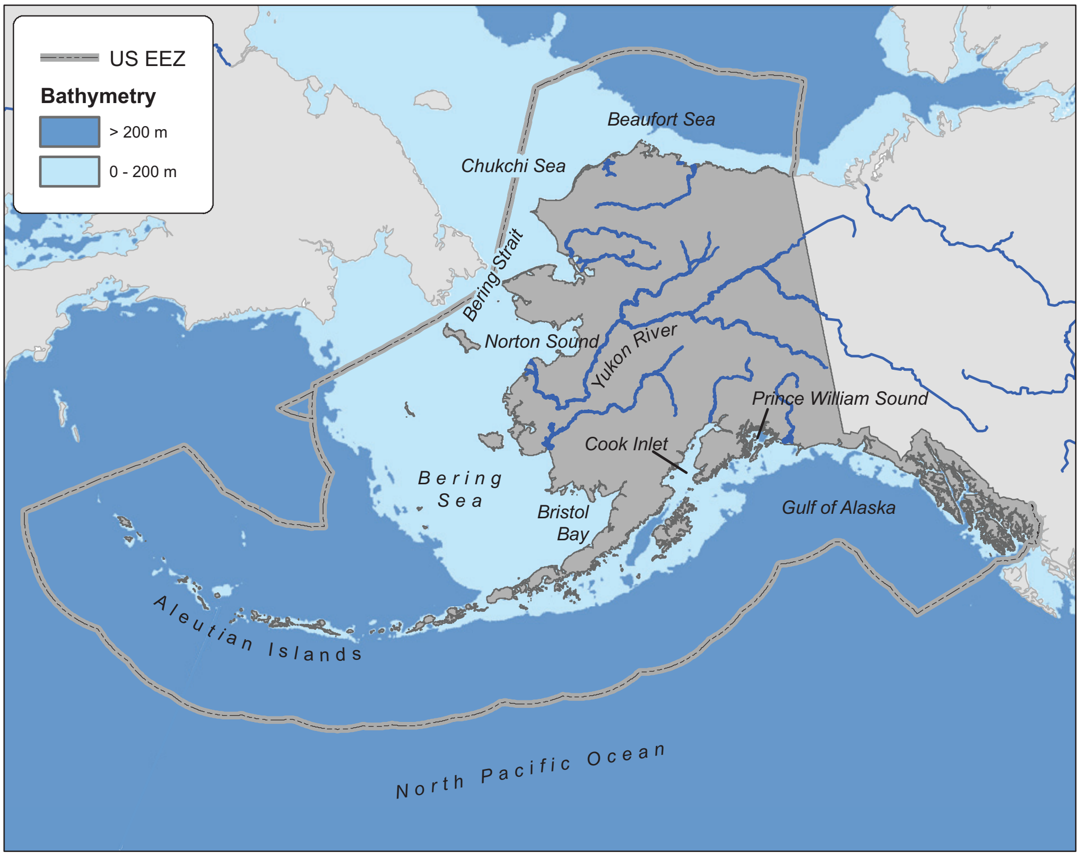
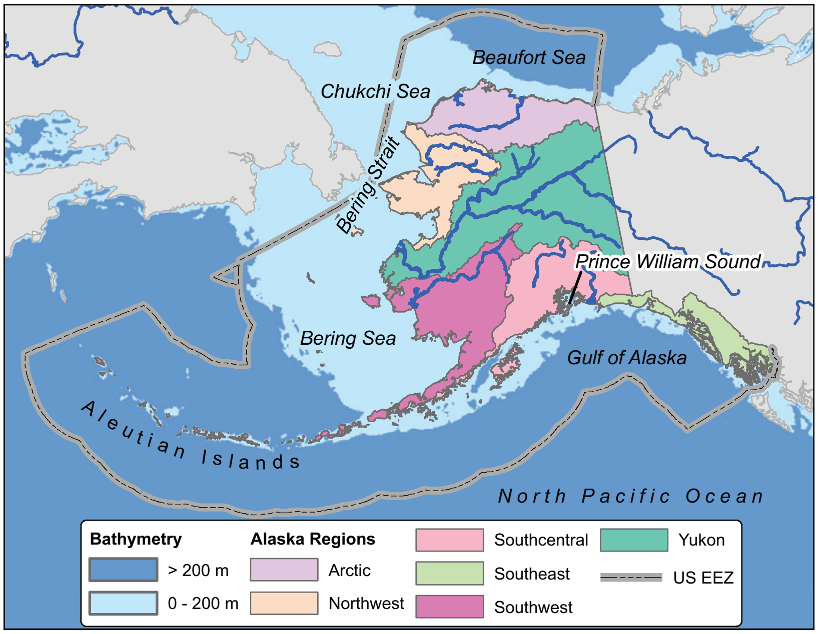
Alaska Region



