Pacific Salmon

California's salmon resources are many things to the people of California. They are a source of highly nutritious food for the general population and an important source of income for commercial fishermen. Recreational anglers value them for their excellent sporting qualities and American Indians celebrate them in annual events welcoming the returning adults. Salmon play a key role, and occupy a unique niche, within the State's highly diverse marine and inland ecosystems. They are a high level predator, but also contribute to the sustenance of other high level predators. In addition, their spawned-out carcasses enhance the nutrient base of their ancestral spawning streams. Like other anadromous species, their survival depends on the quantity and quality of fresh water spawning and rearing habitat available to them. The destruction of that habitat over the past 150 years has resulted in many naturally spawning populations of salmon becoming so diminished that, in some cases, they face biological extinction. We provide a brief overview of the importance and role of salmon in the management of California's living marine fishery resources.

History of the Fishery

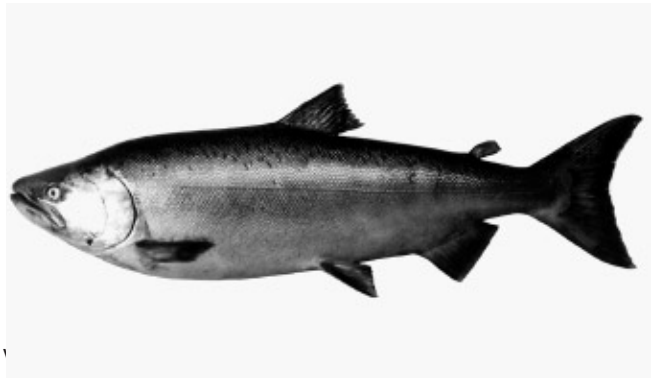
Of the five species of Pacific salmon found on the West Coast, chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) are most frequently encountered off California. Small numbers of pink salmon (*O. gorbuscha*) are landed on occasion, mainly in odd-numbered years. Chum salmon (*O. keta*) and sockeye salmon (*O. nerka*) are rarely seen in California.

Salmon fisheries existed in California long before European settlers made their first appearance in the state circa 1775. Harvests of Central Valley salmon by American Indians may have exceeded 8.5 million pounds annually. In northern coastal areas, native peoples subsisted primarily on salmon. Not only did salmon form the bulk of their diet – a family might eat up to 2,000 pounds of fish in a year – but it was also used as barter with other tribes. Salmon was consumed fresh or dried and smoked for later use throughout the year. The fish were of such significance to these early fishers that ceremonies and rituals honoring their existence and importance were created. Traditional fishing methods included the use of gill and dip nets, fishing spears, and communal fish dams.

Commercial salmon fishing in California began in the early 1850s, coincidental with the massive inflow of miners into the gold country. By 1860, these gillnet salmon fisheries were well established in Suisun Bay, San Pablo Bay, and the lower Sacramento and San Joaquin Rivers. The fishery gradually spread to include rivers north of San Francisco, although the Sacramento-San Joaquin fishery remained the largest. Growth of this fishery was stimulated by the canning industry; the first salmon cannery on the Pacific coast started operations on the Sacramento River in 1864. By 1880, there were 20 canneries operating in the Sacramento-San Joaquin river system and intensified fishing efforts provided them with an ample supply of salmon for processing. The fishery reached its peak in 1882 when about 12 million pounds were landed. Shortly thereafter, the fishery collapsed due to a sudden decline in salmon stocks caused primarily by the pollution and degradation of rivers by mining, agriculture, and timber operations combined with increased landings. By 1919, the last cannery had shut down and one by one, the rivers were closed to commercial fishing. Legislation closed the Mad River fishery in 1919, the Eel River fishery in 1922, and fisheries (including tribal) on the Smith and Klamath rivers in 1933. In 1957, the last inland commercial fishing area open to the general citizens of California (Sacramento-San Joaquin rivers) was permanently closed.

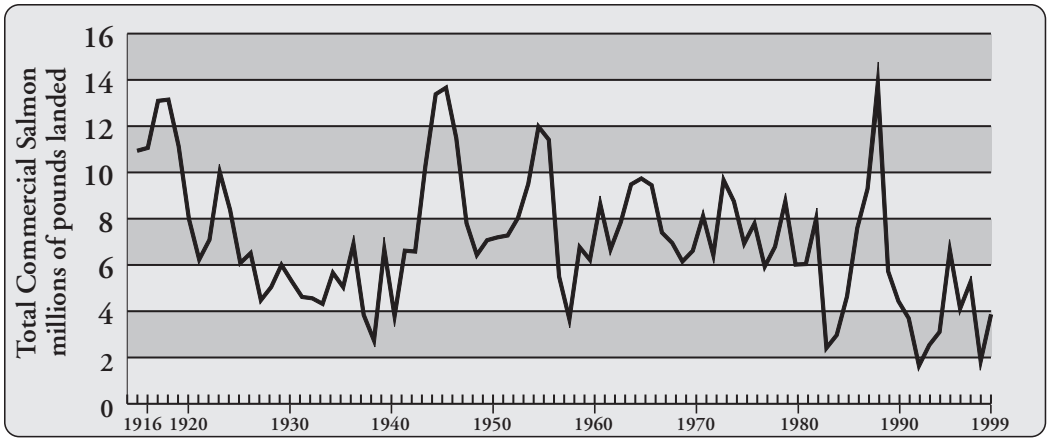
The commercial ocean troll fishery began in Monterey Bay during the 1880s. These early fishers trolled for salmon using small sailboats that supported two hand rods, one over each side with one hook and leader attached to each line. The leader was approximately 30 feet long and carried a lead sinker midway between the main line and the lure. Circa 1908, several Sacramento River fishermen transported their powered gillnet boats to Monterey Bay and began trolling for salmon. These boats were a great improvement over the sailboats, but were still small compared to present standards. The fishery grew to approximately 200 boats and by 1916, had expanded north to Fort Bragg, Eureka, and Crescent City.

