Northern Sea Lion

Northern sea lions range along the North Pacific Ocean rim from northern Japan to California, with centers of abundance and distribution in the Gulf of Alaska and the Aleutian Islands, respectively. The species is not known to migrate, but individuals disperse widely outside of the breeding season (late May through early July), potentially intermixing with animals from other areas. Two separate stocks of Northern sea lions are recognized within U.S. waters: an eastern stock, which includes animals east of Cape Suckling, Alaska (that is, southeastern Alaska, British Columbia, Washington, Oregon, and California), and a western stock, which includes animals at and west of Cape Suckling (that is, the western Gulf of Alaska, the Aleutian Islands, and the Bering Sea).

In the 1960's, the worldwide population of Northern sea lions was about 250,000 adult and juvenile animals (nonpups) and was presumed to be healthy and stable. By the mid-1970's, the population in Alaska began to decline at about the same time as declines in other top predators were occurring. Subsequent declines reduced the worldwide population of Northern sea lions to 91,000 by 1989 (Loughlin et al. 1992). The current Northern sea lion population (including British Columbia) is estimated at 80,900 animals, with 43,200 in the western stock and 37,700 in the eastern stock.

The Alaska population of nonpups, which had numbered more than 157,000 animals in the 1970's, declined by 60% to less than 64,000 animals by 1989. Counts of sea lions from the Gulf of Alaska through the Aleutian Islands declined from 67,600 in 1985 to 18,700 in 1994, a decline of 72% in 9 years and more than 80% since the early 1970's. In some areas, such as the eastern Aleutian Islands, the decline was nearly 95%. The only area essentially unaffected by the decline has been southeast Alaska to northern California.

As a result of these population declines, the western stock of Northern sea lions was listed as an endangered species under provisions of the Endangered Species Act in 1990. The eastern stock was reclassified as threatened in 1996. The recovery outlook for the western stock is poor.

See end of chapter for references

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Pacific Coast Region

Environment and Physical Features

The Pacific coast region is adjacent to the three Pacific coast states, California, Oregon, and Washington. The continental shelf is narrow—the 200-meter depth contour typically occurs from 8 to 32 kilometers offshore. The eastward-moving North Pacific Current (also called the West Wind Drift) impinges on North America off the state of Washington and splits to form the northward warm Alaska Current and the southward cold California Current (Fig. 31). The California Current travels the full length of the Pacific coast and turns offshore to flow west across the Pacific off the coast of Baja California. A northward-flowing countercurrent underlies the California Current and surfaces each winter to form the warm, inshore Davidson Current.

Variability in the Pacific coast ocean climate is driven by large-scale atmospheric influences, including the El Niño-Southern Oscillation in the equatorial Pacific and the North Pacific low pressure atmospheric cell known as the Aleutian Low. Every few years the California Current weakens and upwelling is reduced, resulting in a warm condition that has become known as El Niño. The El Niño conditions strongly affect the southern California end of the California Current but may influence ocean conditions as far north as Alaska.

There is also a between-decades pattern of climate variability that is clearest at the southern end of the region. The California Current appears to exhibit warm and cold periods, or *regimes*, each lasting decades and causing large biological shifts in the ecosystem. The most recent temperature shifts were from warm to cold in the early 1940's and back to warm in 1976 (lasting to the present). Samples of fish scales preserved in anaerobic sediments off Santa Barbara, California, provide a 2,000-year record of sardine and anchovy abundances, whose fluctuations show a periodicity of about 60 years. These temperature regimes appear to be associated with long-term variability in the amount of North Pacific Current flow that is directed northward into the Alaska Current as opposed to southward into the California Current.

The predominant ecosystem types on the Pacific coast include nearshore–coastal, continental shelf, and oceanic systems. The nearshore–coastal ecosystem extends from the intertidal zone out to 3 kilometers from shore and includes a diversity of habitats. The rocky intertidal habitat is dominated by macroalgae and sea anemones, barnacles, snails, starfishes, abalones, and mussels. The fish found here include smaller individuals of more offshore taxa like rockfishes and sculpins. Several

Effect of El Niño on the Southern California Bight

El Niño is a warmwater phenomenon in the Pacific Ocean that can have a great effect on the distribution and production of marine mammals and fishes. In the Southern California Bight ecosystem, reduced availability of prey species such as chub mackerel resulted in reduced reproductive success of California sea lions. Along the west coast of North America, the particularly strong 1982–1983 El Niño was associated with unusually warm sea surface temperatures (+4°C off California), high coastal sea levels, and strong northward currents along the California and Oregon coasts in the summer of 1983 (Bailey and Incze 1985; Pearcy and Schoener 1987). These changes altered the distribution of chub mackerel, including the areas where they spawned and the distribution and survival of their eggs and larvae. A 1983–1984 decrease of chub mackerel in the diet of California sea lions in the California Channel Islands was likely caused by the northward displacement of the fish out of the bight in response to ocean warming (Brodeur and Pearcy 1986). Chub mackerel were uncharacteristically abundant off the Washington and Oregon coasts during that period; it was the second most common species collected in purse seines off the Oregon coast in 1983–1984, whereas in most other years it did not rank in the top ten species collected (Pearcy and Schoener 1987).

The 1982–1983 El Niño resulted in decreased prey availability for female sea lions (Fig. 1) in the Southern California Bight. This reduced food availability meant that females had to spend more time and energy foraging for food, resulting in lowered reproductive success and pup growth. Thus, there were large declines in both pup numbers and weights at Channel Island rookeries in 1983 and 1984. Mortality of adults and juveniles was also higher than normal. Although the California sea lion population had increased about 5% annually between 1971 and 1981, their numbers declined 30%–70% at all rookeries in the Channel Islands in 1983 (DeLong et al. 1991). However, births declined the least (a drop of 30%) at San Miguel (Fig. 2), the most northern island, where sea surface temperatures were not as warm.

