAA that lead in each instance are typically the National Marine Fisheries Service (NMFS) or the National Ocean Service (NOS). The primary mandates discussed in this report, shown in bold below, and include the Magnuson-Stevens Fishery Conservation and Management Act, the Marine Mammal Protection Act, and the Endangered Species Act.

Acts and Executive Orders	Summary	Lead in NOAA	Date
Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Act)	Requires NOAA to support the interjurisdictional fishery management efforts of the Atlantic States Marine Fisheries Commission, and when regulating interjurisdictional fisheries, to do so in coordination with Commission fishery management plans. The Act also allows NOAA to issue a fishing moratorium in state waters if a state does not comply with a Commission Plan to the extent that the state's compliance is necessary for the conservation of the fish species.	NMFS	1993 (as amended)
Coastal Wetlands Planning, Protection, and Restoration Act	Established a task force that includes NOAA (represented by NMFS) to develop a comprehensive approach to restoring and preventing loss of coastal wetlands in Louisiana.	NOAA	1990
Coastal Zone Management Act	Provides for the management of the Nation's coastal resources, including the Great Lakes, and balances economic development with environmental conservation. Established the National Coastal Zone Management Program and the National Estuarine Research Reserve System. The Act also enables states to conserve habitat through the federal permitting process.	NOS	1972 (as amended)
Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act)	Requires NOAA to seek damages from those who have released hazardous substances that have caused injury to natural resources (e.g. habitats). Accordingly, NOAA (NOS) determines injuries to natural resources and seeks recoveries from the potentially responsible parties to restore, replace, or acquire the equivalent of natural resources and to cover the costs of damage assessment. (NMFS assists in developing and implementing restoration in certain cases.)	NOS	1980

Acts and Executive Orders	Summary	Lead in NOAA	Date
Coral Reef Conservation Act	Requires NOAA to establish a national program to conserve coral reefs and coral reef ecosystems. The Act authorizes NOAA to: 1) Map, monitor, assess, restore, and conduct scientific research that benefits the understanding, sustainable use, and long-term conservation of coral reefs and coral reef ecosystems; 2) Enhance public awareness, education, understanding, and appreciation of coral reefs and coral reef ecosystems; 3) Provide assistance to States in conserving coral reefs and living marine resources; and 4) Engage in cooperative conservation and management of coral reefs and coral reef ecosystems with local, regional or international programs and partners. The Act also authorizes NOAA to provide financial assistance for coral reef conservation projects and award grants for emergencies to address unforeseen or disaster-related circumstances pertaining to coral reefs and coral reef ecosystems. There is also a coral reef conservation fund administered by NOAA and a non-profit organization to build public-private partnership to reduce and prevent degradation of coral reefs and associated reef habitats, and solicit donations.	NOS	2000
Coral Reef Protection, Executive Order 13089	Established the interagency U.S. Coral Reef Task Force and charged it with developing and implementing a comprehensive program of mapping and monitoring of U.S. coral reefs, research on coral reef ecosystem degradation, and development of mitigation and restoration measures. In addition, directs federal agencies with actions that may affect U.S. coral reef ecosystems to: 1) Identify actions that may affect coral reef ecosystems; 2) Apply authorities to ensure that those actions do not degrade such ecosystems; and 3) Utilize programs and authorities to protect and enhance such ecosystems.	NMFS and NOS share lead	1998
Endangered Species Act	**Provides for the conservation of endangered and threatened species as well as the ecosystems and habitats upon which they depend. Habitat of listed species necessary for breeding, spawning, rearing, migrating, feeding, or sheltering is protected under the Endangered Species Act.**	**NMFS**	**1973 (as amended)**
Estuary Restoration Act	Established Estuary Habitat Restoration Council that includes NOAA, and authorizes funding for a comprehensive program to restore habitat in America's estuaries.	NOS	2000
Federal Power Act	Provides authority to include conditions for fish protection in licenses issued by the Federal Energy Regulatory Commission for non-federal hydropower projects.	NMFS	1920
Fish & Wildlife Coordination Act	Directs federal agencies to consult with NMFS or the U.S. Fish and Wildlife Service as appropriate before undertaking any water resource development project to ensure that wildlife conservation receives equal consideration and is coordinated with other project features.	NMFS	1958
Federal Water Pollution Control Act (Clean Water Act)	Provides for federal regulation of water quality through measures such as water quality standards, discharge limits, and permits, as well as permits to dredge and fill waters of the United States, including wetlands.	NMFS	1972

Acts and Executive Orders	Summary	Lead in NOAA	Date
Harmful Algal Blooms and Hypoxia Research and Control Act	Established an interagency task force, chaired by the Secretary of Commerce, to assess ecological and economic impacts of marine and freshwater harmful algal blooms, identify alternatives for reducing, mitigating, and controlling those impacts, and examine the social and economic costs and benefits of such alternatives. The Act also charges the task force to assess the ecological and economic impacts of hypoxia (reduced oxygen concentration within sea water, caused in part by the presence of harmful algal blooms) in U.S. coastal waters, identify alternatives for reducing, mitigating and controlling hypoxia, and examine the social and economic costs and benefits of such alternatives. Finally, the Act charges the task force to assess hypoxia in the Northern Gulf of Mexico, specifically the sources and loads of nutrients transported to the Gulf by the Mississippi River, the effects of nutrient load, methods for reducing nutrient loads, and social and economic costs and benefits of such alternatives.	NOS	1998 (as amended)
Magnuson-Stevens Fishery Conservation and Management Act	**Provides for U.S. management authority over fishing within the U.S. Exclusive Economic Zone (typically 5.6–370 km [3–200 nautical miles [nmi] from shore), all anadromous fish throughout their migratory range (except when in foreign waters), and all fish on the Continental Shelf. Also established eight Regional Fishery Management Councils with responsibility for the preparation of fishery management plans to prevent overfishing while achieving optimum yield from U.S. Fisheries in their regions. Defines Essential Fish Habitat (EFH) and includes provisions for conserving EFH through the following: 1) Identification and description of EFH for species managed under fisheries management plans; 2) Minimization of fishing impacts on EFH to the extent practicable; 3) Identification of non-fishing impacts; and 4) Requiring federal action agencies to consult with NMFS on actions that may adversely affect EFH. The Act was recently reauthorized but did not include any changes that would affect existing EFH regulations, guidance, or management approaches.**	**NMFS**	**2007 (as amended and reauthorized on 12 January 2007 and previously amended by the Sustainable Fisheries Act in 1996)**
Marine Mammal Protection Act	**Provides for the protection of marine mammals. Places restrictions on any habitat alteration that could adversely impact a marine mammal by disrupting behavioral patterns that include, but are not limited to, migration, breathing, nursing, breeding, feeding, and sheltering.**	**NMFS**	**1972 (as amended)**
Marine Protected Areas, Executive Order 13158	Directed the Departments of Commerce and Interior to establish a national system of marine protected areas (MPA). Requires federal action agencies to identify actions that affect MPA resources and, to the maximum extent practicable, avoid harm to MPA resources when taking such actions.	NOS	2000
National Environmental Policy Act	Requires federal action agencies to analyze the environmental effects of proposed actions on the human environment. The analysis must include consideration of the environmental effects of a range of alternatives for the proposed actions.	NOAA	1969

Acts and Executive Orders	Summary	Lead in NOAA	Date
National Marine Sanctuaries Act (Title III of the Marine Protection, Research, and Sanctuaries Act)	Provides for protection of areas designated as marine sanctuaries due to their special natural or cultural resource qualities by the following methods: 1) Requiring NOAA to issue regulations and providing for civil penalties; 2) Requiring NOAA to seek damages from those who have injured sanctuary resources (NOAA uses the money mainly to restore the injured resources); and 3) requiring other federal agencies to consult with NOAA if they are proposing an action likely to injure sanctuary resources and, should they fail to follow NOAA's recommendations, to restore any injured sanctuary resources.	NOS	1972 (as amended)
Non-indigenous Aquatic Nuisance Prevention and Control Act	Established a task force co-chaired by NOAA to: 1) Prevent introduction and dispersal of aquatic nuisance species in U.S. waters; 2) Monitor, control, and study such species; 3) Conduct research concerning environmental risks and impacts associated with the introduction of aquatic nuisance species in U.S. waters; 4) Disseminate related information; and 5) Provide competitive research grants (administered through the National Sea Grant College Program and the Cooperative Fishery and Wildlife Research Units) to study all aspects of aquatic nuisance species.	NMFS	1990
Oil Pollution Act	Requires NOAA to seek damages from those who have released oil and caused injury to natural resources. Accordingly, NOAA (NOS) determines the injuries to natural resources and seeks recoveries from the potentially responsible parties to restore, replace, or acquire the equivalent of natural resources and to cover the costs of damage assessment.	NOS	1990

Appendix 3
Current Fishery Management Plans and Fishery Ecosystem Plans

Fishery Management Plans (FMPs) are grouped by the section of this publication where they are discussed. There were 46 current FMPs at the time this report was created.[1]

Northeast Region
- Atlantic Herring
- Atlantic Mackerel, Squid, and Butterfish
- Atlantic Salmon
- Atlantic Sea Scallop
- Atlantic Surfclam and Ocean Quahog
- Bluefish
- Deep-Sea Red Crab
- Monkfish
- Northeast Multispecies
- Northeast Skate Complex
- Spiny Dogfish
- Summer Flounder, Scup, and Black Sea Bass
- Tilefish

Southeast Region
- Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic
- Consolidated Atlantic Highly Migratory Species[2]
- Coral and Coral Reefs of the Gulf of Mexico
- Coral, Coral Reefs, and Live/Hard Bottom Habitats of the South Atlantic Region
- Corals and Reef-Associated Plants and Invertebrates of Puerto Rico and the U.S. Virgin Islands
- Dolphin and Wahoo Fishery of the Atlantic
- Golden Crab Fishery of the South Atlantic Region
- Pelagic Sargassum Habitat of the South Atlantic Region
- Queen Conch Resources of Puerto Rico and the U.S. Virgin Islands
- Red Drum Fishery of the Gulf of Mexico
- Reef Fish Resources of the Gulf of Mexico
- Regulating Offshore Marine Aquaculture in the Gulf of Mexico
- Shallow Water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands
- Shrimp Fishery of the Gulf of Mexico
- Shrimp Fishery of the South Atlantic Region
- Snapper-Grouper Fishery of the South Atlantic Region
- Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands
- Spiny Lobster in the Gulf of Mexico and South Atlantic

[1]These listings may have changed since this report was completed in 2014. Please refer to individual Council websites or FMPs listed within the latest status updates on U.S. fisheries found at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm to check for any up-to-date information.
[2]Species in this FMP are also found in the Northeast Region.

Pacific Coast Region

- Coastal Pelagic Species
- Pacific Coast Groundfish
- Pacific Coast Salmon
- U.S. West Coast Fisheries for Highly Migratory Species

Alaska Region

- Bering Sea/Aleutian Islands King and Tanner Crabs
- Fish Resources of the Arctic Management Area
- Groundfish of the Bering Sea and Aleutian Islands Management Area
- Groundfish of the Gulf of Alaska
- Salmon Fisheries in the Exclusive Economic Zone (EEZ) off the Coast of Alaska
- Scallop Fishery off Alaska

Pacific Islands Region

Note: The Western Pacific Regional Fishery Management Council operated using five Fishery Management Plans (FMPs) until 2010, when five new Fishery Ecosystem Plans (FEPs) were approved.

Former FMPs

- Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region
- Coral Reef Ecosystems of the Western Pacific Region
- Crustacean Fisheries of the Western Pacific Region
- Pelagic Fisheries of the Western Pacific Region
- Precious Coral Fisheries of the Western Pacific Region

FEPs

- American Samoa Archipelago
- Hawaii Archipelago
- Marianas Archipelago
- Pacific Pelagic Fisheries of the Western Pacific Region
- Pacific Remote Islands Area

Appendix 4
Habitat-Use Table Methodology

HABITAT-USE TABLES: DEFINITIONS

The four habitat categories used in this publication are defined below.

Category	Definition	Examples
Freshwater habitat	Habitats located between headwater and head-of-tide, with negligible salinity. (Headwater is the inland source from which a river originates; head-of-tide is the inland limit of water affected by tides.)	Columbia River, Penobscot River, Togus Stream, Bond Brook (latter two are both Kennebec River tributaries)
Estuarine habitat	Habitats 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.	Chesapeake Bay, Puget Sound
Shallow marine habitat	Habitats 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 open water column over areas shallower than 200 m (656 ft).	Continental Shelf habitats, fringe and barrier reefs, atolls (e.g. Johnston Atoll), Gulf of the Farallones, Heceta Bank
Oceanic habitat	Habitats 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).	Slope habitats, Bear Seamount, Hudson Canyon, Gulf of Maine basins, Monterey Canyon, abyssal plains

Geographic Regions

The information presented in this report is divided into five regions: Northeast, Southeast, Pacific Coast, Alaska, and Pacific Islands. These regions correspond to the NMFS regional structure. All the report's regions extend from the upper reaches of watersheds utilized by anadromous fishes to the U.S. EEZ boundary, which is either an international boundary (e.g. with Canada or Mexico), or 370 km (200 nmi) off the U.S. coast. It should be noted, however, that most states have jurisdiction over waters out to 5.6 km (3 nmi) from the U.S. baseline, which is the mean lower low-water line along the coast. The exceptions are Texas, Puerto Rico, and the Gulf Coast of Florida, which have jurisdiction out to 16.7 km (9 nmi) from the U.S. baseline. The distributions of some highly migratory fish and marine mammals extend beyond these regions, into the territorial seas of other counties and/or into the international waters of the open ocean.