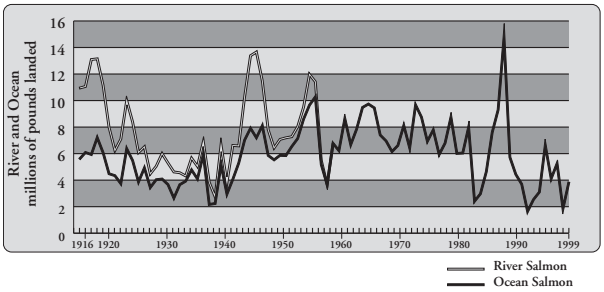
During the 1920s and 1930s, a typical salmon troller fished four to nine lines that each carried five or more hooks with up to 30 pounds of lead attached to keep the line at the proper depth. Pulling weights, lines, and salmon onto a moving boat by hand was a backbreaking job. Power gurdies were soon developed to pull the lines and, by the late 1940s, most of the professional salmon trollers



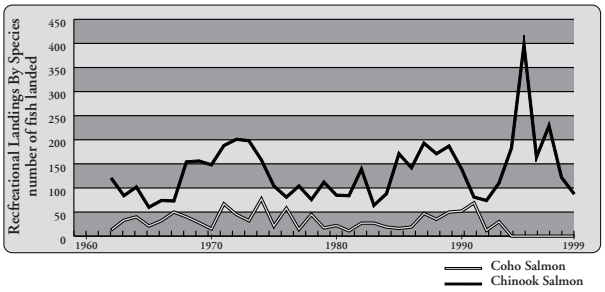
Chinook Salmon, *Oncorhynchus tshawytscha*
Credit: DFG

Commercial Landings 1916-1999, All Salmon
Catch Data includes salmon taken in the ocean, and coastal rivers including the Sacramento and Klamath. The Klamath River commercial fishery closed after 1933; and the Sacramento commercial fishery closed after 1959. Coho were no longer permitted for take after 1992.
Data Source: DFG Catch Bulletins and commercial landing receipts.

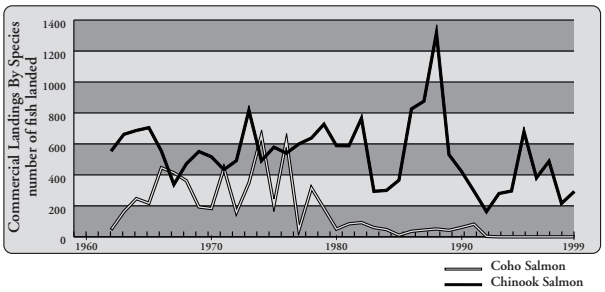




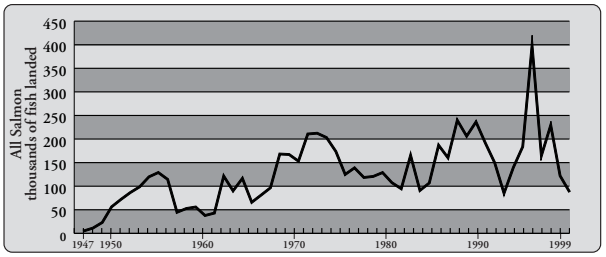
Commercial Catch 1947-1999 , River and Ocean
Data Source: DFG Catch Bulletins and commercial landing receipts. Catch Data includes salmon taken in the ocean, and coastal rivers including the Sacramento and Klamath. The Klamath River commercial fishery closed after 1933; and the Sacramento commercial fishery closed after 1959. Coho were no longer permitted for take after 1992.



Recreational Catch 1960-1999 , By Species
Data Source: DFG, Ocean Salmon Project. Differentiation by salmon species (chinook or coho) was not reported prior to 1962. Coho were no longer permitted for take after 1992.



Commercial Catch 1960-1999 , By Salmon Species
Data Source: DFG Ocean Salmon Project. Coho were no longer permitted for take after 1992.



Recreational Catch 1960-1999 , All Salmon
Data Source: DFG, commercial passenger fishing vessel logbooks.

1940s. After the end of World War II, a significant increase in fishing effort occurred in conjunction with improved transportation and a rebound in salmon populations. In 1935, an estimated 570 trollers were active in the fishery; by 1947 the fleet had nearly doubled to 1,100 vessels. During the 1970s, the salmon fleet grew to almost 5,000 vessels and included many summer fishers who had other jobs during the remainder of the year. Some of these fishers were serious about commercial fishing and had adequate ocean-going boats, but most used small sport-type boats that could be conveniently towed on a trailer.