Courtesy S. R. Melin, National Marine Fisheries Service

Fig. 1. California sea lions on San Miguel Island, California.

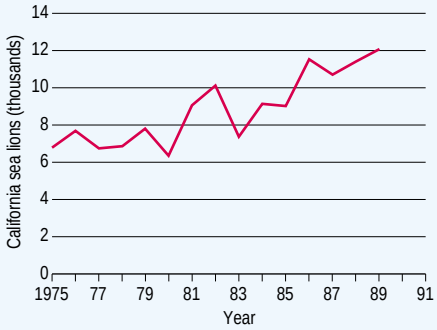

Fig. 2. California sea lion live pup counts, San Miguel Island, California, 1975–1989 (R. L. DeLong and S. R. Melin, National Marine Fisheries Service National Marine Mammal Laboratory, unpublished data).

See end of chapter for references

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estuarine bays and major embayments are found in the nearshore–coastal ecosystem. The Pacific coast region accounts for almost 98,420 square kilometers of estuarine drainage area. The larger estuaries—Puget Sound, Columbia River, and San Francisco Bay—together account for 53% of the estuarine drainage along the Pacific coast (National Oceanic and Atmospheric Administration 1990a). San Francisco Bay contains more than half of all wetlands in this region, even though it is estimated to have lost almost 95% of its wetlands since the time of its settlement by humans. The continental shelf ecosystem encompasses the upwelling zone and the inner portions of the California Current, between the nearshore–coastal ecosystem and the offshore oceanic ecosystem. The continental shelf extends to the 200-meter isobath, beyond which lies the continental slope. Associated benthic habitats are highly productive and support extensive fisheries for benthic fishes and invertebrates. Beyond the continental shelf edge (200-meter isobath) is the oceanic ecosystem,

where three broad depth zones are recognized: epipelagic (0–200 meters), mesopelagic (200–600 meters), and bathypelagic (600 meters to near bottom). The epipelagic zone is the most productive of the three zones.

Primary and Secondary Production

Like other boundary currents on eastern rims of large oceans, the California Current is an area of high primary and secondary productivity. Nutrients are added to the ecosystem through a combination of coastal upwelling and advection. Initially upwelled water is characteristically low in plankton, but microalgae grow rapidly in the presence of nutrients and can achieve substantial blooms in a few days. Diatoms are the most abundant phytoplankton, but dinoflagellates can be especially important as food for larval fishes or as the source of red tides. Primary production is followed by secondary production of zooplankton, especially copepods and krill. Secondary production is most notable in the core of the California Current, far offshore. Also, krill densities are highest at the northern end of the system, where they are preyed on by marine birds, baleen whales, and coastal migrating fishes such as Pacific whiting, jack mackerel, and salmon. Large gelatinous zooplankton are very abundant on the shelf in late summer, particularly north of Cape Mendocino, although their importance in the ecosystem is not well understood.

The continental shelf ecosystem is trophically based on phytoplankton production responding to nutrients obtained from coastal processes, including upwelling, turbulent mixing, and river discharging. Secondary production of copepods, krill, and other zooplankton provides a rich pelagic environment for schooling fishes (anchovy, sardine), marine birds, and large whales. Other piscivorous fish and marine mammals also occupy higher trophic levels. The mesopelagic and bathypelagic zones are probably the largest habitats in oceanic ecosystems. However, since they depend on settling of production from the surface layer for most of their productivity, they generally contain small, slow-growing nekton species of little commercial importance, such as lanternfishes.

Benthic Resources

Within the nearshore–coastal ecosystem, kelp forests are a prominent feature of much of the rocky coastal areas and the few offshore islands present in the region (Fig. 38). These forests are vertically stratified much as terrestrial forests are and include a canopy of fast-growing giant or bull kelp, an upper understory of larger macrophytes, and a lower understory of coralline and filamentous algae. Only a few invertebrates—such as limpets, kelp crabs, and sea urchins—are commonly found well off the bottom, although many species use the cover provided by the understory and holdfasts of the kelp. The subtidal sandy-bottom habitats are generally devoid of most attached vegetation but may contain a substantial biomass of detritus that has been deposited from nearshore regions. This detritus supports a high biomass of scavenging epifauna such as starfishes, crabs, and small crustaceans in the inshore area, which progressively gives way, with increasing depth, to suspension-feeding polychaete worms, sea pens, sand dollars, shrimp, and bivalves.

The nearshore–coastal ecosystem is heavily exploited for a variety of shellfish, including crabs, sea urchins, and abalone. The Dungeness crab population is naturally cyclic, so the fishery experiences booms and busts with a 6- to 7-year periodicity. Along the central California coast, foraging by the recovering sea otter population has eliminated most nearshore shellfish of commercial or recreational interest, but elsewhere these resources are subject to intense exploitation. The once-thriving commercial abalone industry has declined severely (see box on California Abalone in California chapter). Sea urchins are harvested for their eggs, mainly for use in Japanese sushi. This industry grew rapidly during the 1980's but has recently declined as the favored red sea urchins have become depleted. Kelp forests briefly

Courtesy National Marine Fisheries Service

Fig. 38. Kelp forest teeming with marine life.

flourished when grazing by urchins was reduced, and the population of smaller purple urchins subsequently grew in the absence of competing red urchins. Markets are now becoming established for purple sea urchins, and the population is expected to decline substantially from its present high level.