Region in the *Our Living Oceans* habitat report	Geographic extent
Northeast	From the U.S.–Canada border (Maine–New Brunswick) to Cape Hatteras, North Carolina
Southeast	From Cape Hatteras, North Carolina, to the U.S.–Mexico border (Texas–Tamaulipas); also Puerto Rico and U.S. Virgin Islands
Pacific Coast	From the U.S.–Canada border (Washington–British Columbia) to the U.S.–Mexico border (California–Baja California)
Alaska	Alaska
Pacific Islands	Hawaii, Northwest Hawaiian Islands, and several small island territories extending nearly as far west as Japan and to nearly 20 degrees south of the equator

HABITAT-USE TABLES: SPECIES GROUPINGS

Habitat use for the Nation's federally managed and protected species is described in the tables in terms of the following species groupings.

Fishery Management Plan (FMP)

Habitat use for the Nation's federally managed fishery species is primarily described by FMP. Some FMPs cover only one species, and, in these instances, the table entries describe the habitat use for all life stages of that species. Other FMPs cover multiple species. In these cases, a single table entry represents the compiled habitat-use patterns available for all the life stages of all species included in the FMP that use the particular habitat. See Appendix 5 for a complete list of FMP species.

Fishery Ecosystem Plan (FEP) Management Unit Species (MUS) Groups

Until 2010, the Western Pacific Regional Fishery Management Council (WPRFMC) utilized five Fishery Management Plans (FMPs). These included the Bottomfish FMP, Coral Reef Ecosystems FMP, Crustaceans FMP, Pelagics FMP, and Precious Corals FMP. Beginning in 2010, the WPRFMC adopted five new Fishery Ecosystem Plans (FEPs). The FEPs (American Samoa FEP, Hawaii FEP, Marianas FEP, Pacific Islands Remote Area FEP, and Pelagics FEP) shifted management focus from species-based to place-based, and began the implementation of ecosystem-based approaches to fisheries management in the Pacific Islands. The FEPs have recently established new fishing regulations, and have created the organizational structure to incorporate additional information, community input, and local knowledge into development of fishery ecosystem management.[1] The Management Unit Species (MUS) in each FEP include crustaceans, bottomfishes, coral reef ecosystem species, pelagics, and precious corals. Habitat use is described only once for each MUS group but applies to each of the location-based FEPs. For example, the crustacean MUS habitat-use table entry applies to crustaceans in the American Samoa, Marianas, Hawaii, and Pacific Islands Remote Area FEPs. As with the FMPs, a table entry describing habitat use often applies to multiple species (and all their respective life stages).

Protected Species

NMFS provides oversight and guidance on the conservation of marine mammals and threatened or endangered marine species.[2] See Appendix 5 for a complete list of protected species included in this report. To include habitat-use information for these species, they are grouped into the following categories:

- Cetaceans: marine mammals of the Order Cetacea, which includes whales, dolphins, and porpoises.
- Pinnipeds: marine mammals of the Suborder Pinnipedia, which includes seals and sea lions.[3]
- Sea Turtles: marine reptiles of the Superfamily Chelonioidea.[4]

For a full listing of the protected species included in these groupings, refer to Appendix 5.

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[1]See the Western Pacific Regional Fishery Management Council website at http://www.wpcouncil.org/fishery-plans-policies-reports/ (accessed October 2013).

[2]Conservation duties are administered by NMFS for all U.S. marine mammals except the polar bear, sea otter, Pacific walrus, and West Indian manatee.

[3]Conservation duties are administered by NMFS for all U.S. pinnipeds except the Pacific walrus.

[4]Federal conservation duties are shared by NMFS and the U.S. Fish and Wildlife Service.

Habitat-Use Categories

Habitat-use estimates incorporate the use of one of the four habitat categories by all life stages of a given species; and in some cases, multiple species. These estimates are based on the tendency of a marine organism(s) to be found in the given habitat type.

Usage of each habitat category is defined as the following:

- Frequent (F): commonly used as habitat by at least one life stage (>25% of the time).
- Occasionally (O): occasionally used for habitat by at least one life stage (<25% of the time).
- Never (N): never used as habitat by any life stage.

HABITAT-USE TABLES: ESTIMATING HABITAT USE

The values in the habitat-use tables represent the likelihood of all species within the FMP, FEP Management Unit Species Group, or group of cetaceans, pinnipeds, or sea turtles (which may be one or multiple species) being found in a particular habitat, not necessarily the amount of time spent in the habitat. For example, if a given species depends on estuarine habitat as a juvenile for foraging and protection from predators, but only uses that habitat for a short part of its life cycle, the use estimate would still be characterized as "frequent" (F), because of its dependency upon that particular habitat type. Alternatively, a species may sometimes be found in a particular habitat, though its use is more incidental than deliberate. For example, it is not uncommon to find beluga whales traveling up rivers into freshwater environments, though this is often a case of following a prey source rather than deliberately seeking freshwater habitat. Such usage would best be characterized as "occasional" (O). For species that never use a particular habitat (e.g. corals never use freshwater habitats), the habitat-use value recorded is "never" (N). In addition, the habitat-use ratings in each table represent the highest level of usage for a species within the particular FMP, FEP Management Unit Species (MUS) Group, or group of cetaceans, pinnipeds, or sea turtles. For example, an FMP may have multiple species, some of which frequently use shallow marine habitats and some of which frequently use oceanic habitats, but not all of which frequently use both habitats. The table entries for this FMP, however, would show a habitat-use rating of "frequent in both shallow marine and oceanic habitats," to indicate that both habitats are used on a regular basis by one or more species within the FMP.

HABITAT-USE TABLES: REGIONAL CHAPTERS AND NATIONAL SUMMARY

Habitat tables are included in each regional chapter. The Northeast has 13 FMPs, Southeast has 17 FMPs (excluding the Aquaculture FMP), Pacific Coast has 4 FMPs, Alaska has 6 FMPs, and the Pacific Islands has 5 MUS groups that apply to all FEPs. Each region's table has entries provided for each of the region's FMPs or FEP MUS groups in freshwater, estuarine, shallow marine, and ocean habitat types. The percentage of the number of FMPs or FEP MUS groups with species that use each habitat type is also provided. In addition, table entries are provided for groups of cetaceans, pinnipeds, and sea turtles in each region. A table entry for a region's cetaceans, for example, represents the combined habitat use for all cetaceans (and their respective life stages) in each habitat type. The National Summary has a table that summarizes habitat use on a national scale for the Nation's fishery species. It is based on all the regional tables and uses a total number of 45[5] FMP and FEP MUS groups to formulate the national percentage of FMPs and FEP MUS groups with species that use each habitat type, and a total number of 15 nationwide groups of cetaceans, pinnipeds, and sea turtles to formulate the national percentage of cetacean, pinniped, and sea turtles groups with species that use each habitat type.

[5]Appendix 3 lists a total of 46 FMPs that were present at the time of report production. The habitat-use tables do not include information for the Aquaculture FMP and therefore include information for only 45 of the 46 FMPs.

Appendix 5
Common and Scientific Names of Species

This appendix contains the species pertinent to the *Our Living Oceans* (*OLO*) habitat report. The Fishery Management Plans (FMPs) referred to in this report are listed along with the common and scientific names of all species in each FMP. Some species are listed multiple times in this appendix because they are managed under more than one FMP, or because an FMP species also has particular stocks that are protected under the Endangered Species Act. The protected species under NMFS purview are also included in this appendix along with the National Marine Fisheries Service (NMFS) regions where they are found. In addition, the species of fishes and invertebrates managed by the coastal U.S. states and by U.S.–Canada agreement addressed in the report are listed. Please refer to http://www.nmfs.noaa.gov to check for any updates. The following sites in particular may be of use: http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/status_updates.html (fishery species) and http://www.nmfs.noaa.gov/pr (protected species) (sites accessed May 2015).

KEY TO THIS APPENDIX

FMP NAME
NMFS office that implemented the FMP (or other applicable law).
Fishery Management Council (or other governmental agency) that developed the FMP.

Common name	Scientific name	Local name (Pacific Islands Region only)	Primary *OLO* regions where the species is found (protected species only)

NORTHEAST REGION

Atlantic Herring FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

Atlantic herring	*Clupea harengus*

Atlantic Mackerel, Squid, and Butterfish FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the Mid-Atlantic Fishery Management Council.

Atlantic mackerel	*Scomber scombrus*
Butterfish	*Peprilus triacanthus*
Longfin inshore squid	*Loligo pealeii*
Northern shortfin squid	*Illex illecebrosus*

Atlantic Salmon FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

Atlantic salmon	*Salmo salar*

Atlantic Sea Scallop FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

Atlantic sea scallop	*Placopecten magellanicus*

Atlantic Surfclam and Ocean Quahog FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the Mid-Atlantic Fishery Management Council.

Atlantic surfclam	*Spisula solidissima*
Ocean quahog	*Arctica islandica*

Bluefish FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the Mid-Atlantic Fishery Management Council.

Bluefish	*Pomatomus saltatrix*

Deep-Sea Red Crab FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

Deep-sea red crab (red deepsea crab)	*Chaceon quinquedens*

Monkfish FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

Monkfish (goosefish)	*Lophius americanus*

Northeast Multispecies FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

American plaice	*Hippoglossoides platessoides*
Atlantic cod	*Gadus morhua*
Atlantic halibut	*Hippoglossus hippoglossus*
Haddock	*Melanogrammus aeglefinus*
Ocean pout	*Macrozoarces americanus*
Offshore hake	*Merluccius albidus*
Pollock	*Pollachius virens*
Red hake	*Urophycis chuss*
Redfish (Acadian redfish)	*Sebastes fasciatus*
Silver hake	*Merluccius bilinearis*
White hake	*Urophycis tenuis*
Windowpane flounder	*Scophthalmus aquosus*
Winter flounder	*Pseudopleuronectes americanus*
Witch flounder	*Glyptocephalus cynoglossus*
Yellowtail flounder	*Limanda ferrruginea*

Northeast Skate Complex FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the New England Fishery Management Council.

Barndoor skate	*Dipturus laevis*
Clearnose skate	*Raja eglanteria*
Little skate	*Leucoraja erinacea*
Rosette skate	*Leucoraja garmani*
Smooth skate	*Malacoraja senta*
Thorny skate	*Amblyraja radiata*
Winter skate	*Leucoraja ocellata*

Spiny Dogfish FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed jointly by the Mid-Atlantic Fishery Management Council (administrative lead) and the New England Fishery Management Council.

Spiny dogfish	*Squalus acanthias*

Summer Flounder, Scup, and Black Sea Bass FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the Mid-Atlantic Fishery Management Council.

Black sea bass	*Centropristis striata*
Scup	*Stenotomus chrysops*
Summer flounder	*Paralichthys dentatus*

Tilefish FMP
Implemented by the NMFS Greater Atlantic Regional Fisheries Office.
Developed by the Mid-Atlantic Fishery Management Council.

Tilefish (golden tilefish)	*Lopholatilus chamaeleonticeps*

SOUTHEAST REGION

Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic FMP
Implemented by the NMFS Southeast Regional Office.
Developed jointly by the Gulf of Mexico Fishery Management Council (administrative lead) and the South Atlantic Fishery Management Council.

Cobia	*Rachycentron canadum*
King mackerel	*Scomberomorus cavalla*
Spanish mackerel	*Scomberomorus maculatus*

Consolidated Atlantic Highly Migratory Species FMP[1]
Implemented by the NMFS Office of Sustainable Fisheries.
Developed by the NMFS Office of Sustainable Fisheries.

Albacore	*Thunnus alalunga*
Arrowhead dogfish	*Deania profundorum*
Atlantic angel shark	*Squatina dumeril*
Atlantic bluefin tuna	*Thunnus thynnus*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Bahamas sawshark	*Pristiophorus schroederi*
Basking shark	*Cetorhinus maximus*
Bigeye sand tiger shark	*Odontaspis noronhai*
Bigeye sixgill shark	*Hexanchus vitulus*
Bigeye thresher shark	*Alopias superciliosus*
Bigeye tuna	*Thunnus obesus*
Bignose shark	*Carcharhinus altimus*
Bigtooth cookiecutter shark	*Isistius plutodus*
Blacknose shark	*Carcharhinus acronotus*
Blacktip shark	*Carcharhinus limbatus*
Blotched catshark	*Scyliorhinus meadi*
Blue marlin	*Makaira nigricans*
Blue shark	*Prionace glauca*
Bonnethead shark	*Sphyrna tiburo*
Bramble shark	*Echinorhinus brucus*
Broadband lantern shark	*Etmopterus gracilispinis*
Broadgill catshark	*Apristurus riveri*
Bull shark	*Carcharhinus leucas*
Caribbean lanternshark	*Etmopterus hillianus*
Caribbean reef shark	*Carcharhinus perezii*
Caribbean sharpnose shark	*Rhizoprionodon porosus*
Chain dogfish	*Scyliorhinus retifer*
Cookiecutter shark	*Isistius brasiliensis*
Cuban dogfish	*Squalus cubensis*
Deepwater catshark	*Apristurus profundorum*
Dusky shark	*Carcharhinus obscurus*

[1]Species in this FMP are also found in the Northeast Region.