Today's salmon troller still uses the basic fishing techniques developed during the 1940s, including powered gurdies and four to six main trolling lines. Now, however, the vessels are also equipped with various electronic devices that greatly aid in finding and staying on the fish. Radio communications are possible among several vessels simultaneously over large distances. Highly sensitive sonar

equipment aids the troller in finding the salmon or baitfish schools and in pinpointing the depth at which to position lures. Precise vessel positioning is made possible through the use of global positioning systems. It is easy today to replicate a troll path or "tack" within a few feet of a previous or suggested path. Collectively, these instruments have probably more than doubled the efficiency of the modern troller compared to 70 years ago.

Estimates of commercial salmon catches are available in one form or another for years as early as 1874. In 1952, DFG began a systematic sampling of commercial ocean salmon landings. During the 1960s and 1970s, the industry enjoyed relatively high and consistent harvests, mainly of chinook, averaging about seven million pounds dressed weight. The following two decades produced much more variable catches. The largest commercial landings observed in California occurred in 1988 when more than 1.3 million chinook (14.4 million pounds) and 51,000 coho (319,000 pounds) were landed. The lowest landings occurred in 1992, an El Niño year, when only 163,400 chinook (1.6 million pounds) and 2,500 coho (11,300 pounds) were taken in the commercial fishery. Although oceanic and in-river conditions play a major role in salmon catches, variation among years can also be attributed to changes in fishery regulations; since 1988, progressively more restrictive regulations have been placed on the fishery to protect salmon stocks of special concern.

The state's jurisdiction over tribal commercial fishing in the Klamath Basin was challenged in 1969 when a Yurok fisherman had his gillnets confiscated for fishing on the lower Klamath River. After years in the lower courts, the First District Court of Appeals decided the issue in 1975 and found that the right of a tribal member to fish on a reservation was created by presidential executive order, which was derived from statute and thus not subject to state regulation. In 1977, the Bureau of Indian Affairs (BIA) took over the management of tribal reservation fisheries in the Klamath Basin and the lower 20 miles of the Klamath River was opened to tribal gillnet fishing for subsistence and commercial harvest; however in 1978, the BIA closed the fishery. The so-called conservation moratorium remained in effect until 1987 when the BIA reopened commercial fishing by American Indians on the lower Klamath River. In 1993, the Department of the Interior determined that the Yurok and Hoopa Valley Indian tribes possessed a federally reserved right to harvest 50 percent of the total available harvest of Klamath Basin salmon.

Ocean sport fishing for salmon became popular with the development of the commercial passenger fishing vessel (CPFV) industry after World War II. In 1962, the department expanded its dockside monitoring to include recreational landings (private skiffs and charterboats). Between 1947 and 1990, the sport industry contributed about 17 percent to the total salmon catch annually in California. During the last decade, however, the sport fishery has accounted for about 31 percent of the total landings due to increased regulation of the commercial fishery. The catch has also been more evenly distributed between CPFVs and private skiff anglers. Before the 1990s, CPFVs accounted for more than 65 percent of the salmon catch; during the 1990s, CPFVs landed 51 percent of the total sport catch. The highest sport landings occurred in 1995 when sport anglers landed a record 397,200 chinook salmon; the lowest landings during the last 30 years occurred in 1983, following the extreme 1982-1983 El Niño event.

During the 1990s, a fishing technique known as mooching gained popularity among salmon sport anglers in California. Mooching is generally used when salmon are feeding on forage fish such as anchovies or herring in fairly shallow, nearshore areas. Mooching differs from trolling in that the bait is drifted to resemble dead or wounded prey instead of being pulled through the water to simulate live swimming prey. When trolling, the hook generally sets itself as the salmon attacks the moving prey whereas during mooching, line is fed out to the salmon when it strikes to encourage the salmon to swallow the bait and hook. Thus more salmon are gut-hooked when caught by mooching. Onboard observations conducted by the department's Ocean Salmon Project (OSP) on commercial passenger fishing vessels during 1993-1995 found that 60 percent of the sublegal salmon (<20 inches total length) caught via mooching were hooked in the guts or gills. Since studies have found that 80 to 90 percent of sublegal salmon hooked in the gut or gills die, there was concern that this new fishing technique could seriously impact stocks of special concern. Beginning in September 1997, all sport anglers mooching with bait were required to use circle hooks to reduce the hooking mortality on all released salmon. Studies conducted by OSP during 1995 through 1997 found that the use of circle hooks significantly reduced the hooking mortality on sublegal salmon.

Salmon Management History

In 1948, the Pacific Marine Fisheries Commission (PMFC) was formed by the states of Alaska, Washington, Oregon, Idaho and California. A primary objective of the compact was to make better use of the marine resources shared by the member states. Prior to that time, there was minimal coordination of marine fishing regulations between the states. For example, in 1947 California had a 25-inch minimum size limit and an April 1 to September 15 season for both chinook and coho. Washington and Oregon both had a 27-inch limit and year-round season for chinook and

a July 1 to November 15 season for coho. Washington had an 18-inch limit for coho, while Oregon had no size limit for the species. The first commercial salmon recommendation of the PMFC was a 26-inch total length minimum size and March 15 to October 31 maximum season length for chinook. For coho the recommended season was June 15 to October 31 except that California could open May 1 provided it retained its 25-inch minimum size limit for the species. For many years the states uniformly adopted the 26-inch standard and an April 15 opening date for commercial chinook fishing with a general September 30 closing date. The coho season opening was June 15 in both Oregon and Washington with no, or a very low, minimum size limit. California retained its 25-inch coho standard until about 1970 when it was dropped to 22 inches and the season opening date delayed until May 15.