Only a few benthic invertebrate resources are harvested as extensively as demersal fishes along the Pacific coast. The most commonly exploited is the Dungeness crab, which ranges throughout the region but occurs in commercial quantities mainly north of Cape Mendocino. This species is found in many bays and shallow coastal water, where the crabs are caught by recreational fishermen, and extends onto the shelf to a depth of about 90 meters, where the crabs are caught in commercial crabbing operations using baited traps. Commercial landings of Dungeness crab are characterized by substantial fluctuations over time and indicate a 10–12-year cycle. A 1991 outbreak of domoic acid produced by toxic dinoflagellates, which commonly affects bivalves and is bioconcentrated by crabs, curtailed the fishery for a season because of perceived health threats to humans. The outbreak was no longer a problem by the following year.

Pink shrimp are abundant on the continental shelf from Washington through northern California but are found deeper (70–200 meters) than Dungeness crabs. Shrimps are important in the demersal food web. They are pursued commercially mainly by trawling with special shrimp nets. The fishery peaked in 1977, declined for a number of years following the 1982–1983 El Niño event, and then was revived in the early 1990's. The population size of pink shrimp appears to be related to levels of summer upwelling and is not as cyclic as that of the Dungeness crab.

Recently, new benthic communities have been discovered that are associated with hydrothermal vents off Washington and Oregon. These are composed of animal life forms that are entirely *chemosynthetic* in origin (that is, they synthesize organic substances using energy solely from chemical reactions rather than from photosynthesis).

Fisheries Resources

Most of the fisheries production in the Pacific coast region is taken from the continental shelf ecosystem. The status and trends of the major pelagic fishes are summarized in Table 8. Sea turtles, including the olive ridley, leatherback, hawksbill, loggerhead, and green turtle, also inhabit the epipelagic zone and undertake extensive migrations.

Table 8. Status and trends of major fish resources off the Pacific coast region.

Species	Status and trend
Pelagic	
Chub mackerel	Average abundance, fully utilized, declining
Jack mackerel	Below-average abundance, underutilized, stable
Northern anchovy	Below-average abundance, fully utilized, declining slowly
Pacific herring	Low abundance, fully utilized, cyclic
Pacific sardine	Abundance rebuilt from depleted levels, fully utilized, increasing
Groundfish	
Dover sole	Above-average abundance, fully utilized, stable
English sole	Average abundance, fully utilized, stable
Pacific whiting	Above-average abundance, fully utilized, stable
Petrale sole	Average abundance, fully utilized, stable
Rockfishes	Average to below-average abundances, fully to overutilized, declining
Sablefish	Average abundance, fully utilized, declining
Salmonids	
Chinook salmon	Many depressed stocks, overutilized, low abundance
Chum salmon	Fairly good condition, overutilized, stable
Coho salmon	Low abundance, overutilized, depressed
Sockeye salmon	Overutilized, and stable at low levels
Cutthroat trout	Low abundance, overutilized, depressed
Pink salmon	Fairly good condition, overutilized, stable
Steelhead	Low abundance, overutilized, depressed

Nearshore Fishes

Minimal fish spawning occurs in kelp beds in nearshore areas; however, juveniles of many fish families such as rockfishes, kelpfishes, and sculpins use kelp beds as nurseries. Many small, cryptic fishes are found within the understory. Fishes occupying the sandy-bottom segments of the nearshore zone include bottom-feeding flatfishes and plankton-feeding surfperch, northern anchovy, and smelt, as well as juvenile salmon migrating through the region.

Continental Shelf Pelagic Fishes

Pacific sardine is the most well known of Pacific coast pelagic fishes. Its fishery was made famous by John Steinbeck's novel *Cannery Row*, a story woven around the sardine fleet in Monterey, California, during the 1930's. The actual fishery underwent a tremendous boom and decline when sardine biomass dropped from 3 million metric tons in the early 1930's to unmeasurably low levels (perhaps a few hundred metric tons) by the 1970's. This decline engendered much debate as to whether fishing or an adverse change in the natural environment was to blame. Discovery and analysis of a 2,000-year paleosedimentary record off Santa Barbara, combined with recent data on status of the stock, have allowed resolution of the debate. Coastal pelagic fishes such as the sardine show natural long-term fluctuations of very large amplitude, presumably in response to decadal-scale warm and cold ocean regimes. During warm periods, the populations can withstand high fishing rates, but during cold periods they decline even in the absence of fishing (that is, sustainable yields are very low, and no sustainable harvest may be possible

during coldest conditions). When the ocean entered a cold regime in the 1940's, continued heavy fishing accelerated the otherwise natural decline and drove the sardine population to an extremely low level, hindering recovery once conditions warmed and became favorable again beginning in the late 1970's. Sardines have staged a moderate recovery in the last decade, and the fishery has reached 200,000 metric tons (Alaska Fisheries Science Center 1993).

The northern anchovy is another pelagic fish that has responded to between-decades climate change. Under virtually unfished conditions, the northern anchovy resource grew from tens of thousands of metric tons in the early 1950's to more than 2 million metric tons briefly in the mid-1970's. Reduction fisheries (for production of fish meal) subsequently developed in California and Mexico but ceased operation several years ago. The resource biomass is now about 200,000 metric tons and continues to decline slowly.

Chub mackerel has a history parallel to that of sardines. The chub mackerel supported a large fishery in the 1930's and 1940's and declined to very low levels by the early 1970's. In response to the post-1976 warming, this resource grew rapidly, reaching unprecedented size in the 1980's, but has declined precipitously since then. Because of a combination of population pressure and warm ocean conditions (including El Niño) in recent years, chub mackerel have occasionally migrated as far north as Vancouver Island, British Columbia.

Pacific herring is an important pelagic fish in the Pacific coast region, although it has a more northerly affinity and is most abundant off Canada and Alaska. Small populations are associated with estuaries, and the San Francisco Bay spawning population is at the southern end of the range. Not surprisingly, the San Francisco Bay population has declined in recent years, with warm ocean conditions being compounded by a long drought in California that has reduced freshwater flows thought to be favorable for herring reproduction. The heavy winter rains associated with the 1997 El Niño event have reversed this condition, with unknown long-term consequences.