Dwarf catshark	*Scyliorhinus torrei*
Finetooth shark	*Carcharhinus isodon*
Flatnose gulper shark	*Deania profundorum*
Florida smoothhound	*Mustelus norrisi*
Fringefin lanternshark	*Etmopterus schultzi*
Galapagos shark	*Carcharhinus galapagensis*
Great hammerhead shark	*Sphyrna mokarran*
Great lanternshark	*Etmopterus princeps*
Green lanternshark	*Etmopterus virens*
Greenland shark	*Somniosus microcephalus*
Gulper shark	*Centrophorus granulosus*
Iceland catshark	*Apristurus laurussonii*
Japanese gulper shark	*Centrophorus acus*
Kitefin shark	*Dalatias licha*
Largetooth cookiecutter shark	*Isistius plutodus*
Lemon shark	*Negaprion brevirostris*
Lined lanternshark	*Etmopterus bullisi*
Little gulper shark	*Centrophorus uyato*
Longbill spearfish	*Tetrapturus pfluegeri*
Longfin mako shark	*Isurus paucus*
Marbled catshark	*Galeus arae*
Narrowtooth shark	*Carcharhinus brachyurus*
Needle dogfish	*Centrophorus acus*
Night shark	*Carcharhinus signatus*
Nurse shark	*Ginglymostoma cirratum*
Oceanic whitetip shark	*Carcharhinus longimanus*
Porbeagle	*Lamna nasus*
Portuguese shark	*Centroscymnus coelolepis*
Pygmy shark	*Euprotomicrus bispinatus*
Roughskin dogfish	*Cirrhigaleus asper*
Roundscale spearfish	*Tetrapturus georgii*
Sailfish	*Istiophorus platypterus*
Sand tiger shark	*Carcharias taurus*
Sandbar shark	*Carcharhinus plumbeus*
Scalloped hammerhead shark	*Sphyrna lewini*
Sevengill shark	*Heptranchias perlo*
Shortfin mako shark	*Isurus oxyrinchus*
Shortspine dogfish	*Squalus mitsukurii*
Silky shark	*Carcharhinus falciformis*
Sixgill shark	*Hexanchus griseus*
Skipjack tuna	*Katsuwonus pelamis*
Smallfin catshark	*Apristurus parvipinnis*
Smallmouth velvet dogfish	*Scymnodon obscurus*
Smalltail shark	*Carcharhinus porosus*
Smooth dogfish	*Mustelus canis*
Smooth hammerhead shark	*Sphyrna zygaena*
Smooth lanternshark	*Etmopterus pusillus*
Spinner shark	*Carcharhinus brevipinna*
Swordfish	*Xiphias gladius*
Thresher shark	*Alopias vulpinus*

Tiger shark	*Galeocerdo cuvier*
Whale shark	*Rhincodon typus*
White marlin	*Tetrapturus albidus*
White shark	*Carcharodon carcharias*
Yellowfin tuna	*Thunnus albacares*

Coral and Coral Reefs of the Gulf of Mexico FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Gulf of Mexico Fishery Management Council.

Black corals	Order Antipatharia
Fire corals	Family Milleporidae
Hydrocorals	Family Stylasteridae
Stony corals	Order Scleractinia

Corals and Reef-associated Plants and Invertebrates of Puerto Rico and the U.S. Virgin Islands FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Caribbean Fishery Management Council.

Anemones	Order Actiniaria
Annelid worms	Phylum Annelida
Anthozoans	Class Anthozoa
Bivalves	Class Bivalvia
Black corals	Order Antipatharia
Brittle and basket stars	Class Ophiuroidea
Bryozoans	Phylum Ectoprocta
Cephalopods	Class Cephalopoda
Colonial anemones	Order Zoanthidea
Crustaceans	Subphylum Crustacea
False coral	Order Corallimorpharia
Feather stars	Class Crinoidea
Fire corals	Family Milleporidae
Gastropods	Class Gastropoda
Gorgonian corals	Order Gordonacea
Green algae	Phylum Chlorophyta
Hydrocorals	Family Stylasteridae
Hydroids	Class Hydrozoa
Red algae	Phylum Rhodophya
Rose lace corals	Family Stylasteridae
Sea cucumbers	Class Holothuroidea
Sea stars	Class Asteroidea
Sea urchins	Class Echinoidea
Seagrasses	Phylum Angiospermae
Sponges	Phylum Porifera
Soft corals	Order Alcyonacea
Stony corals	Order Scleractinia
Tunicates	Subphylum Tunicata

Corals, Coral Reefs, and Live/Hard Bottom Habitats of the South Atlantic Region FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the South Atlantic Fishery Management Council.

Black corals	Order Antipatharia
Fire corals	Family Milleporidae
Hydrocorals	Family Stylasteridae
Octocorals (Soft corals)	Subclass Octocorallia
Stony corals	Order Scleractinia

Dolphin and Wahoo FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils.

Dolphinfish	*Coryphaena hippurus*
Wahoo	*Acanthocybium solandri*

Golden Crab Fishery of the South Atlantic FMP[2]
Implemented by the NMFS Southeast Regional Office.
Developed by the South Atlantic Fishery Management Council.

Deep-sea red crab (red deepsea crab)	*Chaceon quinquedens*
Golden deepsea crab	*Chaceon fenneri*
Jonah crab	*Cancer borealis*

Pelagic *Sargassum* Habitat of the South Atlantic Region FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the South Atlantic Fishery Management Council.

Sargassum	*Sargassum natans, Sargassum fluitans*

Queen Conch Resources of Puerto Rico and the U.S. Virgin Islands FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Caribbean Fishery Management Council.

Queen conch	*Strombus gigas*

Red Drum Fishery of the Gulf of Mexico FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Gulf of Mexico Fishery Management Council.

Red drum	*Sciaenops ocellatus*

[2]The red deepsea crab and the Jonah crab are part of the fishery but are not included in the management unit.

Reef Fish Resources of the Gulf of Mexico FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Gulf of Mexico Fishery Management Council.

Almaco jack	*Seriola rivoliana*
Banded rudderfish	*Seriola zonata*
Black grouper	*Mycteroperca bonaci*
Blackfin snapper	*Lutjanus buccanella*
Blueline tilefish	*Caulolatilus microps*
Cubera snapper	*Lutjanus cyanopterus*
Gag	*Mycteroperca microlepis*
Goldface tilefish	*Caulolatilus chrysops*
Goliath grouper	*Epinephelus itajara*
Gray snapper	*Lutjanus griseus*
Gray triggerfish	*Balistes capriscus*
Greater amberjack	*Seriola dumerili*
Hogfish	*Lachnolaimus maximus*
Lane snapper	*Lutjanus synagris*
Lesser amberjack	*Seriola fasciata*
Mutton snapper	*Lutjanus analis*
Nassau grouper	*Epinephelus striatus*
Queen snapper	*Etelis oculatus*
Red grouper	*Epinephelus morio*
Red snapper	*Lutjanus campechanus*
Scamp	*Mycteroperca phenax*
Silk snapper	*Lutjanus vivanus*
Snowy grouper	*Epinephelus niveatus*
Speckled hind	*Epinephelus drummondhayi*
Tilefish	*Lopholatilus chamaeleonticeps*
Vermilion snapper	*Rhomboplites aurorubens*
Warsaw grouper	*Epinephelus nigritus*
Wenchman	*Pristipomoides aquilonaris*
Yellowedge grouper	*Epinephelus flavolimbatus*
Yellowfin grouper	*Mycteroperca venenosa*
Yellowmouth grouper	*Mycteroperca interstitialis*
Yellowtail snapper	*Ocyurus chrysurus*

Regulating Offshore Marine Aquaculture in the Gulf of Mexico FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Gulf of Mexico Fishery Management Council.

This FMP focuses on providing a framework for regulating aquaculture, so species are not included here.

Shallow Water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Caribbean Fishery Management Council.

Almaco jack	*Seriola rivoliana*
Atlantic batfish	*Dibranchus atlanticus*
Atlantic spadefish	*Chaetodipterus faber*
Banded butterflyfish	*Chaetodon striatus*
Bar jack	*Caranx ruber*
Beaugregory	*Stegastes leucostictus*
Bicolor damselfish	*Stegastes partitus*
Bigeye	*Priacanthus arenatus*
Black durgon	*Melichthys niger*
Black jack	*Caranx lugubris*
Black snapper	*Apsilus dentatus*
Blackbar soldierfish	*Myripristis jacobus*
Blackfin snapper	*Lutjanus buccanella*
Blackline tilefish	*Caulolatilus cyanops*
Blue chromis	*Chromis cyanea*
Blue parrotfish	*Scarus coeruleus*
Blue tang	*Acanthurus coeruleus*
Blue runner	*Caranx crysos*
Bluehead wrasse	*Thalassoma bifasciatum*
Bluestriped grunt	*Haemulon sciurus*
Butter hamlet	*Hypoplectrus unicolor*
Cardinal soldierfish	*Plectrypops retrospinis*
Caribbean tonguefish	*Symphurus arawak*
Chain moray	*Echidna catenata*
Chalk bass	*Serranus tortugarum*
Cherubfish	*Centropyge argi*
Clown wrasse	*Halichoeres maculipinna*
Conchfish	*Astrapogon stellatus*
Coney	*Cephalopholis fulva*
Creole wrasse	*Clepticus parrae*
Atlantic creolefish	*Paranthias furcifer*
Doctorfish	*Acanthurus chirurgus*
Dog snapper	*Lutjanus jocu*
Dusky damselfish	*Stegastesadustus*
Dusky jawfish	*Opistognathus whitehursti*
Flamefish	*Apogon maculatus*
Flying gurnard	*Dactylopterus volitans*
Foureye butterflyfish	*Chaetodon capistratus*
French angelfish	*Pomacanthus paru*
French grunt	*Haemulon flavolineatum*
Frogfishes	*Antennarius* spp.
Glasseye snapper	*Priacanthus cruentatus*
Goldentail moray	*Gymnothorax miliaris*
Goldspotted eel	*Myrichthys ocellatus*
Goliath grouper	*Epinephelus itajara*
Gray angelfish	*Pomacanthus arcuatus*

Gray snapper	*Lutjanus griseus*
Graysby	*Cephalopholis cruentata*
Greater amberjack	*Seriola dumerili*
Greater soapfish	*Rypticus saponaceus*
Green moray	*Gymnothorax funebris*
Green razorfish	*Xyrichtys splendens*
Harlequin bass	*Serranus tigrinus*
High-hat	*Pareques acuminatus*
Hogfish	*Lachnolaimus maximus*
Honeycomb cowfish	*Lactophrys polygonia*
Horse-eye jack	*Caranx latus*
Jackknife-fish	*Equetus lanceolatus*
Jolthead porgy	*Calamus bajonado*
Lane snapper	*Lutjanus synagris*
Lantern bass	*Serranus baldwini*
Longsnout butterflyfish	*Chaetodon aculeatus*
Longspine squirrelfish	*Holocentrus rufus*
Mahogany snapper	*Lutjanus mahogoni*
Margate	*Haemulon album*
Midnight parrotfish	*Scarus coelestinus*
Misty grouper	*Epinephelus mystacinus*
Mutton snapper	*Lutjanus analis*
Nassau grouper	*Epinephelus striatus*
Neon goby	*Gobiosoma oceanops*
Ocean surgeon	*Acanthurus bahianus*
Ocean triggerfish	*Canthidermis sufflamen*
Orangeback bass	*Serranus annularis*
Peacock flounder	*Bothus lunatus*
Pearly razorfish	*Xyrichtys novacula*
Pipefishes	*Syngnathus* spp.
Pluma	*Calamus pennatula*
Porcupinefish	*Diodon hystrix*
Porkfish	*Anisotremus virginicus*
Princess parrotfish	*Scarus taeniopterus*
Puddingwife	*Halichoeres radiatus*
Queen angelfish	*Holacanthus ciliaris*
Queen parrotfish	*Scarus vetula*
Queen snapper	*Etelis oculatus*
Queen triggerfish	*Balistes vetula*
Rainbow parrotfish	*Scarus guacamaia*
Red grouper	*Epinephelus morio*
Red hind	*Epinephelus guttatus*
Redband parrotfish	*Sparisoma aurofrenatum*
Redfin parrotfish	*Sparisoma rubripinne*
Redlip blenny	*Ophioblennius atlanticus*
Redspotted hawkfish	*Amblycirrhitus pinos*
Redtail parrotfish	*Sparisoma chrysopterum*
Rock beauty	*Holacanthus tricolor*
Rock hind	*Epinephelus adscensionis*
Rusty goby	*Priolepis hipoliti*

Sand diver	*Synodus intermedius*
Sand tilefish	*Malacanthus plumieri*
Sargassum triggerfish	*Xanthichthys ringens*
Schoolmaster	*Lutjanus apodus*
Scorpionfishes	Family Scorpaenidae
Scrawled cowfish	*Acanthostracion quadricornis*
Scrawled filefish	*Aluterus scriptus*
Sea bream	*Archosargus rhomboidalis*
Seahorses	*Hippocampus* spp.
Sergeant major	*Abudefduf saxatilis*
Sharpnose puffer	*Canthigaster rostrata*
Sheepshead porgy	*Calamus penna*
Silk snapper	*Lutjanus vivanus*
Smooth trunkfish	*Lactophrys triqueter*
Spanish hogfish	*Bodianus rufus*
Spotfin butterflyfish	*Chaetodon ocellatus*
Spotted drum	*Equetus punctatus*
Spotted goatfish	*Pseudupeneus maculatus*
Spotted trunkfish	*Lactophrys bicaudalis*
Squirrelfish	*Holocentrus adscensionis*
Stoplight parrotfish	*Sparisoma viride*
Striped parrotfish	*Scarus iseri*
Sunshinefish	*Chromis insolata*
Swissguard basslet (peppermint basslet)	*Liopropoma rubre*
Threespot damselfish	*Stegastes planifrons*
Tiger grouper	*Mycteroperca tigris*
Tobaccofish	*Serranus tabacarius*
Tomtate	*Haemulon aurolineatum*
Trunkfish	*Lactophrys trigonus*
Vermilion snapper	*Rhomboplites aurorubens*
Wenchman	*Pristipomoides aquilonaris*
White grunt	*Haemulon plumierii*
Whitespotted filefish	*Cantherhines macrocerus*
Yellow goatfish	*Mulloidichthys martinicus*
Yellow jack	*Caranx bartholomaei*
Yellowcheek wrasse	*Halichoeres cyanocephalus*
Yellowedge grouper	*Epinephelus flavolimbatus*
Yellowfin grouper	*Mycteroperca venenosa*
Yellowhead jawfish	*Opistognathus aurifrons*
Yellowhead wrasse	*Halichoeres garnoti*
Yellowtail damselfish	*Microspathodon chrysurus*
Yellowtail snapper	*Ocyurus chrysurus*

Shrimp Fishery of the Gulf of Mexico FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Gulf of Mexico Fishery Management Council.

Brown shrimp	*Farfantepenaeus aztecus*
Pink shrimp	*Farfantepenaeus duorarum*
Royal red shrimp	*Pleoticus robustus*
White shrimp	*Litopenaeus setiferus*

Shrimp Fishery of the South Atlantic FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the South Atlantic Fishery Management Council.