In 1976, the Magnuson Fishery Conservation and Management Act (Act) established the Exclusive Economic Zone and the authority of the Secretary of Commerce to manage fisheries covered under federal fishery management plans from 3 to 200 miles offshore. The Act created regional fishery management councils to develop fishery management plans (FMPs) and recommend fishing regulations to the states, tribes, and the National Marine Fisheries Service (NMFS). It also created the Pacific Fishery Management Council (PFMC) that had management authority over the federal fisheries off the coasts of Washington, Oregon and California. Representation on the PFMC currently includes the chief fishery officials of California, Idaho, Oregon, and Washington, the NMFS, a Tribal representative, and eight knowledgeable private citizens. The PFMC receives advice from a Salmon Technical Team and an advisory panel of various industry, tribal, and environmental representatives. The PFMC's salmon plan was developed in 1977 and was the first FMP developed by the organization. The PFMC annually develops management measures that establish fishing areas, seasons, quotas, legal gear, possession and landing restrictions, and minimum lengths for salmon taken in federal waters off Washington, Oregon, and California. The management measures are intended to prevent overfishing and to allocate the ocean harvest equitably among ocean commercial and recreational fisheries. The measures must meet the goals of the FMP that address spawning escapement needs and allow for fresh water fisheries. The needs of salmon species listed under the federal Endangered Species Act (ESA) must also be met as part of the process. The measures recommended by the PFMC must be approved and implemented by the U.S. Department of Commerce.

During the 1980s, California ocean salmon fisheries were increasingly regulated under quotas and area closures. In 1980, a moratorium was placed on the issuance of permits to new participants in the ocean commercial salmon fishery. This was done to increase profits of individual fishermen and to reduce overall fishery impacts on the resource. In 1983, a limited-entry program was implemented that capped the fishery at just over 4,600 commercial salmon vessels.

In 1989, Sacramento River winter-run chinook was listed under the California and federal endangered species acts. This, and subsequent listings, added another dimension to salmon management. The ESA requires that NMFS assess the impacts of ocean fisheries on listed salmon populations and develop standards that avoid the likelihood of jeopardizing their continued existence. As more salmon populations have become listed, the ESA "jeopardy standards" have become a dominant factor in shaping ocean fisheries.

NMFS has concluded that the harvest of the relatively abundant Central Valley fall chinook stocks could continue at reduced levels without jeopardizing the recovery of listed chinook and coho populations. The California Fish and Game Commission, PFMC and NMFS have implemented various protective regulations to reduce fishery impacts on California populations of Central Valley winter and spring chinook, and coastal chinook and coho, all of which are listed. The PFMC began in 1992 to severely curtail the ocean harvest of coho salmon in California due to the depressed condition of most coastal stocks. Following the federal listing of California coho stocks in 1996 and 1997, NMFS extended the protective measures to a complete prohibition of coho retention off California.

Although not listed under the ESA, Klamath River fall chinook salmon have continued to play an important role in shaping ocean fishing seasons. Ocean harvests of chinook must be constrained to meet the spawning escapement goal of the Klamath River fall chinook and to provide for the federally reserved fishing rights of the Yurok and Hoopa Valley Indian tribes.

Status of Biological Knowledge

Pacific salmon are anadromous (they migrate from the ocean to the freshwater streams to spawn) and semelparous (die after spawning). Both chinook and coho salmon have similar spawning requirements and habits. Successful spawning requires water temperatures less than 56° F, clear water, suitable gravel riffles, and a stream velocity sufficient to permit excavation of nests (redds) and provide high subgravel flow to the deposited, fertilized eggs. The female digs the nest, lays the eggs, and covers them after the male fertilizes them. After a period of time, depending primarily on water temperature (usually 50 to 60 days in California), the eggs hatch into yolk sac larvae (alevins), which remain buried in the

gravel until the yolk sac is absorbed. The young salmon (fry) wriggle up out of the gravel and begin feeding on microscopic organisms.

When the salmon are about two inches long, their backs become brown and their bellies a light silver so that they blend inconspicuously with their background. Referred to as fingerlings, the length of stream-residency by these juveniles varies according to species and race. Following a period of rapid growth, the salmon begin changing physiologically in preparation for life in the ocean. A young salmon that has undergone the anatomical and physiological changes that allow it to live in the ocean is called a smolt. Following an instinctive internal cue, the smolts begin migrating in schools downstream towards the ocean. Many of the fish pause in estuaries, remaining there until the smoltification process is completed. The salmon then enter the sea where they begin a period of rapid growth. After spending two to six years in the ocean, depending on species, the sexually mature salmon begin their arduous journey upriver.

Chinook salmon

Chinook are the largest of the salmon species. Historically, juvenile chinook have been reported in coastal streams as far south as the Ventura River in southern California. Currently, they spawn in suitable rivers from the Sacramento-San Joaquin system northward. Spawning migrations can require minimal effort, with spawning occurring within a few hundred feet of the ocean, or it can be a major undertaking, with spawning occurring hundreds of miles upstream. In addition, dams and other diversion structures can seriously impede the upstream passage of adults by creating physical barriers and confounding migration cues due to changes in river flow and water temperatures.