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-



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).

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).

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

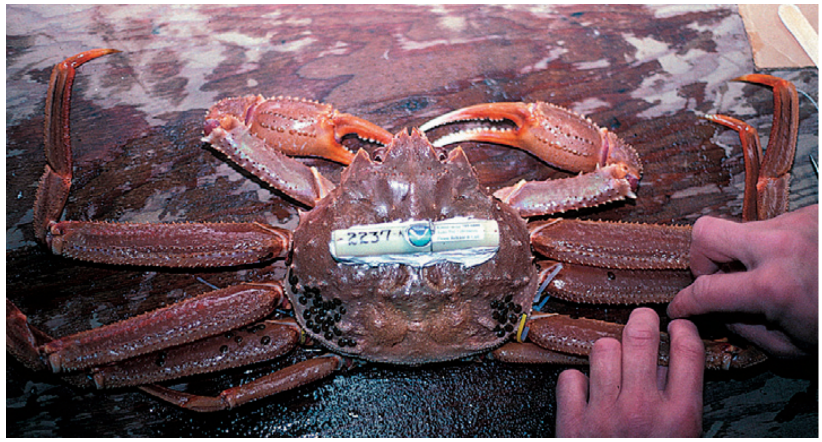
[5]Shell hash: a mixture of sand or mud with gravel and unconsolidated broken shells of clams, oysters, or other shellfish.

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).