Continental Shelf and Slope Groundfish

The commercial groundfish fishery presently includes 83 species, 55 of which are rockfishes. Most of the abundant species, with the possible exception of the short-lived shortbelly rockfish, are fully utilized, with harvests near long-term potential yield (Table 8). Several of the rockfish species are abundant enough to support directed commercial trawl and hook-and-line fisheries. Because these species are often very long-lived (greater than 50 years), and some concentrate in schools that are easily harvested, the potential for overharvesting rockfishes is great. Most species are found near high-relief bottom, but some species (widow rockfish and shortbelly rockfish) are pelagic. The Pacific ocean perch supported a substantial foreign fishery in the 1970's, but its population level is below that which will support long-term maximum potential yield. A fishery for another deepwater rockfish, the thornyhead, has recently developed and is reducing population levels of this species as well.

Of the dominant species, Pacific whiting (also known as hake) contributed 70% of the groundfish biomass in 1992. Pacific whiting are generally found in midwater and migrate annually from offshore spawning grounds off southern California to summer feeding grounds as far north as British Columbia. They migrate back in the fall, following an offshore migration route. Whiting mature at 3 years and undergo large fluctuations in recruitment success. The successful year-classes have fueled a substantial trawl fishery that started as a foreign fishery in the 1960's, switched to a joint-venture fishery in the 1980's, and has been a domestic fishery since 1991. Pacific whiting reached full use in 1989, but potential yield will vary substantially because this species has greater short-term natural fluctuations than most other groundfish species.

Sablefish (or blackcod) are found along the outer shelf and upper slope, with the larger fish found deeper. Their distribution shifts from inshore in summer to offshore in winter. Sablefish can live up to 60 years but mature at 5 years. They are caught by pots and longlines and also in mixed-species trawl fisheries. During the last decade, their stock size appears to have declined.

Dover sole is the most important commercial species of the flatfish group. English and petrale soles have long histories of stable harvests, and the arrowtooth flounder fishery has recently expanded. All flatfish assessments are hampered by limited and inadequate survey data.

Oceanic Pelagic Fishes

The epipelagic zone of the oceanic system is inhabited by fast-growing fishes and squids whose ranges extend well beyond this region in these animals' search for concentrations of prey fishes or zooplankton. Among the most important of these predators are albacore tuna, yellowtail, and swordfish. Other species of lesser commercial importance are pomfret, ocean sunfish, blue sharks, and pelagic squids. The zone is also a rich feeding ground for migrating salmon and steelhead.

Pacific salmon are perhaps the most important living marine resource in the region. Salmon support important traditional, commercial, and recreational fisheries in Washington, Oregon, and California. They have long been an integral part of the Native American culture and heritage in the Pacific Northwest. Pacific salmonids are anadromous. There are seven salmonid species: chinook salmon, coho salmon, sockeye salmon, pink salmon, chum salmon, steelhead, and sea-run cutthroat trout. Salmon runs are inherently highly variable in abundance. Catches have fluctuated widely, and all seven species are overutilized. Environmental conditions tend to play a large role in salmon survival and abundance. For example, an El Niño event of unusual warm ocean and nutrient-poor conditions devastated chinook salmon and coho salmon ocean survival in 1983–1985. Stocks later rebounded but have recently declined, necessitating very restrictive salmon-fishing seasons in 1994. There are many competing user groups vying to catch salmon, and strict limitations are required to protect the stocks. Thus, salmon management issues are concentrated on catch allocations among user groups and adequate protection of migrating adults, spawners, and juvenile salmon during their outbound migration from home streams to the ocean. The status and trends of salmon off the Pacific coast are summarized in Table 8. The history of catches, which largely reflects changes in abundance of the populations, is shown in Fig. 39.

Recent annual commercial salmon catches were 1.8 million sockeye salmon (1990–1993 average), 2.6 million pink salmon (1989–1993 average), and 1.2 million chum salmon (1990–1993 average). Recreational catches of these species, though important, are comparatively small. Most Pacific Northwest stocks of pink salmon and chum salmon appear to be fairly stable and are in good condition. However, some Oregon and Washington chum salmon stocks are of special concern and, in 1991, the Snake River stock of sockeye salmon was listed as endangered under the U.S. Endangered Species Act.

For the period 1990–1992, commercial catches of chinook salmon, both natural and hatchery-produced, averaged 815,000 fish, while recreational catches averaged 354,000 fish. Because of catch restrictions, the landings have been much smaller in recent years. A significant share of the catch now comes from hatchery-produced fish. Some chinook salmon stocks are extremely depressed. The spring–summer and fall chinook salmon runs in the Snake River have been listed as endangered under the U.S. Endangered Species Act; so has the Sacramento River winter run of chinook salmon. In recent years, other chinook salmon stocks like the Columbia River summer run, Shasta River run, Skagit River spring run, Stillaguamish River summer–fall run, Snohomish River summer–fall run, Rogue River runs, and Klamath River runs have generally been depressed and have not met escapement goals. The National Marine Fisheries Service is conducting a status review under the U.S. Endangered Species Act of Pacific coast chinook salmon populations.