The female chinook selects a nesting site that has good subgravel flows to ensure adequate oxygenation. Since chinook eggs are larger and have a smaller surface-to-volume ratio, they are also more sensitive to reduced oxygen levels than eggs of other Pacific salmon. Female chinook will defend their redds once spawning has begun and will stay on the nests from four days to two weeks, depending on the time in the spawning period. Spawning adults can be easily chased off redds by minor disturbances which may result in unsuccessful spawning. At the time of emergence, fry generally swim or are displaced downstream, although some fry are able to maintain their residency at the spawning site. As they grow older, the fingerlings tend to move away from shore into midstream and higher velocity areas. Once smoltification is complete, the young chinook migrate to the ocean, where they tend to be distributed deeper in the water column than other Pacific salmon species.

Chinook spend two to five years at sea before returning to spawn in their natal streams. The small percentage of chinook that mature at age two are predominately males and are commonly referred to as "grilse," or "jacks." The older age classes of chinook are composed of about equal proportions of males and females.

The state record for a sport-caught chinook is 88 pounds, landed by an angler on the Sacramento River in 1979. The largest chinook on record is a 127-pounder taken from a trap in Alaska. Ocean fisheries can have a significant impact on the average age of spawning chinook because ocean-fishing gear often selects for larger, older fish. In addition, minimum size limits allow for the harvest of chinook in the sport fishery starting at age two (20-inch minimum) and in the commercial fishery at age three (26-inch minimum). As ocean harvest rates increase, the average age of adult spawners declines. Fish destined to mature at age five must survive two more years of ocean fisheries than fish destined to mature at age three. It has not been documented that the selectivity of the ocean fisheries for older maturing fish has adversely affected the genetics of the populations, but it has probably reduced the utilization of spawning habitats that are best suited for larger, older fish. Larger fish, for example, are probably better able to utilize the larger gravel found in the main stems of most river systems. High rates of ocean harvest in recent decades have led to the virtual disappearance of five-year-olds in chinook salmon runs throughout the state.

All Pacific salmon exhibit a strong tendency to return at a specific time each year to spawn in their natal streams. This has resulted in the development of distinct stocks, or populations, within each species that are, to varying degrees, both reproductively and behaviorally isolated. Stocks are often grouped into "runs" based on the time of the year during which their upstream spawning migration occurs. There are four distinct chinook runs in California - fall, late-fall, winter, and spring. In a river where all four runs of chinook spawn, adults migrate upstream and juveniles migrate downstream during all months of the year. The timing of chinook spawning is often influenced by stream flow and water temperature, and therefore

Steelhead, *Oncorhynchus mykiss*
Credit: DFG

varies somewhat from river to river, and even within river systems.

All four runs use the Central Valley (Sacramento River-San Joaquin River) basin with the fall run being the most numerous. Historical runs of winter and spring chinook in the upper Sacramento drainage were significantly reduced by the construction of Shasta Dam in 1945. Spring chinook also formed a major run in the San Joaquin River, but the completion of Friant Dam in 1942 contributed to the run's subsequent extinction.

On the coast, the Klamath, Eel, Mad and Smith rivers have fall and late fall runs. Spring chinook are also present in several streams within the Klamath River basin and occasionally appear in the Eel and Smith rivers. In the Klamath Basin, the abundance of spring and fall chinook are believed to have been comparable prior to the completion of barrier dams in upper river areas in the late 1800s. Smaller coastal rivers have only fall chinook.

Fall run. Fall chinook salmon are the most numerous salmon in California today. They arrive in spawning areas between September and December, depending upon the river system, but peak arrival time is usually during October and November. Under current ocean harvest rates, the fall chinook runs are dominated by three-year-old fish followed by jacks and four-year-olds. Five-year-old fish are rare. Spawning occurs in the main stem of rivers, as well as in tributaries, from early October through December. In general, there is a large outmigration of fry and fingerlings from the spawning areas between January and March. An additional outmigration from the spawning areas, consisting primarily of smolts, occurs from April through June. The juveniles enter the ocean as smolts between April and July.

Late fall run. In California, late fall chinook salmon are found primarily in the Sacramento River system, but have been reported from the Eel River as well. They arrive in upper-river spawning areas between October and mid-April. The runs of late-fall chinook tend to consist of equal numbers of three and four-year-old fish. Spawning occurs from January through mid-April, primarily in the main stem of the Sacramento River. Some of the juveniles start migrating seaward as fry during May, but the bulk of the juveniles leave the upper river between October and February. Late fall smolts enter the ocean between November and April.

Winter run. Winter chinook salmon are unique to the Sacramento River system. Adults arrive in the upper Sacramento River spawning area from mid-December through early August, with a peak in March. Spawning occurs primarily in the main stem of the upper Sacramento River below Shasta Dam between late-April and mid-August. May and June are peak spawning months. The juveniles migrate seaward from early July though the following March, but the bulk of the juveniles move seaward in September. Winter-run smolts enter the ocean between December and May. The adults mature and spawn as three-year-olds, unlike the other races, which include many four-year-old fish. Because of winter chinook's unique life history, ocean fisheries, which are structured to harvest the more abundant fall chinook runs during spring and summer months, have less of an impact on winter chinook than on other runs.