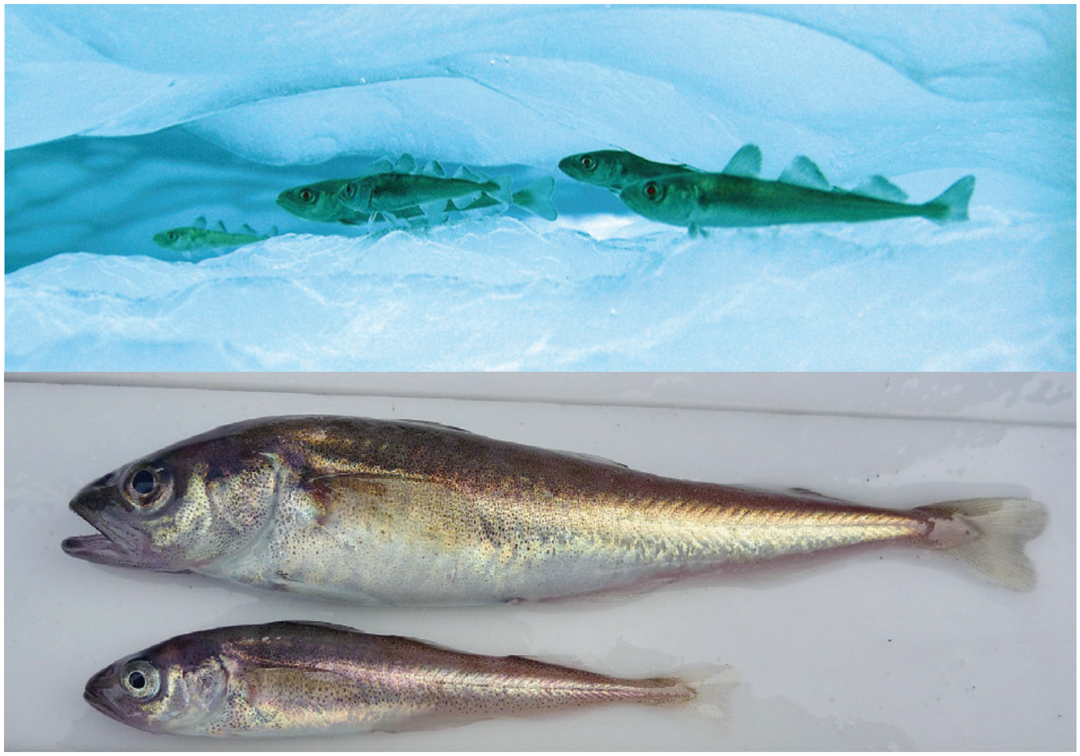


NMFS

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

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



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


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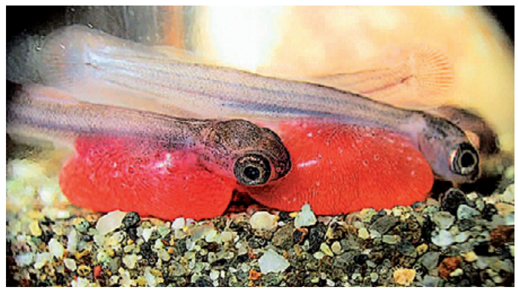
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Left: A salmon spawning stream in the southeastern part of Alaska.

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

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

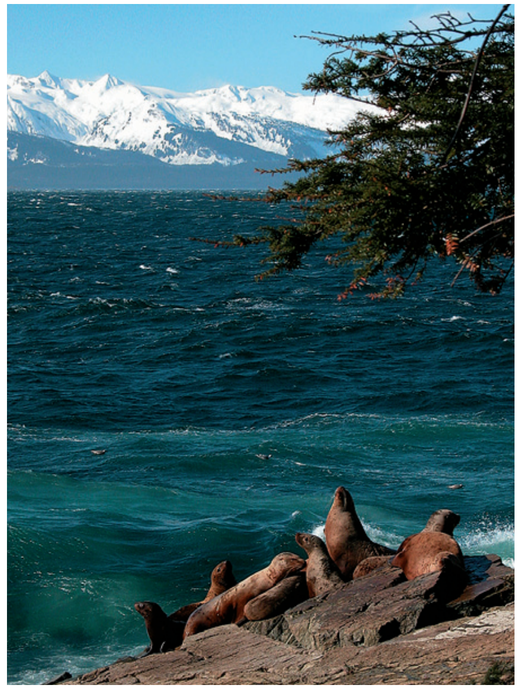
whales, which were delisted under the ESA, all large whales occurring in Alaskan waters are listed as endangered due to over-exploitation by commercial whaling operations. Among the large whales that occur in Alaskan waters, the North Pacific right whale is the only cetacean for which critical habitat 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, 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.


NMFS

Steller sea lions hauled out on Benjamin Island near Juneau, Alaska.