Brown shrimp	*Farfantepenaeus aztecus*
Pink shrimp	*Farfantepenaeus duorarum*
Rock shrimp (brown rock shrimp)	*Sicyonia brevirostris*
White shrimp	*Litopenaeus setiferus*

Snapper–Grouper Fishery of the South Atlantic FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the South Atlantic Fishery Management Council.

Almaco jack	*Seriola rivoliana*
Atlantic spadefish	*Chaetodipterus faber*
Banded rudderfish	*Seriola zonata*
Bank sea bass	*Centropristis ocyurus*
Bar jack	*Caranx ruber*
Black grouper	*Mycteroperca bonaci*
Black sea bass	*Centropristis striata*
Black snapper	*Apsilus dentatus*
Blackfin snapper	*Lutjanus buccanella*
Blue runner	*Caranx crysos*
Blueline tilefish	*Caulolatilus microps*
Coney	*Cephalopholis fulva*
Cottonwick	*Haemulon melanurum*
Cubera snapper	*Lutjanus cyanopterus*
Dog snapper	*Lutjanus jocu*
Gag	*Mycteroperca microlepis*
Goliath grouper	*Epinephelus itajara*
Gray snapper	*Lutjanus griseus*
Gray triggerfish	*Balistes capriscus*
Graysby	*Cephalopholis cruentata*
Greater amberjack	*Seriola dumerili*
Hogfish	*Lachnolaimus maximus*
Jolthead porgy	*Calamus bajonado*
Knobbed porgy	*Calamus nodosus*
Lane snapper	*Lutjanus synagris*
Lesser amberjack	*Seriola fasciata*

Longspine porgy	*Stenotomus caprinus*
Mahogany snapper	*Lutjanus mahogoni*
Margate	*Haemulon album*
Misty grouper	*Epinephelus mystacinus*
Mutton snapper	*Lutjanus analis*
Nassau grouper	*Epinephelus striatus*
Ocean triggerfish	*Canthidermis sufflamen*
Queen snapper	*Etelis oculatus*
Red grouper	*Epinephelus morio*
Red hind	*Epinephelus guttatus*
Red porgy	*Pagrus pagrus*
Red snapper	*Lutjanus campechanus*
Rock hind	*Epinephelus adscensionis*
Rock sea bass	*Centropristis philadelphica*
Sailors choice	*Haemulon parra*
Sand tilefish	*Malacanthus plumieri*
Saucereye porgy	*Calamus calamus*
Scamp	*Mycteroperca phenax*
Schoolmaster	*Lutjanus apodus*
Scup	*Stenotomus chrysops*
Silk snapper	*Lutjanus vivanus*
Snowy grouper	*Epinephelus niveatus*
Speckled hind	*Epinephelus drummondhayi*
Tilefish	*Lopholatilus chamaeleonticeps*
Tomtate	*Haemulon aurolineatum*
Vermilion snapper	*Rhomboplites aurorubens*
Warsaw grouper	*Epinephelus nigritus*
White grunt	*Haemulon plumierii*
Whitebone porgy	*Calamus leucosteus*
Wreckfish	*Polyprion americanus*
Yellowedge grouper	*Epinephelus flavolimbatus*
Yellowfin grouper	*Mycteroperca venenosa*
Yellowmouth grouper	*Mycteroperca interstitialis*
Yellowtail snapper	*Ocyurus chrysurus*

Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands FMP
Implemented by the NMFS Southeast Regional Office.
Developed by the Caribbean Fishery Management Council.

Caribbean spiny lobster	*Panulirus argus*

Spiny Lobster in the Gulf of Mexico and South Atlantic FMP
Implemented by the NMFS Southeast Regional Office.
Developed jointly by the Gulf of Mexico Fishery Management Council (administrative lead) and the South Atlantic Fishery Management Council.

Caribbean spiny lobster	*Panulirus argus*

PACIFIC COAST REGION

Coastal Pelagic Species FMP
Implemented by the NMFS West Coast Regional Office.
Developed by the Pacific Fishery Management Council.

Market squid	*Doryteuthis opalescens*
Jack mackerel	*Trachurus symmetricus*
Krill	*Euphausia pacifica*, *Thysanoessa spinifera*
Northern anchovy	*Engraulis mordax*
Pacific (chub) mackerel	*Scomber japonicus*
Pacific sardine	*Sardinops sagax*

Pacific Coast Groundfish FMP
Implemented by the NMFS West Coast Regional Office.
Developed by the Pacific Fishery Management Council.

Arrowtooth flounder	*Atheresthes stomias*
Aurora rockfish	*Sebastes aurora*
Bank rockfish	*Sebastes rufus*
Big skate	*Raja binoculata*
Black rockfish	*Sebastes melanops*
Black-and-yellow rockfish	*Sebastes chrysomelas*
Blackgill rockfish	*Sebastes melanostomus*
Blue rockfish	*Sebastes mystinus*
Bocaccio	*Sebastes paucispinis*
Bronzespotted rockfish	*Sebastes gilli*
Brown rockfish	*Sebastes auriculatus*
Butter sole	*Isopsetta isolepis*
Cabezon	*Scorpaenichthys marmoratus*
Calico rockfish	*Sebastes dalli*
California scorpionfish	*Scorpaena guttata*
California skate	*Raja inornata*
Canary rockfish	*Sebastes pinniger*
Chameleon rockfish	*Sebastes phillipsi*
Chilipepper	*Sebastes goodei*
China rockfish	*Sebastes nebulosus*
Copper rockfish	*Sebastes caurinus*
Cowcod	*Sebastes levis*
Curlfin sole	*Pleuronichthys decurrens*
Darkblotched rockfish	*Sebastes crameri*
Dover sole	*Microstomus pacificus*
Dusky rockfish	*Sebastes ciliatus*
Dwarf-red rockfish	*Sebastes rufinanus*
English sole	*Parophrys vetulus*
Finescale codling	*Antimora microlepis*
Flag rockfish	*Sebastes rubrivinctus*
Flathead sole	*Hippoglossoides elassodon*

Freckled rockfish	*Sebastes lentiginosus*
Gopher rockfish	*Sebastes carnatus*
Grass rockfish	*Sebastes rastrelliger*
Greenblotched rockfish	*Sebastes rosenblatti*
Greenspotted rockfish	*Sebastes chlorostictus*
Greenstriped rockfish	*Sebastes elongatus*
Halfbanded rockfish	*Sebastes semicinctus*
Harlequin rockfish	*Sebastes variegatus*
Honeycomb rockfish	*Sebastes umbrosus*
Kelp greenling	*Hexagrammos decagrammus*
Kelp rockfish	*Sebastes atrovirens*
Leopard shark	*Triakis semifasciata*
Lingcod	*Ophiodon elongatus*
Longnose skate	*Raja rhina*
Longspine thornyhead	*Sebastolobus altivelis*
Mexican rockfish	*Sebastes macdonaldi*
Olive rockfish	*Sebastes serranoides*
Pacific cod	*Gadus macrocephalus*
Pacific ocean perch	*Sebastes alutus*
Pacific rattail (grenadier)	*Coryphaenoides acrolepis*
Pacific sanddab	*Citharichthys sordidus*
Pacific whiting (hake)	*Merluccius productus*
Petrale sole	*Eopsetta jordani*
Pink rockfish	*Sebastes eos*
Pinkrose rockfish	*Sebastes simulator*
Pygmy rockfish	*Sebastes wilsoni*
Quillback rockfish	*Sebastes maliger*
Ratfish	*Hydrolagus colliei*
Redbanded rockfish	*Sebastes babcocki*
Redstripe rockfish	*Sebastes proriger*
Rex sole	*Glyptocephalus zachirus*
Rock sole	*Lepidopsetta bilineata*
Rosethorn rockfish	*Sebastes helvomaculatus*
Rosy rockfish	*Sebastes rosaceus*
Rougheye rockfish	*Sebastes aleutianus*
Sablefish	*Anoplopoma fimbria*
Sand sole	*Psettichthys melanostictus*
Sharpchin rockfish	*Sebastes zacentrus*
Shortbelly rockfish	*Sebastes jordani*
Shortraker rockfish	*Sebastes borealis*
Swordspine rockfish	*Sebastes ensifer*
Shortspine thornyhead	*Sebastolobus alascanus*
Silvergray rockfish	*Sebastes brevispinis*
Speckled rockfish	*Sebastes ovalis*
Spiny dogfish	*Squalus suckleyi*
Splitnose rockfish	*Sebastes diploproa*
Squarespot rockfish	*Sebastes hopkinsi*
Starry flounder	*Platichthys stellatus*
Starry rockfish	*Sebastes constellatus*
Stripetail rockfish	*Sebastes saxicola*

Tiger rockfish	*Sebastes nigrocinctus*
Tope (soupfin shark)	*Galeorhinus galeus*
Treefish	*Sebastes serriceps*
Vermilion rockfish	*Sebastes miniatus*
Widow rockfish	*Sebastes entomelas*
Yelloweye rockfish	*Sebastes ruberrimus*
Yellowmouth rockfish	*Sebastes reedi*
Yellowtail rockfish	*Sebastes flavidus*

Pacific Coast Salmon FMP
Implemented by the NMFS West Coast Regional Office.
Developed by the Pacific Fishery Management Council (some stocks also are protected under the Endangered Species Act).

Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Pink salmon	*Oncorhynchus gorbuscha*

U.S. West Coast Fisheries for Highly Migratory Species FMP
Implemented by the NMFS West Coast Regional Office.
Developed by the Pacific Fishery Management Council.

Albacore	*Thunnus alalunga*
Bigeye tuna	*Thunnus obesus*
Blue shark	*Prionace glauca*
Common thresher shark	*Alopias vulpinus*
Dolphinfish	*Coryphaena hippurus*
Pacific bluefin tuna	*Thunnus orientalis*
Shortfin mako shark	*Isurus oxyrinchus*
Skipjack tuna	*Katsuwonus pelamis*
Striped marlin	*Tetrapturus audax*
Swordfish	*Xiphias gladius*
Yellowfin tuna	*Thunnus albacares*

ALASKA REGION

Bering Sea/Aleutian Islands King and Tanner Crabs FMP
Implemented by the NMFS Alaska Regional Office.
Developed by the North Pacific Fishery Management Council.

Blue king crab	*Paralithodes platypus*
Golden king crab	*Lithodes aequispina*
Red king crab	*Paralithodes camtschaticus*
Snow crab	*Chionoecetes opilio*
Tanner crab	*Chionoecetes bairdi*

Fish Resources of the Arctic Management Area FMP
Implemented by the NMFS Alaska Regional Office.
Developed by the North Pacific Fishery Management Council.
Target species are Arctic cod, saffron cod, and snow crab; other species are component species.

Arctic cod	*Boreogadus saida*
Arctic staghorn sculpin	*Gymnocanthus tricuspis*
Alaska plaice	*Pleuronectes quadrituberculatus*
Alaska lyre crab	*Hyas lyratus*
Bering flounder	*Hippoglossoides robustus*
Blue king crab	*Paralithodes platypus*
Canadian eelpout	*Lycodes polaris*
Capelin	*Mallotus villosus*
Eelpouts	Family Zoarcidae
Greenland halibut	*Reinhardtius hippoglossoides*
Marbled eelpout	*Lycodes raridens*
Notched brittlestar	*Ophiura sarsi*
Pacific cod	*Gadus macrocephalus*
Pacific herring	*Clupea pallasii*
Pricklebacks	Family Stichaeidae
Red king crab	*Paralithodes camtschaticus*
Saffron cod	*Eleginus gracilis*
Sculpins	Family Cottidae
Snailfishes	Family Liparidae
Snow crab	*Chionoecetes opilio*
Walleye pollock	*Theragra chalcogramma*
Warty sculpin	*Myoxocephalus verrucosus*
Yellowfin sole	*Limanda aspera*

Groundfish of the Bering Sea and Aleutian Islands Management Area FMP
Implemented by the NMFS Alaska Regional Office.
Developed by the North Pacific Fishery Management Council.