Spring run. Spring chinook salmon arrive in the spawning areas between March and June, with the peak time of arrival usually occurring in May or June, depending upon flows. They rest in the deep, cooler pools during the summer and then move onto the gravel riffles and spawn between late August and early October. Emergence of fry varies among drainages with fry emerging in some tributaries as early as November, while fry in other areas wait until late March to appear. Juveniles either exit their natal tributaries soon after emergence or remain throughout the summer, exiting the following fall as yearlings, usually with the onset of storms starting in October. Yearling emigration from the tributaries may continue through the following March, with peak movement usually occurring in November and December. Juvenile emigration alternates between active movement, resting and feeding. Juvenile salmon may rear for up to several months within the Delta before ocean entry. Spring chinook runs tend to be dominated by three-year-old fish followed by four-year-olds and jacks.

Ocean distribution. The development and widespread use of the coded wire tag since the mid-1970s have provided extensive data on the ocean distributions of Pacific coast salmon stocks. Tagging studies in California, particularly on Central Valley and Klamath River fall chinook salmon stocks, have provided better definition of the coastal areas used by these stocks, as well as the mix of stocks in a particular ocean area. Although Central Valley fall chinook are distributed primarily off of California and Oregon, some fish have ventured as far north as Alaska. Klamath River fall chinook are more narrowly distributed between Point Arena in northern California and Cape Falcon in Oregon. Ocean conditions have been found to affect the ocean distribution patterns of these and other Pacific coast salmon stocks.

Coho salmon

Coho salmon are smaller than chinook salmon; the average size of a mature coho is seven to 12 pounds. The California record for a sport-caught coho salmon is 22 pounds, taken on Paper Mill Creek (Marin County) in 1959. The world record is a 33-pound sport-caught coho landed in British Columbia.

In California, coho spawn in suitable streams from northern Monterey Bay northward, but they rarely enter the Sacramento-San Joaquin River system. Coho enter many small coastal streams that are not utilized by chinook, but they also spawn in some larger river systems where chinook occur. Compared to chinook salmon, there are relatively few coho in California today. Most California streams utilized by coho salmon are short in length, but some coho do make relatively long migrations, particularly into the Eel River system. Many smaller coastal rivers have runs of coho salmon that enter during brief periods after the first heavy fall rains and move upstream.

Within California river systems, coho salmon populations include only one race, or run, which is generally consistent as to spawning area used and time of spawning. Most spawning occurs between December and February. The juveniles usually spend a little more than a year in fresh water before migrating to the ocean; a few spend two years. Most coho mature at the end of their third year of life. Coho salmon older than three years are relatively rare. A few males, or grilse, mature at age two.

Genetic analysis of California coho populations has indicated a wide degree of mixing of the stocks in the past, probably reflecting past stocking and transplantation practices involving hatchery fish.

Coded wire tagging of California hatchery coho stocks has indicated that nearly all are harvested in ocean fisheries in their third year of life. Some are caught as far north as the central Washington coast, but most are caught within 100 miles of the stream from which they entered the ocean.

Status of Spawning Populations

Central Valley Fall Chinook - Fall chinook are the most abundant of the four races of Central Valley salmon,

Baird Station, first Pacific Coast salmon hatchery.
Photo courtesy of Smithsonian Institution.

Members of the Wintu tribe drying salmon on the McCloud River, circa 1882.
Credit: Thomas Houseworth, U.S. Fish Commission. Photo courtesy of Smithsonian Institution.

spawning predominately in the Sacramento River basin. The run is heavily supplemented by production at five hatcheries. The spawning populations of fall chinook in the Sacramento and San Joaquin river drainages averaged about 340,000 between 1953 and 1963; 209,300 from 1970 to 1979; 249,800 from 1980 to 1989; 166,600 from 1990 to 1995; and 365,700 from 1996 to 2000. The recent increases in spawning runs, as well as commercial and recreational harvests, suggest a reversal in the decline of fall chinook, which hopefully will be sustained through the various restoration efforts to rebuild salmon stocks in the Central Valley. In addition, since fall chinook is one of the primary stocks harvested by ocean fisheries in California, the more restrictive regulations applied on these fisheries in recent years appears to have also improved their freshwater returns.

Central Valley Spring Chinook - Spring chinook, which were historically the second most abundant run, now spawn in relatively small numbers in streams in the northern Sacramento River basin. Spawning populations increased during the late 1990s, particularly the Deer and Butte Creek stocks. Spring chinook are listed as threatened under the ESA (1999) and CESA (1999).

Central Valley Late-fall Chinook - Late-fall chinook spawn primarily in the main stem of the Sacramento River. The run, which was not identified until the construction of a dam and fish ladder at Red Bluff enabled monthly counts of spawners, averaged about 25,000 from 1967 to 1976, 9,500 from 1977 to 1986 and 10,400 from 1987 to 1994. More recent estimates of run size have been made difficult by changes in the operation of the Red Bluff Diversion Dam.

Sacramento River Winter Chinook - Winter chinook was the first anadromous fish to receive protection under the ESA (1989), following its listing under CESA (1989). Winter chinook no longer exist in any of its original spawning habitat above Shasta Dam and the run persists only because of the new habitat created by cold water releases from the dam into the mainstem Sacramento River. The spawning populations below Shasta declined from the 20,000 to 80,000 fish observed in the 1970s to a few hundred in the early 1990s. Spawning populations between 1998 and 2000 numbered between 1,400 and 3,200 fish.