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

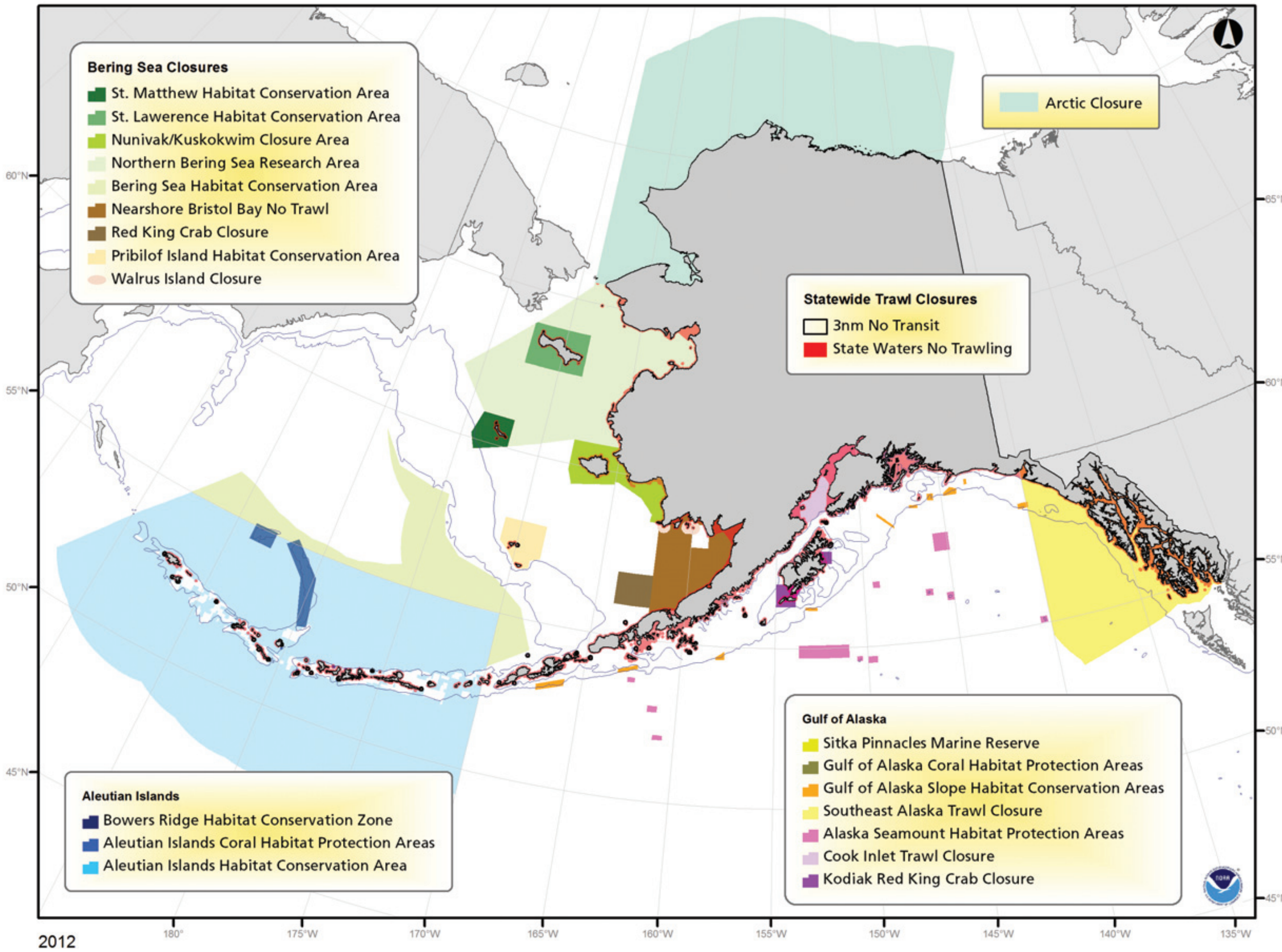


Figure 2
Alaska habitat conservation areas as of 2012.

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.

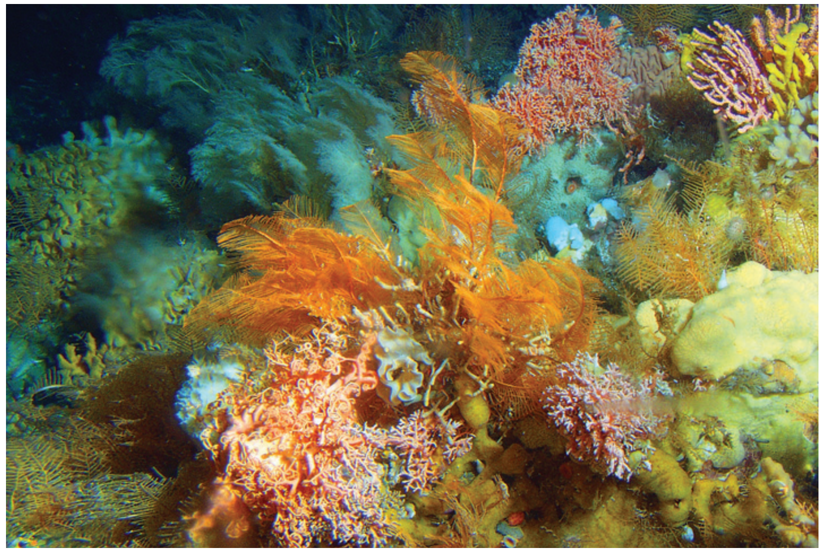
Deep-sea corals are widespread throughout Alaskan waters, including the Continental Shelf and upper slope of the Gulf of Alaska, Aleutian Islands, and the eastern Bering Sea, and extending as far north as the Beaufort Sea. Coral distribution, abundance, and species assemblages differ among geographic 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.