Alaska plaice	*Pleuronectes quadrituberculatus*
Alaska skate	*Bathyraja parmifera*
Aleutian skate	*Bathyraja aleutica*
Antlered sculpin	*Enophrys diceraus*
Arctic flounder	*Pleuronectes glacialis*
Arctic staghorn sculpin	*Gymnocanthus tricuspis*
Armorhead sculpin	*Gymnocanthus galeatus*
Arrowtooth flounder	*Reinhardtius stomias*
Atka mackerel	*Pleurogrammus monopterygius*
Aurora rockfish	*Sebastes aurora*
Banded Irish lord	*Hemilepidotus gilberti*
Bering flounder	*Hippoglossoides robustus*
Bering skate	*Bathyraja interrupta*
Big skate	*Raja binoculata*
Bigmouth sculpin	*Hemitripterus bolini*
Blackfin sculpin	*Malacocottus kincaidi*
Blacknose sculpin	*Icelus canaliculatus*
Blackspotted rockfish	*Sebastes melanostictus*
Blob sculpin	*Psychrolutes phrictus*
Boreopacific armhook squid	*Gonatopsis borealis*
Bride sculpin	*Artediellus miacanthus*
Broadfin sculpin	*Bolinia euryptera*
Butter sole	*Isopsetta isolepis*
Butterfly sculpin	*Hemilepidotus papilio*
Butterfly skate	*Bathyraja papilionifera*
Commander skate	*Bathyraja lindbergi*
Crescent-tail sculpin	*Triglops metopias*
Crested sculpin	*Blepsias bilobus*
Curlfin sole	*Pleuronichthys decurrens*
Dark rockfish	*Sebastes ciliatus*
Darkfin sculpin	*Malacocottus zonurus*
Deepsea skate	*Bathyraja abyssicola*
Deepsea sole	*Microstomus bathybius*
Dover sole	*Microstomus pacificus*
Dusky rockfish	*Sebastes ciliatus*
English sole	*Parophrys vetulus*
Eyeshade sculpin	*Nautichthys pribilovius*
Flapjack octopus	*Opisthoteuthis californiana*
Flabby sculpin	*Zesticelus profundorum*
Flathead sole	*Hippoglossoides elassodon*
Fourhorn sculpin	*Triglopsis quadricornis*
Great sculpin	*Myoxocephalus polyacanthocephalus*
Greenland turbot (Greenland halibut)	*Reinhardtius hippoglossoides*
Grunt sculpin	*Rhamphocottus richardsonii*
Harlequin rockfish	*Sebastes variegatus*
Kamchatka flounder	*Reinhardtius evermanni*

Leister sculpin	*Enophrys lucasi*
Longfin Irish lord	*Hemilepidotus zapus*
Longfin sculpin	*Jordania zonope*
Longhead dab	*Limanda proboscidea*
Magister armhook squid	*Berryteuthis magister*
Mud skate	*Bathyraja hubbsi*
North Pacific giant octopus	*Enteroctopus dofleini*
Northern rockfish	*Sebastes polyspinis*
Northern rock sole	*Lepidopsetta polyxystra*
Northern sculpin	*Icelinus borealis*
Octopus complex	Family Octopodidae
Okhotsk skate	*Bathyraja violacea*
Pacific cod	*Gadus macrocephalus*
Pacific hookear sculpin	*Artediellus pacificus*
Pacific ocean perch	*Sebastes alutus*
Pacific sanddab	*Citharichthys sordidus*
Pacific sleeper shark	*Somniosus pacificus*
Pacific staghorn sculpin	*Leptocottus armatus*
Petrale sole	*Eopsetta jordani*
Plain sculpin	*Myoxocephalus jaok*
Purplegray sculpin	*Gymnocanthus detrisus*
Red Irish lord	*Hemilepidotus hemilepidotus*
Redbanded rockfish	*Sebastes babcocki*
Redstripe rockfish	*Sebastes proriger*
Rex sole	*Glyptocephalus zachirus*
Ribbed sculpin	*Triglops pingeli*
Rougheye rockfish	*Sebastes aleutianus*
Roughscale sole	*Clidoderma asperrimum*
Roughshoulder skate	*Amblyraja badia*
Roughskin sculpin	*Trachidermus fasciatus*
Roughspine sculpin	*Triglops macellus*
Roughtail skate	*Bathyraja trachura*
Sablefish	*Anoplopoma fimbria*
Sailfin sculpin	*Nautichthys oculofasciatus*
Sakhalin sole	*Limanda sakhalinensis*
Salmon shark	*Lamna ditropis*
Sand sole	*Psettichthys melanostictus*
Scaled sculpin	*Archistes biseriatus*
Scalybreasted sculpin	*Triglops xenostethus*
Scissortail sculpin	*Triglops forficatus*
Sharpchin rockfish	*Sebastes zacentrus*
Shortraker rockfish	*Sebastes borealis*
Shortspine thornyhead	*Sebastolobus alascanus*
Slender sole	*Lyopsetta exilis*
Slim sculpin	*Radulinus asprellus*
Smoothcheek sculpin	*Eurymen gyrinus*
Southern rock sole	*Lepidopsetta bilineata*
Spatulate sculpin	*Icelus spatula*
Spectacled sculpin	*Triglops scepticus*
Spiny dogfish	*Squalus acanthias*

Spinyhead sculpin	*Dasycottus setiger*
Sponge sculpin	*Thyriscus anoplus*
Starry flounder	*Platichthys stellatus*
Squid complex	Suborder Oegopsina
Tadpole sculpin	*Psychrolutes paradoxus*
Thorny sculpin	*Icelus spiniger*
Threaded sculpin	*Gymnocanthus pistilliger*
Uncinate sculpin	*Icelus uncinalis*
Walleye pollock	*Theragra chalcogramma*
Warty sculpin	*Myoxocephalus verrucosus*
Whiteblotched skate	*Bathyraja maculata*
Whitebrow skate	*Bathyraja minispinosa*
Wide-eye sculpin	*Icelus euryops*
Yellow Irish lord	*Hemilepidotus jordani*
Yelloweye rockfish	*Sebastes ruberrimus*
Yellowfin sole	*Limanda aspera*

Groundfish of the Gulf of Alaska FMP
Implemented by the NMFS Alaska Regional Office.
Developed by the North Pacific Fishery Management Council.

Alaska plaice	*Pleuronectes quadrituberculatus*
Alaska skate	*Bathyraja parmifera*
Aleutian skate	*Bathyraja aleutica*
Antlered sculpin	*Enophrys diceraus*
Armorhead sculpin	*Gymnocanthus galeatus*
Arrowtooth flounder	*Reinhardtius stomias*
Atka mackerel	*Pleurogrammus monopterygius*
Bering skate	*Bathyraja interrupta*
Big skate	*Raja binoculata*
Bigmouth sculpin	*Hemitripterus bolini*
Blackfin sculpin	*Malacocottus kincaidi*
Blackgill rockfish	*Sebastes melanostomus*
Blackspotted rockfish	*Sebastes melanostictus*
Blob sculpin	*Psychrolutes phrictus*
Bocaccio	*Sebastes paucispinis*
Boreal clubhook squid	*Onychoteuthis borealijaponicus*
Brightbelly sculpin	*Microcottus sellaris*
Brown Irish lord	*Hemilepidotus spinosus*
Buffalo sculpin	*Enophrys bison*
Butter sole	*Isopsetta isolepis*
California market squid	*Loligo opalescens*
Canary rockfish	*Sebastes pinniger*
Chilipepper	*Sebastes goodei*
China rockfish	*Sebastes nebulosus*
C-O sole	*Pleuronichthys coenosus*
Copper rockfish	*Sebastes caurinus*
Crested sculpin	*Blepsias bilobus*
Curlfin sole	*Pleuronichthys decurrens*

Dark dusky rockfish	*Sebastes ciliatus*
Darkblotched rockfish	*Sebastes crameri*
Darkfin sculpin	*Malacocottus zonurus*
Deepsea skate	*Bathyraja abyssicola*
Deepsea sole	*Microstomus bathybius*
Dover sole	*Microstomus pacificus*
Dusky sculpin	*Icelinus burchami*
English sole	*Parophrys vetulus*
Eyeshade sculpin	*Nautichthys pribilovius*
Flapjack octopus	*Opisthoteuthis californiana*
Flathead sole	*Hippoglossoides elassodon*
Fourhorn sculpin	*Myoxocephalus quadricornis*
Frog sculpin	*Myoxocephalus stelleri*
Frogmouth sculpin	*Icelinus oculatus*
Giant octopus	*Enteroctopus dofleini*
Great sculpin	*Myoxocephalus polyacanthocephalus*
Greenland turbot	*Reinhardtius hippoglossoides*
Greenstriped rockfish	*Sebastes elongatus*
Grunt sculpin	*Rhamphocottus richardsonii*
Harlequin rockfish	*Sebastes variegatus*
Light dusky rockfish	*Sebastes variabilis*
Longfin sculpin	*Jordania zonope*
Longnose skate	*Raja rhina*
Longspine thornyhead	*Sebastolobus altivelis*
Magister armhook squid	*Berryteuthis magister*
Makko armhook squid	*Gonatopsis makko*
North Pacific bigeye octopus	*Octopus californicus*
Northern rock sole	*Lepidopsetta polyxystra*
Northern rockfish	*Sebastes polyspinis*
Northern sculpin	*Icelinus borealis*
Pacific cod	*Gadus macrocephalus*
Pacific ocean perch	*Sebastes alutus*
Pacific sanddab	*Citharichthys sordidus*
Pacific sleeper shark	*Somniosus pacificus*
Pacific staghorn sculpin	*Leptocottus armatus*
Pelagic octopus	Class Cephalopoda
Petrale sole	*Eopsetta jordani*
Plain sculpin	*Myoxocephalus jaok*
Pygmy rockfish	*Sebastes wilsoni*
Quillback rockfish	*Sebastes maliger*
Red Irish lord	*Hemilepidotus hemilepidotus*
Red octopus	*Octopus rubescens*
Redbanded rockfish	*Sebastes babcocki*
Redstripe rockfish	*Sebastes proriger*
Rex sole	*Glyptocephalus zachirus*
Ribbed sculpin	*Triglops pingeli*
Robust clubhook squid	*Moroteuthis robusta*
Rosethorn rockfish	*Sebastes helvomaculatus*
Rougheye rockfish	*Sebastes aleutianus*
Roughshoulder skate	*Amblyraja badia*

Roughskin sculpin	*Trachidermus fasciatus*
Roughspine sculpin	*Triglops macellus*
Roughtail skate	*Bathyraja trachura*
Sablefish	*Anoplopoma fimbria*
Sailfin sculpin	*Nautichthys oculofasciatus*
Salmon shark	*Lamna ditropis*
Sand sole	*Psettichthys melanostictus*
Scissortail sculpin	*Triglops forficatus*
Sculpin	*Arediellus* sp.
Wide-eye sculpin	*Icelus euryops*
Sharpchin rockfish	*Sebastes zacentrus*
Shortraker rockfish	*Sebastes borealis*
Shortspine thornyhead	*Sebastolobus alascanus*
Silvergray rockfish	*Sebastes brevispinis*
Silverspotted sculpin	*Blepsias cirrhosus*
Slender sole	*Lyopsetta exilis*
Slim sculpin	*Radulinus asprellus*
Smoothcheek sculpin	*Eurymen gyrinus*
Smoothhead sculpin	*Artedius lateralis*
Smoothskin octopus	*Benthoctopus leioderma*
Southern rock sole	*Lepidopsetta bilineata*
Spatulate sculpin	*Icelus spatula*
Speckled sanddab	*Citharichthys stigmaeus*
Spectacled sculpin	*Triglops scepticus*
Spiny dogfish	*Squalus acanthias*
Spinyhead sculpin	*Dasycottus setiger*
Splitnose rockfish	*Sebastes diploproa*
Sponge sculpin	*Thyriscus anoplus*
Spotfin sculpin	*Icelinus tenuis*
Squid complex	Suborder Oegopsina
Starry flounder	*Platichthys stellatus*
Stripetail rockfish	*Sebastes saxicola*
Tadpole sculpin	*Psychrolutes paradoxus*
Thorny sculpin	*Icelus spiniger*
Threaded sculpin	*Gymnocanthus pistilliger*
Threadfin sculpin	*Icelinus filamentosus*
Tiger rockfish	*Sebastes nigrocinctus*
Vampire squid	*Vampyroteuthis infernalis*
Vermilion rockfish	*Sebastes miniatus*
Walleye pollock	*Theragra chalcogramma*
Warty sculpin	*Myoxocephalus verrucosus*
Whiteblotched skate	*Bathyraja maculata*
Widow rockfish	*Sebastes entomelas*
Yellow Irish lord	*Hemilepidotus jordani*
Yelloweye rockfish	*Sebastes ruberrimus*
Yellowfin sole	*Limanda aspera*
Yellowmouth rockfish	*Sebastes reedi*

Salmon Fisheries in the EEZ off the Coast of Alaska FMP
Implemented by the NMFS Alaska Regional Office.
Developed by the North Pacific Fishery Management Council.

Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Pink salmon	*Oncorhynchus gorbuscha*
Sockeye salmon	*Oncorhynchus nerka*

Scallop Fishery off Alaska FMP
Implemented by the NMFS Alaska Regional Office.
Developed by the North Pacific Fishery Management Council.

Bering scallop	*Chlamys behringiana*
Giant rock scallop	*Crassadoma gigantea*
Reddish scallop	*Chlamys rubida*
Spiny scallop	*Chlamys hastata*
Weathervane scallop	*Patinopecten caurinus*
White scallop	*Chlamys albida*

PACIFIC ISLANDS REGION

Western Pacific FMPs and FEPs

Until 2010, the Western Pacific Regional Fishery Management Council (WPRFMC) utilized five Fishery Management Plans (FMPs). These included the Pelagics FMP, Bottomfish FMP, Crustaceans FMP, Precious Corals FMP, and Coral Reef Ecosystems FMP.

Beginning in 2010, the WPRFMC adopted five new Fishery Ecosystem Plans (FEPs). The FEPs (Pelagics FEP, American Samoa FEP, Marianas FEP, Hawaii FEP, and Pacific Islands Remote Area FEP) shifted management focus from being species-based to being place-based. The FEPs have recently established new fishing regulations, and created the organizational structure to incorporate additional information, community input, and local knowledge into development of fishery ecosystem management.[3]

The Management Unit Species (MUS) in each FEP include crustaceans, bottomfishes, coral reef ecosystem species, pelagics, and precious corals. Since habitat use is described only once for each MUS group, the MUS groups' species are listed below.

Some of the species in the Pacific Island Region have the local names included (e.g. Hawaiian, Samoan, Chamorro, or Carolinian names).