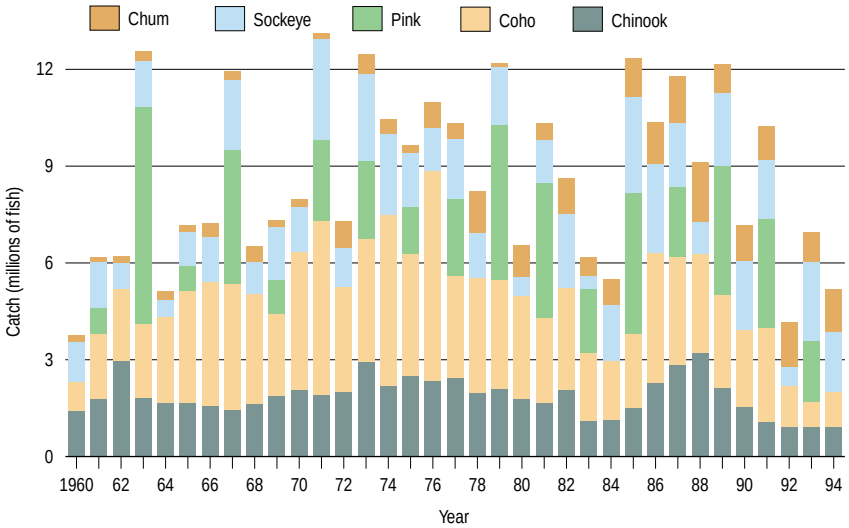

Fig. 39. Trends in salmon catches off the Pacific coast, 1960–1994.

For 1990–1993, commercial catches of coho salmon averaged 1.1 million fish, while recreational catches averaged 706,575 fish. To an even greater extent than with chinook salmon, hatchery-produced coho salmon have become an increasingly important proportion of the catch, and in some areas account for more than 80% of the catch. Combined coho salmon landings from the ocean fisheries peaked at more than 5 million fish in 1976, then declined rather steeply in recent years to about 1 million fish. This decrease is in part due to a shifting of most of the allowable catch from the ocean fisheries to fisheries within rivers and estuaries. The shift mainly resulted from a 1974 federal judicial decision that entitles tribal fishermen to as much as 50% of the catch of returning salmon that migrate through their traditional tribal fishing areas.

In 1996 the National Marine Fisheries Service listed the central California and southern Oregon/northern California stocks of coho salmon as threatened under the U.S. Endangered Species Act. Also in 1996, stocks of coho salmon from Puget Sound/Strait of Georgia and Lower Columbia River/southwest Washington were placed on the candidate list. The release of hatchery-reared fish, degradation of salmon habitat, and overharvesting are major factors that contributed to the decline of the wild coho salmon populations in the Columbia

River. Oregon coast coho salmon stocks were placed on the candidate list in 1997.

Unlike other salmonids, steelhead and sea-run cutthroat trout do not always die after spawning. A very valuable sport fish because of its size, fighting ability, and flavor, steelhead are harvested commercially only by Native American fishermen. All fisheries occur primarily in rivers and streams. During 1990–1993, a minimum average estimate of 266,000 steelhead (data on California catches are not available) were caught by recreation anglers. Tribal fisheries harvested an estimated 177,425 steelhead during 1987–1988 for commercial, ceremonial, and subsistence purposes. As with other salmonids, steelhead harvests have been augmented by large hatchery releases. Wild populations in many rivers are at very low levels, often restricting sport harvests to only hatchery fish. In response to a May 1992 petition to list Illinois River winter steelhead, the National Marine Fisheries Service initiated a status review for the broader unit that included this population. In August 1997, the National Marine Fisheries Service listed five Pacific coast steelhead populations. Listed as endangered are steelhead in the upper Columbia River and in southern California from the Santa Maria River to just south of Malibu Creek, which is north of Los Angeles; listed as threatened are steelhead in the Snake River Basin (encompassing parts of Idaho, Washington, and Oregon), and along the central California coast and the south-central California coast.

Sea-run cutthroat trout is another popular game fish and is not harvested commercially. The total catch is unknown, but populations appear to be severely depressed in many rivers. The north and south Umpqua River run was petitioned for listing under the U.S. Endangered Species Act, and as a result of its status review, the National Marine Fisheries Service listed Umpqua River cutthroat trout as endangered. The National Marine Fisheries Service is currently conducting a status review under the U.S. Endangered Species Act of all Pacific coast cutthroat trout populations.

Marine Birds

More than 2 million marine birds of 29 species nest along the California, Oregon, and Washington coasts (Carter et al. 1995), including three species listed on the U.S. List of Threatened and Endangered Wildlife: the brown pelican, least tern, and marbled murrelet. The marbled murrelet nests inland in old-growth conifer forests and only forages at sea. Including breeding species, migrants, overwintering birds, and rare vagrants, more than 80 species of marine birds have been found in Pacific coast nearshore and pelagic waters (Stallcup 1990). For example, many millions of sooty shearwaters pass along the coast during their annual migrations between the Arctic and the southern hemisphere nesting islands. Moreover, the marine bird populations inhabiting the oceanic zone are also highly migratory and move seasonally between northern feeding and breeding grounds and southern overwintering grounds; these species include albatrosses, storm-petrels, shearwaters, phalaropes, and jaegers. Large marine fish-eating birds include loons, murres, cormorants, and gulls and are generally found in nearshore waters.

Breeding marine bird populations along the Pacific coast have declined since European settlement began in the 1700's. Numerous causes for their decline include human occupation or disturbance of nesting sites; introduction of mammalian predators (such as rats or cats) to nesting islands; and most recently, intense commercial use of natural resources, resulting in habitat loss, declines in forage abundance, and direct mortality of birds due to oil spills and entanglement in fishing gear (Jehl 1984). Many of these factors have been or are being resolved through improved management of marine and coastal habitats, fisheries, and resources, but many critical problems remain.