Coastal Populations - Coastal California streams support small populations of coho and chinook salmon. Habitat blockages, logging, agriculture, urbanization and water withdrawals have resulted in widespread declines of both species. All coastal coho populations in California are listed as threatened under the ESA and coho south of San Francisco are listed as threatened under CESA. Coastal chinook south of the Klamath River are listed as threatened under the ESA (1999).

Klamath Basin - The recovery and analysis of coded wire tagged fish produced at the two hatcheries in the Klamath Basin allow estimates of ocean abundance. Pre-fishing season abundance of fall chinook during the 1980s averaged 395,000 fish; during the 1990s, the average decreased to 164,000 and included very low abundance in 1991 and 1992. In 2000-2001, the pre-fishing season abundance of fall chinook averaged 400,000. Spring chinook in the Trinity and Salmon rivers in the Klamath Basin have been at very low levels in recent years.

Many salmon anglers are attracted to rivers north of Monterey County. Historically, almost half of the effort was in the Sacramento-San Joaquin River system. Most of this activity occurs upstream from the city of Sacramento. The main stem of the Sacramento River is the most important Central Valley stream, followed by the Feather and American rivers. Of the coastal streams, the Klamath system receives by far the most effort, followed by the Smith and Eel systems. Much of the fishing in coastal river systems occurs in estuaries. The Klamath and Smith River mouths draw large numbers of anglers from great distances and concentrate them in a small area. The term "madhouse" is appropriate during the peak of a good run. The catch in both of these rivers consists of chinook salmon.

Past over-harvest has undoubtedly contributed to the current plight of salmon. However, harvest constraints, which are easily and quickly implemented, have no effect on the root causes of the decline of wild salmon. Reasons for the decline in California's salmon populations vary somewhat from river to river, but there are two major causes: (1) destruction or loss of habitat, and (2) water diversion.

In the Central Valley, a multitude of factors has contributed to the decline. These include several hundred unscreened irrigation diversions in the Sacramento Valley, 1,800 unscreened diversions in the Delta and about 150 unscreened diversions in the San Joaquin Valley; poor or lost gravel deposition in salmon spawning and rearing areas; pollution; aberrant river flow fluctuations caused by alternating water-release schedules from dams to meet downstream water-quality standards and water diversion contracts; elevated water temperatures stemming from power generation operations and reduction in cold water storage as reservoirs are emptied to meet agricultural contracts; and impediments to migration such as dams or diversions. The massive export of water from the southern Sacramento-San Joaquin Delta has probably been the greatest cause of decline in Central Valley salmon.

Red Bluff Diversion Dam on the upper Sacramento River continues to be an impediment to adult upstream migration, a major point of diversion and loss of downstream migrating juveniles, and a haven for predatory Sacramento pikeminnow. Lifting of the gates at this facility has been implemented in the fall through spring to protect all races

of chinook; alternative diversion facilities are being evaluated that would allow the dam to be removed.

Declines in coastal river chinook and coho salmon populations have been caused by many of the same factors. But, in addition, these areas have been affected by past and, in some instances, present timber harvest practices. These practices have reduced stream shading, resulting in high temperatures, and have accelerated erosion and filling of pools.

Although many of California's naturally spawning populations are listed as threatened or endangered, the production of large numbers of salmon by state and federal hatcheries has continued. The trucking of fish from state hatcheries in the Central Valley for release in the lower Delta began in the late 1970s. The program was started with the intent of bypassing the many hazards that were known to exist for juvenile salmon in the lower river and Delta areas. Tagging studies have shown that survival of trucked fish is much higher than fish released at the hatchery and the program has continued to this day. The average annual escapement of fall chinook to the Central Valley between 1995 and 2000 was almost 85 percent greater than the average observed during the previous 25 years (1970-1994) and was due primarily to the restrictive regulations placed on ocean salmon fisheries in recent years. When salmon return to the Central Valley in near record numbers, the public understandably has difficulty appreciating the need for harvest constraints to protect endangered salmon. Commercial and sport fishermen expect fishing regulations that permit harvest of the hatchery "surplus." Full utilization of hatchery production subjects naturally spawning fish, which cannot sustain nearly as high a rate of harvest as hatchery stocks, to over-harvest. Responsible hatchery management means not only producing a healthy and robust fish, but also educating sport and commercial fishermen on the importance of managing the fisheries for natural production while accepting a surplus of hatchery adults.

Salmon: Discussion

Challenges to Inland Salmon Management

Maintaining salmon runs in California depends on the restoration and preservation of the state's rivers and streams as living systems. A poor law or regulation affecting fishing can be changed long before the damage it causes becomes permanent, but a stream that is blocked near its mouth by an impassable dam will produce no more salmon. A stream kept dry through the spawning season by diversion is no better, but may prove salvageable if water can eventually be provided. Diverting all the water from a stream during the downstream migration period of juveniles will prevent any of them from reaching the ocean, even if adequate fish screens are in place to keep them from entering the irrigation canals. Reducing stream flows or shade may result in a stream becoming too warm for salmon. Siltation from logging or road construction can smother salmon eggs and suppress production of aquatic invertebrates upon which the young fish depend for food.

Substantial efforts have been made during the past decade to ensure that the ecological requirements of anadromous fish receive equal consideration with all the other economic and social demands placed on the state's water resources. The Central Valley Improvement Act of 1992 required a program designed to double natural production of anadromous fish in Central Valley streams. In 1995, the federal government and California initiated the CALFED Bay-Delta program to address environmental and water management problems associated with the Bay-Delta system. The primary mission is to develop a long-term comprehensive plan that will restore ecological health and improve water management for the beneficial uses of the Bay-Delta system.