Key to the tables in the Pacific Islands Region:

Common name(s)	Scientific name	Local name(s)

Bottomfish Management Unit Species of the Western Pacific Region (in all 5 FEPs)

Alfonsin	*Beryx splendens*	
Amberjack	*Seriola dumerili*	malauli, kahala, tarakiton
Ambon emperor	*Lethrinus amboinensis*	filoa-gutumumu
Armorhead	*Pseudopentaceros wheeleri*	
Black trevally	*Caranx lugubris*	tafauli, ulua la'uli, tarakiton attelong/orong
Blacktip grouper	*Epinephelus fasciatus*	fausi, gadao/meteyil
Blueline/blue stripe snapper	*Lutjanus coeruleolineatus*	savane, ta'ape, funai/saas
Crimson snapper	*Pristipomoides filamentosus*	palu-'ena'ena, 'ōpakapaka, buninas/falaghal-maroobw
Giant trevally	*Caranx ignobilis*	sapoanae, tarakitu/etam, white papio, ulua aukea
Gray snapper	*Aprion virescens*	asoama, gogunafon/aiwe, uku
Groupers	*Family Serranidae*	
Lunartail grouper	*Variola louti*	papa, velo, bueli/bwele
Longtail snapper	*Etelis coruscans*	palu-loa, onaga, 'ula'ula koa'e, buninas/taighulupegh
Oblique-banded snapper	*Pristipomoides zonatus*	palu-ula, palu-sega, gindai, buninas rayao amiriyu/falaghal-maroobw
Pelagic armorhead	*Pentaceros richardsoni*	
Ratfish	*Hydrolagus colliei*	
Redgill emperor	*Lethrinus rubrioperculatus*	filoa-paomumu, mafuti/atigh
Seabass	*Epinephelus quernus*	hāpu'upu'u
Red snapper/silvermouth	*Aphareus rutilans*	lehi/maroobw/palu-gutusiliva
Squirrelfish snapper/red snapper	*Etelis carbunculus*	palu malau, ehu, buninas agaga/falaghal moroobw
Thick lipped trevally	*Caranx dentex*	pig ulua, butaguchi
Von Siebolds snapper/pink snapper	*Pristipomoides sieboldii*	palu, kalekale

[3]See the Western Pacific Regional Fishery Management Council website for more information: http://www.wpcouncil.org/fishery-plans-policies-reports/ (accessed November 2013).

Yelloweye snapper	*Pristipomoides flavipinnis*	palu-sina, buninas/falaghal-maroobw
Yellowtail kalekale/snapper	*Pristipomoides auricilla*	palu-iʻusama, kalekale, buninas/falaghal-maroobw

Coral Reef Ecosystem Management Unit Species of the Western Pacific Region (in all 5 FEPs)

Currently harvested coral reef taxa:

Barracuda	Family Sphyraenidae	
Great barracuda	*Sphyraena barracuda*	saosao, kaku
Heller's barracuda	*Sphyraena helleri*	kaku, kaweleʻa, sapatu
Bigeyes	Family Pricanthidae	
Bigeye	*Priacanthus hamrur*	ʻaweoweo, matapula
Glasseye	*Heteropriacanthus cruentatus*	ʻaweoweo, matapula
Butterflyfishes	Family Chaetodontidae	
Butterflyfish	*Chaetodon auriga*	kikakapu
Raccoon butterflyfish	*Chaetodon lunula*	kikakapu
Saddleback butterflyfish	*Chaetodon ephippium*	kikakapu
Featherduster worms	Family Sabellidae	
Flagtails	Family Kuhliidae	
Barred flag-tail	*Kuhlia mugil*	inato, safole
Hawaiian flag-tail	*Kuhlia sandvicensis*	ʻaholehole
Goatfish	Family Mullidae	
Banded goatfish	*Parupeneus* spp.	afoul, afulu, kumu, moano
Bantail goatfish	*Upeneus arge*	weke pueo
Dash-dot goatfish	*Parupeneus barberinus*	satmonetiyo/failighi, taʻuleia, tulausaena, tusia
Doublebar goatfish	*Parupeneus bifasciatus*	matulau-moana, munu, satmoneti acho/sungoongo
Multi-barred goatfish	*Parupeneus multifaciatus*	afulu, iʻasina, moano, satmoneti, vete
Orange goatfish	*Mulloidichthys pfleugeri*	weke nono
Redspot goatfish	*Parupeneus heptacanthus*	moana-ula
Side-spot goatfish	*Parupeneus pleurostigma*	malu, matulau-ilamutu, satmoneti
White-lined goatfish	*Parupeneus ciliatus*	satmoneti
Yellow goatfish	*Mulloidichthys* spp.	afulu, i'asina, vete, weke
Yellowfin goatfish	*Mulloidichthys vanicolensis*	satmoneti/wichugh, vete, wekeʻula
Yellowsaddle goatfish	*Parupeneus cyclostomas*	afulu, iʻasina, moana, moano kale, moano kea, satmoneti, vete
Yellowstripe goatfish	*Mulloidichthys flavolineatus*	afolu, afulu, satmoneti, wekeʻa, weke aʻa
Green snails/turban shells	Family Turbinidae	
Green snails, turban shells	*Turbo* spp.	alili, aliling pulan, aliling tulompu
Jacks, scads	Family Carangidae	
Bigeye scad	*Selar crumenophthalmus*	akule, atule, hahalu
Mackerel scad	*Decapterus macarellus*	atuleau, namuauli, ʻopelu, ʻopelu mama
Moray Eels	Family Muraenidae	
Dragon eel	*Enchelycore paradalis*	puhi
Giant moray eel	*Gymnothorax javanicus*	maoaʻe, puhi
Undulated moray eel	*Gymnothorax undulatus*	puhi laumilo, pusi-pulepule
Yellowmargin moray eel	*Gymnothorax flavimarginatus*	pusi, puhi paka
Moorish idol	Family Zanclidae	
	Zanclus cornutus	kihikihi, laulaufau, peʻapeʻa

Mullets	Family Mugilidae	
Engel's mullet	*Moolgarda engeli*	laiguan
False mullet	*Neomyxus leuciscus*	moi, poi, uouoa
Fringelip mullet	*Crenimugil crenilabis*	anae, aua, fuafua, laiguan
Stripped mullet	*Mugil cephalus*	ʻamaʻama, laiguan
Octopuses	Family Octopodidae	
Day octopus	*Octopus cyanea*	feʻe, gamsun, heʻe mauli, tako
Night octopus	*Octopus ornatus*	gamsun, heʻe, tako
Parrotfishes	Family Scaridae	
Humphead parrotfish	*Bolbometopon muricatum*	atuhong/roow
Pacific longnose parrotfish	*Hipposcarus longiceps*	gualafi/oscha, laeaulapokea, ulapokea
Parrotfish	*Scarus* spp.	fuga, fuga-valea, galo-ulutoʻi, laeamamanu, palakse/laggua, palukaluka, uhu
Stareye parrotfish	*Calotomus carolinus*	fuga, panuhunuhu
Rabbitfish	Family Siganidae	
Forktail rabbitfish	*Siganus aregenteus*	hiting, manahok, llegh, lo, loloa
Golden rabbitfish	*Siganus guttatus*	hiting
Gold-spot rabbitfish	*Siganus punctatissimus*	hiting galagu
Randall's rabbitfish	*Siganus randalli*	
Scribbled rabbitfish	*Siganus spinus*	hiting, sesyon, palawa
Vermiculate rabbitfish	*Siganus vermiculatus*	hiting
Rudderfish	Family Kyphosidae	
	Kyphosus biggibus	mata-mutu, mutumutu, guili, nanue, nenue
	Kyphosus cinerascens	guili/schpwul, nenue
	Kyphosus vaigiensis	nanue, nenue
Sharks	Family Carcharhinidae	
Blacktip reef shark	*Carcharhinus melanopterus*	apeape, maliealamata, manō
Galapagos shark	*Carcharhinus galapagensis*	malie, manō
Grey reef shark	*Carcharhinus amblyrhynchos*	malie-aloalo, manō
Silvertip shark	*Carcharhinus albimarginatus*	aso
Whitetip reef shark	*Triaenodon obesus*	malu, manō lalakea
Soldierfish, squirrelfish	Family Holocentridae	
Bigscale soldierfish	*Myripristis berndti*	malau-ugatele, malau-vaʻavaʻa, menpachi, saksak/mweel, ʻuʻu
Blackspot squirrelfish	*Sargocentron melanospilos*	
Blotcheye soldierfish	*Myripristis murdjan*	sagamelon
Blue-lined squirrelfish	*Sargocentron tiere*	ʻalaʻihi, sagsag/leet
Brick soldierfish	*Myripristis amaena*	menpachi, sagamelon, ʻuʻu
Bronze soldierfish	*Myripristis adusta*	malau-tui, sagamelon
Crown squirrelfish	*Sargocentron diadema*	ʻalaʻihi, malau-tui, malautalapuʻu, malautusitusi, malau-pauli
Double tooth squirrelfish	*Myripristis hexagona*	
File-lined squirrelfish	*Sargocentron microstoma*	ʻalaʻihi, malau-tianiu
Hawaiian squirrelfish	*Sargocentron xantherythrum*	ʻalaʻihi
Pearly soldierfish	*Myripristis kuntee*	malau-puʻu, menpachi, sagamelon, ʻuʻu
Peppered squirrelfish	*Sargocentron punctatissimum*	ʻalaʻihi
Pink squirrelfish	*Sargocentron tiereoides*	
Saber or long jaw squirrelfish	*Sargocentron spiniferum*	ʻalaʻihi, malau-toa, mu-malau, sisiok, tamalu
Scarlet soldierfish	*Myripristis pralinia*	malau-mamo, malauvaʻ avaʻa, sagamelon

Spotfin squirrelfish	*Neoniphon* spp.	‘ala‘ihi, sagsag/leet
Tailspot squirrelfish	*Sargocentron caudimaculatom*	sagamelon
Violet soldierfish	*Myripristis violacea*	malau-tuauli, sagamelon
Whitetip soldierfish	*Myripristis vittata*	sagamelon
Yellowfin soldierfish	*Myripristis chryseres*	menpachi, sagamelon, ‘u‘u
Surgeonfishes	Family Acanthuridae	
Barred unicornfish	*Naso thynnoides*	
Bignose unicornfish	*Naso vlamingii*	ume-masimasi
Black tongue unicornfish	*Naso hexacanthus*	kala holo
Blackstreak surgeonfish	*Acanthurus nigricauda*	pone-i‘usama
Blue-banded surgeonfish	*Acanthurus lineatus*	alogo, hiok/filaang
Blue-lined surgeon	*Acanthurus nigroris*	gaitolama, maiko, ponepone
Bluespine unicornfish	*Naso unicornus*	kala, tataga/igh-falafal, ume-isu
Brown surgeonfish	*Acanthurus nigrofuscus*	mai‘i‘I, ponepone
Convict tang	*Acanthurus triostegus*	aanini, manini, kichu/limell
Elongate surgeonfish	*Acanthurus mata*	
Eye-striped surgeonfish	*Acanthurus dussumieri*	palani
Gray unicornfish	*Naso caesius*	
Humpback unicornfish	*Naso brachycentron*	
Humpnose unicornfish	*Naso tuberosus*	
Mimic surgeonfish	*Acanthurus pyroferus*	
Orangespine unicornfish	*Naso lituratus*	hangon/bwulaalay, ili‘ilia, kalalei, umaumalei, umelei
Orange-spot surgeonfish	*Acanthurus olivaceus*	afinamea, na‘ena‘e
Ringtail surgeonfish	*Acanthurus blochii*	puala
Spotted unicornfish	*Naso brevirostris*	kala lolo, ume-ulutao
Striped bristletooth	*Ctenochaetus striatus*	pala‘ia, pone, logoulia
Two-spot bristletooth	*Ctenochaetus binotatus*	
Whitebar surgeonfish	*Acanthurus leucopareius*	maiko, maikoiko
Whitecheek surgeonfish	*Acanthurus nigricans*	laulama
Whitemargin unicornfish	*Naso annulatus*	kala
White-spotted surgeonfish	*Acanthurus guttatus*	‘api, maogo
Yellow tang	*Zebrasoma flavescens*	lau‘ipala
Yellow-eyed surgeonfish	*Ctenochaetus strigosus*	pone, kole
Yellowfin surgeonfish	*Acanthurus xanthopterus*	hugupoa dangulo/mowagh, pualu
Threadfins	Family Polynemidae	
Threadfin	*Polydactylus sexfilis*	i‘ausi, moi, umiumia
Triggerfishes	Family Balistidae	
Black triggerfish	*Melichthys niger*	humuhumu ‘ele‘ele, sumu-uli
Blue triggerfish	*Pseudobalistes fuscus*	sumu-laulau
Bridled triggerfish	*Sufflamen fraenatum*	sumu-gase‘ele‘ele
Clown triggerfish	*Balistoides conspicillum*	
Red-lined triggerfish	*Balistapus undulatus*	
Picassofish	*Rhinecanthus aculeatus*	humuhumu nukunuku apua‘a, sumualoalo, sumu-uo‘uo
Pinktail triggerfish	*Melichthys vidua*	humuhumu hi‘ukole, sumu-‘apa‘apasina, sumu-si‘umumu
Titan triggerfish	*Balistoides viridescens*	sumu, sumu-laulau
Tunas	Family Scombridae	
Dogtooth tuna	*Gymnosarda unicolor*	ayul, tagi
Wrasses	Family Labridae	

Arenatus wrasse	*Oxycheilinus arenatus*	sugale
Bandcheek wrasse	*Oxycheilinus diagrammus*	sugale
Barred thicklip	*Hemigymnus fasciatus*	sugale-gutumafia
Blackeye thicklip	*Hemigymnus melapterus*	sugale-laugutu, sugale-uli, sugalealoa, sugale-lupe
Checkerboard wrasse	*Halichoeres hortulanus*	ifigi, sugale-a'au, sugalepagota
Cigar wrasse	*Cheilio inermis*	kupoupou, sugale-mo'o
Floral wrasse	*Cheilinus chlorourus*	lalafi-matapua'a
Harlequin tuskfish, red-breasted wrasse	*Cheilinus fasciatus*	lalafi-pulepule
Longface wrasse	*Hologynmosus doilatus*	
Napoleon wrasse	*Cheilinus undulatus*	lalafi, malakea, tagafa, tangison/maam
Razor wrasse	*Xyrichtys pavo*	laenihi, nabeta
Red ribbon wrasse	*Thalassoma quinquevittatum*	lape-moana
Ring-tailed wrasse	*Oxycheilinus unifasciatus*	po'ou, sugale
Rockmover wrasse	*Novaculichthys taeniourus*	sugale-la'o, sugaletaili, sugale-gasufi
Saddleback hogfish	*Bodianus bilunulatus*	'a'awa
Sunset wrasse	*Thalassoma lutescens*	sugale-samasama
Surge wrasse	*Thalassoma purpureum*	ho'u, patagaloa, uloulo-gatala
Three-spot wrasse	*Halichoeres trimaculatus*	lape, sugale-pagota
Triple-tail wrasse	*Cheilinus trilobatus*	lalafi-matamumu, lalcha mamate/porou
Weedy surge wrasse	*Halichoeres margaritaceus*	sugale-uluvela
Whitepatch wrasse	*Xyrichtys aneitensis*	sugale-tatanu