The brown pelican is a good example of an *effect and recovery* situation. In the 1940's and 1950's, a northern breeding colony at Point Lobos, near Monterey, disappeared simultaneously with the end of the sardine fishery in Monterey, suggesting a direct causal relationship. In the late 1960's, pesticide contamination resulted in severe eggshell thinning and nearly complete reproductive failure at the southern California colony at Anacapa Island. Shortly thereafter, the brown pelican was formally declared an endangered species. With reductions in the use of DDT, reproductive success improved, but immigration from Gulf of California colonies may also have contributed to the recovery. In southern California, the northern anchovy is the primary prey of breeding pelicans, and fluctuations in pelican reproductive success have been clearly associated with fluctuations in the abundance of northern anchovies. Thus the potential effect of the fishery on anchovy abundance became an explicit concern to management and led to a management plan for maintaining a large anchovy biomass below which level the commercial fishery would be curtailed. The brown pelican is now being considered for downlisting from its endangered status, based on recent population increases.

The least tern and marbled murrelet are both listed endangered species and are both suffering the effects of habitat loss. The least tern nests in

sandy beach areas that are frequently affected by recreational use and by introduced red foxes; however, intense habitat management seems to be stabilizing the population. Like the better-known spotted owl, in the Pacific Northwest the marbled murrelet nests only in old-growth forests, although farther north it also nests in tundra. In the past, the marbled murrelet has experienced significant declines (Marshall 1988), and the health of its remaining populations in the Pacific Northwest is tied to the continuing existence of sufficient coastal old-growth forests (U.S. Fish and Wildlife Service 1995).

Marine Mammals

When Hawaii is considered, the Pacific region is home to 67 stocks of at least 37 species of marine mammals, including 10 stocks of eastern tropical Pacific dolphins (Table 3). Like the birds and fish in the region, the marine mammal populations inhabiting the oceanic zone are also highly migratory and move seasonally between northern feeding–breeding grounds and southern overwintering grounds. Included in this category are blue whales, fin whales, sei whales, dolphins, and fur seals. In the nearshore zone, sea otters are common in kelp beds. In coastal areas, mammalian predators such as migrating California sea lions, gray whales, dolphins, and harbor seals are relatively common (Stallcup 1990). The U.S. Fish and Wildlife Service is responsible for managing two stocks of sea otters (in central California and in Washington), while the National Marine Fisheries Service has management authority for the remaining cetacean and pinniped stocks. According to the criteria provided in the 1994 amendments to the Marine Mammal Protection Act, these include 16 strategic stocks. In the eastern Pacific (that is, the waters of Washington, Oregon, California, and northern Mexico) these include 8 strategic whale species (humpback, blue, fin, sei, short-finned pilot, minke, sperm, mesoplodont beaked) and a threatened seal species (the Guadalupe fur seal). In addition, the northeastern spotted dolphin and eastern spinner dolphin stocks in the eastern tropical Pacific are considered depleted under the Marine Mammal Protection Act. Of the 43 stocks in the Pacific region, 11 are believed to be increasing, 13 are believed to be stable, 3 are declining, and the population trends of 16 stocks are unknown.

Estuarine Resources

San Francisco Bay

The San Francisco Bay is fed by two main riverine systems. The south San Francisco Bay receives very little freshwater input and is poorly flushed, whereas the northern portion is part of an active river outflow system. The Sacramento and San Joaquin rivers form a complicated network of waterways in California's Central Valley, forming the Sacramento delta. After exiting the delta, the system sequentially opens into Suisun Bay, San Pablo Bay, and San Francisco Bay, then flows out through the Golden Gate. The entire San Francisco Bay–Sacramento delta system is subject to high rates of siltation.

Introduced species have continually reshaped the San Francisco Bay ecosystem. The east coast's shipworm arrived with the Gold Rush of 1849 and quickly destroyed the many unprotected wooden structures in the bay. Striped bass and American shad were introduced in the later 1800's and quickly became dominant fishes in the system. More recently, various species of nonindigenous clams have sequentially claimed the benthic habitat, with the Japanese littleneck recently reaching remarkably high densities of 10,000 per square meter. Currently the green crab (a predaceous swimming crab related to the east coast's blue crab but of little human use) is increasing rapidly in abundance and is expected to reshape the system once again (San Francisco Estuary Project 1992).

The Sacramento and associated rivers historically supported several different large runs of chinook salmon, but present salmon production is mostly from the fall run produced by hatcheries. The winter run was recently added to the U.S. List of Endangered and Threatened Wildlife. Diversion of fresh water has posed problems for many species in the system. Large volumes of fresh water are diverted from the Sacramento delta into two large aqueducts serving San Joaquin Valley farmers and the Los Angeles metropolitan area. Reproductive habitat for native fishes and for popular introduced species such as striped bass depends on flows and interfaces of fresh and saline water. Freshwater diversion can greatly modify those patterns, resulting in poor reproductive success for fishes. Also, diversions may physically divert young life stages of several fish species and are a major source of mortality. Restricted freshwater flow also reduces flushing in portions of the bay, allowing contaminants to build up to high levels.

The Columbia River Estuary

The Columbia River is the largest river on the Pacific coast of the United States. Its estuary covers about 48,564 hectares, about three-quarters of its 1870 size. The Columbia River and its tributaries drain an area of 670,000 square kilometers. 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, when the river plume extends 300–400 kilometers seaward and is detectable in a 1,000-square kilometer area.

The Columbia River once had the largest chinook salmon and steelhead runs in the world. Chinook salmon originally migrated nearly 1,935 kilometers up the Columbia River to Lake Windermere, Canada, and 967 kilometers up the Snake River to Shoshone Falls near Twin Falls, Idaho. Historical estimates of salmonid runs in the Columbia River range between 10 and 16 million fish. However, access to many spawning areas in the Columbia River basin is presently blocked by hydroelectric development. Fourteen hydroelectric dams have been constructed on the main-stem Columbia River, 7 on the Snake River, and 150 on Columbia River basin tributaries. More than 800 kilometers of the upper Columbia River, excluding tributaries, were blocked by the construction of Grand Coulee Dam in 1941. Only 80 kilometers of the Columbia River above Bonneville Dam are now free-flowing. More than 50% of the Snake River basin is no longer accessible to salmonids. Many salmonid hatcheries were built to compensate for losses in spawning and rearing habitat. Currently 57 hatcheries operate in the basin, placing almost 200 million juvenile salmonids into the Columbia River system each year. Hatchery production now accounts for about three-quarters of all adult salmonids returning to the Columbia River. However, hatcheries have high costs and maintenance requirements, often experience low adult returns, and negatively affect wild salmon stocks. Hatchery salmonids often cause overharvesting of wild salmonid stocks, yet hatcheries do not address many inherent salmonid population problems, such as habitat degradation, overfishing, and challenges faced with upstream and downstream migration.