Although the listing of salmon populations under the ESA has meant new restrictions on recreational and commercial fishing, it has also provided a mechanism for addressing the effects of dams, irrigation diversion, logging, road construction, etc. on aquatic environments. Species management under provisions of the ESA requires that existing and proposed federal actions and permitted activities be conducted in a manner that will not jeopardize the continued existence of the animal or result in the destruction or adverse modification of habitat essential to the continuation of the species. Federal agencies must consult with NMFS when they propose to authorize, fund, or carry out an action which could potentially adversely affect listed salmon or steelhead. Likewise, state-sponsored activities that might affect state-listed species must be reviewed under the provisions of CESA.

Typical commercial salmon troller
Credit: Chris Dewees, CA Sea Grant Extension Program

Hatchery fish have been important to maintaining ocean and in-river fisheries, but have incorrectly been perceived as a viable alternative to maintenance of natural spawning populations. Unfortunately, a successful hatchery program can mask the decline in the natural run due to straying of the returning adults, and this appears to be the case for chinook in many areas of the Central Valley and the Klamath River basin. Hatchery adults spawning in the wild can compete with naturally produced fish for adult spawning and juvenile fish rearing areas. Interaction of hatchery and naturally produced salmon is most acute in the close vicinity of the rearing facilities. Battle Creek below Coleman Hatchery and Bogus Creek adjacent to Iron Gate Hatchery typically are overloaded with spawning fish each fall due to straying of hatchery adults. Trucking operations in the Central Valley have greatly increased hatchery fish survival by reducing in-stream losses of fish to diversions and predators but have also increased the rate of straying of returning adults, possibly to the detriment of the naturally produced fish.

Challenges to Ocean Management

Ocean salmon fisheries harvest a mixture of stocks that can differ greatly in their respective abundance and productivity. It has long been recognized that the management of mixed stock salmon fisheries is difficult and complex; fisheries supported by hatcheries can deplete less productive, naturally produced stocks unless programs are in place to monitor and evaluate their status and make necessary adjustments in harvest. Ideally, some differences in distribution of "strong" and "weak" stocks exist that allow managers to develop measures that selectively protect stocks of concern.

NMFS has concluded that the harvest of the relatively abundant Central Valley fall chinook stocks may continue at reduced levels without jeopardizing the recovery of listed California chinook populations. The California Fish and Game Commission, PFMC and NMFS have implemented various protective regulations to reduce fishery impacts on California populations of Central Valley winter and spring chinook, and coastal chinook and coho, all of which are listed. In 1992, the PFMC began to severely curtail the ocean harvest of coho salmon in California due to the depressed condition of most coastal stocks. Following the federal listing of California coho stocks in 1996 and 1997, NMFS extended the protective measures to a complete prohibition of coho retention off California.

Ocean abundance estimates are not available for any of California's listed salmon and harvest rates are subject to speculation. Determining levels of harvest that are appropriate for recovery is challenging. Without age-specific mortality estimates it is difficult to assess the relative effects of reductions in harvest, improvements in freshwater habitats, and changes in ocean productivity or precipitation. An incremental approach to harvest reductions seems to have produced encouraging results with respect to winter chinook. At the time of listing, spawning populations were estimated at less than 200 fish and by the end of the 1990s had increased to several thousand.

In recent years, test fisheries have been conducted off California, which apply the methods of genetic stock identification (GSI) to estimate the contribution of various stocks of chinook to catches. GSI detects the presence of certain proteins that are characteristic of various populations, both hatchery and naturally produced. The technique can be used to verify the coded wire tag data associated with hatchery stocks as well as to estimate the catch of relatively small numbers of naturally produced fish, which would not normally be available for marking with coded wire tags. The test fisheries were initially undertaken with the hope of identifying previously unrecognized distributional differences between Central Valley fall chinook and Klamath River fall chinook. As more populations of salmon have been listed under the ESA and included in the GSI baseline, the search for times and areas in which contact with stocks of concern is minimal has been made increasingly difficult. Listed species are at extremely low abundance and comprise a very small fraction of ocean catches; even GSI methods are unlikely to produce accurate estimates of ocean impacts on threatened and listed populations. When faced with the difficulties of estimating ocean distribution and the presence of salmon from such populations, it seems safest to reduce ocean harvest rates to levels sufficiently low that ocean impacts are unlikely to extinguish these weak ESA populations of salmon.

Ocean salmon managers must continually be prepared to respond to changes in the fisheries. The advent of mooching in central California led to different resource impacts. Likewise, the ocean environment continues to change, physically as well as biologically. Relative to the salmon resource, coastal water quality needs to be monitored and protected. There also appear to be increasing conflicts between ocean fishermen, both recreational and commercial, and marine mammals, in particular harbor seals and sea lions. Federal legislation aimed at protecting these animals has been very effective in increasing their numbers and has led to increased depredation on sport and commercially hooked salmon. Most of the problems have been in the marine area, particularly in the Monterey-San Francisco region, but problems have also occurred in some lower river areas, such as the Klamath River estuary where American Indian and sport anglers annually seek to harvest salmon.

Management Considerations

See the Management Considerations Appendix A for further information.

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