Table 15. Overview of research needs for Alaska Region fishery and protected species.

Research needs	Freshwater habitat	Estuarine habitat	Shallow marine habitat	Oceanic habitat
Conduct life history studies (including studies on age, growth, maturity, fecundity in relation to the environment) for all FMP and protected species.	x	x	x	x
Determine the quantity, quality, and functioning of habitats for all life stages of FMP and protected species, especially poorly known and vulnerable habitats such as deep-sea corals and sea ice.	x	x	x	x
Delineate and map important fishery and protected species' habitats including coastal shorelines, pelagic and benthic zones, 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.	x	x	x	x
Determine effects of fishing, oil and gas development, logging, mining, urbanization, and contaminants on all habitats, including the seafloor, wetlands, freshwater, estuarine, shallow marine, and offshore waters and the impact on the living marine resources that use these habitats.	x	x	x	x
Determine direct and indirect effects of climate change and ocean acidification on fish, shellfish, deep-sea corals, and marine mammals.	x	x	x	x
Monitor natural and human-caused changes in habitat quality, quantity, and use, and the effects of these changes on FMP and protected species.	x	x	x	x
Expand research on restoring habitats for fishery and protected species.	x	x	x	x

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.

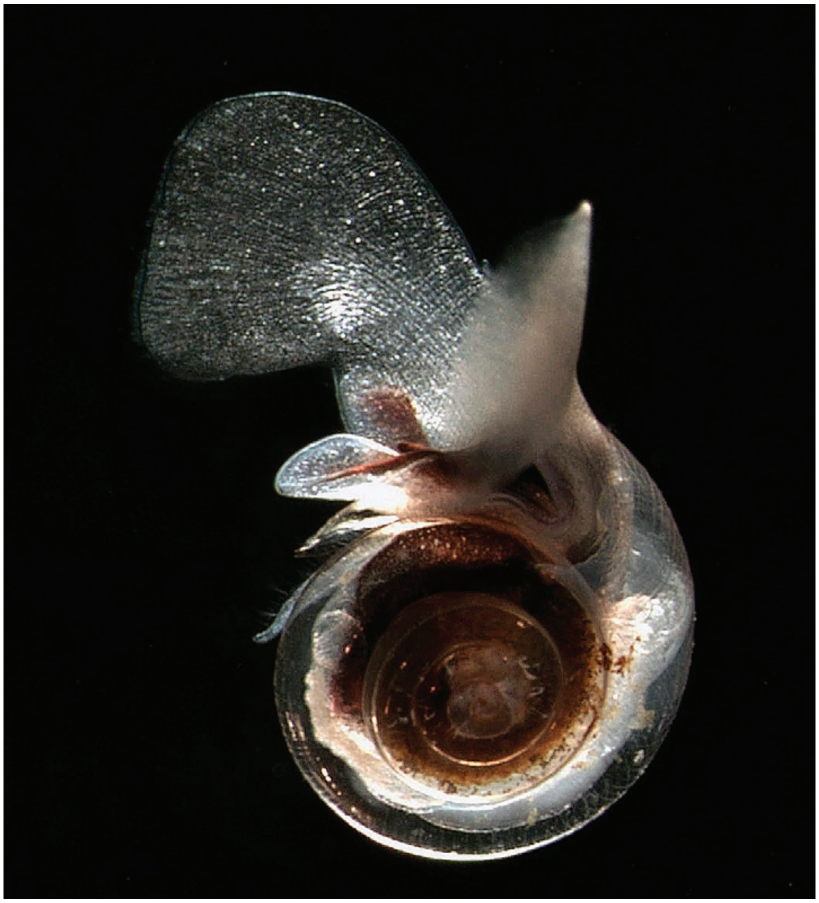

John Jansen, NMFS

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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