The various Columbia River estuary habitats—including mudflats, estuarine and freshwater marshes, and major channels—provide food, refuge from predation, a physiological transition area for anadromous species, and nursery areas for a variety of species. Many of these habitats have been reduced in size or highly modified since the early part of this century. The Columbia River estuary has four large embayments, all of which contain expansive intertidal mud flats that harbor abundant benthic invertebrate populations. These benthic invertebrates, particularly amphipods, are primary prey for many fish and wildlife species. Detritus from rivers, estuaries, and the sea is the primary food for most benthic invertebrate species.

The economy of the lower Columbia River was historically directly tied to its salmonid resources, which were central to the Native American way of life. Native Americans still hold treaty fishing rights and continue to harvest salmon for both commercial and ceremonial purposes. Commercial landings of salmon and steelhead were once as high as 14,350 metric tons (2,112,500 fish). By 1993, only 6,360 metric tons or 115,500 salmon were commercially harvested, in part because of very restricted seasons. Some restrictions resulted from the threatened or endangered listings of three Snake River salmon stocks, sockeye salmon, fall chinook salmon, and spring–summer chinook salmon. All salmonid species in the Columbia River basin are fully utilized to overutilized. The stocks are generally at low to depleted levels. Many are threatened or endangered.

Two species of sturgeon live in the Columbia River estuary, white sturgeon and green sturgeon. The overall white sturgeon population is healthy and productive, but populations upstream from Bonneville Dam, which are confined to reservoirs, are less productive and are considered depressed. In 1993, the total Columbia River white sturgeon catch was more than 50,000 fish, with most caught by the sport fishery in the estuary. In recent years, anglers have spent more days fishing for sturgeon than for any other species in the Columbia River estuary. Green sturgeon are much less abundant than white sturgeon. In 1993, 2,200 green sturgeon were caught commercially, and 100 recreationally. The status of green sturgeon in Oregon and Washington is unknown.

American shad were introduced into the Columbia River in 1885 and are now very abundant. The largest run was an estimated 4 million adult shad in 1990. In 1993, the minimum run size was 2.7 million fish. Poor market conditions and the concurrent timing of depressed salmon runs and the shad run in the spring have hindered the commercial harvesting of this species.

Columbia River smelt, or eulachon, spawn in coastal streams and in the lower Columbia River and its tributaries from mid-January through March and sometimes April. Although commercial landings for 1993 were the second lowest on record (227 metric tons), if the landing numbers for the coastal streams and the Columbia River are combined, the total run may have been near normal.

Other Columbia River estuarine fisheries include Dungeness crab, surf perch, and starry flounder. Northern anchovies are caught by seines and sold as bait for the sturgeon and salmonid sport fisheries. Some of the other species that use the Columbia River estuary, particularly as a nursery area, are longfin smelt, Pacific sand lance, Pacific herring, Pacific tomcod, shiner perch, Pacific staghorn sculpin, and

English sole. The status of these populations in the Columbia River is unknown.

Many species of birds use the Columbia River estuary and its two wildlife refuges. Besides many migrating waterfowl, shorebirds, and marine birds, the estuary supports at least 22 nesting pairs of bald eagles. However, bald eagle reproductive success has been poor. Agricultural and industrial contaminants, specifically DDE, PCB's, and TCDD are at levels that adversely affect eggshell thickness and nestling viability. The recently established Caspian tern colony in the Columbia River estuary may now be the largest in the country, with 5,000 pairs in 1994. Because these birds prey on small fishes, there are concerns that terns are consuming many migrating juvenile salmonids. There is also a relatively large cormorant rookery located on the same island as the Caspian tern colony. Gulls nest in two or three locations throughout the estuary.

Waterfowl primarily use the Columbia River estuary during winter. Although relatively abundant, duck populations in the estuary fluctuate widely, depending on breeding success in other areas, and remain below historical levels. The Canada goose population in the Columbia River estuary is healthy and has doubled in the last couple of years.

Many species of marine, terrestrial, and freshwater mammals use the Columbia River estuary. Species such as harbor seals and California sea lions are increasing in abundance, and because they eat salmon, they are causing conflicts with anglers. The once-abundant mink populations have all but disappeared because mink reproduction is extremely sensitive to PCB's, which in the Columbia River are at concentrations that adversely affect reproduction. Other mammal populations, such as nutria and river otter, are healthy and stable. Marine species such as elephant seals, killer whales, gray whales, harbor porpoises, and Northern sea lions are rarely observed in the estuary.

Puget Sound

Puget Sound is located in Washington State and is one of the three major water systems in the Georgia Basin. The Strait of Juan de Fuca connects Puget Sound and its northern neighbor, the Strait of Georgia, to the Pacific Ocean. Puget Sound covers an area of 2,632 square kilometers at mean high tide. Of the eight major habitat types in the sound, kelp beds and eelgrass cover the largest area, almost 1,000 square kilometers. The other predominant habitat types include subaerial and intertidal wetlands (176 square kilometers), mudflats, and sandflats (246 square kilometers). Marked losses of these habitats have occurred during the last century. At least 76% of the wetlands have been eliminated, mainly within highly urbanized estuaries. Substantial declines of mudflats and sandflats have also occurred in the deltas of these estuaries (Levings and Thom 1994).