Coral Reef Ecosystem Management Unit Species of the Western Pacific Region (in all 5 FEPs)

Potentially harvested coral reef taxa (species that do not appear above in the list of currently harvested taxa):

Ahermatypic corals	Azooxanthellates (informal group)
Anchovies	Family Engraulidae
Anemones	Order Actiniaria
Angelfishes and damselfishes	Family Pomacanthidae
Batfishes	Family Ephippidae
Black lipped pearl oyster	*Pinctada margaritifera*
Blennies	Family Blenniidae
Blue corals	Family Helioporidae
Cardinalfishes	Family Apogonidae
Clams	Class Bivalvia
Coral crouchers	Family Caracanthidae
Cornetfish	*Fistularia commersoni*
Dogtooth tuna	*Gymnosarda unicolor*
Dottybacks	Family Pseudochromidae
Eels	Families Chlopsidae, Congridae, Moringuidae, and Ophichthidae
Emperors	Family Lethrinidae
Fire corals, soft corals, and gorgonians	Family Milleporidae
Flashlightfishes	Family Anomalopidae
Flounders and soles	Families Bothidae, Soleidae, and Pleurnectidae
Frogfishes	Family Antennariidae
Fusiliers	Family Caesionidae
Giant clam	Family Tridacnidae
Gobies	Family Gobiidae
Groupers and seabass	Family Serrandiae

Hawkfishes	Family Cirrhitidae
Herrings	Family Clupeidae
Hydroid corals	Family Solanderidae
Lace corals	Family Stylasteridae
Lobsters, shrimps/mantis shrimps, true crabs, and hermit crabs	Subphylum Crustacea
Monos	Family Monodactylidae
Mushroom corals, coral polyps (small and large), soft corals, and gorgonians	Family Fungiidae
Octopi	Class Cephalopoda
Organpipe corals	*Tubipora* spp.
Pipefishes and seahorses	Family Syngnathidae
Prettyfins	Family Plesiopidae
Puffer fishes and porcupine fishes	Family Tetradontidae
Rabbitfishes	Family Siganidae
Rays and skates	Families Dasyatididae and Myliobatidae
Remoras	Family Echeneidae
Rudderfishes	Family Kyphosidae
Sandperches	Family Pinguipedidae
Scorpionfishes and lionfishes	Family Scorpaenidae
Sea cucumbers and sea urchins	Phylum Echinodermata
Sea slugs	Subclass Opisthobranchia
Sea snails	Class Gastropoda
Sea squirts	Subphylum Tunicata
Seaweed	Algae (informal group)
	Phyla Hyrozoa and Bryzoa
	Live rock (informal group)
Segmented worms	Phylum Annelida
Sharks	Family Sphyrnidae
Snails, clams, squid, and relatives	Phylum Mollusca
Snappers	Family Lutjanidae
Soft zoanthid corals	Order Zoanthinaria
Sponges	Phylum Porifera
Sweetlips	Family Haemulidae
Tilefishes	Family Malacanthidae
Trochus snail	*Trochus* spp.
Trumpetfish	*Aulostomus chinensis*
Trunkfishes	Family Ostraciidae

Pelagic Management Unit Species of the Western Pacific Region (in all 5 FEPs)

Albacore	*Thunnus alalunga*
Bigeye thresher shark	*Alopias superciliosus*
Bigeye tuna	*Thunnus obesus*
Black marlin	*Makaira indica*
Blue shark	*Prionace glauca*
Common thresher shark	*Alopias vulpinus*
Diamondback squid	*Thysanoteuthis rhombus*
Dolphinfish	*Coryphaena* spp.

Escolars	Family Gempylidae
Frigate mackerels	*Auxis* spp.
Indo-Pacific blue marlin	*Makaira mazara*
Kawakawa	*Euthynnus affinis*
Longfin mako shark	*Isurus paucus*
Mackerels	*Scomber* spp.
Moonfish	*Lampris* spp.
Neon flying squid	*Ommastrephes bartamii*
Pacific bluefin tuna	*Thunnus orientalis*
Oceanic whitetip shark	*Carcharhinus longimanus*
Oilfishes	Family Gempylidae
Opah	*Lampris guttatus*
Pacific bluefin tuna	*Thunnus orientalis*
Pacific pomfret	*Brama japonica*
Pelagic thresher shark	*Alopias pelagicus*
Pomfrets	Family Bramidae
Purple flying squid	*Sthenoteuthis oualaniensis*
Sailfish	*Istiophorus platypterus*
Salmon shark	*Lamna ditropis*
Shortfin mako shark	*Isurus oxyrinchus*
Shortbill spearfish	*Tetrapturus angustirostris*
Silky shark	*Carcharhinus falciformis*
Skipjack tuna	*Katsuwonus pelamis*
Slender tunas	*Allothunnus* spp.
Striped marlin	*Tetrapturus audax*
Swordfish	*Xiphias gladius*
Wahoo	*Acanthocybium solandri*
Yellowfin tuna	*Thunnus albacares*

Precious Corals Management Unit Species of the Western Pacific Region (in all 5 FEPs)

Bamboo corals	Family Isididae	amu ofe
Black coral	*Antipathes grandis*, *Antipathes dichotoma*	amu uliuli
Feathery black coral	*Myroipathes ulex*	amu uliuli
Gold corals	Family Primnoidae	amu auro
Pink corals	*Corallium* spp.	amu piniki-mumu
Zoanthid	*Gerardia* spp.	amu auro

PROTECTED SPECIES UNDER NMFS JURISDICTION

Cetaceans

All cetaceans in U.S. waters are protected by the Marine Mammal Protection Act. Additionally, threatened or endangered species are protected by the Endangered Species Act.

Beaked whale, Baird's	*Berardius bairdii*	PC, AK[4]
Beaked whale, Blainville's	*Mesoplodon densirostris*	NE, SE, PC, PI
Beaked whale, Cuvier's	*Ziphius cavirostris*	NE, SE, PC, AK, PI
Beaked whale, Gervais'	*Mesoplodon europaeus*	NE, SE
Beaked whale, Hubbs'	*Mesoplodon carlhubbsi*	PC
Beaked whale, gingko-toothed	*Mesoplodon gingkodens*	PC
Beaked whale, lesser	*Mesoplodon peruvianus*	PC
Beaked whale, Longman's	*Indopacetus pacificus*	PI
Beaked whale, Mesoplodont	*Mesoplodon* spp.	NE, SE, PC
Beaked whale, Perrin's	*Mesoplodon perrini*	PC
Beaked whale, Sowerby's	*Mesoplodon bidens*	NE, SE
Beaked whale, Stejneger's	*Mesoplodon stejnegeri*	PC, AK
Beaked whale, True's	*Mesoplodon mirus*	NE, SE
Beluga whale	*Delphinapterus leucas*	AK
Blue whale	*Balaenoptera musculus*	NE, PC, AK, PI
Bottlenose dolphin	*Tursiops truncatus*	NE, SE, PC
Bowhead whale	*Balaena mysticetus*	AK
Bryde's whale	*Balaenoptera edeni*	PC, PI
Clymene's dolphin	*Stenella clymene*	SE
Common dolphin, long-beaked	*Delphinus capensis*	PC
Common dolphin, short-beaked	*Delphinus delphis*	NE, PC
Dall's porpoise	*Phocoenoides dalli*	PC, AK
Dwarf sperm whale	*Kogia sima*	NE, SE, PC, PI
False killer whale	*Pseudorca crassidens*	SE, PI
Fin whale	*Balaenoptera physalus*	NE, PC, AK, PI
Fraser's dolphin	*Lagenodelphis hosei*	SE, PI
Gray whale	*Eschrichtius robustus*	PC, AK
Harbor porpoise	*Phocoena phocoena*	NE, PC, AK
Humpback whale	*Megaptera novaeangliae*	NE, SE, PC, AK, PI
Killer whale	*Orcinus orca*	NE, SE, PC, AK, PI
Melon-headed whale	*Peponocephala electra*	SE, PI
Minke whale	*Balaenoptera acutorostrata*	NE, PC, AK, PI
Northern bottlenose whale	*Hyperoodon ampullatus*	NE
Northern right whale dolphin	*Lissodelphis borealis*	PC
Pilot whale, long-finned	*Globicephala melas*	NE
Pilot whale, short-finned	*Globicephala macrorhynchus*	NE, SE, PC, PI
Pygmy killer whale	*Feresa attenuata*	SE, PI
Pygmy sperm whale	*Kogia breviceps*	NE, SE, PC, PI
Right whale, North Pacific	*Eubalaena japonica*	PC, AK

[4]This column was added for protected species to indicate the *OLO* regions where the species are found: NE = Northeast Region, SE = Southeast Region, PC = Pacific Coast Region, AK = Alaska Region, and PI = Pacific Islands Region.

Right whale, North Atlantic	*Eubalaena glacialis*	NE, SE
Risso's dolphin	*Grampus griseus*	NE, SE, PC, AK, PI
Rough-toothed dolphin	*Steno bredanensis*	SE, PI
Sei whale	*Balaenoptera borealis*	NE, PC, PI
Sperm whale	*Physeter macrocephalus*	NE, SE, PC, AK, PI
Spinner dolphin	*Stenella longirostris*	SE, NE, PI
Spotted dolphin, Atlantic	*Stenella frontalis*	NE, SE
Spotted dolphin, Pantropical	*Stenella attenuata*	NE, SE, PI
Striped dolphin	*Stenella coeruleoalba*	NE, SE, PC, PI
White-beaked dolphin	*Lagenorhynchus albirostris*	NE
White-sided dolphin	*Lagenorhynchus acutus*	NE
White-sided dolphin, Pacific	*Lagenorhynchus obliquidens*	PC, AK

Pinnipeds

All pinnipeds in U.S. waters are protected by the Marine Mammal Protection Act.
Additionally, threatened or endangered species are protected by the Endangered Species Act.
Conservation duties are administered by NMFS for all U.S. pinnipeds except the Pacific walrus.

Bearded seal	*Erignathus barbatus*	AK
Gray seal	*Halichoerus grypus*	NE
Harbor seal	*Phoca vitulina*	NE, PC, AK
Harp seal	*Pagophilus groenlandicus*	NE
Hawaiian monk seal	*Monachus schauinslandi*	PI
Hooded seal	*Cystophora cristata*	NE, SE
Northern elephant seal	*Mirounga angustirostris*	PC, AK
Ribbon seal	*Phoca fasciata*	AK
Ringed seal	*Phoca hispida*	AK
Spotted seal	*Phoca largha*	AK
Fur seal, Guadalupe	*Arctocephalus townsendi*	PC
Fur seal, northern	*Callorhinus ursinus*	PC, AK
Sea lion, California	*Zalophus californianus*	PC
Sea lion, Steller	*Eumetopias jubatus*	PC, AK

Sea Turtles

All sea turtles in U.S. waters are protected by the Endangered Species Act.
Species federal conservation duties are shared by NMFS and the U.S. Fish and Wildlife Service.

Green turtle	*Chelonia mydas*	NE, SE, PC, AK, PI
Hawksbill turtle	*Eretmochelys imbricata*	NE, SE, PI
Kemp's ridley turtle	*Lepidochelys kempii*	NE, SE
Leatherback turtle	*Dermochelys coriacea*	NE, SE, PC, AK, PI
Loggerhead turtle	*Caretta caretta*	NE, SE, PC, AK, PI
Olive ridley turtle	*Lepidochelys olivacea*	SE, PC, PI

Marine Invertebrates and Plants

The following marine invertebrates and plants are protected by the Endangered Species Act.

Abalone, black	*Haliotis cracherodii*	PC
Abalone, white	*Haliotis sorenseni*	PC
Coral	*Acropora globiceps*	PI
Coral	*Acropora jacquelineae*	PI
Coral	*Acropora lokani*	PI
Coral	*Acropora pharaonis*	PI
Coral	*Acropora retusa*	PI
Coral	*Acropora rudis*	PI
Coral	*Acropora speciosa*	PI
Coral	*Acropora tenella*	PI
Coral	*Anacropora spinosa*	PI
Coral	*Euphyllia paradivisa*	PI
Coral	*Isopora crateriformis*	PI
Coral	*Montipora australiensis*	PI
Coral	*Pavona diffluens*	PI
Coral	*Porites napopora*	PI
Coral	*Seriatopora aculeata*	PI
Coral, boulder star	*Orbicella franksi*	SE
Coral, elkhorn	*Acropora palmata*	SE
Coral, lobed star	*Orbicella annularis*	SE
Coral, mountainous star	*Orbicella faveolata*	SE
Coral, pillar	*Dendrogyra cylindrus*	SE
Coral, rough catcus	*Mycetophyllia ferox*	SE
Coral, staghorn	*Acropora cervicornis*	SE
Johnson's seagrass	*Halophila johnsonii*	SE

Marine and Anadromous Fishes

Federal conservation duties for salmonid species are shared by NMFS and the U.S. Fish and Wildlife Service. The following marine and anadromous fishes are protected by the Endangered Species Act.

Bocaccio	*Sebastes paucispinis*	PC
Eulachon	*Thaleichthys pacificus*	PC
Hammerhead, scalloped	*Sphyrna lewini*	NE, SE, PI, PC
Rockfish, canary	*Sebastes pinniger*	PC
Rockfish, yelloweye	*Sebastes ruberrimus*	PC
Salmon, Atlantic	*Salmo salar*	NE
Salmon, Chinook[5]	*Oncorhynchus tshawytscha*	PC, AK
Salmon, chum[5]	*Oncorhynchus keta*	PC
Salmon, coho[5]	*Oncorhynchus kisutch*	PC, AK
Salmon, sockeye[5]	*Oncorhynchus nerka*	PC, AK
Sawfish, largetooth	*Pristis perotteti*	SE
Sawfish, smalltooth	*Pristis pectinata*	SE

[5]Pacific salmonids are listed under the ESA as "Evolutionarily Significant Units," with some populations listed and others not. All ESA-listed Pacific salmonid populations spawn in the continental United States, but some Pacific Northwest spawners migrate to Alaska waters to forage. For more details see http://www.nmfs.noaa.gov/pr/species/esa/fish.htm (accessed May 2015).