Several invertebrate species are commercially and recreationally important in Puget Sound. Among the crustaceans, Dungeness crab and several species of shrimp (for example, side-stripe shrimp and pink shrimp) are the most commonly harvested. The Pacific oyster accounts for 90% of the bivalve harvest. Japanese littlenecks and Pacific geoducks are the primary components of remaining bivalve harvests. Blooms of dinoflagellate species have been linked to the uptake of paralytic shellfish poisoning by various bivalves. Humans who ingest bivalves containing paralytic shellfish poisoning may experience neurological changes and, in a few cases, death. In Puget Sound, illnesses related to paralytic shellfish poisoning were not reported until the 1970's, and since then high toxin levels have been reported in various parts of the sound every year (Taylor and Horner 1994).

Within Puget Sound, salmon are presently the most economically valuable fish resource. In 1994, 45% of the approximately 210 stocks were classified as healthy, 21% as depressed, and 5% as critical by the Washington Department of Fish and Wildlife and the Oregon Department of Fish and Wildlife (1994). Chum salmon and pink salmon had the highest percentages of healthy stocks (70% and 60%, respectively) compared to chinook, coho, and sockeye salmon (35%, 44%, and 0%, respectively).

Historically, the most important commercial marine fish species in Puget Sound have been Pacific herring, Pacific whiting, Pacific cod, rockfish, and English sole. The population sizes of all of these species have declined during the last 10 to 20 years. Stocks of herring reached peak abundance in the mid-1970's, declined to low levels in the 1980's, and have since remained low. Commercial harvests of herring are now used primarily as bait for recreational salmon fishing. Whiting populations declined from a peak in the early 1980's to levels in the 1990's that are below the threshold required for a commercial fishery. Stocks of whiting in the waters north of Puget Sound and the Strait of Georgia are currently at a historical peak. Although cod and walleye pollock in Puget Sound are at their southern limit of abundance, commercial and recreational catches were relatively high during the 1980's. Present populations are severely depressed and the commercial fishery has been closed for several years. In contrast, the abundance of rockfish species has remained at low but constant levels during the

last two decades. Populations of English sole are thought to be relatively healthy in the central portions of Puget Sound; however, significant declines have been recorded in populations in localized embayments, such as Bellingham Bay and Discovery Bay.

Approximately 66,000 marine birds breed in or near Puget Sound. About 70% of them breed on Protection Island, located just outside the northern entrance to the sound. The most abundant species are rhinoceros auklet, glaucous-winged gull, pigeon guillemot, cormorants, marbled murrelet, and Canada goose. Examples of less abundant species include common murres and tufted puffins. Populations of rhinoceros auklets and pigeon guillemots appear to be stable, whereas populations of glaucous-winged gulls have increased slightly in recent years, especially in urban areas (Mahaffy et al. 1994). Accurate estimates of current populations of marbled murrelets and Canada geese are not available, but the population of marbled murrelets has been greatly reduced, and this species has been listed as threatened. Thirty years ago, year-round resident Canada geese were rare in Puget Sound, but their population is growing rapidly. The common murre and tufted puffin populations have declined drastically during the last two decades.

The nine primary marine mammal species that are short-term or long-term residents of Puget Sound include (listed in order of abundance): harbor seal, California sea lion, Northern sea lion, northern elephant seal, harbor porpoise, Dall's porpoise, killer whale, gray whale, and minke whale. Harbor seals and California sea lions are year-round residents, and their abundance has increased each year in Puget Sound by 5%–15% at most sites (Calambokidis and Baird 1994; Fig. 40). Populations of the remaining species are quite small. Northern sea lions and elephant seals are transitory residents, and whereas the Northern sea lion is currently listed as threatened in the United States, the elephant seal is abundant in the eastern North Pacific but has few haul-out areas in Puget Sound. Although harbor porpoises are also abundant in the eastern North Pacific and were common in Puget Sound 50 or more years ago, they are now rarely seen there (Calambokidis and Baird 1994). Low numbers of Dall's porpoise are observed in Puget Sound throughout the year, but little is known about their population size; they are also abundant in the North Pacific. Three pods of resident fish-feeding killer whales, numbering about 100 total, reside just north of the entrance to Puget Sound, and the size of this group is increasing about 2% each year. Minke whales are also primarily observed is this same northern area, but their population size is unknown. Gray whales migrate past the Georgia Basin en route to or from their feeding or breeding grounds; a few of them enter Puget Sound during the spring and summer to feed.

Courtesy P. J. Gearin, National Marine Fisheries Service

Fig. 40. California sea lions in Puget Sound.

Southern California Bight

The area called the Southern California Bight stretches from Point Conception to the United States–Mexico border (about 1,000 kilometers) and is around 300 kilometers at its widest point. The mainland nearshore habitats of the Southern California Bight are mostly composed of sandy beaches, whereas the roughly equivalent length of coastline on the islands is composed of rocky shores. Most of the sublittoral bottom of the Southern California Bight is sandy with rocky outcrops. Dense kelp forests and other aquatic macrophytes are particularly common around the Channel Islands, providing substantial habitat for the invertebrates, fishes, and marine mammals found there. Many of the islands, because of their relatively undisturbed condition, provide nesting and rearing sites for numerous pelagic birds, although bird production within the Southern California Bight is fairly low. Fish production, however, is high relative to primary production and approaches that of some upwelling areas because of high turnover rates and the low trophic levels of many of the pelagic fishes.

Western Pacific Oceanic Region

The western Pacific region contains a huge number of species and few resource assessment agencies, compared to the continental United States. Great distances between the islands of the region, many of which are uninhabited,

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