Sturgeon, Atlantic	*Acipenser oxyrinchus oxyrinchus*	NE, SE
Sturgeon, green	*Acipenser medirostris*	PC
Sturgeon, Gulf	*Acipenser oxyrinchus desotoi*	SE
Sturgeon, shortnose	*Acipenser brevirostrum*	NE, SE
Trout, steelhead[5]	*Oncorhynchus mykiss*	NW, SW, AK

SPECIES MANAGED UNDER INTERNATIONAL AGREEMENT

International Pacific Halibut Commission (United States of America, and Canada).

Pacific halibut	*Hippoglossus stenolepis*

NON-FEDERALLY MANAGED SPECIES

The following are species mentioned in each section of this publication that are generally managed by Fisheries Commissions or the states and do not fall in the categories of species managed by FMP, species managed by international agreement, or species protected by the Endangered Species Act or the Marine Mammal Protection Act.

Northeast Region

American eel	*Anguilla rostrata*
Atlantic croaker	*Micropogonias undulatus*
Brittle starfish	Class Ophiuroidea
Bryozoans	Phylum Bryozoa
Bivalves	
Bay scallop	*Argopecten irradians irradians, A. irradians concentricus*
Blue mussel	*Mytilus edulis*
Eastern oyster	*Crassostrea virginica*
Mussels	Class Bivalvia
Northern quahog	*Mercenaria mercenaria*
Softshell clam	*Mya arenaria*
Corals	
Deep-sea hard and soft corals	Orders Scleractinia, Antipatharia, and Alcyonacea
Gorgonians	Order Alcyonacea
Paramurecia coral	*Paramurecia* sp.
Crustaceans	
American lobster	*Homarus americanus*
Blue crab	*Callinectes sapidus*
Horseshoe crab	*Limulus polyphemus*
Northern shrimp	*Pandalus borealis*
Croakers	Family Sciaenidae
Green sea urchins	*Strongylocentrotus droebachiensis*
Hydroids	Class Hydrozoa

Ocean pout	*Macrozoarces americanus*
Polychaete worms	Class Polychaeta
Sea pens	Order Pennatulacea
Shortnose sturgeon	*Acipenser brevirostrum*
Sponges	Phylum Porifera
Shads	
Hickory shad	*Alosa mediocris*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorosoma petenense*
Striped bass	*Morone saxatilis*
Tautog	*Tautoga onitis*
Tunicate	*Didemnum* sp.
Weakfish	*Cynoscion regalis*
White perch	*Morone americana*

Southeast Region

American eel	*Anguilla rostrata*
Atlantic croaker	*Micropogonias undulatus*
Atlantic flyingfish	*Cypselurus melanurus*
Atlantic menhaden	*Brevoortia tyrannus*
Atlantic thread herring	*Opisthonema oglinum*
Ballyhoo	*Hemiramphus brasiliensis*
Bigeye scad	*Selar crumenophthalmus*
Blackbelly rosefish	*Helicolenus dactylopterus*
Crustaceans	
Blue crab	*Callinectes sapidus*
Fiddler crab	*Uca* spp.
Florida stone crab	*Menippe mercenaria*
Horseshoe crab	*Limulus polyphemus*
Gulf stone crab	*Menippe adina*
Echinoderms	Phylum Echinodermata
Gulf flounder	*Paralichthys albigutta*
Gulf menhaden	*Brevoortia patronus*
Grunts	Family Haemulidae
Mollusks	Phylum Mollusca
Calico scallop	*Argopecten gibbus*
Eastern oyster	*Crassostrea virginica*
Northern quahog	*Mercenaria mercenaria*
Mullets	Family Mugilidae
Polychaetes (annelid worms)	Class Polychaeta
Red drum (Atlantic coast only)	*Sciaenops ocellatus*
Round herring	*Etrumeus teres*
Sheepshead	*Archosargus probatocephalus*
Southern flounder	*Paralichthys lethostigma*
Spanish sardine	*Sardinella aurita*
Spot	*Leiostomus xanthurus*
Spotted seatrout	*Cynoscion nebulosus*
Striped bass	*Morone saxatilis*

Summer flounder	*Paralichlthys dentatus*
Triggerfish	Family Balistidae

Pacific Coast Region

Abalones	
Black abalone	*Haliotis cracherodii*
Flat abalone	*Haliotis walallensis*
Green abalone	*Haliotis fulgens*
Pink abalone	*Haliotis corrugata*
Pinto abalone	*Haliotis kamtschatkana*
Red abalone	*Haliotis rufescens*
Threaded abalone	*Haliotis assimilis*
White abalone	*Haliotis sorenseni*
Pacific barracuda	*Sphyraena argentea*
California halibut	*Paralichthys californicus*
Clams	
California butter clam	*Saxidomus nuttali*
California venus clam	*Chione californiensis*
Frilled venus clam	*Chione undatella*
Gaper clam	*Tresus* spp.
Japanese littleneck (Manilla clam)	*Venerupis philippinarum*
Pacific geoduck clam	*Panopea abrupta*
Pacific littleneck clam	*Protothaca staminea*
Pacific razor clam	*Siliqua patula*
Pismo clam	*Tivela stultorum*
Rough littleneck clam	*Protothaca laciniata*
Smooth venus clam	*Chionista fluctifraga*
Softshell clam	*Mya arenaria*
Thin-shell littleneck clam	*Protothaca tenerrima*
Washington butter clam	*Saxidomus giganta*
Crabs	
Brown rock crab	*Cancer antennarius*
Dungeness crab	*Cancer magister*
Pelagic red crab	*Pleuroncodes planipes*
Red rock crab	*Cancer productus*
Sheep crab	*Loxorhynchus grandis*
Yellow rock crab	*Cancer anthonyi*
Croakers	Family Sciaenidae
Cutthroat trout	*Oncorhynchus clarkii*
Guitarfishes, skates and rays	Order Rajiformes
Jellyfish	Class Scyphozoa
Lobsters and shrimps	
Bay/mud shrimp (four species)	*Crangon* spp.
California spiny lobster	*Panulirus interruptus*
Coonstriped shrimp	*Pandalus hypsinotis*
Dock shrimp	*Pandalus danae*
Humpy shrimp	*Pandalus goniurus*
Pacific ocean (pink) shrimp	*Pandalus jordani*

Red rock shrimp	*Lysmata californica*
Ridgeback shrimp	*Sicyonia ingentis*
Spot shrimp	*Pandalus platyceros*
Mussels	
California mussel	*Mytilus californianus*
Mediterranean mussel	*Mytilus galloprovincialis*
Foolish mussel	*Mytilus trossulus*
Pacific bonito	*Sarda chiliensis*
Pacific herring	*Clupea pallasi*
Sea cucumbers	
California sea cucumber	*Parastichopus californicus*
Warty sea cucumber	*Parastichopus parvimensis*
Sea urchins	
Purple urchin	*Strongylocentrotus purpuratus*
Red urchin	*Stronglyocentrotus franciscanus*
Sharks	Subclass Elasmobranchii
Basking shark	*Cetorhinus maximus*
Salmon shark	*Lamna ditropis*
Broadnose sevengill shark	*Notorhynchus cepedianus*
Bluntnose sixgill shark	*Hexanchus griseus*
White shark	*Carcharodon carcharia*
Smelt	Family Osmeridae
Squids	Class Cephalopoda
Sturgeon	
Green sturgeon	*Acipenser medirostris*
White sturgeon	*Acipenser transmontanus*
Surfperches	Family Embiotocidae
Yellowtail	*Seriola lalandi*

Alaska Region

Anemones	Order Actiniaria
Arctic cisco	*Coregonus autumnalis*
Barnacles	Class Maxillopoda
Broad whitefish	*Coregonus nasus*
Capelin	*Mallotus villosus*
California sea cucumber	*Parastichopus californicus*
Clams	
Butter clam	*Saxidomus giganteus*
Cockles	*Clinocardium nuttallii*
Geoduck clam	*Panopea abrupta*
Pacific littleneck clam	*Leukoma staminea*
Razor clam	*Siliqua patula*
Softshell clam	*Mya arenaria*
Truncated softshell clam	*Mya truncata*
Deep-sea corals	Phylum Cnidaria
Dolly Varden char	*Salvelinus malma*
Dungeness crab	*Cancer magister*
Green sea urchin	*Strongylocentrotus droebachiensis*

Eulachon	*Thaleichthys pacificus*
Least cisco	*Coregonus sardinella*
Lingcod	*Ophiodon elongatus*
Pacific herring	*Clupea pallasi*
Pacific sand lance	*Ammodytes hexapterus*
Pinto abalone	*Haliotis kamtschatkana*
Sea star	Class Asteroidea
Shrimp	
Alaskan pink shrimp	*Pandalus eous*
Coonstriped shrimp	*Pandalus hypsinotus*
Humpy shrimp	*Pandalus goniurus*
Sidestriped shrimp	*Pandalus dispar*
Spot shrimp	*Pandalus platyceros*
Sponges	Phylum Porifera

Pacific Islands Region

Snowflake coral	*Carijoa riisei*

Appendix 6
Abbreviations

ACC	Alaska Coastal Current
ADFG	Alaska Department of Fish and Game
AFSC	Alaska Fisheries Science Center
AIFEP	Aleutian Islands Fisheries Ecosystem Plan
APM	adaptive program management
ASMFC	Atlantic States Marine Fisheries Commission
BOEM	Bureau of Ocean Energy Management
BSAI	Bering Sea / Aleutian Islands
BSEE	Bureau of Safety and Environmental Enforcement
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (the “Superfund Act”)
CFMC	Caribbean Fishery Management Council
CHPP	cooperative habitat protection partnership
cm	centimeter
CMECS	Coastal and Marine Ecological Classification Standard
CMSP	coastal and marine spatial planning
CNMI	Commonwealth of the Northern Mariana Islands
CPS	coastal pelagic species
CRCA	Coral Reef Conservation Act
CRP	Community-Based Restoration Program
CSO	combined sewer outflows
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
DARRP	Damage, Assessment, Remediation and Restoration Program
dB	decibels
DDT	dichlorodiphenyl tricholorethlyene
DNA	deoxyribonucleic acid
DPS	distinct population segment
EBM	ecosystem-based management
EESLR	ecological effects of sea level rise
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
ENSO	El Niño Southern Oscillation
ERA	Estuary Restoration Act
ESA	Endangered Species Act
ESU	evolutionary significant unit
FATE	Fisheries and the Environment (program)

FEP	fishery ecosystem plan
FERC	Federal Energy Regulatory Commission
FGDC	Federal Geographic Data Committee
FHP	fish habitat partnership
FMC	fishery management council
FMP	fishery management plan
FPA	Federal Power Act
FWCA	Fish and Wildlife Coordination Act
FWPCA	Federal Water Pollution Control Act (the "Clean Water Act")
HAIP	Habitat Assessment Improvement Plan
HEPR	Habitat and Ecological Processes Research Program
GIS	geographic information system
GMFMC	Gulf of Mexico Fishery Management Council
GOA	Gulf of Alaska
GPS	global positioning system
GSMFC	Gulf States Marine Fisheries Commission
HAPC	habitat area of particular concern
HMS	highly migratory species
ICC	International Coastal Cleanup
IEA	Integrative Ecosystem Assessment
IPCC	Intergovernmental Panel on Climate Change
IPHC	International Pacific Halibut Commission
kg	kilogram
kHz	kilohertz
km	kilometer
L	liter
LME	large marine ecosystem
LNG	liquid natural gas
m	meter
MAFMC	Mid-Atlantic Fishery Management Council
mg	milligram
MHI	Main Hawaiian Islands
mi	mile
mL	milliliter
mL/L	milliliter per liter (in this report: milliliters of dissolved O_2 per liter of seawater)
mm	millimeter
μmol	micromole
μmol/kg	micromoles per kilogram (in this report: micromoles of dissolved O_2 per kilogram of seawater)
MMPA	Marine Mammal Protection Act
MPA	marine protected area
MSA	Magnuson-Stevens Fishery Conservation and Management Act (the "Magnuson-Stevens Act")
MUS	management unit species
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act (the "National Invasive Species Act")
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NEP	National Estuary Program
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NFHP	National Fish Habitat Partnership
NMFS	National Marine Fisheries Service

nmi	nautical mile
NMS	national marine sanctuary
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPDES	National Pollution Discharge Elimination System
NPFMC	North Pacific Fishery Management Council
NPS	National Park Service
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NWFSC	Northwest Fisheries Science Center
NWHI	Northwestern Hawaiian Islands
OER	Office of Ocean Exploration and Research
OHC	Office of Habitat Conservation
OLO	*Our Living Oceans* (publication series)
OMZ	oxygen minimum zone
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PDO	Pacific Decadal Oscillation
PEIS	programmatic environmental impact statement
PFMC	Pacific Fishery Management Council
PIFSC	Pacific Islands Fisheries Science Center
ppm	parts per million
ppt	parts per thousand
PRIA	Pacific Remote Island Areas
PSMFC	Pacific States Marine Fisheries Commission
RAMP	Reef Assessment and Monitoring Project
ROV	remotely operated vehicle
SAFMC	South Atlantic Fishery Management Council
SAV	submerged aquatic vegetation
Sea Grant	National Sea Grant College Program
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SLH	sea level height
SMZ	special management zones
SONAR	sound navigation and ranging
SWFSC	Southwest Fisheries Science Center
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOC	United States Department of Commerce
USDOD	United States Department of Defense
USDOI	United States Department of Interior
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USVI	United States Virgin Islands
WPFMC	Western Pacific Regional Fishery Management Council


NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE