STATUS OF THE FISHERIES REPORT
AN UPDATE THROUGH 2011

Brailing squid. Photo credit: Department archives.

Report to the California Fish and Game Commission
as directed by the
Marine Life Management Act of 1998

Prepared by
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Marine Region
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Acknowledgements

Many of the fishery reviews in this report are updates of the reviews contained in *California's Living Marine Resources: A Status Report published in 2001*. *California's Living Marine Resources* provides a complete review of California's three major marine ecosystems (nearshore, offshore, and bays and estuaries) along with all the important plants and marine animals that dwell there. This report, along with the Updates for 2003, 2006, and 2008, is available on the California Department of Fish and Wildlife's (Department) website http://www.wildlife.ca.gov/marine/status/index.asp.

All the reviews in this report were contributed by Department biologists unless another affiliation is indicated. Author's names and email addresses are provided with each review.

The Editor would like to thank the contributors for their efforts. All the contributors endeavored to make their reviews as accurate and up-to-date as possible. Additionally, thanks go to the photographers whose photos are included in this report.

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Introduction

The Marine Life Management Act (MLMA) changed the way the California Department of Fish and Wildlife (Department) approached management of the State's marine resources. The goal of the act, which became law on January 1, 1999, was to ensure that the marine resources of the State, and the habitats upon which they depend, are used in a sustainable fashion and conserved. When species have been depleted or habitats degraded, restoration is the management goal. The Department is expected to use the best available science to guide management efforts.

Acknowledging that the Department's resources are limited, the Act also prescribed a collaborative and public involvement approach to management. This approach includes all interest groups that have a stake in the State's marine resources, users and non-users alike.

The MLMA also required the Department to prepare regular reports on the status of recreational and commercial marine fisheries managed by the State. In 2001, *California's Living Marine Resources: A Status Report* was published.

The comprehensive 2001 document provides baseline information and references on all of California's economically and ecologically important marine species. In 2004, an *Annual Status of the Fisheries Report Through 2003* was completed by the Department and updated information was provided on 14 species or species groups. In 2008, the *Status of the Fisheries Report-An Update Through 2006* was completed providing updated information on 15 species. In 2010, the *Status of the Fisheries Report-An Update through 2008* was completed providing information for 23 species or species groups. This report continues the series, with updates on 20 species or species groups, focusing on new species of interest (garibaldi, white shark, longnose skate), species with new information (California halibut, California sheephead, California spiny lobster, Dungeness crab, petrale sole, salmon), as well as new sections on algal blooms and the federal groundfish trawl individual quota program. This continuing series of reports allows those who are interested in or participants in California's marine management, to have a common and updated source of information about important marine resources. All of the mentioned reports can be found on the Department's website at: http://www.wildlife.ca.gov/marine/status/index.asp.

Several key sources of information were used in writing these species reviews. Fishery dependent data (information collected from fishermen or fishing activities) include:

- ***Commercial Fisheries Information System (CFIS)*** – Every time a commercial fisherman lands his/her catch, a landing receipt is filled out documenting the market category, poundage, gear, price paid to the fisherman, and other relevant information (FGC §8043). Market categories may be single species (Pacific bonito, sablefish) or groups of species (unidentified skate, group deep nearshore rockfish). Landing receipts have been collected since 1916 to the present.

- ***Marine Recreational Fisheries Statistics Survey (MRFSS)*** – This national survey provided estimates of the fish caught recreationally in California through interviews with anglers, creel surveys (examination of anglers' catches), and observations onboard commercial passenger fishing vessels (CPFVs). This program began in 1980, with a brief hiatus from 1990 through 1992. Northern California party/charter boat sampling was temporarily reduced from 1993 through 1995. The MRFSS program was terminated in California on December 31, 2003.

- ***California Recreational Fisheries Survey (CRFS)*** – This statewide survey began on January 1, 2004. The CRFS uses interviews with anglers, creel surveys, and observations onboard CPFVs to collect data on California's marine recreational fisheries, and estimates the catch and effort of anglers fishing for marine finfish. Beach/bank (BB) mode sampling was temporarily reduced in 2010 and BB and man made modes were reduced in 2011. Due to differences in sampling methodology MRFSS and CRFS are not directly comparable.

- ***Commercial Passenger Fishing Vessel (CPFV) logbooks*** – Every CPFV captain is required to submit a log for each fishing trip which documents the number of anglers aboard, and the species and numbers and type of fish caught and released (FGC §7923; Title 14, CCR, §190). Species may be individual (Pacific bonito, cabezon) or groups of species (unspecified rockfish, unspecified sturgeon). This program began in 1936; data for 1941-1946 are not available.

Whenever available, fishery independent data (information that is not collected from fishermen or fishing activities) was also used in the species reviews. This information is primarily research data collected by the Department, other management agencies or academics using research methodology and technology.

1 California Spiny Lobster, *Panulirus interruptus*

California spiny lobster, *Panulirus interruptus*. Credit: D Stein, CDFW.

History of the Fishery

California spiny lobster, *Panulirus interruptus*, have been fished in southern California since at least 1872. The commercial fishery originated in Santa Barbara County and expanded as the number of fishermen increased. By 1900, the fishery encompassed the entire Southern California Bight (SCB) and most of the offshore islands. Today's lobster population is the product of a century of commercial fishing with few areas historically off limits to fishermen.

Over the decades commercial landings have fluctuated, reaching a high in the early 1950s, followed by a decline until the mid 1970s (Figure 1-1). There were multiple reasons for this decline, but a major contributing factor was the landing of sub-legal size (short) lobster. Recognizing this problem, in 1957 the California Department of Fish and Wildlife (Department) implemented a minimum 2 inch by 4 inch (5 centimeter by 10.2 centimeter) mesh size requirement for commercial traps specifically to reduce the taking of short lobster. However, this gear requirement did not fully solve the problem. Consequently, in 1976, the Department required an escape port in all commercial traps. The size of this horizontal escape port enables a short lobster to freely exit the trap.

Requiring escape ports addressed the immediate problem of landing short lobster and initiated the rebuilding of the spawning stock, allowing for an associated increase in the number of legal size lobster entering the fishery. Beginning in 1976, total landings improved each season (October through March), reaching a high of 952,000 pounds (432 metric tons) during the 1997/98 season. Commercial landings have remained higher than the pre-1976 levels (pre-escape port), totaling 753,000 pounds (342 metric tons) and 695,000 pounds (316 metric tons) for the 2009-10 and 2010-11 seasons, respectively. Aside from total landings, other characteristics of the catch have been remarkably consistent over this same period of time.

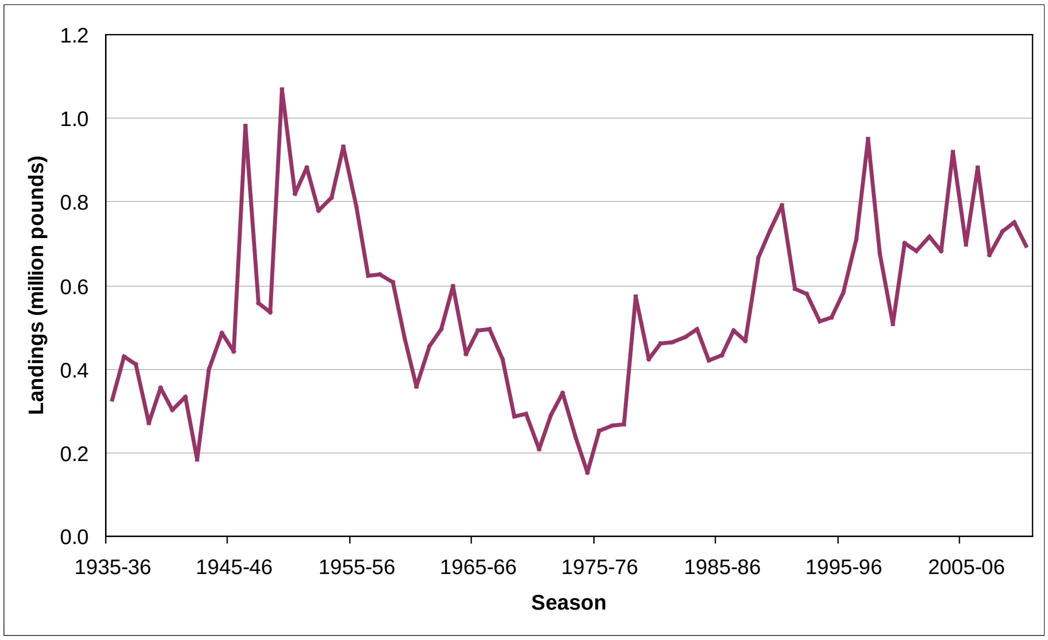

Figure 1-1. Spiny lobster commercial landings by season (October-March), 1935-36 to 2010-11. Data source: Department catch bulletins (1936-1989) and Commercial Fisheries Information System (CFIS) data (1990-2011), all gear types combined.

Since 2000, the total catch over time each season has accumulated at the same rate as each season progresses. The largest landings occur within the first two weeks of the 26-week season. Eighty percent of the season's total catch is landed by the fifteenth week of the season. The catch is usually evenly divided between three regions: Santa Barbara/Ventura counties, Los Angeles/Orange counties, and San Diego County. A relatively small area extending from Point Loma to La Jolla in San Diego has dominated the catch since at least 1975, consistently accounting for approximately 15 percent of the total southern California catch.

The average weight of an individual lobster in the catch has been fairly consistent over the last decade at 1.4 pounds (0.6 kilograms). Department lobster survey data shows that both recreational and commercial catch are composed mostly of lobster that have attained legal size within the last one or two years. Although larger sized lobster exist, the majority of the lobster catch consists of individuals that have just reached legal size. Further support for this is found in the number of short lobster released each season. Over the last decade, fishermen have had to release 70 to 80 percent of the lobster caught within the SCB each season because they were undersized. Within each county, the percentage of lobster released has also remained fairly consistent over the last decade.

The number of commercial lobster permits issued in 1998 was 274. This number has steadily declined, and in 2011 there were 197 permits issued. Since 2008, the number of lobster permits actively fished has hovered around 150. In 2005, over two-thirds of the commercial lobster permits became transferable. Permit transfers were limited to

10 per season for the first three years, and now there is no restriction on the number of permits that may be transferred. Given the high cost of these permits ($50,000-$100,000) which are sold in private transactions, it's possible that fishermen with newly acquired permits will fish more traps to recoup the cost of the permit. It's not clear if this will adversely affect the lobster population, since the majority of spawning females are undersized and cannot be retained. Since 2005, there have been 92 permit transfers, and some of those permits have been transferred more than once.

In recent years, most of the lobster catch has been exported to Asian countries. The median ex-vessel price ranged from $6.75 to $8.00 per pound ($14.90 to $17.60 per kilogram) in 2000, but by the 2010-11 season market demand from China increased the price to as high as $18.50 per pound ($39.70 per kilogram). The total ex-vessel value for the 2010-11 lobster season was $11.5 million.

In the fall of 2008, the Department required anyone recreationally fishing for lobster in California to purchase a spiny lobster report card. Prior to this, the Department had limited data on where recreational fishermen were fishing, what gear they were using, and how many lobsters were actually being caught. Now, every time a recreational fisherman is fishing for lobster, this information is required to be recorded along with the date of the trip. Lobster report cards are issued for the calendar year just like the annual fishing license. Approximately 30,000 report cards are sold each year. The return rate of cards fell from a high of 22 percent in 2008 to around 11 percent in 2010. Increased outreach, by both Department and recreational spokesmen, has helped to increase the number of cards returned. As of April 2012, a count of returned report cards from the 2011 calendar year has already reached 15 percent of the total sold.

Recreational fishermen are allowed to catch lobster by hand when skin or scuba diving, or by using hoop nets. Historically, diving was the dominant recreational method for catching lobster in southern California. In 1992, a Department recreational creel survey found that divers accounted for 80 percent of the total recorded lobster catch and hoop net gear accounted for the remaining 20 percent. In 2007, another Department recreational creel survey found the 1992 pattern had reversed, and 80 percent of the catch was made using hoop nets. This reversal is attributed to the popularization of hoop nets among the non-diving public.

Hoop nets have evolved into a more efficient gear for catching lobster. Traditional hoop nets lie flat on the bottom and only take their funnel shape when being pulled to the surface (Figure 1-2A). A slow or jerky pull can allow lobster to escape out the top or sides of the net before reaching the surface. The new hoop net design is a rigid, conical net with a smaller ring suspended above a base ring, with netting fully enclosing the space between and below. This new type of hoop net does not lie flat on the bottom, and the lobster must climb up and into the net to reach the bait (Figure 1-2B). Since the only exit is straight up through the smaller, suspended ring, and disturbed lobster tend to swim sideways, conical nets will retain more lobster during recovery regardless of the quality of the pull. A recent Department study found that conical nets caught 57 percent more lobster than traditional style nets over the course of a season. Conical hoop nets have overtaken traditional hoop nets in usage by the majority of fishermen due to their effectiveness.

A

B

Figure 1-2. Lobster hoop net styles. A) Fully expanded traditional-style hoop net. This style lies flat on the bottom during deployment and takes the pictured, basket shape when pulled. B) Rigid, conical-style hoop net. This style maintains the same shape when pulled. Bait is placed in webbing inside the small ring in both types of net. Photo credit: D Nielson, CDFW.

Since the report cards were introduced, 12 to 14 percent of returned cards have consistently reported no fishing effort for any given year. For cards reporting fishing activity, there has been a consistent average of two lobster per trip and around four trips per card. Each year, approximately 40 percent of all lobster fishing trips result in a catch of zero lobster.

Extrapolating results from returned cards to the entire recreational lobster fishery requires that assumptions be made about how many unreturned card holders actually went fishing and how many zero catch trips are recorded. With a small return rate, the uncertainty associated with any estimated figure will be large. As a consequence, the Department estimates that the size of the recreational catch falls somewhere in the range of 30 to 61 percent of the total commercial catch. The traditional view that the recreational catch is insignificant relative to the commercial catch is inaccurate. However, the recent stock assessment performed by the Department took into account both the commercial and estimated recreational catch, and assessment results suggest the lobster population is healthy and the fisheries are sustainable.

Status of Biological Knowledge

The California spiny lobster is found along the west coast of California from Monterey to Bahía Magdalena, Baja California, Mexico, with a small isolated population in the northwest corner of the Gulf of California. Very few lobster are found north of Point Conception (Santa Barbara County).

Spiny lobster are commonly found in rocky areas from the intertidal zone to depths exceeding 240 feet (73 meters). These areas often consist of plant communities dominated by giant kelp, feather boa kelp, coralline algae, and surf and eel grasses.

Spawning occurs once per year during the late spring through summer months with maximum activity in May, June, and July. Male lobster attach a gummy packet of sperm, called a spermatophore, on the underside of the female’s carapace. Females produce 50,000 to 800,000 eggs depending on the size of the female, which are carried on the underside of her tail. Females fertilize the eggs by ripping open the spermatophore with a small claw on the end of each of their last pair of walking legs, releasing the enclosed sperm. The fertilized eggs remain attached to the underside of the female’s tail until they hatch approximately 10 weeks later.

After hatching, lobster pass through 11 larval stages known as phyllosoma, which have tiny flattened and transparent bodies with spider-like legs. Phyllosoma drift with the prevailing currents feeding on other planktonic animals for up to 10 months, and have been found from the surface to depths over 400 feet (121 meters). They appear to be concentrated by prevailing oceanographic currents mostly offshore, where they have been found as far as 350 miles (217 kilometers) off the coast. The final phyllosoma stage transforms into a puerulus larva which looks like a transparent, miniature adult with extremely long antennae. Pueruli are strong directional swimmers, and are thought to swim towards the shallow water along the coast. Pueruli eventually settle into shallow, vegetated habitats where they begin a bottom-dwelling existence that will last the rest of their lives.

The spiny lobster’s outer shell serves as its skeleton, and is referred to as an exoskeleton. The shell does not grow; so, in order to make room as the lobster grows, the shell must be shed periodically. The process of shedding the exoskeleton, or molting, is preceded by the formation of a new, soft shell under the old one. After shedding the old shell, an uptake of water expands the new shell which then hardens in place. Lobster usually remain secluded for several days after shedding the old shell to allow the new shell to harden sufficiently for protection. It may take several months for the shell to harden completely. Once the molting process is over, the lobster develops tissue in place of the water used to expand the shell, and effectively grows into its new exoskeleton. A lobster does not grow in length between molts.

The number of molts per year decreases as the lobster ages and is assumed to be similar to those of the Japanese spiny lobster. In Japan, spiny lobster go through 20 molts in their first year, four molts in their second, and three molts in their third. In California, by the time lobster reach sexual maturity (3 to 9 years of age) they are molting once each year. Lobster take from 7 to 13 years to reach the legal size of 3.25 inches (8.26 centimeters) carapace length. Males grow faster than females. Growth rates for both sexes are highly variable and affected by external conditions such as food availability, water temperature, and age. Injuries and disease will often result in a slowing or complete cessation of growth until the injury has been repaired. Lobster usually spawn at least 2 to 3 times before they reach the minimum legal harvest size. The largest lobster caught on record weighed 26 pounds (11.8 kilograms). The maximum age of the California spiny lobster is unknown, but it is thought that this species lives at least 30 years or more. The majority of fishable, legal size lobster are believed to be harvested within a couple years of becoming legal size.

Lobster are known to congregate together during the day in crevices. During the night, lobster may travel great distances, averaging almost 2000 feet (610 meters) in search of food. Lobster tend to utilize areas with high algal coverage and avoid areas of open sand or mud. While lobster do sometimes return to the previously occupied shelter, they more commonly return to the same general area.

Tagging and tracking studies of lobster over the years have not documented any organized migration of lobster between inshore and offshore waters. However, Department divers have observed what was interpreted as a seasonal movement of adults. During the winter months, they found both sexes offshore in 50 to at least 100 feet (15 to 30 meters) of water. During late March and early April, female lobster moved into shallow water. Adult males began a general movement inshore in May. A similar pattern was documented in San Diego Bay where trapped lobster were almost exclusively male in May, but transitioned to mostly female during the summer months. The transition began at the mouth of the bay, progressing farther into the bay as the summer progressed. Commercial and recreational fishermen have observed that lobster are caught in shallow water when the fishing season starts and in deeper water after the onset of winter storms. Correspondingly, many commercial fishermen move their traps farther offshore as the season progresses.

Lobster are omnivorous and consume algae, as well as a wide variety of benthic invertebrates in addition to fish. They are thought to act as a keystone species preying on mussels along rocky shores and on sea urchins within kelp forests. Lobster will also feed on dead and decaying matter and have been known to be cannibalistic. Lobster are eaten by a wide variety of animals including California sheephead, cabezon, kelp bass, octopuses, California moray eels, horn sharks, leopard sharks, rockfishes, giant sea bass, and, of course, humans.

Status of the Population

In 2010 and 2011, the Department performed a stock assessment of the spiny lobster population in southern California. This assessment relied on SCB-wide Department datasets, modeled results, and published life history parameters (e.g., growth rates). Based on this assessment, the spiny lobster population off southern California appears to be stable and the fisheries targeting this species can be considered sustainable at present. Support for this conclusion follows from conditions outlined previously and include consistently large harvest levels, harvest rates, and sizes of animals caught by both the commercial and recreational fisheries.

The sub-legal population appears large and robust. The number of short lobster released as a percentage of the total SCB-wide catch has remained consistent over the decade, regardless of the overall size of the seasonal harvest. This sub-legal population is also probably responsible for the majority of seasonal spawning.

Management Considerations

The Department is currently in the process of developing a Fishery Management Plan for spiny lobster (Spiny Lobster FMP) as required by the Marine Life Management Act. The Spiny Lobster FMP will ensure a sustainable lobster resource, and healthy commercial and recreational fisheries. The Spiny Lobster FMP effort is timely because of the recent implementation of marine protected areas along the south coast of California that impact both the recreational and commercial lobster fisheries. The Spiny Lobster FMP is a multi-year project, and the draft plan is scheduled to be delivered to the California Fish and Game Commission for adoption in early 2015. The Spiny Lobster FMP will contain a management strategy evaluation procedure that will allow the Department to monitor and evaluate the health of the fishery as future data becomes available. In addition to developing the Spiny Lobster FMP, continuing existing public education and Department enforcement efforts are essential because an illegal market has always existed for shorts, which are very important to the health of the population,

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Further Reading

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Lindberg RG. 1955. Growth, population dynamics, and field behavior in the spiny lobster, *Panulirus interruptus* (Randall). Univ Calif Publ Zool 59:157-248.

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California spiny lobster commercial landings by season (October-March), 1935-36 to 2010-11.

Season	Pounds	Season	Pounds	Season	Pounds
1935-36	327,300	1961-62	455,400	1987-88	469,061
1936-37	430,900	1962-63	496,900	1988-89	667,817
1937-38	409,900	1963-64	597,000	1989-90	731,110
1938-39	271,800	1964-65	435,600	1990-91	792,260
1939-40	356,700	1965-66	492,000	1991-92	590,979
1940-41	303,500	1966-67	496,800	1992-93	579,701
1941-42	334,100	1967-68	424,200	1993-94	514,036
1942-43	182,700	1968-69	286,146	1994-95	523,132
1943-44	399,000	1969-70	294,058	1995-96	583,838
1944-45	486,300	1970-71	207,624	1996-97	711,861
1945-46	443,900	1971-72	289,520	1997-98	951,518
1946-47	980,600	1972-73	342,482	1998-99	674,878
1947-48	558,400	1973-74	237,011	1999-00	506,865
1948-49	535,200	1974-75	152,196	2000-01	702,207
1949-50	1,069,400	1975-76	251,036	2001-02	681,670
1950-51	820,400	1976-77	266,272	2002-03	717,832
1951-52	880,900	1977-78	269,016	2003-04	681,647
1952-53	777,900	1978-79	572,167	2004-05	919,809
1953-54	809,500	1979-80	423,961	2005-06	698,478
1954-55	931,700	1980-81	461,667	2006-07	881,025
1955-56	789,700	1981-82	463,321	2007-08	674,049
1956-57	624,200	1982-83	477,718	2008-09	728,186
1957-58	626,300	1983-84	495,802	2009-10	752,673

California spiny lobster commercial landings by season (October-March), 1935-36 to 2010-11.					
Season	**Pounds**	**Season**	**Pounds**	**Season**	**Pounds**
1958-59	608,500	1984-85	422,257	2010-11	695,361
1959-60	474,200	1985-86	432,550		
1960-61	360,000	1986-87	493,229		

Data Source: Department catch bulletins (1936-1989) and CFIS (1990-2011).

2 Dungeness crab, *Metacarcinus magister*

Dungeness crabs, *Metacarcinus magister*, in a crab trap caught near Bodega Bay, California. Photo credit: J Newman.

History of the Fishery

The Dungeness crab, *Metacarcinus magister* (formerly *Cancer magister*), fishery is one of the oldest commercial fisheries in California. It began in San Francisco Bay around the time of the Gold Rush and expanded as population increased in the region. Presently, Dungeness crab are taken in waters of the state from Crescent City to the Morro Bay-Avila area.

The fishery has been regulated by the California State Legislature since 1895 when reports filed by the State Board of Fish Commissioners described the subsequent effects of decreasing catch from previously fished areas, as fishermen were traveling greater distances to meet the increasing demand for crab, and suggested the Legislature oversee and restore the fishery. In 1897, the first legislative statute for the fishery was passed that prohibited the take and sale of females. In 1903, a season closure was instituted and in 1905 a minimum size limit was set at 6 inches (15.2 centimeters) across the back of the crab. Until recently, these regulations continued to be the only tools to manage the west coast states' crab fisheries and are known as the 3-S principle, which refers to sex, size, and season limits. Currently, only male crabs that are greater than 6.25 inches (15.9 centimeters) across the widest part of their carapace (CW) can be landed and the fishery is closed during the time of year when legal-sized crabs are molting and mating.

The Sonoma-Mendocino county line demarcates the central and northern management areas of California. These two distinct regions have different seasons, the central management area opens November 15 and continues through June 30, whereas the northern management area opens conditionally on December 1, provided the muscle tissue in post-molt males has adequately filled out the newly formed shell, and continues through July 15.

The recreational seasons for these two areas begin on the first Saturday of November, allowing recreational anglers an opportunity to place traps in the water a few weeks before the commercial season begins. The recreationally caught Dungeness crab size limit is lower than that for commercially caught crab, at 5.75 inches CW (14.6 centimeters) and anglers can take 10 crab of either sex per day, unless fishing from a commercial passenger fishing vessel from Sonoma to Monterey counties, where anglers are only allowed 6 crab that are 6 inches CW (15.2 centimeters) or greater. These regulations give recreational anglers a greater opportunity to fish crabs before they are subject to being caught by the commercial fishery.

Dungeness crab are primarily fished with baited traps, also referred to as crab pots. They were introduced to the Crescent City-Eureka area in 1938 and by the mid to late 1940s had replaced the hoop net as the primary method of take. The traps are made from 2 circular iron frames 3 to 3.5 feet (0.9-1.1 meters) in diameter that are connected with spokes on the outer edges. The frame is wrapped with strips of rubber and the entire frame is enmeshed with stainless steel wire. Two entrance tunnels fitted with trigger bars prevent escapement of larger crabs and every trap must contain at least two escape ports with openings not less than 4.25 inches (10.8 centimeters) for the purpose of decreasing the likelihood of catching and retaining the generally smaller females and sublegal males. In the event the trap is not recovered, traps are equipped with a destruct device to allow the eventual escape of all crabs. New legislation in 2009 now permits the incidental commercial take of other rock crab species in Dungeness crab traps and Dungeness crab in rock crab traps, provided that all crabs retained are in season and fishermen possess the proper licenses and permits.

Dungeness crab landings for both management areas have been recorded since the 1915-1916 season (November 15 through June 30 of the following year) with the passing of a legislative statute requiring all wholesale fish dealers to submit landing receipts for all fish (FGC §8043). The larger fishing grounds and more productive waters of the northern management area have generally yielded greater landings than the central area since the 1945-46 season (Figure 2-1). Central California landings peaked during the 1956-57 season at 9.3 million pounds (4200 metric tons) and subsequently declined while remaining depressed until this past decade when landings finally surpassed 5.0 million pounds (2300 metric tons), yields not landed since the late 1950s (Figure 2-1).

Total statewide Dungeness crab landings have averaged, for the past 50 seasons 10.3 million pounds (4700 metric tons), for the past 20 seasons 12.7 million pounds (5800 metric tons), and for the past 10 seasons 16.0 million pounds (7300 metric tons). Four of the top five record seasons have occurred in the past ten years. A new statewide record of 27.5 million pounds (12,500 metric tons) landed in 2010-11, the most recent season in the time series, broke the previous record of 26.3 million pounds (11,900 metric tons) landed during the 1976-77 season. A total of 98 percent of the 1976-77 catch was landed in the northern management area, however, the 2010-11 season was not only a record breaking season for total landings statewide, but central California landings totaled 19.1 million pounds (8700 metric tons), which were more than twice those in the north at 8.4 million pounds (3800 metric tons) (Figure 2-1).

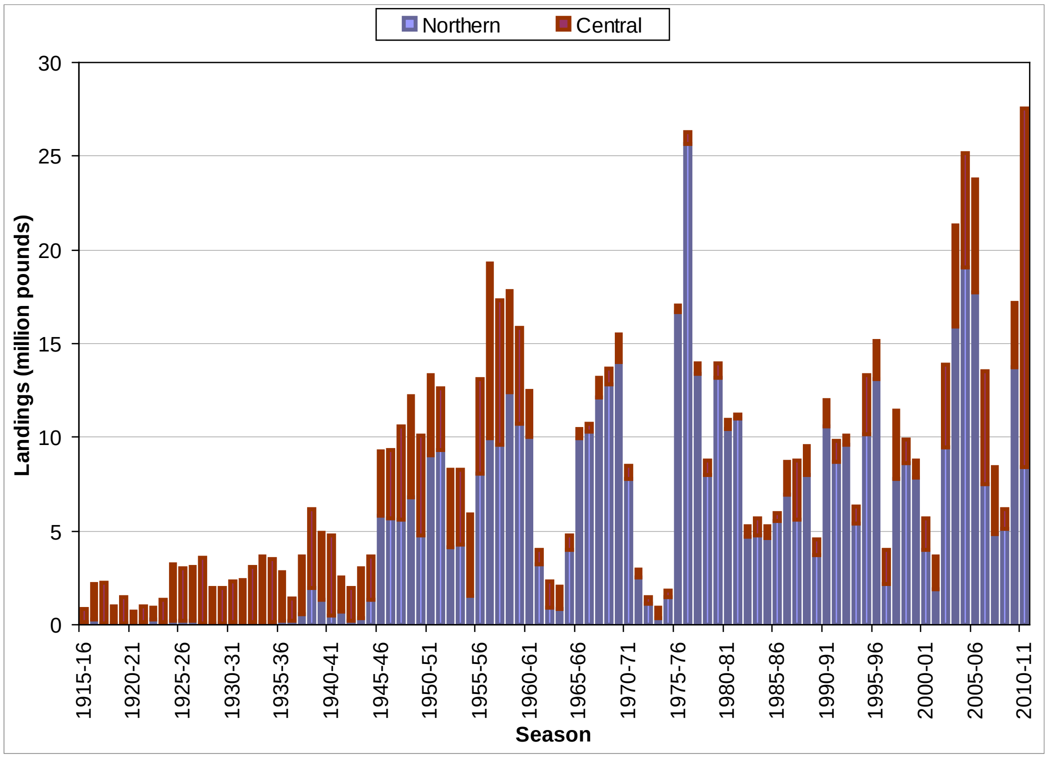

Figure 2-1. Dungeness crab commercial landings by season (November 15-July 15), 1915-2011. Data source: Department catch bulletins (1915-1986) and Commercial Fisheries Information System (CFIS) (1986-2011), all gear types combined.

Ex-vessel value during the past 10 seasons has averaged $30.4 million, maintaining Dungeness crab as one of the most valuable fisheries in California. For the past 10 years Dungeness crab has ranked first compared to all other commercial fisheries in ex-vessel value for the following years: 2003, 2004, and 2006, and second after market squid for all other years. The 2010-11 catch was valued at $56.8 million ex-vessel value, a record for Dungeness crab (Figure 2-2).

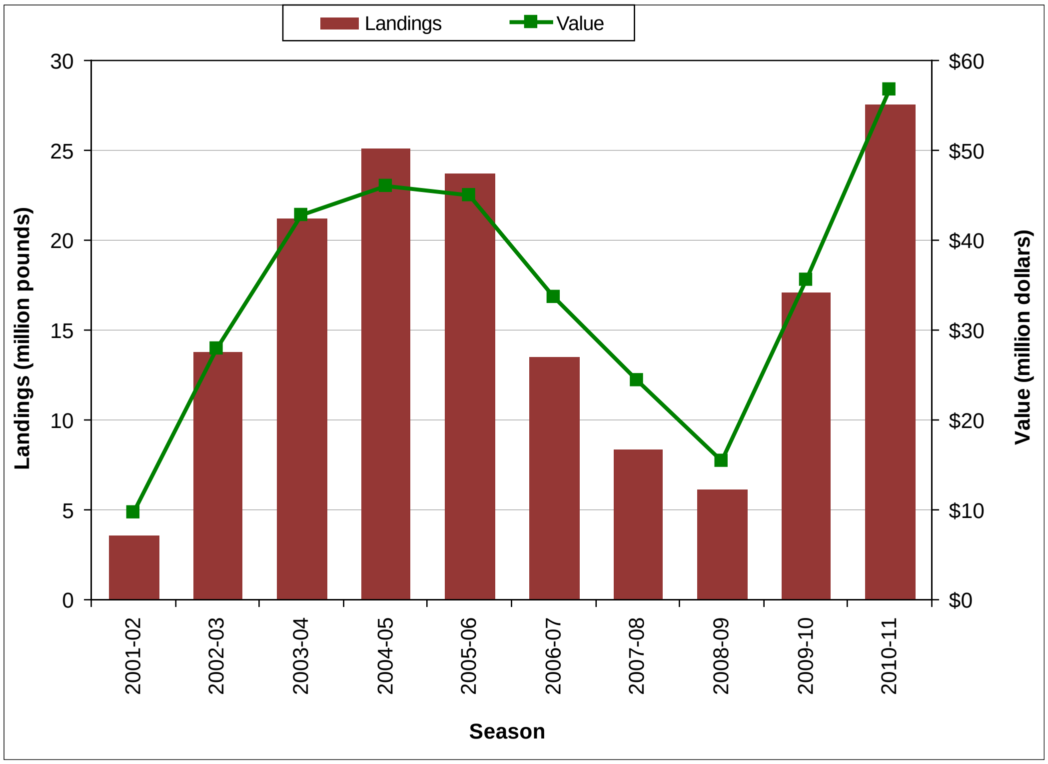

Figure 2-2. Dungeness crab commercial landings and ex-vessel value by season (November 15-July 15), 2001-2011. Data source: CFIS, all gear types combined. Ex-vessel values were adjusted for inflation and reflect 2011 values.

Historically, the sport catch was informally estimated at about one percent of commercial catch. Recently, the California Recreational Fisheries Sampling program began opportunistic sampling of the Dungeness crab catch for CPUE, size and sex ratios beginning with the 2009-10 season. However, due to funding restrictions the sampling is not rigorous enough to create reliable estimates of catch and effort at this time.

The Legislature enacted a limited entry permit system for the Dungeness crab fishery beginning in 1995, with the provision that most permits are transferable. Currently, there are less than 600 permits, and about 435 of those recorded landings in the 2010-11 season. This includes both resident and nonresident vessel permit holders. However, there is a concern that an increase in the use of the ”latent permits”, those that typically do not make landings, could cause overfishing and worsen overcrowding on crab fishing grounds. Such an increase could be triggered by the recent increase in demand and price of Dungeness crab, for example.

California, Oregon, and Washington share many Dungeness crab fishery management concerns and coordinate on interstate issues through the Tri-State Dungeness Crab Committee, which is overseen by the Pacific States Marine Fisheries Commission. One outcome of this concerted effort is the implementation of the pre-season crab quality test to ensure crabs are ready for harvest on the target opening date. Commencing with the 1995-96 season, the State Legislature authorized an industry-funded crab quality test for California's northern management area that is conducted concurrently with tests in Washington and Oregon. The states then mutually decide, through the Tri-state Dungeness Crab Committee, whether to delay the opening of the season in order to let the crabs accumulate more body meat weight. In the case of a northern California season delay, "fair start" statutes mandate that anyone fishing in the central California area must wait 30 days after the delayed northern season opener to fish in those northern waters.

The recent decade of high landings has also increased the exportation of Dungeness crab products overseas, particularly to China. According to U.S. foreign trade figures gathered by the National Oceanic and Atmospheric Administration, the two California ports of Los Angeles and San Francisco exported a total of 53,000 pounds (24 metric tons) of Dungeness crab to China in 2009, 540,000 pounds (245 metric tons) in 2010 and 1.3 million pounds (590 metric tons) in 2011. This growing demand from China has contributed to a higher ex-vessel value for crab as processors supply crab product overseas.

Status of Biological Knowledge

Dungeness crab are highly motile, benthic crustaceans residing on sandy to sand-mud substrate of bays, estuaries and the open coast, usually found at depths less than 750 feet (230 meters). Juveniles also prefer eel grass habitat in bays and estuaries due to the availability of prey items and for protection. Dungeness crabs are reported from Amchitka Island in the Aleutians, Alaska to Point Conception, California, but are less common south of Morro Bay. The following details of the Dungeness crab reproductive cycle are specific to the California coast as time periods are longer and later further northward in its geographic range.

The mating period of Dungeness crabs occurs in coastal waters between February and June when pre-molt female crabs are located by adult males, possibly through pheromone detection. The male holds the female in a premating embrace for up to 7 days prior to her molting, and approximately one hour after the female molts, the male gonopods are inserted into the female spermothecae and the spermatophores are deposited (Figure 2-3). Females then store these spermatophores and fertilization occurs from October to December when the eggs are finally extruded (Figure 2-4). However, females that skip a molting period and, therefore, cannot mate are able to fertilize eggs from the stored

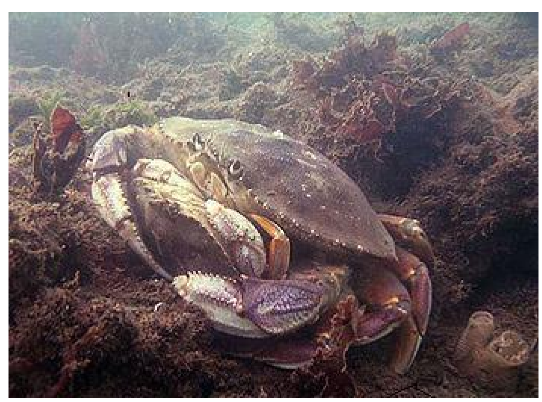

Figure 2-3. Larger male Dungeness crab in mating embrace with smaller female crab. Photo credit: S. Groth, ODFW.

spermatophores of the previous season. Females have been observed to store viable sperm for up to 2.5 years. It is estimated that smaller females produce on average 0.5 million eggs while larger females produce 1.5-2.0 million eggs.

During November to February the fertilized eggs hatch in to the first of five zoeal stages. Larvae are pelagic, consuming both zooplankton and phytoplankton, and make vertical diel migrations in the water column as a potential means to forage at night in surface waters, while avoiding predation during the day at depths of 45-75 feet (14-23 meters). Late stage zoea are also found further offshore as they may be transported seaward and alongshore when they migrate to surface waters. They finally develop into megalopae larvae after 80-95 days as zoea.

Figure 2-4. Female Dungeness crab with extruded, fertilized eggs. Photo credit: S. Groth, Oregon Department of Fish and Wildlife.

Dungeness crab megalopae (Figure 2-5) are pelagic and found offshore in central California around March, at which time they move further inshore and can also be found in bays and estuaries. An ongoing California Department of Fish and Wildlife (Department) study utilizing light traps to attract megalopae at night, and monitored daily, has captured megalopae in Bodega Bay, Fort Bragg's Noyo Harbor, and in Humboldt Bay from about mid-March to July. The mechanism by which shoreward transport of megalopae occurs during spring months of intense upwelling has been discussed in a University of Oregon study using similar light traps at two sites in Coos Bay, Oregon; one on the outer coast and the other in the estuary. Researchers found megalopae abundance peaked during spring tides at the outer coast site, in between spring and neap tides at the estuary site, and was significantly correlated with upwelling, favorable winds, and colder waters at both sites. Both upwelling and favorable, or southward winds, cause the net flow of the surface Ekman layer offshore, allowing denser subsurface water to rise and replace the surface waters. Organisms, such as Dungeness crab megalopae found below the Ekman layer, or greater than 60 feet (18 meters), would then be transported upward and during the strong spring tidal influxes would move toward the coast, promoting estuarine ingress.

Figure 2-5. Dungeness crab megalope collected from Bodega harbor. Length is 0.3 inches from tip of rostrum to back of the carapace. Photo credit: R Dondanville.

After 25-30 days, megalopae larvae finally settle out into the benthic environment and metamorphose into the first juvenile crab instar phase, for a total of 105-125 days spent as larvae. Growth occurs through a series of molts and the rate at which these occur are proportional to ocean temperature. Growth rates are slower and molting cycles are later in colder waters of northern latitudes, hence contributing to the different fishing season start dates in the central and northern management areas in California.

The majority of juveniles are reared nearshore in open coastal waters, but juveniles also reside in bays and estuaries. A Department study in the late 1970s found that juveniles in San Francisco Bay reach sexual maturity at about 1 year of age and enter the fishery at 3 years of age, almost an entire year before open coast juvenile crabs. This faster growth may be attributed to more frequent molts in the warmer waters of the estuary. Size at sexual maturity is about 4 inches CW (10 centimeters) for females and about 4.5 inches CW (11 centimeters) for males. At this size, crabs in estuaries will then move towards the open coast at the start of the mating period.

While Dungeness crab larvae are a food source for planktivores, megalopae have been found in the gut contents of Coho and Chinook salmon. A wide range of fish from starry flounder, rock sole, lingcod, cabezon, copper rockfish, and wolf eels, as well as octopus are known predators of juvenile instars. Cannibalism is common among juvenile size classes that are less than 2.4 inches CW (6 centimeters) who feed on recently molted smaller crabs of the same year class. This within-year-class cannibalism may play a role in the recruitment failure of megalopae later in the settlement season where it has been observed that first and second juvenile instars prey upon cohorts of settling megalopae larvae.

Adult crabs are non-specific feeders that generally feed on clams and other soft-sediment organisms. They also shift feeding behavior the larger they grow, eating bivalves the first year, shifting to shrimp the second year, and to teleost fish the third year. Cannibalism also occurs in adult populations and it has been proposed that density-dependent cannibalism between year classes may be responsible for the population fluctuations of the Dungeness crab fishery in California although no studies have been conducted to test this hypothesis.

The maximum life span of Dungeness crab is about 8-10 years of age where male crabs can grow up to a length of 8.6 inches CW (22 centimeters) while females can grow to 6.3 inches CW (16 centimeters), although crabs attaining these ages and sizes are not common.

Status of the Population

The pattern of statewide Dungeness crab landings over the past 60 years has been highly cyclic but with an irregular amplitude. An explanation for the decadal fluctuations of high landings followed by years of reduced landings, particularly in central California, may be explained by the Pacific Decadal Oscillation (PDO), a climate-based index derived from sea surface temperature data resulting from the periodic shifting of warm and cool ocean water regimes of the northeastern Pacific Ocean. These periods of warm and cool regimes result from the winter wind patterns in the North Pacific.

This index has been shown to be correlated with salmon landings from Alaska. Dungeness crab larval abundance has been correlated with lower water temperatures and on average, larvae will enter the commercial fishery within three years. Dungeness crab landings from the 1925-26 to 2010-11 seasons, when deviated from the season median, and then lagged three years and plotted within the warm and cold regimes of the PDO index, suggest higher than average larval abundance during the colder regime cycles of the PDO (Figure 2-6).

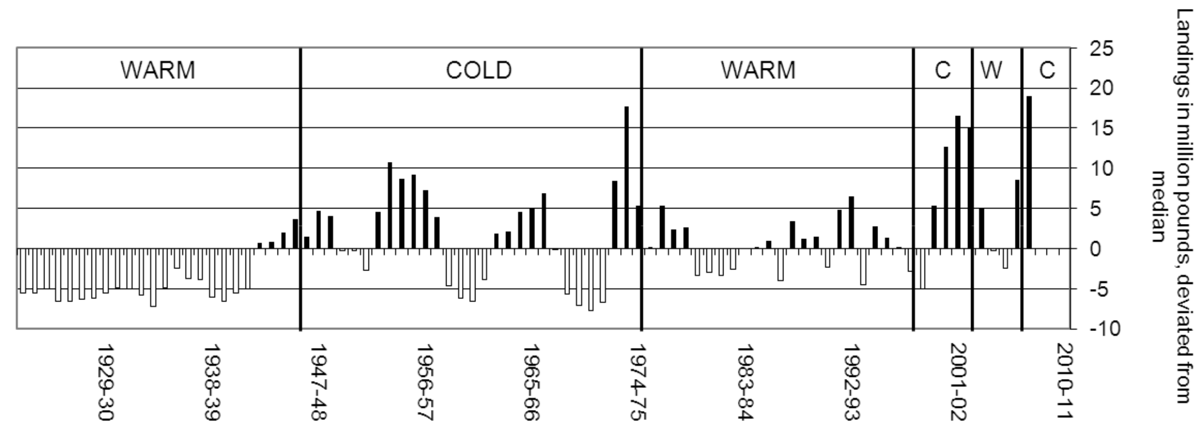

Figure 2-6. Dungeness crab commercial landings, deviated from the season median with a three year lag, as an index of larval abundance during warm and cold water regimes of the Pacific Decadal Oscillation. Data source: Department Fish Bulletins (1925-1986) and CFIS (1986-2011), all gear types combined. Warm and cold regime years were found at: http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm.

The Dungeness crab fisheries along the coastal western states are considered sustainable due in part to the combination of crab life history and a simple but effective fishery management scheme. Dungeness crab reach sexual maturity in a relatively short period of time and only the larger older males are removed from the population. The consensus among fishery managers based on research from northern California is that while the fishery removes most of the legal males each year, enough sublegal males remain that virtually every female is fertilized. The wide fluctuations in catch appear to be directly related to crab abundance which in turn seems to be a function of ocean conditions.

Management Considerations

Management of the Dungeness crab fishery currently relies on the limits imposed by the 3-S principle (size, sex, season). It is estimated that 80-90 percent of legal sized males are removed by the fishery each season and so landings data are a relatively accurate index of crab abundance.

Dungeness Crab Task Force and Trap Limit Program

In 2008, Dungeness crab commercial fishermen began working on a cooperative approach to managing their fishery. Their efforts resulted in legislation which mandated the Ocean Protection Council facilitate a limited-term Dungeness Crab Task Force (task force) from 2009 through 2011. The task force is composed of Dungeness crab fishermen from ports between Morro Bay and Crescent City and crab processors, as well as non-voting members from the Department, Sea Grant, and non-governmental organizations. The task force objective was to make recommendations on management measures such as trap limits, fleet size reduction, and season opening date changes, among others, to the Legislature's Joint Committee on Fisheries and Aquaculture, the Department, and the California Fish and Game Commission (Commission) by January 2010. Through the efforts of the task force, new legislation was passed in 2011, which re-established the task force and implemented trap limits on Dungeness crab vessel permit holders.

The trap limit program is scheduled to take effect by the 2013-14 season. Permit holders are ranked into one of seven tiers based on their total California landings from a prescribed, 5-season window period. The highest tier is set at a maximum of 500 traps while the lowest tier is set at 175 traps. Permit holders will also be required to purchase a biennial trap limit permit along with all the Department-issued trap tags for each trap in their tier. If they fail to purchase all tags, their commercial permit will no longer be valid, potentially removing latent permits from the fishery.

The task force is expected to generate recommendations addressing the need for a permanent task force; the economic impact of the trap limit program; the cost of the program to the Department, including enforcement costs; refining commercial and sport Dungeness crab management; and the need for statutory changes to accomplish task force objectives. These initial recommendations will then be reported to the Joint Committee on Fisheries and Aquaculture, the Department, and the Commission by January 2015 with final recommendations due by January 2017. The extension of the task force and trap limit program will ultimately be decided by the State Legislature before April 1, 2019.

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Further Reading

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Dungeness crab commercial landings (pounds) by season (November 15-July 15), 1915-16 to 2010-11.

Season	Northern	Central	Statewide	Season	Northern	Central	Statewide
1915-16	107,016	748,632	855,648	**1963-64**	814,997	1,183,338	1,998,335
1916-17	289,464	1,880,952	2,170,416	**1964-65**	3,978,997	770,569	4,749,566
1917-18	99,552	2,164,824	2,264,376	**1965-66**	9,985,618	456,159	10,441,777
1918-19	55,032	940,536	995,568	**1966-67**	10,299,169	406,251	10,705,420
1919-20	71,184	1,376,280	1,447,464	**1967-68**	12,142,853	1,016,472	13,159,325
1920-21	66,792	665,544	732,336	**1968-69**	12,829,375	836,588	13,665,963
1921-22	141,312	832,864	974,176	**1969-70**	13,987,990	1,480,404	15,468,394
1922-23	263,328	633,552	896,880	**1970-71**	7,812,747	662,513	8,475,260
1923-24	165,792	1,149,024	1,314,816	**1971-72**	2,540,163	405,593	2,945,756
1924-25	183,768	3,074,112	3,257,880	**1972-73**	1,144,345	345,616	1,489,961
1925-26	207,960	2,802,120	3,010,080	**1973-74**	354,282	526,400	880,682
1926-27	177,792	2,885,520	3,063,312	**1974-75**	1,474,485	356,700	1,831,185
1927-28	95,928	3,448,656	3,544,584	**1975-76**	16,686,970	354,000	17,040,970
1928-29	62,880	1,920,624	1,983,504	**1976-77**	25,631,936	635,700	26,267,636
1929-30	99,168	1,891,632	1,990,800	**1977-78**	13,389,555	589,203	13,978,758
1930-31	110,896	2,173,524	2,284,420	**1978-79**	7,991,382	759,565	8,750,947
1931-32	113,878	2,234,741	2,348,619	**1979-80**	13,204,565	736,980	13,941,545
1932-33	126,428	2,934,670	3,061,098	**1980-81**	10,420,824	541,471	10,962,295

Dungeness crab commercial landings (pounds) by season (November 15-July 15), 1915-16 to 2010-11.							
Season	**Northern**	**Central**	**Statewide**	**Season**	**Northern**	**Central**	**Statewide**
1933-34	113,775	3,535,566	3,649,341	**1981-82**	10,996,936	217,981	11,214,917
1934-35	152,366	3,367,496	3,519,862	**1982-83**	4,702,531	573,275	5,275,806
1935-36	231,684	2,567,392	2,799,076	**1983-84**	4,731,961	916,697	5,648,658
1936-37	180,504	1,230,959	1,411,463	**1984-85**	4,616,243	635,265	5,251,508
1937-38	528,108	3,109,564	3,637,672	**1985-86**	5,558,362	431,329	5,989,691
1938-39	1,993,633	4,139,612	6,133,245	**1986-87**	6,969,837	1,701,559	8,671,396
1939-40	1,299,142	3,590,072	4,889,214	**1987-88**	5,627,938	3,119,823	8,747,761
1940-41	477,718	4,298,574	4,776,292	**1988-89**	7,974,503	1,580,158	9,554,661
1941-42	688,386	1,845,952	2,534,338	**1989-90**	3,715,949	834,475	4,550,424
1942-43	232,372	1,721,234	1,953,606	**1990-91**	10,592,045	1,364,255	11,956,300
1943-44	340,400	2,696,398	3,036,798	**1991-92**	8,678,034	1,154,905	9,832,939
1944-45	1,340,717	2,269,873	3,610,590	**1992-93**	9,607,833	466,025	10,073,858
1945-46	5,812,574	3,448,224	9,260,798	**1993-94**	5,362,162	915,943	6,278,105
1946-47	5,653,754	3,694,312	9,348,066	**1994-95**	10,175,284	3,170,183	13,345,467
1947-48	5,619,089	4,934,919	10,554,008	**1995-96**	13,084,053	2,042,519	15,126,572
1948-49	6,764,248	5,454,396	12,218,644	**1996-97**	2,202,960	1,805,651	4,008,611
1949-50	4,772,314	5,295,485	10,067,799	**1997-98**	7,795,745	3,605,434	11,401,179
1950-51	9,066,177	4,242,052	13,308,229	**1998-99**	8,594,637	1,295,967	9,890,604
1951-52	9,292,763	3,316,645	12,609,408	**1999-00**	7,841,311	946,385	8,787,696
1952-53	4,118,754	4,158,171	8,276,925	**2000-01**	4,024,677	1,674,664	5,699,341
1953-54	4,309,220	3,956,529	8,265,749	**2001-02**	1,897,992	1,720,141	3,618,133
1954-55	1,524,511	4,329,138	5,853,649	**2002-03**	9,493,499	4,364,853	13,858,352
1955-56	8,063,261	5,019,852	13,083,113	**2003-04**	15,925,301	5,349,415	21,274,716
1956-57	9,980,254	9,299,151	19,279,405	**2004-05**	19,061,375	6,115,401	25,176,776
1957-58	9,610,277	7,677,359	17,287,636	**2005-06**	17,763,180	5,984,892	23,748,072
1958-59	12,377,569	5,408,104	17,785,673	**2006-07**	7,533,829	5,974,679	13,508,508
1959-60	10,728,132	5,137,053	15,865,185	**2007-08**	4,802,296	3,575,389	8,377,685
1960-61	10,042,841	2,403,196	12,446,037	**2008-09**	5,089,209	1,098,313	6,187,521
1961-62	3,251,318	735,371	3,986,689	**2009-10**	13,771,393	3,392,026	17,163,419
1962-63	900,733	1,440,955	2,341,688	**2010-11**	8,435,195	19,105,841	27,541,037

Data source: Department catch bulletins (1915-1986) and CFIS data (1986-2011), all gear types combined.

Dungeness crab commercial landings and value by season (November 15-July 30), 1991-2011.					
Season	**Pounds**	**Value**	**Season**	**Pounds**	**Value**
1991-92	9,832,939	$20,782,593	**2001-02**	3,618,133	$9,700,577
1992-93	10,073,858	$17,710,520	**2002-03**	13,858,352	$27,917,563
1993-94	6,278,105	$11,872,642	**2003-04**	21,274,716	$42,837,655
1994-95	13,345,467	$31,218,272	**2004-05**	25,176,776	$45,987,156
1995-96	15,126,572	$29,065,534	**2005-06**	23,748,072	$44,945,658
1996-97	4,008,611	$12,084,233	**2006-07**	13,508,508	$33,615,740
1997-98	11,401,179	$30,665,666	**2007-08**	8,377,685	$24,422,852
1998-99	9,890,604	$23,837,780	**2008-09**	6,187,521	$15,368,841
1999-00	8,787,696	$23,681,678	**2009-10**	17,163,419	$35,583,120
2000-01	5,699,341	$16,390,483	**2010-11**	27,541,037	$56,810,465

Data Source: CFIS data, all gear types combined. Values were adjusted for inflation and reflect 2011 values.

3 Abalones, Haliotidae

Red abalone, *Haliotis rufescens*, clinging to a boulder.
Photo credit: D Stein, CDFW.

History of the Fishery

The nearshore waters of California are home to seven species of abalone, five of which have historically supported commercial or recreational fisheries: red abalone (*Haliotis rufescens*), pink abalone (*H. corrugata*), green abalone (*H. fulgens*), black abalone (*H. cracherodii*), and white abalone (*H. sorenseni*). Pinto abalone (*H. kamtschatkana*) and flat abalone (*H. walallensis*) occur in numbers too low to support fishing.

Dating back to the early 1900s, central and southern California supported commercial fisheries for red, pink, green, black, and white abalone, with red abalone dominating the landings from 1916 through 1943. Landings increased rapidly beginning in the 1940s and began a steady decline in the late 1960s which continued until the 1997 moratorium on all abalone fishing south of San Francisco (Figure 3-1). Fishing depleted the stocks by species and area, with sea otter predation in central California, withering syndrome and pollution adding to the decline. Serial depletion of species (sequential decline in landings) was initially masked in the combined landings data, which suggested a stable fishery until the late 1960s. In fact, declining pink abalone landings were replaced by landings of red abalone and then green abalone, which were then supplemented with white abalone and black abalone landings before the eventual decline of the abalone species complex. Low population numbers and disease triggered the closure of the commercial black abalone fishery in 1993 and was followed by closures of the commercial pink, green, and white abalone fisheries in 1996. Extremely low populations lead to the listing of white abalone as a federally endangered species in 2001 and black abalone were listed in 2009.

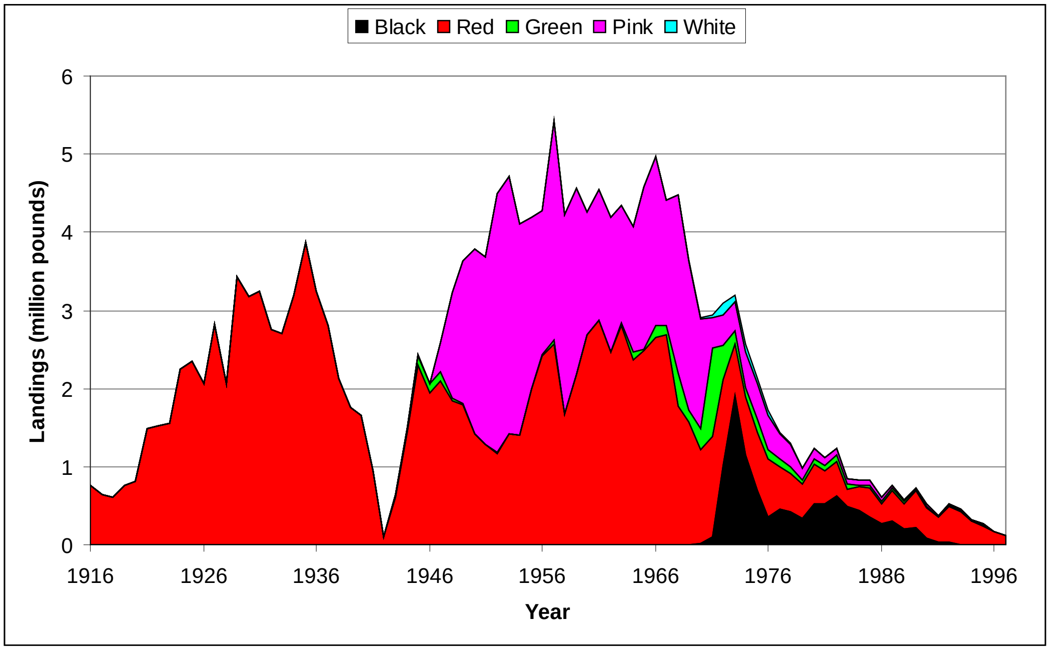

Figure 3-1. Abalone commercial landings, 1916-1997. Data source: Department catch bulletins (1916-1983) and Commercial Fisheries Information System (CFIS) data (1984-1997).

The northern California recreational red abalone fishery is the only abalone fishery currently open in California. In 2005, the California Fish and Game Commission (Commission) adopted the Abalone Recovery and Management Plan (ARMP), which governs the management of the recreational fishery and recovery of southern abalone stocks. This plan sets management guidelines and triggers for Total Allowable Catch (TAC) adjustments based on 3 criteria – density, recruitment, and catch-per-unit-effort (CPUE). Data for these criteria come from fishery independent dive surveys, fishery dependent creel surveys, and report card data combined with telephone surveys of fishermen.

Fishery independent dive surveys are conducted at eight index sites on a triennial basis. These surveys are the primary method for providing density and recruitment data for management. The main strategy for the ARMP is to prevent abalone densities from declining below the minimum viable population (MVP) level which could cause the fishery to collapse (see Abalone Life History section below).

Abalone cards were first implemented in 2000 as an enforcement tool designed to control the number of abalone taken in a day and for the season. Fishermen were required to record date, time, and county on a line for each abalone they caught and to return the card to the California Department of Fish and Wildlife (Department). In subsequent years the report card was modified to collect more precise location data and has become an important management tool to help monitor the fishery. Report card data combined with systematic telephone surveys from 2002 through 2009 provide an estimate of the total annual catch (Figure 3-2). The telephone survey provides unbiased data on report card purchasers from those who do and do not return their abalone cards at the end of the season. The most recent catch data available are from the 2010 season in which an estimated 877,500 pounds (400 metric tons) of abalone were fished, the lowest recorded catch since the report card was introduced in 2002 (Figure 3-2). In 2007, the highest catch was recorded at 1,158,749 pounds (526 metric tons) of abalone landed in the recreational fishery. Overall, catch has remained stable at close to 1 million pounds (450 metric tons; approximately 267,000 abalone) per year since 2002.

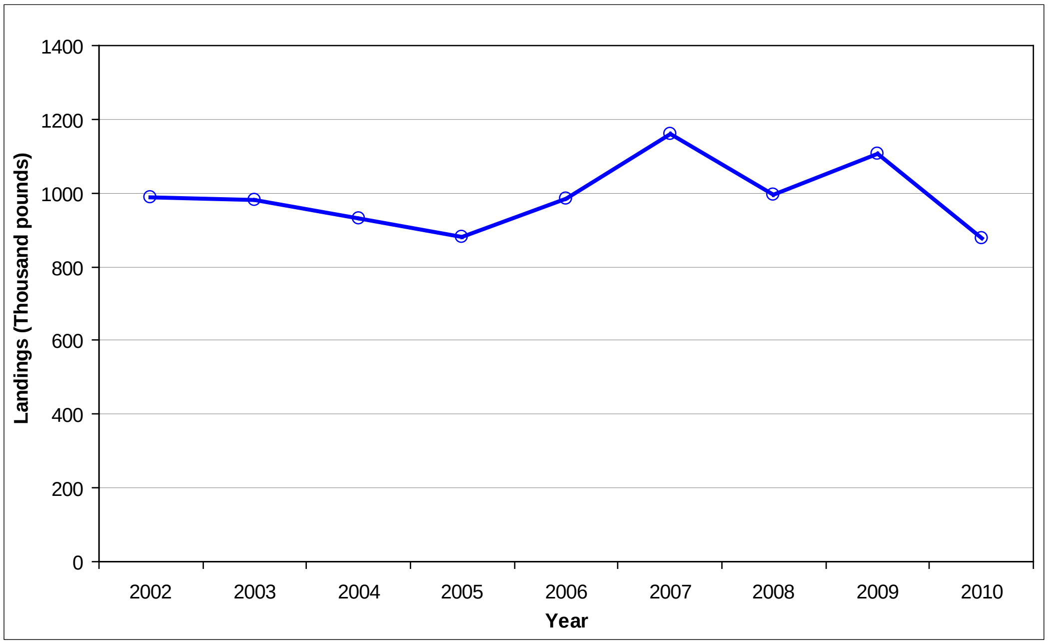

Figure 3-2. Red abalone recreational catch, 2002-2010. Data source: Department abalone report card database and telephone survey database.

Creel surveys are completed in alternate years and are used to collect CPUE data in the form of take per picker day or take per picker hour by fishing mode, as well as detailed catch location information and catch size frequencies. Variations from year to year in CPUE can be influenced by ocean conditions present during the survey periods. For management decisions, CPUE is compared statistically using blocks of several years in conjunction with CPUE from the report cards.

New regulations requiring the tagging of each abalone retained were implemented in 2008 to help reduce illegal take and ensure compliance with the daily bag and annual limits of 3 and 24 abalone, respectively. Also new as of 2008, report cards are required for everyone taking abalone, regardless of age (anglers less than 16 years of age do not have to purchase a sportfishing license), in order to provide more accurate take estimates. New regulations for 2012 include the requirement for each person taking abalone to retain separate possession of their abalone prior to tagging, and closure of the Fort Ross State Historical Park (Sonoma County) for the first two months of the season (April and May) each year to reduce effort.

Status of Biological Knowledge

Abalones are in the Phylum Mollusca, along with clams, snails and squid, and belong to the class Gastropod and the genus *Haliotis*. Abalone have only one shell, the same as other Gastropods, and have a spiral shell structure with open respiratory pores. The shells are composed of aragonite tiles with sheets of protein matrix between the tiles. Pinto abalone morphology is different north and south of Point Conception, with pinto abalone sometimes called threaded abalone south of Point Conception. Other abalone species have a single morphology throughout their distribution. Abalone are found on rocky intertidal and subtidal habitats along the California coast. Of the seven species of abalone found in California, two are commonly found in shallow water, the black in the intertidal and the green abalone. Red, flat, and pinto are found in the intertidal as well as shallow and intermediate depths down to at least 100 feet (30 meters). Pink and white abalone are the deepest living species down to 120 and 200 feet (37 and 61 meters), respectively. Flat, pinto, and red abalone are found in northern California while pink, white, green, and red abalone are found in southern California. Black and red abalone are found throughout California with only a few black abalone individuals found north of San Francisco.

Abalone Life History

Abalone are slow growing, long lived, herbivorous invertebrates. Tag recapture studies show it takes an average of 12 years for red abalone to grow to the minimum legal size of 7 inches (18 centimeters) in northern California. Studies suggest they live between 30 and 40 years. Abalone eat algae, preferring kelp and red algae, using their rasping tongue (radula) to scrape algae bits. In central and southern California the kelp is giant kelp and in the north is predominantly bull kelp. Kelp abundance is driven by water temperature which when high, such as during El Niño events, can lead to declines in algal food supply and slow growth. Wild red abalone mature at age 6 when they are approximately 4 inches (10 centimeters) in shell length.

Abalone shed their eggs and sperm into the water column where fertilization takes place. Fertilization success declines precipitously as the distance between males and females increases. When nearest neighbor distances increase as occurs with low density populations the chances of fertilization decline. Abalone populations which have low densities are in danger of collapse due to low fertilization rates, particularly if they are also subjected to additional mortality from fishing. The sex ratio is one male to one female. Embryos undergo cell division developing into blastula and gastrula before hatching into free swimming larvae. Larvae have yolk reserves (lecithotrophic) which fuel development and larval shell formation. After 5-7 days larvae settle and metamorphose into benthic juveniles. Juveniles settle out of the plankton at a tiny size, less than 0.02 inches (0.5 millimeters). The settling cue is crustose coralline algae which appears as pink paint on rocks under water. Newly settled larvae develop a gut and feeding structures and scrape bacterial films on coralline algae until they are able to eat the surface layer of fleshy algae at about 4 weeks. Larval dispersal is thought to be minimal since the larval period is short and larvae are found in nearshore waters. Genetic analyses suggest that there may be some geographic structure to intertidal black abalone populations while less structure has been found in subtidal red abalone populations.

Mortality of larval and newly settled abalone in the first year is unknown but thought to be exceedingly high and may exceed 98 percent. As abalone get larger mortality decreases, becoming low for adults. Predation pressures on abalone decrease with increasing size. The one major exception is with sea otter predators which are capable of taking full grown abalone. Octopus, lobster, sea stars, crab, fish and other major abalone predators mainly take smaller abalone. Shell parasites such as the boring clam and sponge can weaken shells causing mortality, particularly in large, old abalone. Mortality may increase in winter months when storms can wash away weakened abalone that spend their energy combating shell parasites. Storms also rip out algae leading to poor food resources in winter and spring. Warm El Niño events can enhance abalone mortality by speeding up metabolism yet at the same time decreasing kelp resources, as warm water is nitrogen poor hindering kelp productivity. Ocean conditions in addition to temperature may also play a role in the survival of abalone. As ocean waters become more acidic, the ability of abalone and other shellfish to develop and maintain their shell can be hampered. Ocean acidification is likely to enhance mortality if it impacts larval development, shell thickness or hinders shell calcification.

Withering Syndrome

An infectious disease known as withering syndrome is a key factor contributing to abalone population declines and failed recoveries in California. In 1985, abalone fishermen at the Channel Islands began noticing black abalone falling off rocks in large numbers. The dying abalone had shrunken bodies and the term Withering Syndrome (WS) was used to describe the condition. Over the next decade, WS spread throughout the Channel Islands, to the mainland and up the coast, reaching San Mateo County in 1997. The pattern of spread strongly indicated that the condition was caused by an infectious disease, and the causative agent was subsequently identified as a previously unknown bacterial pathogen. The bacterium, named *Xenohaliotis californiensis*, grows within cells of the abalone gastrointestinal tract where it likely interferes with nutrient absorption.

All California abalone species are susceptible to the bacterial infection that causes WS. Whether an abalone that is infected succumbs to WS and dies depends on a variety of factors, such as abalone species and water temperature. Infected black abalone tend to show signs of the disease, i.e. body shrinkage and ultimately death, in both cool and warm water. Infected red abalone begin to succumb to the disease at temperatures of about 65°F (18°C) or higher, while infected green abalone remain healthy under those and even warmer conditions. The relative resistance of green abalone under typical southern California water temperatures may be playing a role in their apparently increasing numbers at some Channel Islands locations while black and red abalone populations remain low.

The WS bacterium was identified in red abalone at the Farallon Islands in 2007 and at Bodega Head in 2010. Waters at these locations are sufficiently cool that none of the infected abalone showed any body shrinkage or other signs of WS. Similarly, red abalone at San Miguel Island, which experiences cooler waters than the other Channel Islands, exist even though the bacteria has been present for over twenty years. Although the bacteria will likely continue its northerly spread into the red abalone populations in Sonoma and Mendocino counties, expression of WS is expected to remain low to absent. Nevertheless strong El Niño events and eventual warming associated with climate change could result in future expression of the disease in abalone at these cool water locations.

Status of the Populations

Red Abalone

Northern California-Populations of red abalone, *Haliotis rufescens*, (Figure 3-3) in northern California support a popular recreational fishery. While landings (2002-2011) appear to be stable, recent declines in subtidal stocks have been recorded. Fishery independent dive surveys at index sites indicate a decline in the average density of abalone in Sonoma County in the southern portion of the fishery and low levels of recruitment. Fishery dependent creel surveys indicate reduced CPUE at some sites. In late summer of 2011, an unprecedented harmful algal bloom (red tide) lead to a die-off of invertebrates in Sonoma County and resulted in large numbers of dead abalone washing ashore. Surveys revealed an average of 24 percent of the abalone along transects in Sonoma County sites were dead. Abalone mortality was particularly high in the shallower waters (<30 feet or 9 meters) where recreational abalone divers fish for abalone.

Figure 3-3. Red ablaone, *Haliotis rufescens*. Photo credit: A Maguire, CDFW.

The ARMP provides a management framework based on fishery independent and fishery dependent data. Fishery independent dive surveys and two sources of fishery dependent data (creel surveys and abalone report card data combined with a systematic telephone survey) are the primary data sources used to manage the recreational red abalone fishery. In the ARMP, catch reduction triggers are based on average abalone density (number along stratified random transects) at eight index sites in Sonoma and Mendocino Counties. These sites are surveyed using scuba on a triennial basis. If the average density of the index sites falls below the trigger of 0.42 abalone/square yard (0.50 abalone/square meter), the Department will recommend regulation changes to reduce the catch according to ARMP guidelines. The current

TAC is a guideline, rather than a fixed inseason quota which would cause the fishery to close if exceeded. The catch is calculated after abalone report cards have been returned.

Two sets of triennial surveys have been completed since the adoption of the ARMP. The overall density for the most recent set of surveys was 0.43 abalone/square yard (0.52 abalone/square meter) which is close to the trigger for reducing the catch. The average density at the four Sonoma County index sites 0.37 abalone/square yard (0.44 abalone/square meter) is currently below the trigger while the Mendocino sites are above the trigger. Therefore, the Department and the Commission may consider focused management for the Sonoma County area, in addition to catch reductions for the entire fishery. Zonal management would allow more precise control over the abalone catch to prevent large numbers of abalone from being taken from one site or zone depleting local abalone populations.

Creel survey data are collected as interviews with abalone fishermen when they exit fishing areas. There are more than 35 years of creel interviews which include: numbers caught, time used to catch abalone, and specific location of catch. The ARMP uses creel data to trigger dive surveys if sites show significant declines in catch-per-unit-effort or distance traveled for catch. Creel data from Fort Ross State Historic Park have been showing reduced average daily catches over the years, an indication of a decline in local abalone populations. In addition, Fort Ross also generally has the lowest densities of abalone observed during dive surveys. In response, the Commission voted to shorten the season by 2 months at Fort Ross starting in 2012. Shelter Cove and MacKerricher State Marine Conservation Area (Mendocino County) have low numbers of abalone caught per day but dive surveys are not planned for these sites as the success rate for fishermen is still relatively high at 2.4 abalone per day.

Southern California- Red abalone populations are at very low levels in most areas of southern California and offshore islands. At the close of the fishery in 1997, San Miguel Island was one of the few locations in southern California with red abalone populations, and continues to show signs of recovery fifteen years later. At the request of the Commission, the Department began a population assessment of red abalone at the island in 2006 to determine whether a limited-take fishery should be considered under the guidance of the ARMP. Three years of surveys from 2006-2008 resulted in 985 underwater transects in three geographical zones. A total of 15,624 abalone were counted resulting in densities between 0.0084-0.14 abalone/square yard (0.01-0.17 abalone/square meter). The overall density at the island for the three survey years combined was 0.11 abalone/square yard (0.13 abalone/square meter), which is below the minimum viable population level of 0.17 abalone/square yard (0.20 abalone/square meter) listed in the ARMP for recovered abalone populations and well below the level of 0.55 abalone/square yard (0.66 abalone/square meter) required for a sustainable fishery.

The size structure of the measured abalone compared to past surveys in 1997 and 2002 showed more individuals over the historical commercial size limits, indicative of individual growth. This is to be expected in a population that has been closed to fishing for over ten years. The distribution of abalone were patchy, with only 32 percent of the 12 square yard (10 square meter) transect segments having abalone and solitary abalone making up about 8 percent of the surveyed population. Two or more abalone were found in 23 percent of the segments accounting for 93 percent of the counted abalone. Given the overall density of the island, ARMP density requirements would not allow for a fishery to open.

Red abalone populations elsewhere in southern California are still depressed and occur only in localized areas along the mainland and offshore islands. Aside from San Miguel Island, higher densities have been found at Santa Rosa and Santa Cruz islands. At the west end of Santa Cruz Island, Department divers using a timed-swim survey found 7.8 red abalone per hour after nine hours of search time. Although this is a crude measure of abalone density, the results indicate how sparsely populated the other abalone populations are in southern California.

Pink Abalone

Populations of pink abalone, *Haliotis corrugata*, (Figure 3-4) are still depleted in southern California, and were identified as a "species of concern" by NOAA Fisheries Service in 2004. Department surveys conducted in 2007-2009 at the northern Channel Islands resulted in low counts of pink abalone for recovery index sites listed in the ARMP. For Anacapa Island, divers report finding 0.3 abalone per hour for 38 hours of search time, and at Santa Cruz Island, divers report finding 1.1 abalone per hour for 99 hours of search time. The east end of Santa Cruz Island appears to be the only location where small pink abalone aggregations occur. Given that both these islands once supported a major pink abalone fishery, the findings from recent Department surveys are not encouraging.

Figure 3-4. Pink abalone, *Haliotis corrugata*. Photo credit: D Stein, CDFW.

The Point Loma kelp forest, off San Diego, is one of the more densely populated areas for pink abalone on the mainland coast. However, these populations are still not near historical levels. Recent research reports an average density 0.014 abalone/square yard (0.017 abalone/square meter) for combined transect data from 2006 and 2007.

Green Abalone

Similar to pink abalone, green abalone (*Haliotis fulgens*) (Figure 3-5) were also identified as a "species of concern" by NOAA Fisheries Service in 2004. Recent

Department surveys from 2007-2009 at the northern Channel Islands resulted in very few green abalone. At Anacapa Island for instance, only 0.1 abalone were found per hour and at Santa Cruz Island, only 0.03 abalone per hour were found. The counts are based on depth ranges for all abalone species, so it is possible that more green abalone may have been found if more dives were conducted in only shallow water (less than 15 feet or 5 meters). Still, the fact that only seven green abalone were found for over 137 hours of dive time indicates the depressed status of green abalone stocks at the northern Channel Islands.

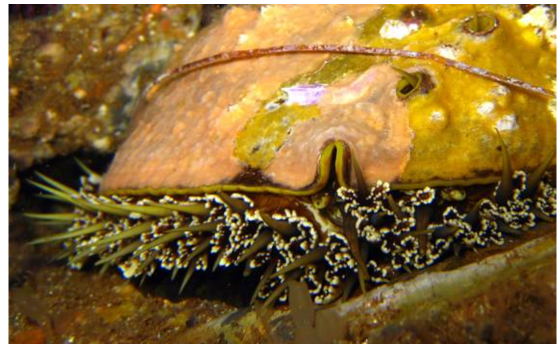

Figure 3-5. Green abalone, Haliotis fulgens. Photo credit: D Stein, CDFW.

Contrasting to the northern Channel Island surveys, Department surveys in the same timeframe at Santa Catalina Island are showing results indicative of limited green abalone recovery. Surveys conducted around the island resulted in 2.4 abalone per hour for 33 hours of search time, and in a few localized areas around the island had densities of abalone upwards of 1.5 abalone/square yard (1.8 abalone/square meter). In addition to higher abundances, green abalone are being found in a wide range of size classes, indicating multiple years of recruitment. Similar observations are being made on the mainland near San Diego where recreational divers and fishery scientists are observing aggregations of green abalone. Although these recent findings are encouraging, managers should be highly cautious since the reported high densities are mostly localized and do not reflect the overall population numbers, which are still nowhere near historical levels.

A recent Department study showed even more good news for green abalone regarding WS, an endemic abalone disease that contributed to the population collapse in southern California. The study found that green abalone are more resilient to the disease given an increase in water temperature where it would affect other abalone species, further suggesting that green abalone would make an excellent target species for recovery actions in southern California.

Black Abalone

Populations of black abalone, *Haliotis cracherodii*, (Figure 3-6) currently remain very low throughout southern California after a drastic decline due to fishing and WS. The continued low populations resulted in the listing of the species as a federally endangered species by NOAA Fisheries Service in 2009. Since then, NOAA Fisheries Service has also proposed designation of critical habitat for black abalone. The critical habitat designation covers 242 square miles (390 square kilometers) of rocky habitat for black abalone along the California coastline from the mean high water line down to 20 feet (6 meters). The critical habitat designation area generally spans from Del Mar Landing in northern Sonoma County down to the entrance to Los Angeles Harbor, including all of the offshore islands. Most recently, NOAA Fisheries Service has convened a panel of experts as the black abalone recovery team to begin formulating a recovery plan for the species.

Figure 3-6. Black abalone, *Haliotis cracherodii*. Photo credit: D Stein, CDFW.

Although black abalone populations in southern California have been protected from fishing since 1993, there are only a few areas that have shown some evidence of recovery. San Nicolas Island is one area that has exhibited recovery over the past 10 years. Island wide density estimates have increased by 2.5 times during the period between 2001 and 2008 based on long term population monitoring sites. Despite the evidence of recovery at San Nicolas island and at a couple of sites in the northern Channel Islands, the rest of the southern California continues to exhibit very low populations of black abalone.

<u>White Abalone</u>

White abalone, (*Haliotis sorenseni*) (Figure 3-7) the first marine invertebrate to be federally listed as endangered, still remains at very depressed levels of population throughout the Southern California Bight. Since its listing in 2001, the empanelled White Abalone Recovery Team has developed a recovery plan to guide recovery of the species to the point of delisting. A captive rearing program for white abalone continues, however, few new broodstock have been added to the program since the initial collection in 1999. Since then, broodstock have been slowly succumbing to various mortality causes (disease, age, harmful algal bloom events). Captive bred offspring have not been out planted yet due to disease and other concerns.

Figure 3-7. White abalone*, Haliotis sorenseni*. Photo credit: D Whitting, NOAA Fisheries Service.

Remnant populations in the deeper portion of the species depth range at offshore banks have been steadily declining since population assessment monitoring began in 2002. White abalone total abundance and density at one offshore bank has declined by approximately 78 percent between 2002 and 2010.

Management Considerations

Northern California Red Abalone

Like many other abalone species, the red abalone has several characteristics which limit its ability to withstand fishing pressure. Tagging studies estimate it takes 12 years to reach the legal size limit of 7 inches (18 centimeters) and 5 or 6 more years to grow another inch. When abalone densities drop too low, the expectation for unsuccessful reproduction is compounded, thus increasing the risk of population collapse.

Size limits allow abalone a number of years to reproduce before being vulnerable to the fishery and in the case of red abalone we estimate there are 5-6 years of reproduction prior to entry into the fishery. While this may support reproduction there are problems with inexperienced pickers and divers removing abalone that are under sized. Abalone have no blood clotting mechanism and undersize abalone might not survive cuts caused during removal. This incidental mortality may decrease the benefits of the size limit that is designed to allow smaller abalone to reproduce for a number of years, prior to being fished. Smaller abalone produce fewer eggs and sperm than larger ones as gonad size increases exponentially with shell length. As legal size abalone are harder to find, wardens have observed people removing more abalone to find legal size abalone. Intertidal surveys at heavily used sites revealed few abalone of any size, suggesting in some cases people may not be obeying the size limits.

The prohibition of scuba or surface supplied air sources is thought to be an instrumental regulation in sustaining abalone populations in northern California. This management measure is unique to northern California as the south allowed scuba in the past. This regulation creates a reserve in deeper water since most fishermen do not free dive deeper than 28 feet (9 meters). Abalone populations in deeper water remain relatively undisturbed and this measure is thought to promote reproduction at levels high enough to sustain the fishery in shallow water.

Eight new Marine Protected Areas (MPAs) which prohibit the take of abalone, as well as other species, were established in May 2010 at sites between Point Reyes and Point Arena in Marin and Sonoma Counties. The newly closed areas may have reduced the abalone catch by 15,000 abalone based on 2009 abalone card data (approximately 9 percent of the catch for the area). Abalone card data for 2010 showed little evidence for a shift in effort to open sites. Two small MPAs established earlier at Del Mar Landing and Gerstle Cove (both in Sonoma County) continue to protect abalone populations. Studies are needed to determine the value of MPAs compared to adjacent fished sites as a source of larvae and adults. One area that is now an MPA was a “de facto” reserve when held as private property near Point Arena. This area once opened to the public for 6 years was heavily fished and Department data indicates abalone of all size were illegally taken.

Violations of abalone regulations continue to be a great concern because of the apparent magnitude of the problem and the difficulty in accurately assessing the impact on the fishery. A newly adopted tag system was developed for abalone which wardens believe has greatly increased compliance with abalone regulations. The recent implementation of an Automated License Data System will also help improve control over the illegal purchase of multiple cards reducing violations of annual take limits. Wardens commonly encounter people violating regulations and although the magnitude of the illegal catch is not known, it is believed to have a significant impact on red abalone populations.

Southern California Red Abalone

As part of the adoption of the ARMP in 2005, the Commission initiated a process to provide information to consider opening a limited fishery for red abalone at San Miguel Island. The fishery consideration process involves the Department, a constituent advisory group that developed fishery management options, a technical panel that developed stock assessment models, and a review committee that provided a review of the stock assessment work. The process has provided the Commission with four fishery options, stock assessment information and supplementary modeling work to assess the conservation risk associated with conducting a limited fishery. At its February 2013 meeting, the Commission decided not to move forward with a fishery at San Miguel Island.

The process has provided an opportunity for the Department and the Commission to explore different ways to manage an abalone fishery. This process was a collaborative venture that was developed together with the Department's constituents. Involving constituents from the outset is intended to reduce disagreements in the recommendations from various stake holders. This will help inform the Commission when deciding whether to conduct a fishery or not, and, if a fishery is allowed, what type of management to use. The San Miguel Island process has set an example for future fishery consideration processes as other abalone species stocks begin to recover.

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Abalone commercial landings (pounds), 1916-1997.							
Year	**Black**	**Red**	**Green**	**Pink**	**White**	**Unspecified**	**Total**
1916	0	762,003	0	0	0	0	762,003
1917	0	637,773	0	0	0	0	637,773
1918	0	602,918	0	0	0	0	602,918
1919	0	759,203	0	0	0	0	759,203
1920	0	806,714	0	0	0	0	806,714
1921	0	1,481,178	0	0	0	0	1,481,178
1922	0	1,523,402	0	0	0	0	1,523,402
1923	0	1,555,142	0	0	0	0	1,555,142
1924	0	2,241,792	0	0	0	0	2,241,792
1925	0	2,352,896	0	0	0	0	2,352,896
1926	0	2,060,778	0	0	0	0	2,060,778
1927	0	2,816,576	0	0	0	0	2,816,576
1928	0	2,066,243	0	0	0	0	2,066,243
1929	0	3,438,848	0	0	0	0	3,438,848
1930	0	3,176,544	0	0	0	0	3,176,544
1931	0	3,250,016	0	0	0	0	3,250,016
1932	0	2,750,048	0	0	0	0	2,750,048
1933	0	2,700,096	0	0	0	0	2,700,096
1934	0	3,200,064	0	0	0	0	3,200,064
1935	0	3,870,944	0	0	0	0	3,870,944
1936	0	3,250,016	0	0	0	0	3,250,016
1937	0	2,800,000	0	0	0	0	2,800,000
1938	0	2,121,459	0	0	0	0	2,121,459
1939	0	1,750,000	0	0	0	0	1,750,000
1940	0	1,650,006	5,152	0	0	0	1,655,158
1941	0	950,006	0	0	0	0	950,006
1942	0	100,000	0	0	0	0	100,000
1943	0	600,006	46,144	0	0	0	646,150
1944	0	1,449,997	59,136	336	0	0	1,509,469
1945	0	2,298,464	126,112	4,704	0	0	2,429,280
1946	0	1,950,010	119,168	0	0	0	2,069,178
1947	0	2,100,000	109,312	376,096	0	0	2,585,408

Abalone commercial landings (pounds), 1916-1997.							
Year	**Black**	**Red**	**Green**	**Pink**	**White**	**Unspecified**	**Total**
1948	0	1,849,994	19,936	1,351,168	0	0	3,221,098
1949	0	1,799,997	10,080	1,818,208	0	0	3,628,285
1950	0	1,411,692	12,798	2,355,770	0	0	3,780,260
1951	0	1,283,695	4,621	2,399,530	0	0	3,687,846
1952	0	1,173,586	1,684	3,323,619	0	0	4,498,889
1953	0	1,411,949	5,852	3,301,549	0	0	4,719,350
1954	0	1,394,485	721	2,704,211	0	0	4,099,417
1955	0	1,996,511	1,255	2,188,139	0	0	4,185,905
1956	0	2,424,393	14,004	1,845,006	0	0	4,283,403
1957	0	2,569,025	47,880	2,803,059	0	0	5,419,964
1958	0	1,677,404	905	2,545,709	0	0	4,224,018
1959	0	2,180,658	560	2,375,534	0	0	4,556,752
1960	0	2,693,857	455	1,572,096	0	0	4,266,408
1961	0	2,873,628	526	1,678,275	0	0	4,552,429
1962	0	2,462,200	3,710	1,717,271	0	0	4,183,181
1963	0	2,807,921	33,319	1,502,639	0	0	4,343,879
1964	0	2,369,574	97,273	1,612,376	0	0	4,079,223
1965	0	2,490,875	12,129	2,072,642	438	0	4,576,084
1966	0	2,656,408	144,207	2,162,941	0	0	4,963,556
1967	0	2,691,610	106,545	1,619,126	0	0	4,417,281
1968	700	1,776,054	427,135	2,270,108	845	0	4,474,842
1969	4,791	1,564,205	157,263	1,903,026	28,009	0	3,657,294
1970	15,327	1,194,788	270,200	1,408,921	11,212	0	2,900,448
1971	106,401	1,283,567	1,125,620	386,141	43,395	0	2,945,124
1972	1,014,892	1,104,462	424,828	403,709	143,819	1,868	3,093,578
1973	1,912,949	663,919	156,804	371,352	83,112	5,008	3,193,144
1974	1,145,396	751,060	121,563	445,325	113,765	7,885	2,584,994
1975	687,428	742,769	170,927	458,235	71,821	7,290	2,138,470
1976	356,751	739,621	120,498	431,143	81,907	2,907	1,732,827
1977	463,301	537,450	97,457	318,494	17,603	1,841	1,436,146
1978	419,976	489,147	93,042	287,335	3,648	1,877	1,295,025
1979	330,928	439,469	61,327	156,383	502	3,898	992,507

Abalone commercial landings (pounds), 1916-1997.							
Year	**Black**	**Red**	**Green**	**Pink**	**White**	**Unspecified**	**Total**
1980	518,538	516,731	63,181	138,907	1,076	556	1,238,989
1981	520,948	430,315	63,950	94,127	167	140	1,109,647
1982	633,307	431,285	88,645	86,178	908	267	1,240,590
1983	484,310	231,210	56,861	67,152	482	102	840,117
1984	436,294	299,759	31,910	57,030	449	1,236	826,678
1985	359,835	368,782	23,952	68,623	1,654	1,022	823,868
1986	267,542	263,302	25,750	51,830	876	5,824	615,124
1987	309,727	391,278	28,965	31,539	2	1,550	763,061
1988	201,604	324,635	23,498	19,003	2	75	568,817
1989	218,489	469,407	19,723	22,469	22	775	730,885
1990	91,379	379,143	27,089	23,226	17	217	521,071
1991	26,226	328,466	8,154	12,780	4	1,350	376,980
1992	37,696	452,901	10,296	18,210	0	0	519,103
1993	2,032	428,216	10,011	18,409	0	0	458,668
1994	0	309,478	1,682	15,765	33	38	326,996
1995	0	244,988	1,586	17,654	38	68	264,334
1996	0	165,486	0	0	0	6	165,492
1997	0	112,323	0	0	0	0	112,323

Data source: Department catch bulletins (1916-1983) and CFIS data (1984-1997).

Red abalone recreational catch, 2002-2010.		
Year	**Number**	**Pounds**
2002	264,000	990,000
2003	262,000	982,500
2004	248,000	930,000
2005	235,000	881,250
2006	263,000	986,251
2007	309,000	1,158,749
2008	265,000	993,750
2009	295,000	1,106,250
2010	234,000	877,500

Data source: Recreational red abalone report card database and telephone survey database.

4 White Shark, *Carcharodon carcharias*

White shark, *Carcharodon carcharias*. Photo credit: P Klimley, PhD, UC Davis

History of the Fishery

The white shark, *Carcharodon carcharias*, has never been a target of commercial or recreational fisheries off California. Although attempts were made to establish a market for white shark meat in the 1970s and 1980s, the species' reputation for human attacks made this a difficult product to market, and their low relative abundance made fishing in a profitable manner challenging. In 1979, the California Department of Fish and Wildlife (Department) added a market category for white shark; prior to 1979, white sharks were grouped in the unspecified shark market category in landing records.

White shark is taken incidentally in some commercial fisheries, with most interactions occurring in the set gill net and other gill net (drift gill net and trammel net) fisheries (Figure 4-1). An increased appearance of white shark in the commercial catch coincided with an increase in the popularity of gill nets after the introduction of monofilament line in the 1970s.

Since 1994, the directed take of white shark has been prohibited, although incidental landings in the gill net and seine fisheries are allowed (FGC§ 8599). White sharks caught incidentally are primarily sold for research rather than human consumption. The majority of incidental white shark landings occur in the Southern California Bight (SCB), most often in the set gill net fisheries targeting California halibut, Pacific angel shark, and white seabass (Figure 4-1). The SCB is recognized as an important nursery area for white shark in the northeastern Pacific (NEP), and a majority of documented white shark fishery interactions occur within this area and involve juveniles and young of the year (YOY). An additional factor for the predominance of this demographic in the catch data is that larger white sharks are likely able to break through monofilament nets and hook-and-line gear without steel leaders.

In 1994, two significant regulations went into effect that increased protections for the white shark population in California waters. The first was Proposition 132, the Marine Resources Protection Act of 1990 (FGC §8610 et seq.), which, when implemented in 1994, banned entangling nets (set and drift gill nets, and trammel nets) in state waters (<3 nautical miles [5.6 kilometers] from shore) between the California/Oregon border and Point Reyes (Marin County), and around the Farallon Islands. Between Point Reyes and Point Arguello (Santa Barbara County) entangling nets were limited by depth (originally 30 fathoms, currently 60 fathoms [55 and 109 meters, respectively]). Between Point Arguello and the U.S./Mexico border entangling nets were closed in state waters (<3 nautical miles from shore and <1 nautical mile around offshore islands; <5.6 and <1.8 kilometers, respectively). The second was FGC §8599 and Title 14, CCR, §28.06 which prohibits take of white sharks except when taken incidental to legal commercial fishing activity utilizing gill net or roundhaul net (seine net), or under a Scientific Collecting Permit for scientific or educational purposes. These prohibitions and an overall decrease in effort of the set and drift gill net fisheries resulted in significant declines in white shark landings in commercial fisheries through the 1990s and early 2000s (Figure 4-1).

In 2004, white sharks gained federal and international protection in a treaty approved by the United Nations affiliated Convention on International Trade in Endangered Species (CITES). Under CITES, white shark is listed under Appendix II, which includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival.

The increase in commercial white shark landings since 2005 (Figure 4-1) in conjunction with the continued decrease of commercial gill net effort has been cited in recent literature as a possible sign that the population is increasing and as a result more juveniles are utilizing the SCB in areas where commercial set gill nets fish.

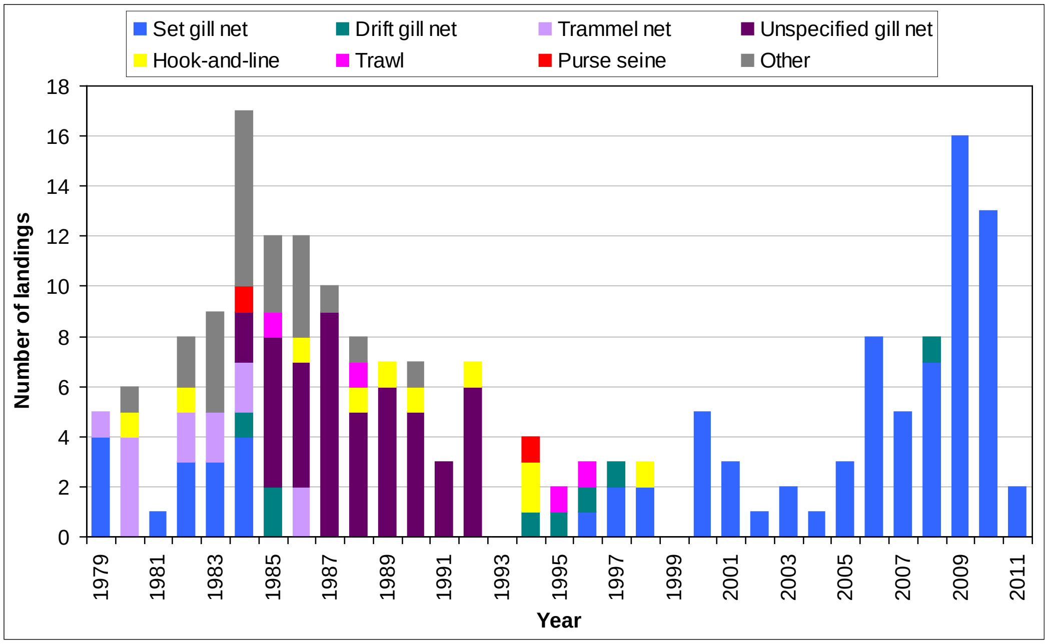

Figure 4-1. White shark incidental commercial landings by gear type, 1979-2011. Data source: Commercial Fisheries Information System (CFIS) data. Data prior to 1979 are not available.

California recreational anglers do not target white shark and rarely catch them, based on available data from the commercial passenger fishing vessel (CPFV) logbook program and the RecFIN database. There have only been seven white shark interactions recorded in CPFV logbook records (Table 4-1), and only one record in the RecFIN database (Marine Recreational Fisheries Statistics Survey [1980-2003] and CRFS [2004-2011]) since these recreational survey efforts began in 1980. These records are not a full accounting of recreational activity, but they do show that this species is not common in the recreational catch.

Table 4-1. White shark CPFV landings, 1980-2011.

Year	Fish	Year	Fish	Year	Fish	Year	Fish
1980	0	**1988**	0	**1996**	0	**2004**	2
1981	0	**1989**	0	**1997**	1	**2005**	0
1982	0	**1990**	0	**1998**	0	**2006**	1
1983	0	**1991**	0	**1999**	0	**2007**	0
1984	0	**1992**	0	**2000**	1	**2008**	0
1985	0	**1993**	1	**2001**	0	**2009**	0
1986	0	**1994**	0	**2002**	0	**2010**	1
1987	0	**1995**	0	**2003**	0	**2011**	0

Data Source: Department CPFV logbook data. Landings in this table include kept and released sharks. Data prior to 1979 are not available.

Status of Biological Knowledge

The study and understanding of the life history of white sharks has been limited until quite recently. White sharks did not come under focused study until the 1970s, and the first species-specific symposium on the biology of white shark research did not occur until May 1983 at the California State University, Fullerton campus. A majority of the presentations from this first meeting were anecdotal and the few quantitative studies were small and limited in scope. Over the next ten years more empirical and experimental studies were conducted, but there was still relatively little mention of white shark in the scientific literature. In March 1993 a symposium on white shark was organized at the Bodega Marine Laboratory of the University of California that drew scientists from six continents, presenting on a broad range of research topics. This meeting presented both traditional scientific papers on the biology of the species, and a forum to discuss and evaluate controversial ideas and misconceptions about the species in the media and public perception. The result of this meeting was a book titled Great White Sharks: The Biology of *Carcharodon carcharias*, which began two decades of increased focus and research on white sharks.

Through the late 1990s understanding of the biology and life history of this species was hindered by its solitary nature and distribution throughout a large range. White sharks are large, aggressive predators and have a naturally small population. Understanding of this species has dramatically increased due to advances in electronic tagging technology over the last decade. Electronic tagging programs and photo-identification studies have increased scientific knowledge and understanding of migration patterns, habitat preference and use, behavior, and have provided a clearer picture of the interaction and segregation of global populations. In addition, recent genetic studies have shown that the NEP population is genetically distinct from other populations of white shark.

Despite these advances, there are still large gaps in our understanding of the basic life history of white sharks such as age, growth, and reproductive biology. Obtaining this knowledge may be slow due to the small population and restrictions imposed by important protections afforded to the species over the last decade. These factors limit samples to opportunistic interactions with commercial fisheries and nonlethal fishery independent methods. The amount of available literature focused on the NEP population of white sharks (the population found off the coast of California) is much greater than what is available for other populations (Australia/New Zealand and western South Africa).

Globally, white sharks are found throughout most seas and oceans with concentrations in temperate coastal waters. The NEP population ranges from Alaska south to Baja California, Mexico and the Gulf of California, Mexico, and as far west as the Hawaiian Islands. Adults of this population have been observed aggregating seasonally at two primary sites along the west coast of North America. One site is a network of hot spots off the coast of central California (CC) west of San Francisco Bay, and the other is off

Guadalupe Island, Mexico (GI). Both of these locations support large breeding colonies of northern elephant seals, California sea lions and other pinniped species. But availability of preferred prey does not account for the density of adult white sharks in the aggregation areas. It is believed the primary reason for these aggregations is mating.

No white sharks have been observed mating anywhere in the world, so a lack of direct observation does not invalidate this theory. Several studies using pop-up archival transmitting (PAT) tags and satellite-linked radio transmitting (SLRT) tags to track individual movements and migration patterns have found significant circumstantial and indirect evidence that these two aggregations are where mating occurs for the NEP population. Near aggregation sites, adult sharks are captured and restrained for sample collection and tagging. Researchers measure the animals, collect blood samples for hormone analysis, take genetic samples and make physical observations of mating activity (condition of claspers on males and presence of conspecific bite marks on females). Observations at both aggregation sites have shown the presence of running-ripe males and females with fresh conspecific bite marks, two possible indicators that mating has occurred. Additional studies tag free swimming sharks attracted to the vessel with decoys and scent, and others photograph identifying markers to track site use by individuals. Tracking data shows sex-specific seasonal migration patterns, with adult males returning annually to aggregation sites (CC or GI) while females usually show a biennial return pattern. This pattern is most likely due to a gestation period of approximately 18 months, as no female observed with conspecific bite marks (evidence of mating) returned the following year.

Adult males from both aggregation sites migrate to a Shared Offshore Foraging Area (SOFA) located midway between North America and the Hawaiian Islands. Adult females migrate offshore in a much more diffuse pattern, and are only found passing through the SOFA while males are absent. This sex-specific difference in use of offshore habitat might be due to a difference in prey preference between males and females during the pelagic portions of their migrations. The SOFA has been characterized as an epipelagic “cold spot” with low epipelagic productivity (epipelagic refers to waters from the surface to 109 fathoms deep [surfact-200 meters]), consisting primarily of sperm whales and three species of mesopelagic squid (mesopelagic refers to waters 109-3280 fathoms deep [200-1000 meters]). It has been suggested that these sharks are feeding on a diet of squid or species that target squid, but this has not been confirmed. In contrast, females do not always return to the aggregation sites annually and can be considered primarily pelagic. While their migration is much more dispersed and less predictable than males, they have been tracked going back and forth between the eastern edge of the SOFA and the continental shelf of North America. Utilization of these areas, where small cetaceans are more frequently encountered, may show a preference for these mammals as a prey source.

Some individuals, both male and female, make a separate and distinct migration to the Hawaiian Islands. This occurs at the same time as the other offshore migrations, but these animals avoid the SOFA altogether passing to the north or south. These sharks are potentially targeting small cetacean prey not available in the SOFA, but it is unclear why they would migrate such a great distance when similar prey is available near the continental shelf of North America.

Tagging and photo-identification studies also show that white sharks in the NEP exhibit philopatric behaviors (i.e., returning to the same area annually) and usually return to the same aggregation site where they were tagged. This provides strong evidence that the NEP population is demographically isolated from populations near Australia/New Zealand and western South Africa. In addition the NEP population has also been shown to be genetically distinct. When returning to the adult aggregation sites (CC and GI) males generally arrive over a few weeks from late July through early August, while most females return in October.

There is limited information available on pregnant females and embryonic specimens, but white sharks are believed to be ovoviviparous with oophagy, meaning the embryos hatch from egg capsules inside the mother, are nourished first by a yolk sac (in egg capsule and possibly a short time after hatching) and then by consuming unfertilized eggs produced by the mother and born live. It has been speculated that females give birth to live litters of 4 to 14 pups, but this is based on a very limited number of pregnant females that have been caught and examined worldwide. Size at birth depends on the size and physical condition of the mother, but is believed to range from 3.9-4.9 feet (1.2-1.5 meters) total length (TL). Unlike males that generally migrate directly between offshore areas and aggregation sites, pregnant females will migrate to the nearshore waters of the SCB and Baja California, Mexico to give birth before returning to the adult aggregation sites. Appearance of YOY in scientific collections and as incidental catch in the set gill net fishery suggests that parturition (i.e., birth) occurs May through October, peaking in July with only a minimal amount occurring after August. Young of the year remain in these shallow, warm-water nursery areas for their first summer and fall, feeding on fish and invertebrates. As water temperatures cool in the fall the YOY migrate south to Baja California, Mexico.

As juveniles, the sharks continue to migrate north and south in nearshore waters from the SCB to the Gulf of California, staying in warmer water until they are large enough to exploit colder water areas. Juveniles prey on a variety of fish, invertebrates and opportunistically scavenge marine mammal carcasses. In their third year, at approximately 6.6 feet (2 meters) TL, juveniles begin to venture north of Point Conception, into central California. Sub-adults range widely from Oregon to the Gulf of California, Mexico. They will begin to visit aggregation sites and make inshore/offshore migrations, but little is known about how they locate these sites, or when and how they switch behavior patterns and begin their migrations. It has been suggested that this may be a time when mixing occurs between the CC and GI populations. As sub-adults grow in size and skill, they will also start to actively prey on small marine mammals. This change in prey preference is considered common, but recent research looking at feeding ecology using isotopic analysis of vertebrae suggests that some animals may retain a fish-based diet throughout their lives.

Research focused on YOY and juveniles occurs primarily in the SCB and includes tagging for mark-recapture and tracking, and tissue sampling for contaminant levels and genetic analysis. In addition, the Monterey Bay Aquarium White Shark Program conducts a short term captivity program of YOY white sharks for display, and study of captive feeding and growth, oxygen consumption, other biological measures and post-release behavior.

Only rough estimates can be given for length at which individuals become sexually mature, as a wide range of maturities have been seen amongst sharks of similar size. Given this variance most males become sexually mature at 11.8-15.1 feet (3.6-4.6 meters) TL and females at 14.8-16.4 feet (4.5-5.0 meters) TL. Females are usually larger than males and have been documented with certainty to grow to a maximum of 19.7 feet (6 meters) TL and males to 18 feet (5.5 meters) TL. There are records and reports of larger individuals, but a recent examination of these accounts has shown them to be erroneous or unsubstantiated.

Status of Population

There are no historic estimates of the NEP white shark population. White sharks are challenging to study and have a naturally low abundance. Additionally, The protections afforded white shark and the low natural abundance make it difficult to obtain sufficient data as sampling is limited to nonlethal fishery independent methods (tagging program) and opportunistic interactions with commercial fisheries. As a result, only recently have studies been conducted to estimate the populations of adults and sub-adults utilizing the primary aggregation sites. The occurrence of incidental fishing interactions, habitat loss, other negative pressures on the population, and a lack of effective population estimates may leave the population susceptible to undetected decline until after a significant decrease has occurred. This makes current and future research on migration patterns, individual identification for population estimates, recruitment and general life history, crucial to our understanding of the species and our ability to protect the population from anthropogenic and environmental impacts.

Management Concerns

White shark is not a federally managed species, but is listed in the federal Highly Migratory Species Fishery Management Plan as a prohibited species. Under California law, take of white sharks is prohibited except when taken incidental to legal commercial fishing activity utilizing gill net or roundhaul net (seine net), or under a Scientific Collecting Permit for scientific or educational purposes. Further protections are afforded the species through federal and state bans and restrictions on the practice of shark finning, and the possession, trade and sale of shark fins. Internationally, white shark is listed in CITES as an Appendix II species, which restricts trade of a species that may become threatened with extinction to avoid utilization incompatible with their survival. This includes whole carcasses or their parts.

Although this species has strict protections under state and federal laws, concerns have been raised over the status of the population off California. In February 2013, the California Fish and Game Commission (Commission) declared white shark a candidate species under the California Endangered Species Act (CESA) (FGC §2074.6 (a)(2)), in response to a petition to list NEP white shark as threatened or endangered in the state of California. During the twelve month candidacy period white shark is afforded the same protections as a listed species under CESA, including the prohibition of all take, except where authorized under permit by the Department (FGC §2081 (a & b). At the end of the candidacy period, the Department will provide the Commission with a report on white shark and the Commission will determine whether or not to list white shark as threatened or endangered under CESA.

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Further Reading

Domeier ML, editor. 2012. Global perspectives on the biology and life history of the white shark. Boca Raton, FL: CRC Press, Taylor & Francis Group, LLC. 567 p.

IUCN 2011. IUCN Red List of Threatened Species (ver.3.1). Available from: www.iucnredlist.org. Accessed: 20 March 2012.

Klimley AP, Ainley D, editors. 1996. Great White Sharks: the biology of *Carcharodon carcharias*. San Diego, CA: Academic Press. 517 p.

White shark incidental commercial landings by gear, 1979-2011.

Year	Set gill net	Drift gill net	Trammel net	Unspecified gill net	Hook-and-line	Trawl	Purse seine	Other	Total
1979	4	0	1	0	0	0	0	0	5
1980	0	0	4	0	1	0	0	1	6
1981	1	0	0	0	0	0	0	0	1
1982	3	0	2	0	1	0	0	2	8
1983	3	0	2	0	0	0	0	4	9
1984	4	1	2	2	0	0	1	7	17
1985	0	2	0	6	0	1	0	3	12
1986	0	0	2	5	1	0	0	4	12
1987	0	0	0	9	0	0	0	1	10
1988	0	0	0	5	1	1	0	1	8
1989	0	0	0	6	1	0	0	0	7

White shark incidental commercial landings by gear, 1979-2011.

Year	Set gill net	Drift gill net	Trammel net	Unspecified gill net	Hook-and-line	Trawl	Purse seine	Other	Total
1990	0	0	0	5	1	0	0	1	7
1991	0	0	0	3	0	0	0	0	3
1992	0	0	0	6	1	0	0	0	7
1993	0	0	0	0	0	0	0	0	0
1994	0	1	0	0	2	0	1	0	4
1995	0	1	0	0	0	1	0	0	2
1996	1	1	0	0	0	1	0	0	3
1997	2	1	0	0	0	0	0	0	3
1998	2	0	0	0	1	0	0	0	3
1999	0	0	0	0	0	0	0	0	0
2000	5	0	0	0	0	0	0	0	5
2001	3	0	0	0	0	0	0	0	3
2002	1	0	0	0	0	0	0	0	1
2003	2	0	0	0	0	0	0	0	2
2004	1	0	0	0	0	0	0	0	1
2005	3	0	0	0	0	0	0	0	3
2006	8	0	0	0	0	0	0	0	8
2007	5	0	0	0	0	0	0	0	5
2008	7	1	0	0	0	0	0	0	8
2009	16	0	0	0	0	0	0	0	16
2010	13	0	0	0	0	0	0	0	13
2011	2	0	0	0	0	0	0	0	2

Data source: CFIS data. Data prior to 1979 are not available.

5 Pacific Salmon, Salmonidae

Salmon processing plant circa 1934. Photo credit: Department archives.

Salmon are among California's most valued natural resources. They provide a source of highly nutritious food for the general population and are an important source of income for the commercial salmon industry. Recreational anglers value them for their excellent sporting qualities and Native Americans celebrate them in many aspects of their culture. Salmon play a key role and occupy a unique niche within the State's highly diverse marine and inland ecosystems. They are considered a top predator but also contribute to the sustenance of other aquatic and terrestrial animals. In addition, their carcasses enrich the nutrient base of their natal (birth) streams after spawning is complete. Like other anadromous species (live part of their life in fresh water and part in salt water), their survival depends on the quantity and quality of freshwater spawning and rearing habitat available to them. The destruction of that habitat over the past two centuries has resulted in the biological extinction or extirpation of many naturally spawning populations of salmon. These same habitat issues threaten the viability of Chinook populations today. In the following, 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 Salmon Fisheries

Of the five species of Pacific salmon found on the Pacific coast, Chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, are the species most frequently encountered in California fisheries. Small numbers of pink salmon, *O. gorbuscha*, are caught on occasion, primarily in odd-numbered years. Chum salmon*, O. keta*, and sockeye salmon, *O. nerka*, are rarely seen in California waters.

Salmon fisheries existed in California long before European settlers made their first appearance in the state circa 1775. Native Americans may have harvested over 8.5 million pounds (3855 metric tons) of salmon annually. In northern coastal areas, native peoples subsisted primarily on salmon. Salmon not only formed the bulk of their diet - a family might eat up to 2000 pounds (900 kilograms) a year - but 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 fishermen that ceremonies and rituals honoring their existence and importance were created. Traditional fishing methods included gill and dip nets, fishing spears, and communal fish dams.

Commercial salmon fishing in California began in the early 1850s, coinciding with the massive inflow of miners into the gold country. By 1860, gill net salmon fisheries were well established in the San Francisco Bay area (primarily Suisun Bay and San Pablo Bay) and in the lower Sacramento and San Joaquin rivers. The gill net fishery gradually spread to include coastal rivers north of San Francisco, although the Sacramento-San Joaquin fishery remained the largest. Growth of this fishery was enhanced by the canning industry.

The first salmon cannery on the West Coast started operations on the Sacramento River in 1864. By 1880, there were 20 canneries operating in the Sacramento and San Joaquin rivers and increased fishing effort provided them with an ample supply of salmon. The fishery reached its peak in 1882 when about 12 million pounds (5440 metric tons) were landed and processed. Shortly thereafter, the fishery collapsed due to a sudden decline in salmon stocks caused by the pollution and degradation of rivers from mining, agriculture, and timber operations, combined with an increase in fishing pressure. By 1919, the last inland cannery had shut its doors and one by one, California rivers were closed to commercial fishing. State 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 remaining commercial river fishery closed in the Sacramento-San Joaquin basin.

The ocean troll commercial salmon fishery began in Monterey Bay during the 1880s. These early fishermen trolled for salmon using small sailboats that supported two hand rods, one on each side of the boat with a single hook and leader attached to each line. Circa 1908, several Sacramento-San Joaquin fishermen transported their powered gill net boats to Monterey Bay and began trolling for salmon. These boats were a great improvement over the sailboats, but were still small compared to current standards. The fishery quickly grew to approximately 200 boats and by 1916, had expanded north off the coasts of San Francisco, 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 (13.6 kilograms) of lead attached to keep the line at the proper depth. In 1935, about 600 trollers were active in the fishery. Pulling weights, lines, and salmon by hand onto a moving boat was a backbreaking job. Power gurdies were soon developed to pull the lines and, by the mid 1940s, were used by most of the professional salmon trollers.

A significant increase in fishing effort occurred after World War II, in conjunction with improved transportation and a rebound in salmon populations. By 1947, the commercial fleet had nearly doubled to 1100 vessels and was continuing to grow. The fleet peaked at almost 5000 vessels in 1978 and included many summer fishermen who held other jobs during most of the year. Although some of these part time participants were serious about commercial fishing and had adequate ocean going boats, most used small sport-type boats that could be conveniently towed on a trailer. In 1983, a limited entry program was established in California and the number of active participants has steadily declined since its inception. During the last decade, the number of salmon vessels participating in the fishery has averaged less than 600 boats a year.

Salmon trollers today still use the basic fishing techniques developed during the 1940s, including powered gurdies and trolling four to six main lines (Figure 5-1). Today's vessels, however, 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 bait 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 significantly improved the efficiency of the modern troller compared to 75 years ago.

Figure 5-1. Commercial salmon troller. Photo credit: J Phillips, CDFW.

Estimates of commercial salmon catches are available in one form or another for years as early as 1874. In 1929, the California Department of Fish and Wildlife (Department) began officially reporting state commercial landings by weight, including the salmon catch data (all species combined) back to 1916. In 1952, the Department's Ocean Salmon Project began a systematic sampling of commercial ocean salmon landings to differentiate Chinook from coho harvest.

Prior to 1990, the industry enjoyed relatively high and consistent salmon landings, averaging about 7.5 million pounds (3400 metric tons) annually (Figure 5-2). The largest commercial landings observed in California occurred in 1988 when more than 14. million pounds of Chinook (6500 metric tons; 1.3 million fish) and 319,500 pounds of coho (145 metric tons; 51,000 fish) were landed (Figure 5-3). During the last two decades, salmon landings have been much more variable and overall lower, averaging 3.5 million pounds (1580 metric tons) a year. Although oceanic and river conditions play a major role in annual salmon catches, variation among years can also be attributed to changes in fishery regulations and fishing effort. In 1993, the retention of coho salmon was prohibited in all California commercial fisheries to protect depressed coho stocks in central and northern California coastal streams.

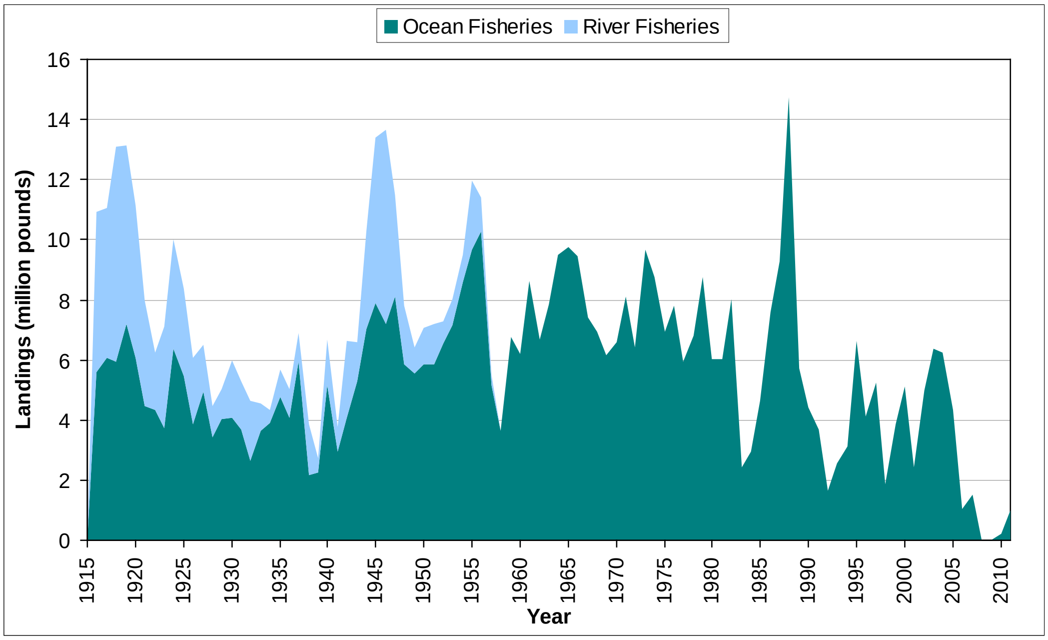

Figure 5-2. Pacific salmon commercial landings, 1916-2011, in California river and ocean fisheries**.** The last river fishery closed in 1957. Data source: Department catch bulletins (1915-1951), and Department Ocean Salmon Project and Pacific Fishery Management Council (PFMC) data (1952-2011), all species and gear types combined.

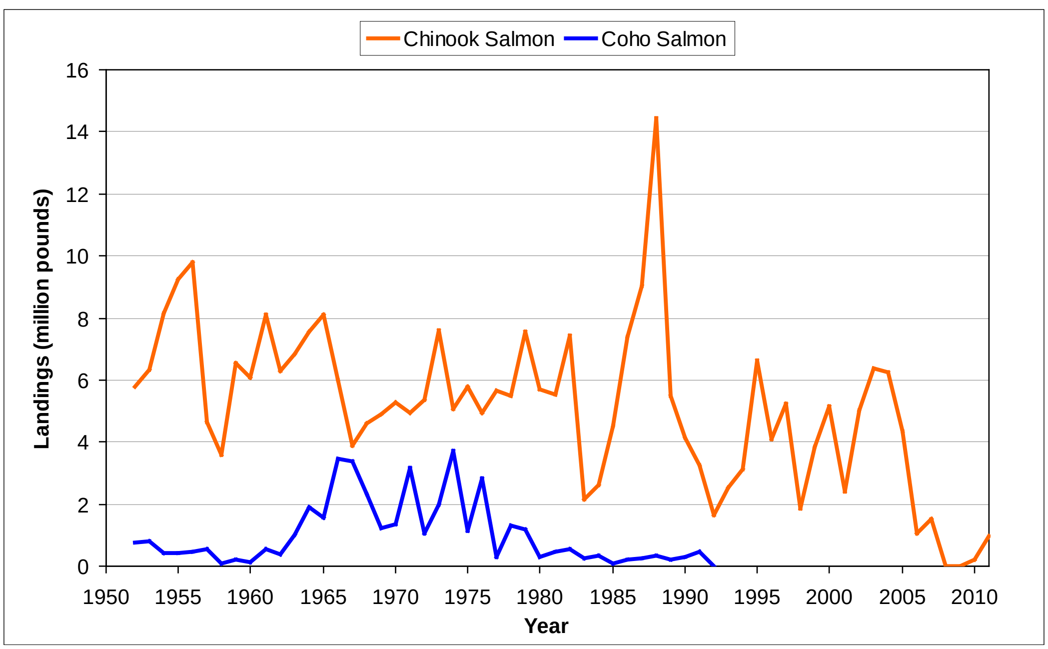

Figure 5-3. Pacific salmon commercial landings by species, 1952-2011. The take of coho salmon was prohibited after 1992. Data source: Department Ocean Salmon Project and Commercial Fisheries Information System (CFIS) data, all gear types combined.

Although California ocean fisheries have been constrained by the Pacific Fishery Management Council (PFMC) to protect various salmon stocks of special concern during the last several decades, it wasn't until the sudden collapse of Sacramento River fall Chinook in 2007 that a complete closure of the fishery was enacted in 2008 and 2009. Although open in 2010 and 2011, commercial ocean salmon fishing remained severely constrained to allow the Sacramento River fall Chinook population to rebuild.

The lowest commercial landings on record occurred during the 2006 through 2011 seasons (Figure 5-2), resulting in a more than doubling of the average price per pound of $5.25 ($2.38 per kilogram) compared to the long term average of $2.11 ($0.96 per kilogram) observed during the previous fifteen years (Figure 5-4). This can be attributed, in large part, to the economics of the fishery today with increased costs to the fisherman and reduced landing totals compared to the historical average.

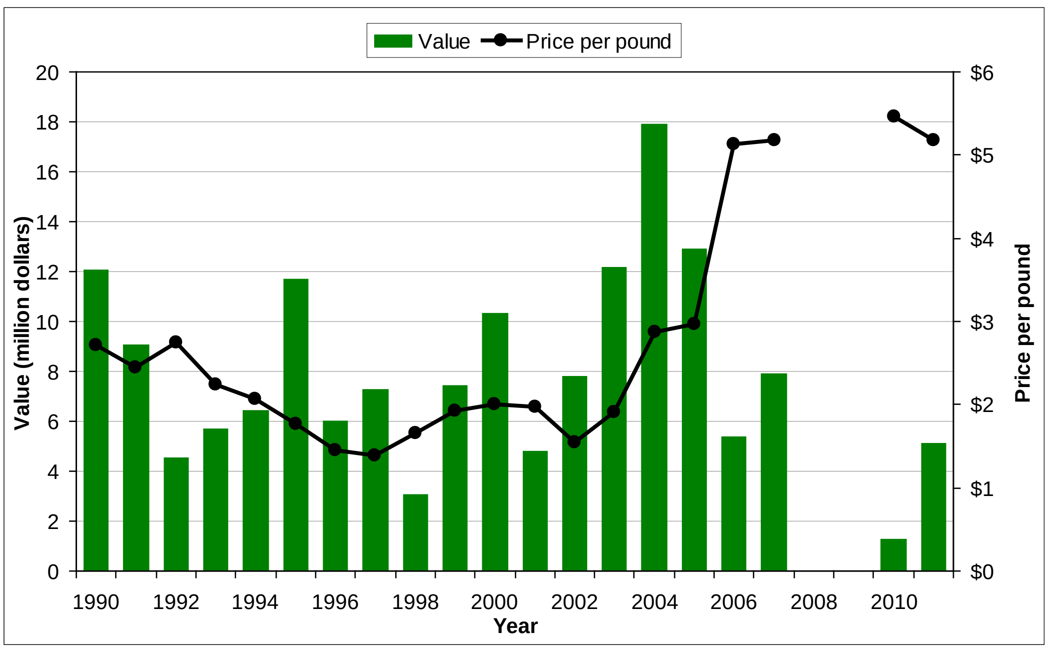

Figure 5-4. Pacific salmon (Chinook and coho) commercial value and average price per pound, 1990-2001. Data source: Department Ocean Salmon Project and CFIS data, all species and gear types combined.

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 of CPFVs and private skiffs (Figure 5-5). From its initial monitoring through 1989, the sport industry contributed 17 percent on average to the total salmon catch landed annually in California. Most of this sport catch (over two-thirds) was by anglers fishing on CPFVs. Since 1990, the sport fishery contribution to total California salmon landings has increased and generally accounts for about a third of the annual Chinook sport harvest.

During the early 1990s, a fishing technique known as mooching began to gain popularity among salmon anglers in San Francisco and Monterey Bay areas. Mooching is preferred when salmon are feeding on forage fish, such as anchovies or herring, in 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 “J” hook generally sets itself in the mouth of the fish 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 or internally damaged when caught by mooching.

Figure 5-5. Department sampler examining a recreationally caught salmon. Photo credit: C Hanson, Media.

Onboard observations conducted by the Department’s Ocean Salmon Project (OSP) on CPFVs during the early 1990s found that 60-80 percent of the sublegal salmon less than 20 inches (51 centimeters) total length (TL) caught via mooching were hooked in the guts or gills (Figure 5-6). Since studies have shown that more than 85 percent of sublegal salmon hooked in the gut or gills eventually die due to these injuries, there was concern that this fishing technique could seriously impact salmon populations. Hooking mortality studies conducted by the OSP during 1995-1997 found that the use of circle hooks significantly reduced the gut-hooking of sublegal salmon. Beginning in September 1997, salmon anglers mooching with bait between Horse Mountain and Point Conception were required to use circle hooks (Title 14 §27.80) and subsequent CPFV onboard studies found that the proportion of sublegal salmon gut-hooked was reduced to 41 percent.

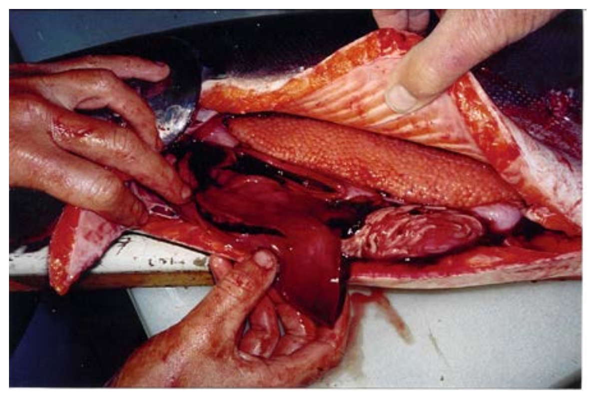

Figure 5-6. Internal injuries of gut-hooked salmon caught via mooching with 'J' hook. Photo credit: M Palmer Zwahlen, CDFW.

The popularity of mooching peaked in 1995 when 80 percent of anglers in the San Francisco and Monterey Bay areas mooched for salmon. Since then, the proportion of anglers mooching has gradually declined each year primarily due to changes in the distribution and schooling patterns of salmon and their prey off of the San Francisco port area. During the last five seasons, the proportion of anglers mooching has averaged 15 percent, with most activity occurring in Monterey Bay.

The highest coho catch in the recreational ocean fishery occurred in 1991 when almost 69,300 fish were caught by anglers (Figure 5-7). As with the commercial fishery the retention of coho in any California ocean sport fishery was prohibited after 1993 specifically to protect declining California coastal coho stocks. The highest Chinook sport landings on record occurred in 1995 when anglers landed 397,200 fish (Figure 5-7). Prior to complete fishery closures in 2008 and 2009, the lowest recreational landings of salmon generally occurred after strong El Niño events (e.g., 1978, 1983, 1992). After the collapse of Sacramento River fall Chinook, the lowest catch on record during an open season occurred in 2010 when only 14,800 Chinook were harvested by anglers statewide.

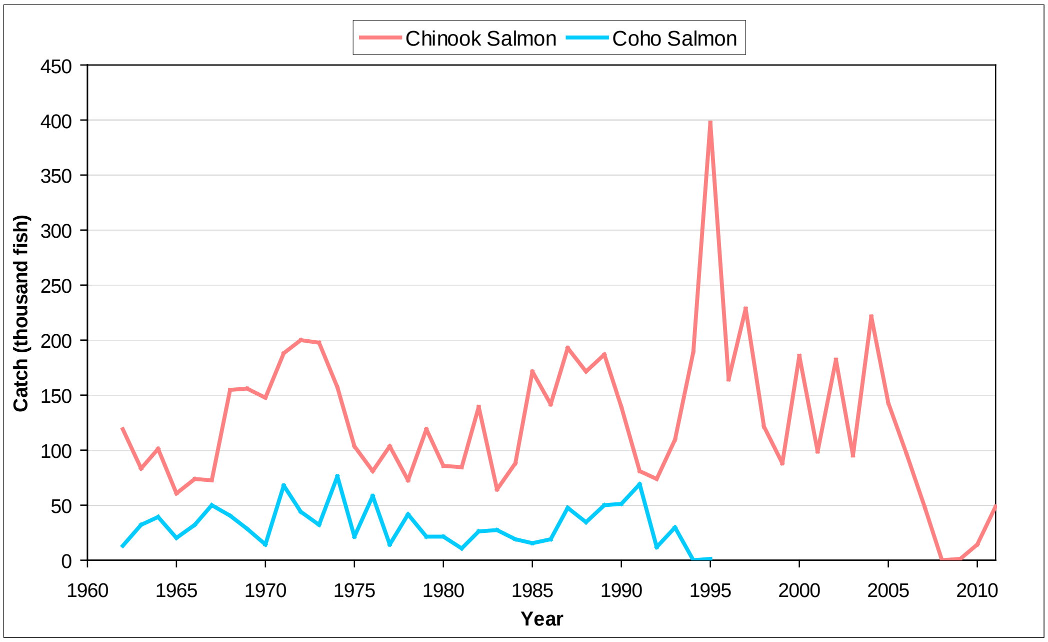

Figure 5-7. Pacific salmon (Chinook and coho) recreational catch, 1962-2011. The take of coho salmon was prohibited statewide after 1993. Data source: Department Ocean Salmon Project and CPFV logbook data.

All commercial river fishing in the Klamath Basin was closed by legislation in 1933; however, the State's jurisdiction over tribal commercial fishing was challenged in 1969 when a Yurok tribe member had his gill nets confiscated by the State for fishing on the lower Klamath River. After years of litigation in the lower courts, the issue was decided by the First District Court of Appeals in 1975. The ruling was 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 (32 kilometers) of the Klamath River was opened to tribal gill net fishing for subsistence and commercial harvest. However, in 1978, the BIA closed the tribal commercial fishery, allowing only subsistence fishing in the Klamath and Trinity rivers. The so-called Conservation Moratorium remained in effect until 1987 when the BIA reopened commercial fishing by Native Americans on the lower

Klamath River. In 1993, the Department of the Interior determined that the Yurok and Hoopa Valley tribes possessed a federally reserved right to take 50 percent of the harvestable surplus of Klamath Basin fall Chinook salmon annually. Since then, the annual tribal harvest has ranged between 8,100 and 56,700 fall run salmon.

Status of Biological Knowledge

Pacific salmon are anadromous and semelparous (die after spawning). Both Chinook and coho salmon have similar spawning requirements and habits. Successful spawning requires cold clear water of temperatures less than 56° F (13° C), suitable gravel, and a stream velocity sufficient to permit excavation of redds (nests) and to provide high subgravel flow to the deposited, fertilized eggs. The female digs the nest, lays the eggs, and covers them after fertilization. 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) swim up out of the gravel and begin feeding on microscopic organisms.

When the salmon are about 2 inches (5 centimeters) long, their backs become brown and their bellies light silver so that they blend inconspicuously with their background. Referred to as fingerlings, the length of residency in the stream 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 one to six years in the ocean, depending on species, they become sexually mature and begin their arduous journey upriver to their natal stream to spawn.

<u>Chinook salmon</u>

Chinook salmon, *Oncorhynchus tshawytscha*, (Figure 5-8) are the largest of the salmon species. The State record for a recreationally-caught Chinook is 88 pounds (40 kilograms), landed by an angler on the Sacramento River in 1979. The largest Chinook on record is a 127-pounder (58 kilograms) taken from a trap in Alaska.

Figure 5-8. Chinook salmon, *Oncorhynchus tshawytscha*. Photo credit: M DuVernay, CDFW.

California has two large basins that support most of the State's Chinook salmon runs: the Central Valley, which contains the Sacramento and San Joaquin river basins and their respective tributaries, and the Klamath Basin, which contains the Klamath and Trinity Rivers and their respective tributaries. Chinook salmon are also found in coastal streams north of San Francisco Bay. Historically, coastal Chinook spawned as far south as the Ventura River in southern California. 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 quality.

The female Chinook selects a nesting site that has good subgravel water flow 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 (nests) once spawning has begun and will stay on the eggs 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. The same impediments that affect the upstream migration of adults also affect the downstream emigration of juveniles out to sea.

California Chinook stocks generally 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 "jacks" or "grilse." The older age classes of Chinook are generally composed of equal proportions of males and females.

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 grouped into "runs" based on the time of the year during which their upstream spawning migration occurs. In California, there are four distinct Chinook runs: fall, late-fall, winter, and spring. In a river where all four runs of Chinook spawn, adults migrate upstream and juveniles migrate downstream during almost all months of the year. The timing of Chinook spawning is often influenced by stream flow and water temperature, and therefore varies somewhat from river to river, and even within river systems.

All four Chinook salmon runs are found in the Central Valley basin, with fall run being the most numerous. Although relatively large numbers of winter and spring Chinook historically occurred in the upper Sacramento basin, they were significantly reduced by the construction of Shasta Dam in 1945, which blocked approximately 50 percent of historical Chinook spawning and rearing habitats. Spring Chinook also existed in the San Joaquin River and reportedly once outnumbered fall Chinook, but the completion of Friant Dam in 1942 contributed to that population's subsequent extinction. Late-fall Chinook are found primarily in the upper Sacramento River.

Fall and spring Chinook salmon are also found in the Klamath basin with the abundance of both runs reduced by barrier dams built in upper river areas during the late 1800s. Fall Chinook also exist in coastal rivers such as the Smith, Eel, Mad, Mattole and Russian. Spring Chinook also appear occasionally in the Eel and Smith rivers. Smaller coastal rivers only have fall Chinook.

Fall run. Fall Chinook salmon are the most abundant salmon run 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. Spawner escapement is generally dominated by three-year-old fish followed by jacks (age 2) and four-year-olds. Five-year-old fish are rare. Spawning occurs in the main stem of rivers and 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. Late-fall Chinook arrive in upper-river spawning areas between October and mid-April. The runs 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 majority 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 April, with a peak in March. Spawning occurs primarily in the main stem of the upper Sacramento River below Keswick Dam between late-April and mid-August. May and June are peak spawning months. The juveniles migrate seaward from early July through the following March, but the majority of the juveniles move seaward in September. Winter-run smolts enter the ocean between December and May. The adults mature and spawn primarily as three-year-olds, unlike the other races, which include many four-year-old fish.

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 to spawn between late August and early October. Outmigration of juveniles varies among drainages; however the majority of fry and fingerlings leave the spawning areas between January and March. While this is true some juveniles 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 coded wire tag (CWT) recoveries since the mid 1970s have provided extensive data on the ocean distributions of Pacific coast salmon stocks. Recovery of CWTs in ocean salmon fisheries has provided a better understanding of the temporal and spatial distribution of various Chinook stocks, particularly those from the Central Valley and Klamath Basin. For example, although Sacramento River fall Chinook are distributed primarily off of California and Oregon, they are also occasionally caught off Washington and British Colombia coasts. A few fish have even ventured as far north as Alaska. Klamath River fall Chinook, on the other hand, are more narrowly distributed primarily between Cape Falcon, Oregon and Point Sur, California. Ocean conditions have also been shown to affect the ocean distribution patterns of these and other Pacific coast salmon stocks.

<u>Coho salmon</u>

Coho salmon, *Oncorhynchus kisutch*, (Figure 5-9) are smaller than Chinook salmon; the average size of a mature coho is 7 to 12 pounds (3 to 5 kilograms). The California record for a recreationally-caught coho is 22 pounds (10 kilograms), taken on Paper Mill Creek (Marin County) in 1959. The world record is a 33 pound (15 kilograms) coho caught by an angler in British Columbia in 1989.

Figure 5-9. Coho salmon, *Oncorhynchus kisutch*. Photo credit: K Lesher, CDFW.

In California, coho salmon spawn in coastal rivers and streams from northern Monterey Bay to the Oregon-California border. They are rarely found in the Central Valley basin. Coho enter many small streams that are not utilized by Chinook, but also spawn in larger river systems where Chinook also reside. Compared to Chinook salmon, there are relatively few coho in California today. Most California streams utilized by coho 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 that enter during brief periods after the first heavy fall rains and move upstream.

Within California river systems, coho salmon populations include only one 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 freshwater 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 jacks, mature at age two.

Genetic analysis of California coho salmon populations has indicated a wide degree of mixing of the stocks in the past, probably reflecting historical stocking and transplantation practices involving hatchery fish. Historical recoveries of CWTs from California hatchery coho stocks showed that most were harvested in the ocean fisheries during their third year of life. Some were caught as far north as the central Washington coast, but most were recovered within 100 miles (161 kilometers) of the stream from which they entered the ocean.

Status of Spawning Populations

In the Central Valley and Klamath Basin, a multitude of factors have contributed to the decline of salmon stocks, including species listed under the California Endangered Species Act (CESA) and the federal Endangered Species Act (ESA). Factors include construction of dams that cut off historical spawning habitat, unscreened irrigation diversions in the Delta and Sacramento-San Joaquin river basins, poor or lost gravel deposition in salmon spawning and rearing areas, water 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 commercial water usage, reduced riparian habitat due to channelization, and other physical impediments to migration and spawning grounds. Populations in these areas have been reduced from their more robust historical abundances. While most of that information was qualitative and anecdotally reported, those abundances were presumably grand in comparison to averages from modern day.

<u>Central Valley Fall Chinook</u> – There are two major fall runs in the Central Valley. The most numerous are the Sacramento River fall Chinook, which includes salmon from the Sacramento River and its tributaries. Major tributaries of the Sacramento River are the Feather, American, and Yuba rivers among others. San Joaquin River fall Chinook include salmon from the San Joaquin River and its tributaries. Major tributaries of the San Joaquin River are the Mokelumne, Merced, and Tuolumne rivers. Both runs are heavily supplemented with hatchery production. Coleman National Fish Hatchery, Feather River Hatchery, and Nimbus Fish Hatchery produce approximately 30-32 million Sacramento River fall Chinook annually while Mokelumne River Hatchery and Merced River Fish Facility produce 2-6 million San Joaquin River fall Chinook, depending on the previous year's adult escapement. During the last four decades, Sacramento River fall Chinook has accounted for approximately 94 percent of all Central Valley fall Chinook escapement.

Prior to 1995, annual Sacramento River fall Chinook escapement was relatively constant, generally ranging between 122,000 and 250,000 adult spawners returning to the Sacramento River Basin each fall (Figure 5-10). Beginning in 1995, Sacramento River fall Chinook escapement began to steadily increase, peaking at a record high 770,000 salmon in 2002, before declining back to near normal levels in 2006. In 2007, Sacramento River fall Chinook escapement suddenly declined resulting in one of the lowest returns (91,400 adults) on record. In addition, the number of Sacramento River fall Chinook jacks (age 2) that returned was an all-time record low (1,900 salmon), which represented 5 percent of the long term average (36,000 salmon) observed during the previous 35 years. This marked the beginning of the Sacramento River fall Chinook collapse as escapement declined even more in 2008 and 2009 when only 65,400 and 40,900 adults returned, respectively, the two lowest returns on record.

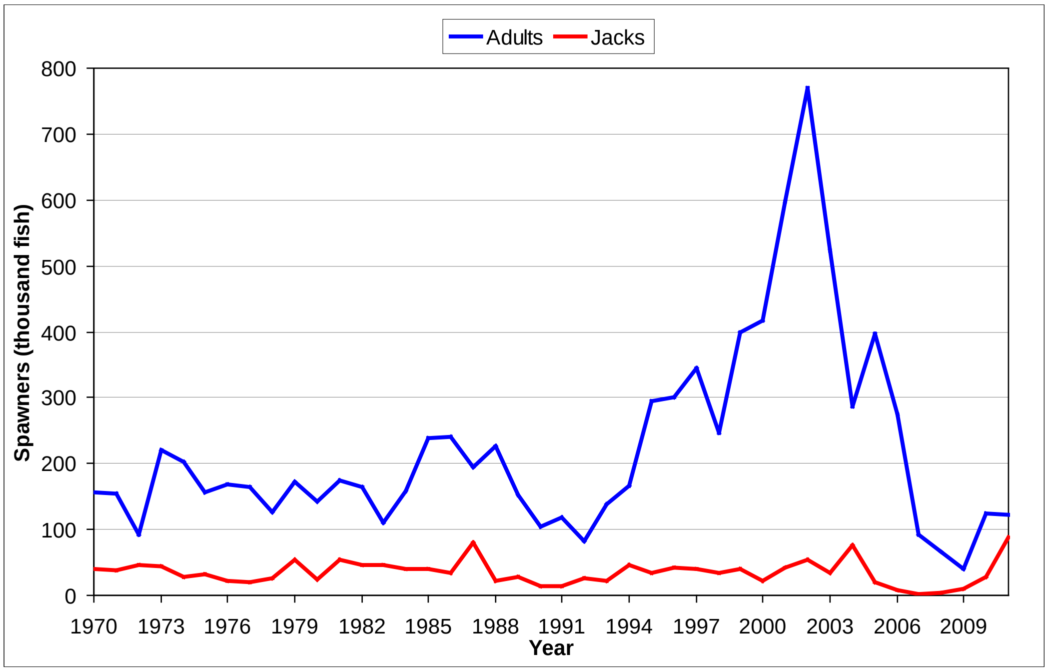

Figure 5-10. Sacramento River fall Chinook salmon escapement to the Central Valley, 1970-2011. Data source: Department Ocean Salmon Project and PFMC data.

A multi-agency, multi-disciplinary scientific panel was assembled to determine the cause of the Sacramento River fall Chinook collapse and began investigating more than 40 potential environmental and physical factors. The panel found that extremely poor ocean conditions off the California coast during 2005 and 2006 had significantly reduced the survival rate for Sacramento River fall Chinook juvenile salmon emigrating to the ocean during this time. These poor ocean conditions were characterized by weak upwelling, warm sea surface temperatures, and a scarcity of food. The panel also identified the long term cumulative effect of poor river conditions as another primary factor. During 2010 and 2011, the stock rebounded slightly with 124,300 and 121,700 Sacramento River fall Chinook adults returning, respectively. More recently, a record number of Sacramento River fall Chinook jacks (88,200) returned in 2011 indicating good survival of juveniles and a relatively high ocean abundance of Sacramento River fall Chinook adults available for harvest in 2012.

Central Valley Spring Chinook – Central Valley spring Chinook from the Sacramento River drainage have been listed as threatened under CESA since February 1999 and under the federal ESA later the same year. Spring Chinook, which historically were the second most abundant run in the Central Valley, now spawn in relatively small numbers in the upper Sacramento River and tributaries (Butte, Deer, and Mill creeks). Central Valley Spring Chinook also occur in the Feather River and the run there is supplemented by Feather River Hatchery, which produces approximately 2 million spring Chinook annually. Genetic analyses have shown that Spring Chinook occurring in Butte, Deer, and Mill creeks are genetically divergent from those found in the Feather River and are thus the only true spring run populations in the Central Valley. Feather River spring run are genetically homogenous to fall run Chinook found throughout the Central Valley, although they continue to express spring run life history traits and are included in the Central Valley Spring Chinook evolutionarily significant unit (ESU). In addition, there are small spring run escapements that occur in other tributaries of the Sacramento River such as Clear Creek and the Yuba River. These populations occur with some frequency however they are not recognized as a part of the Central Valley Spring Chinook ESU. While regular surveys occur in the above tributaries, spawning totals for the upper Sacramento after 2008 are unavailable as changes to the Red Bluff Diversion Dam operations made the counting facility there obsolete. Total escapement to these tributaries has averaged 15,000 fish since 1995 with some years exceeding 20,000 spawners (Figure 5-11). The latest escapement totals have been roughly half the recent average. Although spring Chinook haven't existed in the San Joaquin River since the 1940s, plans are currently underway to reintroduce the run to the San Joaquin basin within the next few years.

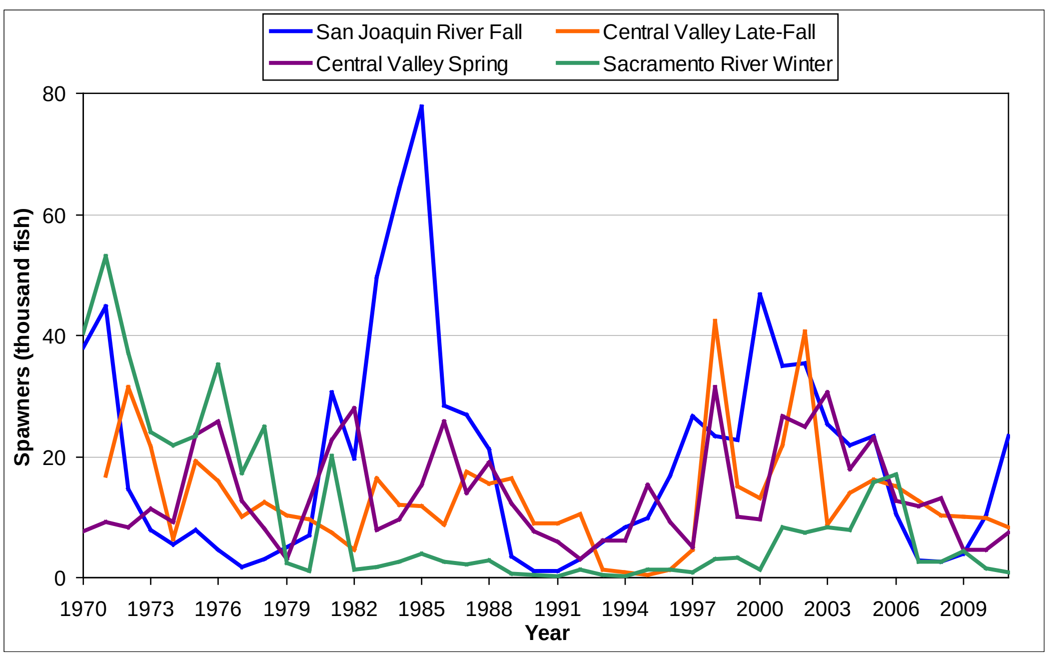

Figure 5-11. Other runs of Chinook salmon escapement to the Central Valley, 1970-2011. Data source: Department Ocean Salmon Project and PFMC data.

Central Valley Late-Fall Chinook – Central Valley Late-Fall Chinook spawn primarily in the upper Sacramento River and Battle Creek although some late-fall escapements have been reported in other Sacramento River tributaries such as the Yuba and American Rivers. The run was not identified until monthly spawner counts began at the Red Bluff Diversion Dam in the 1960s. Prior to that, Late-Fall Chinook were presumably considered to be part of the fall or winter run escapements. A carcass survey has been conducted in recent years on the upper Sacramento River to provide annual escapement totals in lieu of the dam counts. The run is supplemented by Coleman National Fish Hatchery, which produces approximately 1 million fish annually. Since 1995 escapement has averaged roughly 14,000 fish with a peak of nearly 40,000 spawners during that time period (Figure 5-11). The Central Valley Late-Fall Chinook escapement is highly variable and experienced an increasing trend through the mid 2000s after a severe decline in the mid 1990s. Escapement totals have been decreasing since 2006, but not to the levels experienced in the previous decade.

Sacramento River Winter Chinook – Sacramento River Winter Chinook salmon were listed as endangered in 1989 under CESA, and threatened under the federal ESA. The stock was downgraded to endangered under the federal ESA in 1994. Unfortunately Sacramento River Winter Chinook no longer exist in any of the original spawning habitat, all located above Shasta Dam, and the run persists in a relatively short section below the dam made suitable by cold water releases into the upper Sacramento River. The spawning population below Shasta Dam declined from an average of 28,000 fish observed in the 1970s to only a few hundred in the early 1990s (Figure 5-11). For a brief period, Sacramento River Winter Chinook were propagated at Coleman National Fish Hatchery on Battle Creek. However, due to difficulties in operating the hatchery as a conservation facility aimed at recovering Winter Chinook in the upper Sacramento River, the need for a new hatchery located adjacent to the desired spawning habitat was identified. As a result Livingston Stone National Fish Hatchery was built in 1997 at the base of Shasta Dam. The hatchery was specifically designed to develop an integrated-recovery program that collects and utilizes natural-origin Sacramento River Winter Chinook broodstock to produce approximately 200,000 juveniles annually, while preserving the genetic integrity of the ESU. These hatchery-origin Sacramento River Winter Chinook are intended to return as adults to the upper Sacramento River, spawn in the wild, and become reproductively and genetically assimilated with the natural population to aid in recovery of the species. The population experienced an increase in abundance from 2000 to 2006 when it peaked at over 17,000 fish but has since declined similar to the trend observed with Sacramento River Fall Chinook and other Central Valley Chinook stocks. Only 1,596 and 824 Sacramento River Winter Chinook returned to spawn in 2010 and 2011, respectively.

Klamath River Fall Chinook – In the Klamath basin, there are two hatcheries - Iron Gate Hatchery and Trinity River Hatchery - that supplement Fall and Spring Chinook production on the Klamath and Trinity rivers. Adult spawner totals for Klamath River fall Chinook has ranged from a low of 18,000 (hatchery and natural) in 1991 to 180,000 in 1995 (Figure 5-12). Monitoring of Klamath River Spring Chinook escapement has been sporadic over the years and complete counts of hatchery and natural returns are not available at this time. The population seems to be cyclical with several years of high spawners followed by a few years of low returns.

In 2002, an unprecedented fish kill occurred in the Klamath Basin. Approximately 35,000 salmon, among other fishes, died prior to spawning, primarily due to disease outbreaks as a result of reduced water flow, increased water temperature, and high fish density. The two responsible pathogens were the myxozoan parasite *Ichthyopthirius multifilis* (commonly referred to as Ich) and a bacterial pathogen *Flavobacterium columnare* (columnaris). These two common pathogens are found in the Klamath River at all times, but rarely cause significant problems unless other factors such as stressful environmental conditions are present. Reduced water flow, resulting in warm water temperatures, coupled with high fish densities created an ideal condition for the spread of disease which ultimately resulted in the fish kill.

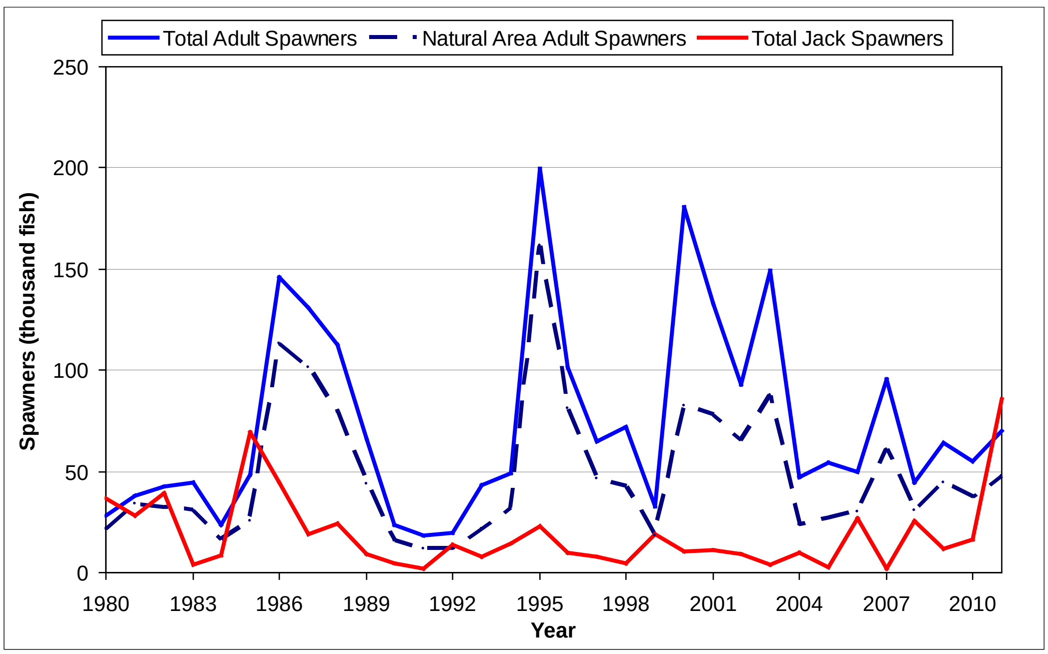

Figure 5-12. Klamath River Fall Chinook salmon escapement, 1980-2011. Data source: Department Ocean Salmon Project and PFMC data.

Total adult returns to the Klamath Basin have averaged 123,000 fish since 1995 with some years exceeding 200,000 Chinook salmon. In 2011, returns of Fall Chinook adult spawners to hatcheries and natural areas in the Klamath Basin totaled more than 22,300 and 47,800 fish, respectively, with another 31,000 being harvested from the river. In addition, a record 74,000 Klamath River Fall Chinook jacks returned in 2011, indicating a large ocean abundance of age 3 Klamath River Fall Chinook available for harvest in 2012.

Coastal Chinook and Coho Populations - Declines in coastal river Chinook and coho salmon populations have been caused by many of the same factors that affect the

Central Valley. Habitat blockages, agriculture, urbanization, and water withdrawals have resulted in widespread declines of both species. In addition, many of these areas have been affected by past and, in some instances, current timber harvest practices. Some of these practices have reduced stream shading, resulting in increased water temperatures, and have accelerated watershed erosion and sedimentation of spawning habitat.

The Central California coast coho south of San Francisco Bay were listed as endangered in 1996 under CESA. This was increased to encompass all waters south of Punta Gorda (just below Cape Mendocino) in 2005. On the federal side, the Central California coast coho ESU was listed as threatened in 1996 and downgraded to endangered in 2005 under the ESA. The Southern Oregon-Northern California coast coho ESU was listed as threatened in 1997 under the ESA. In 2005, California also listed the Southern Oregon-Northern California coast coho (Punta Gorda to the California/Oregon border) as threatened under CESA.

In recent years, there has been a significant decrease in the number of spawning Central California coastal and Southern Oregon-Northern California coast coho adults and the Department is currently part of a Coho Recovery Team focused on implementing strategies aimed at restoring and rebuilding California coho populations. Spawning occurs for Central California coastal coho from the San Lorenzo River in the south to the Big River in the north while Southern Oregon-Northern California coast coho range from the Mattole River in California to the Elk River in Oregon. Monitoring in these streams ranges from annual systematic to sporadic nonsystematic surveys depending on the location and flows.

The California Coastal Chinook ESU, which includes northern California coastal streams between, and including, Redwood Creek and the Russian River, have been listed as threatened under the ESA since 1999. Monitoring occurs annually in the Russian River; however additional spawning population estimates are limited for coastal Chinook to nonsystematic surveys of the remaining coastal streams.

In 2011, the Department published a document entitled “California Coastal Salmonid Population Monitoring: Strategy, Design, and Methods.” This document outlines current needs for monitoring salmonids along the coast for evaluating the effectiveness of restoration, recovery and management practices to date as required by CESA. The plan uses the Viable Salmonid Population concept to assess salmon viability in terms of four key population characteristics: abundance, productivity, spatial structure, and diversity. Implementation of the plan is currently under way.

Salmon Management

In 1947, the Pacific Marine Fisheries Commission, now known as the Pacific States Marine Fisheries Commission (PSMFC), was formed by the states of Alaska, Washington, Oregon, Idaho, and California. The primary objective of the alliance 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, including season dates and size limits. The first commercial salmon recommendation of the PSMFC was a 25 inch (66 centimeters) TL minimum size limit and a March 15 to October 31 maximum season length for Chinook. For many years the states uniformly adopted the 25 inch (66 centimeters) TL size limit and an April 15 opening date for commercial Chinook fishing with a general September 30 closing date.

In 1976, the Magnuson Fishery Conservation and Management Act (Magnuson-Stevens 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 (5 to 322 kilometers) offshore. The Magnuson-Stevens Act created regional fishery management councils to develop fishery management plans and recommend fishing regulations to the states, Native American tribes, and NOAA Fisheries Service. Thus the PFMC was created with management authority over the federal fisheries off the coasts of California, Oregon, and Washington. Representation on the PFMC currently includes the chief fishery officials of California, Idaho, Oregon, and Washington, NOAA Fisheries Service, a Native American representative, and eight knowledgeable private citizens. The PFMC receives advice on salmon issues from a Salmon Technical Team and a Salmon Advisory Sub-panel composed of various industry, tribal, and environmental representatives.

The PFMC's Salmon Fishery Management Plan (Salmon FMP) was developed in 1977 and was the first FMP implemented 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 California, Oregon, and Washington. The management measures are intended to prevent overfishing while achieving optimum yield and to allocate the ocean harvest equitably among commercial and recreational ocean fisheries. The management measures must meet the goals of the Salmon FMP that address spawning escapement needs (i.e., conservation objectives) and allow for freshwater fisheries. The needs of salmon species listed under the ESA must also be met as part of the process. The measures recommended to NOAA Fisheries Service by the PFMC must be approved and implemented by the Secretary of Commerce.

While the PFMC is responsible for recommending management measures within federal waters, the California Fish and Game Commission (Commission) maintains authority to manage salmon fisheries within state waters (in-river and coastal ocean areas within 3 nautical miles [5 kilometers] of shore). The Commission generally adopts fishing seasons and regulations consistent with those recommended by the PFMC.

In 2006, the Magnuson-Stevens Act was reauthorized and included new guidelines and definitions to protect marine resources and prevent overfishing. The law required an amendment to the Salmon FMP, which features new conservation objectives for Klamath River fall Chinook and Sacramento River fall Chinook, and guidelines for establishing ocean fisheries during periods of very low salmon abundance. The new guidelines were first used during the 2012 PFMC management process.

Klamath River fall Chinook was one of the first salmon stocks to be managed under the PFMC's Salmon FMP in 1983. The original Klamath River fall Chinook conservation objective required that a minimum of 35,000 adults return to spawn in natural areas each year and that the natural spawner reduction rate in ocean fisheries did not exceed 67 percent. In 1994, PFMC management was modified to ensure that the Klamath tribes (Yurok and Hoopa Valley) received their federally reserved fishing right of 50 percent of the total allowable Klamath River fall Chinook harvest. In 2011, Amendment 16 to the Salmon FMP revised the minimum natural area spawners to the maximum sustainable yield, which was determined to be 40,700 adults. In addition, the annual spawner reduction rate from ocean fisheries is not permitted to exceed 68 percent.

The Salmon FMP also established a conservation objective for Sacramento River fall Chinook that required ocean fisheries be managed to allow a range of 122,000 to 180,000 natural and hatchery adults to return each year to spawn. In 2007, Sacramento River fall Chinook failed to meet the minimum conservation goal of 122,000 adult spawners required to ensure the long term survival of the stock. Sacramento River fall Chinook is considered the primary salmon stock supporting California ocean fisheries, historically comprising 80-95 percent of the salmon catch. When fishery scientists predicted less than 60,000 Sacramento River fall Chinook would return the following year, the PFMC took emergency action to close all California and Oregon ocean salmon fisheries in 2008 to protect this important stock and the Commission approved the same fishery closure in California state waters. The fisheries remained closed in 2009 and were severely constrained in 2010 when Sacramento River fall Chinook failed to meet the minimum spawner goal.

In response to the Sacramento River fall Chinook collapse, new management tools were developed to estimate relative Sacramento River fall Chinook ocean abundance (Sacramento Index) and evaluate the impacts of California and Oregon ocean salmon fisheries by time and area (Sacramento Harvest Model). In 2010, Sacramento River fall Chinook met their conservation goal and relatively high numbers of returning jacks (age 2 fish) allowed for the resumption of recreational and commercial ocean fisheries, albeit somewhat constrained to protect Sacramento River fall Chinook. In 2011, Amendment 16 to the Salmon FMP established an additional management threshold in the form of a 70 percent marine exploitation rate. The minimum spawning escapement goal range of 122,000 to 180,000 adults was left unchanged in the new amendment, although there is interest in revisiting the suitability of this management goal.

Currently, there are 3 ESA-listed Chinook stocks (Sacramento River winter, Central Valley spring, California Coastal), and 2 coho stocks (Southern Oregon/Northern California, Central California Coast) in California. As the listings have occurred, NOAA Fisheries Service has initiated formal consultation standards and issued Biological Opinions (BO) that consider the impacts resulting from implementation of the Salmon

FMP or from annual management measures to ESA-listed salmon stocks. NOAA Fisheries Service has also reinitiated consultation on certain stocks when new information has become available on their status or on the impacts of the Salmon FMP on these stocks. Amendment 12 of the Salmon FMP added the generic category "species listed under the ESA" to the list of stocks in the salmon management unit and modified respective escapement goals to include "manage consistent with NOAA Fisheries Service jeopardy standards or recovery plans to meet immediate conservation needs and long term recovery of the species." Amendment 14 of the Salmon FMP specified those listed stocks and clarified which stocks in the FMP management unit were representative of the listed stock.

NOAA Fisheries Service has concluded that harvest of the relatively abundant Sacramento River fall Chinook can continue at reduced levels in California's ocean fisheries without jeopardizing the recovery of listed Chinook and coho populations. The Commission, PFMC and NOAA Fisheries Service have implemented various protective regulations to reduce fishery impacts on California populations of Sacramento River winter, Central Valley spring, California coastal Chinook, and coho, all of which are state and federally listed (California coastal Chinook are only federally listed).

When Sacramento River winter Chinook were listed as endangered under the ESA in 1994, a new dimension was added to salmon management. The ESA requires that NOAA Fisheries Service assess the impacts of ocean fisheries on listed salmon populations and develop standards that avoid the likelihood of jeopardizing their continued existence. The original standard for Sacramento River winter Chinook required a 31 percent increase in the adult spawner replacement rate relative to the observed mean rate from the base period of 1989 to 1993. Although contacted only incidentally in California ocean fisheries, primarily in the recreational fishery south of Point Arena, additional restrictions were placed on California's commercial and recreational fisheries in 2002. These restrictions included minimum size limits designed to protect the smaller-at-age Sacramento River winter Chinook and season opening and closing date restrictions. In 2010, NOAA Fisheries Service issued an updated BO with the conclusion that ocean salmon fisheries continued to jeopardize the continued existence of this depressed stock in spite of existing fishing restrictions. The updated BO required the development of new tools to quantify impacts of fisheries on Sacramento River winter Chinook and assess potential impacts of proposed fisheries. Although ocean fishery impacts on Sacramento River winter Chinook have remained relatively constant over the past decade, the spawning population of Sacramento River winter Chinook has fluctuated and most recently declined. This downward trend cannot be readily explained by ocean harvest, especially since California fisheries were completely closed in 2008 and 2009. In 2012, NOAA Fisheries Service issued a new consultation standard limiting ocean fishery impact rates based on the number of fish returning to spawn in the previous three years in addition to the typical minimum size and season restrictions south of Point Arena. The impact rate cap is expected to change annually based on the number of Sacramento River winter Chinook returning to the river to spawn, and may close some ocean salmon fisheries should the three year mean of the population fall below 500 fish. NOAA Fisheries Service has concluded that the conservation measures in place to protect winter run Chinook are sufficient to protect Central Valley spring Chinook as well.

To protect California Coastal Chinook, NOAA Fisheries Service placed a cap on the ocean harvest rate (≤16 percent) of age 4 Klamath fall Chinook in 2000. Since ocean distribution information on California coastal Chinook was very limited, Klamath River fall Chinook were considered the best available surrogate for estimating ocean fishery impacts on these stocks.

In 1992, the PFMC began to severely curtail the ocean harvest of all coho salmon in California due to the depressed condition of most coastal stocks. In anticipation of the federal listing of California coho salmon stocks, NOAA Fisheries Service extended the protective measures to a complete prohibition of coho retention off California.

Inland Management

The decline in California's salmon populations vary somewhat from river to river, but loss of habitat and water diversion are the two major underlying causes. As a result of habitat loss and the associated reduction in life history types that utilize those habitat niches, the resiliency of California salmon stocks as a whole has been diminished. For example, diminished resiliency among salmon stocks in the Central Valley coupled with poor ocean conditions in 2005 and 2006 resulted in historically low escapement during the latter half of the decade. Water diversion is an issue that affects both juveniles and adults alike. Diversions can confuse escapement and emigration routes, decrease water quality for spawners and their progeny, entrain outmigrants, and create predator niches among other things. These two major causes of decline are largely responsible for the eventual listing of stocks under the ESA today.

Although the listing of salmon populations under CESA and/or ESA has meant new restrictions on recreational and commercial fishing, it has also provided a mechanism for addressing the effects of dams, water diversion, logging, gravel extraction, 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 NOAA Fisheries Service when they propose to authorize, fund, or carry out an action that could adversely affect listed salmon or steelhead. Likewise, State-sponsored activities that might affect state-listed species must be reviewed under the provisions of CESA.

Substantial efforts have been made during the past two decades to ensure that the ecological requirements of anadromous fish receive equal consideration with other economic and social demands placed on the State's water resources. The Central Valley Project Improvement Act of 1992 required a program designed to double natural production of anadromous fish in Central Valley streams. In 1995, California and the federal government 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.

In 2002, the California Legislature created the California Bay-Delta Authority to oversee implementation of the Bay-Delta Program. Two years later, Congress approved a 30-year plan that includes goals and science-based planning to facilitate collaborative and informed decisions for future Bay-Delta projects. In 2006, a ten-year action plan was developed to help chart a course for the CALFED, including addressing water supply and ecosystem functioning problems. Projects include providing fish passage ways, dam removal, installing fish screens, aquatic and riparian habitat restoration, channel dynamic and sediment transport improvements, floodplain and bypass restoration, agricultural modifications, local watershed planning, improving natural flow regimes, recovering water and sediment quality, environmental water management, fishery monitoring, and temperature control of water releases.

Red Bluff Diversion Dam, built in 1964 on the upper Sacramento River, was once a major impediment to adult salmon upstream migration, a major point for water diversion and mortality on downstream migrating juveniles, and a haven for predatory Sacramento pikeminnow and non-native striped bass. Lifting of the gates at this facility had been implemented in the fall through spring to protect all races of Chinook; however, after the Bureau of Reclamation determined that dam operations did not adequately allow passage of ESA-listed salmonids, they began raising the gates for ten months (closed July and August) and plans were created to add a new pumping station to provide agricultural water. In 2008, a federal judge ordered the dam gates be lifted permanently to protect ESA-listed species and the Red Bluff Diversion Dam Fish Passage Improvement Project was created. Construction of a new screened pumping station began immediately to reduce the impacts of water diversion on salmonids and other listed species while still delivering water to agricultural interests. During construction, the Red Bluff Diversion Dam continued to operate with the gates open ten months a year to allow optimum conditions for fish passage while honoring water deliveries. In September 2011, the gates were raised for the final time, ending use of the dam as a water diversion. The new screened pumping station went online September 2012 and will improve fish passage conditions while ensuring continued water deliveries to agricultural needs in the Central Valley.

Many similar improvements have also been made in the Klamath Basin. The federal Trinity River Basin Fish and Wildlife Restoration Act was enacted in 1984 to restore fish populations to levels existing prior to the diversion of water to the Central Valley. In 1986, Congress adopted the Klamath River Basin Fishery Resources Restoration Act, a 20-year-long cooperative program to restore anadromous fisheries within the Basin. With a $21 million budget, many conservation projects were completed including instream, riparian, and upland protection and restoration, fish rearing, water conservation and water quality improvement, assessment and research, and community education. In 2010, a coalition of tribes, landowners, local government, state and federal agencies, conservationists, and the local utility that owns and operates the dams on the upper Klamath River reached the Klamath Hydroelectric Settlement Agreement and the Klamath Basin Restoration Agreement. These agreements have most notably paved the way for the removal of four dams on the upper Klamath River, restoring access to hundreds of miles of spawning habitat previously inaccessible due to dam construction. While dam removal continues to be debated further and has yet to commence, these agreements and their potential for the Klamath Basin are significant steps forward in the restoration of salmon habitat in California.

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 sometimes mask the decline in the natural run, and this appears to be the case for Chinook salmon 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. In 2007, the State began a Constant Fractional Marking (CFM) program in which at least 25 percent of the fall Chinook production are marked with an adipose fin clip and tagged with a uniquely-coded CWT (Figure 5-13). The CFM program was designed to allow fishery managers to determine the contribution of hatchery and natural fish in the spawning population, and thus determine the success of habitat restoration efforts and hatchery operations. The CFM program has been successful in marking and tagging the target numbers of salmon each year at each of the Central Valley hatcheries, and has just begun recovering CWTs in a statistically valid manner throughout the Central Valley.

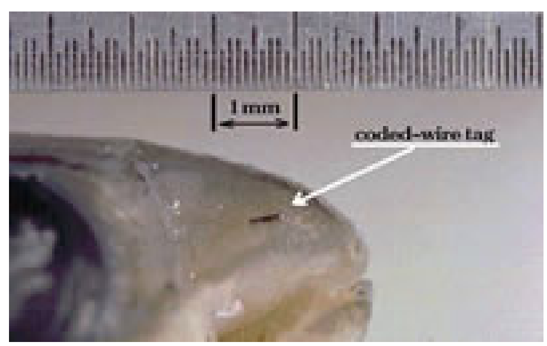

Figure 5-13. Salmon smolt with coded wire tag. Photo credit: USFWS photo.

The CFM program also allows hatchery managers to evaluate various release strategies to improve survival and fishery contribution rates. The 2010 escapement marks the first year when estimates of hatchery and natural proportions have been reported. Additionally, estimates related to the performance of various release strategies were also possible for the first time as a result of the CFM program. Generally speaking, results have shown that hatchery escapement is dominated by hatchery-origin fish while natural escapement is variable. Some streams show a predominance of natural-origin fish while other streams show a predominance of hatchery-origin fish, particularly those with hatcheries. Furthermore, results indicate that releasing Chinook salmon outside of their natal streams via trucking does indeed increase relative survival while showing moderate increases in stray rates. Also, fish that are transported in trucks to the Delta for release contribute at a higher rate to ocean fisheries. The results from this program will provide the best opportunity to manage Chinook based on scientifically defensible data.

Prior to the CFM program, the primary purpose of Central Valley Chinook salmon escapement monitoring was to provide basic status information (e.g., jack and adult escapement counts) by individual stocks and basins for California hatchery and ocean harvest management needs. The marking, tagging, or collection of CWT fish was not a high priority. Central Valley escapement monitoring has expanded to provide data for a broad range of management applications related to recovery planning for listed stocks. These applications include assessing recovery efforts, including habitat restoration work, improving ocean and river fisheries management, and evaluating Central Valley salmon hatchery programs to ensure both mitigation and conservation goals are being met. To meet the needs of these various assessment efforts, a review of current methodologies being employed among Central Valley inland escapement monitoring programs was undertaken by the Department in 2008. The goal of this review was to identify needed changes and/or additions to survey protocols that will ensure both statistically valid estimates of escapement and the collection of biological data, including CWTs and scales, needed for assessment efforts. In 2012, the Department completed the Central Valley Chinook Salmon Escapement Monitoring Plan that recommends methods for estimating escapement and collecting biological data necessary for improved stock assessment. Survey modifications included changes in the current mark-recapture models being utilized, changes in sampling protocols to ensure representative sampling and proper accounting, and the use of counting devices in place of some mark-recapture programs. This monitoring plan is now being implemented to provide the basis for sound Central Valley Chinook assessment and subsequent management.

Many recreational salmon anglers are attracted to rivers from Santa Cruz County north. 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 utilized Central Valley stream, followed by the Feather and American rivers. In 2006, the Central Valley creel census was reinstated to provide improved estimates of inland fishing effort and harvest. The creel survey has continued to sample the Central Valley inland fishery and generate estimates of effort and catch each year since. Of the coastal streams, the Klamath Basin receives by far the most effort, followed by the Smith and Eel rivers. The catch in both of these rivers consists primarily of Chinook salmon. The fishery on the Klamath River is also closely monitored via a creel survey throughout the fishing season.

Ocean Management

Ocean salmon fisheries harvest a mixture of stocks that differ greatly in their respective abundance and productivity. It has long been recognized that the management of mixed stock salmon fisheries is complex. Ocean abundance estimates are not available for most of California's salmon and harvest rates on these stocks are difficult to evaluate. Without stock- and age-specific mortality and population size estimates, it is difficult to assess the relative effects of harvest, improvements in freshwater habitats, or changes in ocean productivity or climate change.

Ideally, some differences in the spatial and temporal distribution of “strong” and “weak” stocks exist that would allow managers to develop measures that selectively protect stocks of concern. However, identifying individual stocks at time of harvest is not possible for salmon populations without a coded-wire tagging program. Regulations are crafted each year to protect weak stocks using the best available information from CWTs and modeling outputs based on past fishing seasons. This sometimes results in constraining the fisheries’ access to more abundant salmon stocks.

During the last two decades, commercial test fisheries have been conducted in California to evaluate the use of Genetic Stock Identification (GSI) techniques in ocean fisheries management. The GSI technology for identifying Chinook stocks has significantly improved over time; however, data for several stocks continue to lack the detail required for salmon fishery management. Additionally, when stocks of special concern are at low abundance and comprise an extremely small fraction of ocean catches, even GSI methods may not produce accurate estimates of ocean impacts on these populations. Although these challenges exist, a great deal of effort has been placed on continuing and improving GSI studies, and may become a component of ocean fishery management in the future.

To begin addressing the lack of age specific data for some stocks, the Department began a scale aging program to determine the age structure of all Central Valley Chinook salmon escapement in 2005. Age specific data will aid in determining cohort strength, proportions of hatchery and natural stocks in the spawning population, and ocean abundance by age. Preliminary results found differences in the age structure of hatchery and natural spawners as well as among the various stocks and runs present in the Central Valley. As previously stated, results from the continuation of CFM program and scale age analysis are expected to provide the best opportunity to manage Chinook salmon based on scientifically defensible data.

Ocean salmon fishery managers must continually be prepared to respond to changes in the fisheries, population status, and ocean environments. Many times, these changes call for modifying the tools used by fishery scientists and managers necessary for adaptive management.

In 2006, Klamath River fall Chinook were declared “overfished” for failing to meet the conservation objective for three consecutive years. While unfavorable in-river and marine conditions likely contributed to the decline in the population, overfishing did occur in 2004-2006 due to under-forecasting commercial mortality before the season began. Modifications were made to the model used for forecasting mortality to avoid overfishing the stock in the future.

In 2007 an unprecedented decline in Sacramento River fall Chinook was observed, continuing with a historically low spawning population of only 40,900 adults in 2009. In response to the decline, the PFMC, NOAA Fisheries Service, and the Commission were required to close all ocean salmon fisheries in 2008 and 2009, and severely restrict fisheries in 2010.

As a result of two major stock declines, fishery managers sought methods to allow management flexibility while continuing to protect the long term viability of each stock. Following the decline of Klamath River fall Chinook, Amendment 15 to the Salmon FMP was developed to allow for limited harvest of Klamath River fall Chinook in ocean fisheries whenever shortfalls were projected. Several years later, when Sacramento River fall Chinook began to decline, it became apparent that additional flexibility in fisheries management was needed during periods of low abundance. As part of the Amendment 16 process in 2011, new harvest control rules were developed to guide west coast management decisions during periods of very low salmon abundance to allow for small scale "de minimus" fisheries while continuing to protect salmon stocks.

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Commercial salmon harvest (pounds), 2000-2011.						
Year[a]	Chinook	Coho[b]	Ocean Total	Sacramento[c]	Klamath[d]	Total
2000	5,130,763	-	5,130,763	-	-	5,130,763
2001	2,408,609	-	2,408,609	-	-	2,408,609
2002	5,007,523	-	5,007,523	-	-	5,007,523
2003	6,391,621	-	6,391,621	-	-	6,391,621
2004	6,230,198	-	6,230,198	-	-	6,230,198
2005	4,347,388	-	4,347,388	-	-	4,347,388
2006	1,043,353	-	1,043,353	-	-	1,043,353
2007	1,525,243	-	1,525,243	-	-	1,525,243
2008[e]	0	-	0	-	-	0
2009[e]	0	-	0	-	-	0
2010	227,582	-	227,582	-	-	227,582
2011	990,977	-	990,977	-	-	990,977

Notes:

a. Data for 1915-1999 available in the Status of the fisheries report – an update through 2006.
b. Coho were no longer permitted for take after 1992.
c. Sacramento ports closed after 1959.
d. Klamath and other coastal ports closed after 1933.
e. The commercial fishery was closed due to low escapement.

Data source: Department Ocean Salmon Project and CFIS data, all gear types combined.

Commercial salmon value and average price per pound, 1990-2011.					
Year	Value	Average price per pound	Year	Value	Average price per pound
1990	$12,056,000	$2.72	2001	$4,773,000	$1.98
1991	$9,047,000	$2.45	2002	$7,776,000	$1.55
1992	$4,505,000	$2.74	2003	$12,181,000	$1.91
1993	$5,707,000	$2.25	2004	$17,895,000	$2.87
1994	$6,437,000	$2.07	2005	$12,913,000	$2.97
1995	$11,693,000	$1.76	2006	$5,350,000	$5.13
1996	$5,984,000	$1.45	2007	$7,902,000	$5.18
1997	$7,288,000	$1.39	2008	--	--
1998	$3,060,000	$1.66	2009	--	--

Commercial salmon value and average price per pound, 1990-2011.					
Year	**Value**	**Average price per pound**	**Year**	**Value**	**Average price per pound**
1999	$7,429,000	$1.93	**2010**	$1,246,000	$5.46
2000	$10,304,000	$2.01	**2011**	$5,130,000	$5.18

Data source: Department Ocean Salmon Project and CFIS data, all gear types combined. The commercial fishery was closed in 2008 and 2009 due to low escapement.

Recreational salmon catch (number of fish), 2000-2011.					
	Chinook		**Coho**[a]		
Year	**CPFV**	**Skiff**	**CPFV**	**Skiff**	**Total**
2000	91,900	94,000	5	400	186,305
2001	43,200	55,600	81	1,243	100,124
2002	85,107	96,937	43	785	182,872
2003	48,300	46,387	100	550	95,337
2004	124,656	96,458	18	1,406	222,538
2005	61,347	81,910	37	662	143,956
2006	35,326	60,966	23	1,603	97,918
2007	12,352	35,352	12	734	48,450
2008[b]	0	6	0	0	6
2009[b]	103	570	0	8	681
2010	4,740	10,069	0	175	14,984
2011	17,883	31,137	4	312	49,336

Notes:

a. Coho no longer permitted for take after 1995. These fish represent misidentified or illegally caught fish.
b. 2008 and 2009 fisheries were either completely closed (2008) or severely constrained (2009).

Data source: Department Ocean Salmon Project.

6 Pacific Sardine, *Sardinops sagax*

Pacific sardine, *Sardinops sagax*. Photo credit: Department archives.

History of the Fishery

At one time the Pacific sardine was California's most valuable fishery; first developed in the early 1900s in response to a growing demand for food during World War I. However, the true beginning of the famed sardine industry started when Frank Booth moved to Monterey in 1900 where he founded the F.E. Booth Company and built a sardine plant in 1902. The fishery boomed during the 1920s and peaked at over 771,600 short tons (700,000 metric tons) in 1936 (Figure 6-1). In the 1930s and 1940s Pacific sardine supported the largest commercial fishery in the western hemisphere, with sardines accounting for nearly 25 percent of all the fish landed in the United States by weight. In the 1940s, the fishing fleet consisted of 376 vessels and more than 100 canneries and reduction plants which employed thousands from San Francisco to San Diego, California.

The fishery declined and collapsed in the late 1940s due to overfishing and changes in environmental conditions, remaining at low levels for nearly 40 years. As the fishery declined, there was a southward shift in the catch, with landings ceasing in Canadian waters during the 1947-1948 season, in Oregon and Washington in the 1948-1949 season, and in the San Francisco Bay in the 1951-1952 season. Season start dates have varied over time, beginning August 1 in the Monterey area and September 1, October 1 and November 1, depending on the decade in the Los Angeles area. The demise of the fishery became a classic example of a 'boom and bust' cycle, a known characteristic of clupeoid stocks.

In 1967, the California Fish and Game Commission (Commission) authorized a moratorium on directed fishing for sardine. Prior to this, sardine harvest was mostly limited by controlling the amount of whole fish used for reduction, case pack requirements, and fishing season restrictions. However, there was no limit on total catch for the commercial fishery. These controls were intended to limit the amount of sardine used for reduction to fishmeal and oil, as this was considered a less desirable use. In an attempt to let the fishery rebound, landings were restricted to an incidental catch limit of 15 percent by weight when mixed with other fish loads between 1967 and 1973. However, liberal requirements to accommodate the use of these incidentally caught sardine and allowances for live and dead bait allowed several hundred tons of sardine to be taken per year. In 1974, a moratorium on fishing sardines was established which halted directed commercial fishing efforts, eliminated sardine for use as live bait, but still allowed a 15 percent incidental catch limit. Up until 1981, sardine landings totaled less than 50 short tons (45 metric tons) per year.

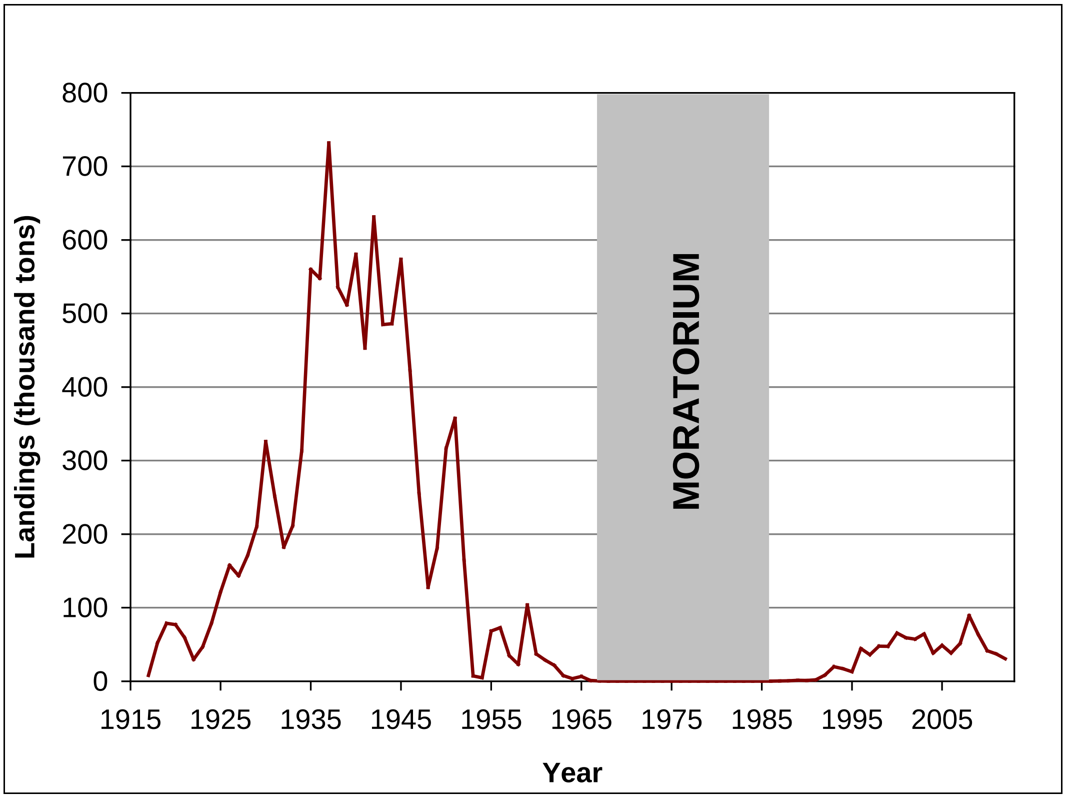

Figure 6-1. Pacific sardine commercial landings, 1916-2011. Data source: California Department of Fish and Wildlife (Department) catch bulletins (1916-1986) and Commercial Fisheries Information System (CFIS) data (1987-2011), all gear types combined.

In the early 1980s sardine were taken as incidental catch in California's Pacific mackerel (chub) and jack mackerel fisheries. Most of the sardines from those sources were used for pet food and an even smaller amount was canned for human consumption. Currently, nearly one quarter of the U.S. sardine harvest is eaten domestically, either fresh or canned. The other three quarters is frozen and exported, mainly to Asia for consumption and bait, but also to Australia for use as feed in bluefin tuna farming. As sardine abundance continued to increase, a directed fishery was reestablished. In 1986, California lifted its eighteen year moratorium and limited the fishery to 1000 short tons (907 metric tons) per year. The season was set to the calendar year, unlike the pre-bust fishery. The sardine population was declared fully recovered in 1999 when the estimated biomass was over 1.1 million short tons (1.0 million metric tons), the stock was found to occupy its historical range from Mexico to Canada, and all age classes were present in the population.

A federal Coastal Pelagic Species Fisheries Management Plan (CPS FMP) was put into place in 2000, for waters off of the west coast of the U.S. The CPS FMP implemented the use of a harvest guideline (HG) for the fishery based on biomass estimates, and divided it into three allocation periods for each season. The allocation periods were set as: 1) January 1 through June 30, 35 percent of the HG; 2) July 1 through September 14, 40 percent along with any portion not harvested from the first allocation period; and, 3) September 15 through December 31, 25 percent along with any remaining balance not harvested earlier in the year. The initial HG in 2000 was based on the 1999 total biomass estimates for sardine. The 2000 sardine fishery opened on January 1, with a harvest guideline of 205,844 short tons (186,791 metric tons) for the west coast fishery (Figure 6-2). This was a large increase, nearly 65 percent, over the previous year's quota set by the Department. The fishing fleet primarily utilizes round haul gear such as: purse seines, drum seines, and lampara nets.

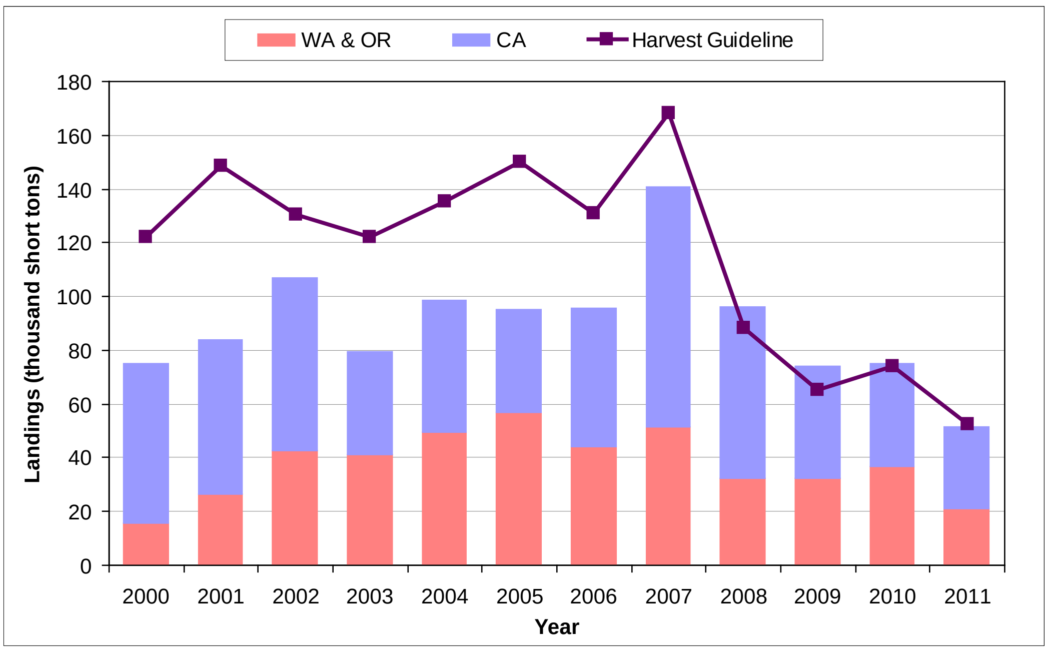

Figure 6-2. Pacific sardine commercial landings and harvest guideline for California, Oregon, and Washington fisheries, 2000-2011. Data source: CFIS data (California) and PacFIN data (Oregon and Washington), all gear types combined.

In 2007, landings in California peaked at nearly 90,000 short tons (81,600 metric tons), which was the highest since the 1950s (Figure 6-3). In 2008, the HG was set at 89,093 short tons (80,825 metric tons) which was a decrease of 42 percent from the previous year. This HG was setting the fishery up for landings to be constrained for the first time since the population had been declared recovered in 1999. This potential for early closures during the allocation periods resulted in a derby style fishery where there was a race to catch sardine. The directed fishery for the first allocation period lasted 150 days and ended over a month prior to the start of the new allocation period. This increased fishing intensity was due to the belief that fishermen were competing for the allocation. Average daily landings increased during the second allocation period and vessels began fishing on the weekends which was previously not a normal occurrence. By the third allocation period, fishing efforts had intensely increased and fueled a frenzied atmosphere. The final fishery allocation for 2008 lasted only nine days.

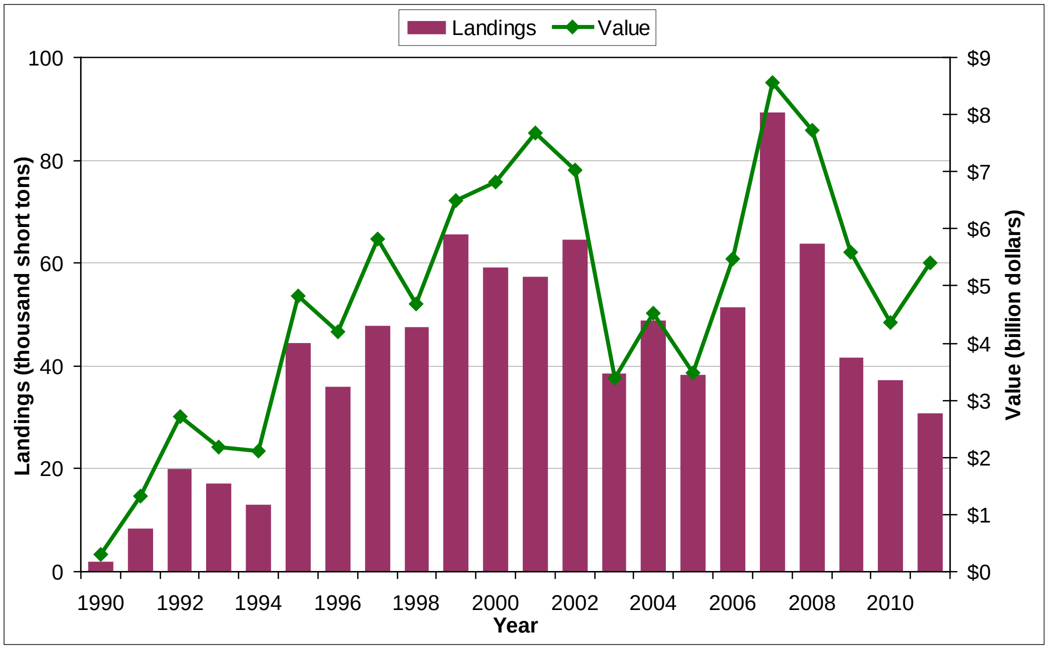

Figure 6-3. Pacific sardine commercial landings and value, 1990-2011. Data source: CFIS data, all gear types combined.

The 2008 sardine fishery was only open 199 days total (55 percent of the year). In 2009, the landings doubled in the number of trips per day compared to 2008. Fishery participants fished with intensity in 2009, believing that the allocation would be reached as quickly as it had the previous year. However, in the last allocation period of 2009, sardine landings dropped significantly as fishermen directed effort to market squid, which commanded a higher market value.

Both 2010 and 2011 showed similar trends compared to the two previous years. In the beginning of 2010, the high abundance of market squid in southern California resulted in little interest in the sardine fishery with squid selling for a much higher price. Inclement weather also played a large role, with vessels not being able to fish due to high surf and winds throughout a large portion of the season. In 2011, Pacific sardine was the second largest fishery in the state of California by volume and the sixth largest in value (Figure 6-3, Table 6-1 and Table 6-2). The fishery continues to be centered in the southern portion of the state with northern fishery (central and northern California) making up only 30 percent of the state's total landed catch (Figure 6-4).

Table 6-1. Largest California commercial fisheries by weight in 2011.			
Rank	**Species**	**Pounds**	**Value**
1	Market squid	267,985,250	$68,579,285
2	**Pacific sardine**	**61,097,986**	**$5,390,048**
3	Dungeness crab	20,643,551	$51,618,869
4	Red sea urchin	11,494,799	$8,179,865
5	Pink shrimp	7,375,139	$3,684,168
6	Northern anchovy	5,734,842	$617,659
7	Dover sole	5,318,533	$2,258,482
8	Sablefish	5,304,779	$15,121,468
9	Pacific herring roe	3,453,089	$859,819
10	Pacific mackerel	2,990,971	$326,433

Data Source: CFIS data, all gear types combined.

Table 6-2. Largest California commercial fisheries by value in 2011			
Rank	**Species**	**Pounds**	**Value**
1	Market squid	267,975,366	$68,576,815
2	Dungeness crab	20,494,789	$51,152,985
3	Sablefish	5,209,444	$14,771,660
4	California spiny lobster	751,075	$12,910,205
5	Red sea urchin	11,478,690	$8,161,570
6	**Pacific sardine**	**61,097,986**	**$5,390,048**
7	Chinook salmon	990,977	$5,130,000
8	Spot prawn	342,389	$3,903,214
9	Pink shrimp	7,375,139	$3,684,168
10	Swordfish	941,425	$3,346,077

Data source: CFIS data, all gear types combined.

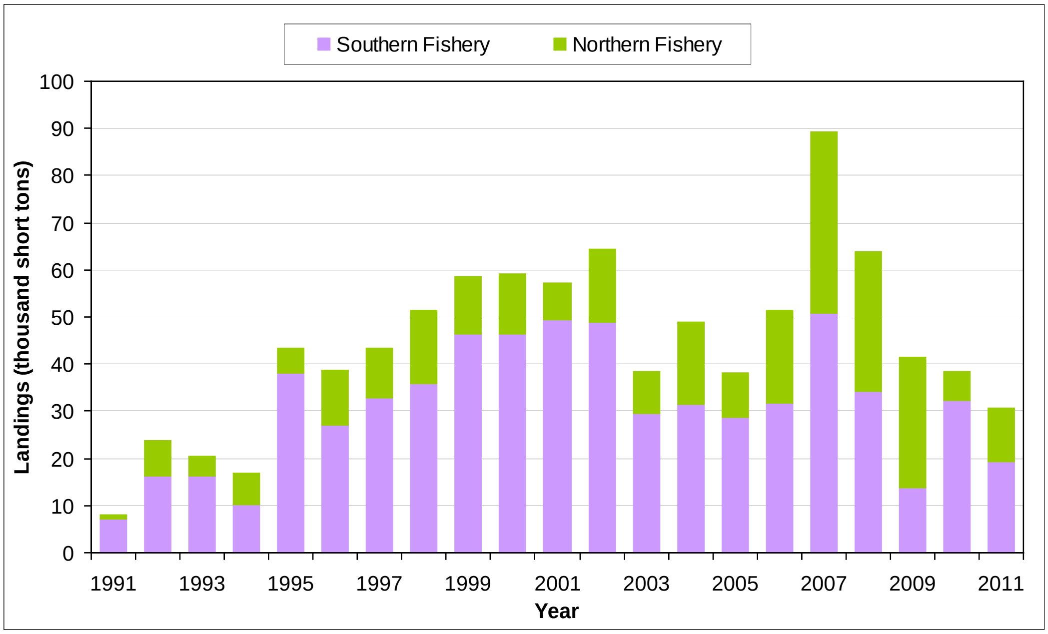

Figure 6-4. Pacific sardine commercial landings in California by region, 1991-2011. Data source: CFIS data, all gear types combined.

Status of the Biological Knowledge

Sardines are small, schooling, pelagic fish that are found in coastal temperate waters and are members of the herring family, Clupeidae. It is one of 18 species from three genera found worldwide. At times, Pacific sardine has been the most abundant fish species in the California Current and are an important forage fish, or prey item, for many species of marine life such as marine mammals, birds, and larger pelagic fish.

Sardine, along with anchovies, vary in abundance due to many different environmental factors. Anchovies tend to favor cold-water oceanic cycles whereas sardine favor the warm-water cycles. The average time for a sardine population to recover is 30 years and it has been found that sardine populations have diminished in the past in the absence of fishing pressure. When the population is abundant, Pacific sardines can be found from the tip of Baja California to southeastern Alaska, but they only occur seasonally in the northern portion of the range. In most areas Pacific sardine can be found with northern anchovy, Pacific whiting, and Pacific mackerel.

It is generally accepted that Pacific sardine form three, possibly even four, subpopulations: a Gulf of California subpopulation, a southern subpopulation off of Baja California, Mexico, a principal northern subpopulation that ranges from northern Baja California, Mexico, to Alaska. The fourth postulated subpopulation is a far northern subset. These subpopulations were assigned on the basis of blood typing. This blood typing shows different surface markers found on the red blood cells between different subpopulations, and helps delineate between 'races' of sardines.

Pacific sardine live as long as 14 years and reach lengths of up to 16 inches (41 centimeters), but 90 percent of the population consists of fish younger than six years old and smaller than 12 inches (30 centimeters). There is a substantial variation in size at age with the size given at a particular age increasing from south to north. It has been found that size and age at maturity decline as biomass decreases. At lower biomass levels, sardine appear to be fully mature at age one, whereas during years with higher biomass levels only some of the age two sardine are mature.

Spawning is thought to be restricted to 55° to 63° F (13° to 20° C), whereas sardine schools have been found in temperatures ranging from 44° to 82° F (7° to 28° C). The most northern and primary spawning ground is located between Point Conception, California and Ensenada, Baja California, Mexico. Spawning occurs in the upper 165 feet (50.3 meters) of the water column, most likely year round, peaking from April through August in the north between Point Conception, California and Bahía Magdalena, Baja California, Mexico, and from January to April in the Gulf of California. The spatial and temporal distribution of spawning is greatly influenced by water temperature. Sardine spawning shifts northward and continues for a longer period of time during warm water conditions. Pacific sardine are serial spawners and spawn several times each season. However, the number of spawning events is unknown. Eggs are found near the water surface and require approximately three days to hatch at 59° F (15° C).

Sardines age three and older were nearly fully vulnerable to the fishery up until 1953, but two and three year old fish became less available as the population declined and fewer fish moved northward. Current catch data suggests that sardine become available to the fishery at age zero, and are fully vulnerable by age three. Sardines younger than age three most likely become vulnerable to the live bait fishery which fishes in the nearshore waters where young sardines are known to occur.

Recruitment of juvenile Pacific sardine, such that they reach the size and age where they are vulnerable to the fishery, is greatly variable. Analyses of the stock-recruitment relationship have been controversial, with some studies showing a density-dependent relationship and others finding no relationship at all. Between 1932 and 1965, mean recruitment only slightly exceeded possible replacement of spawners at all levels of abundance, signifying little resilience to fishing. Recruitments occur in strings, with several years of successful recruitment followed by comparable periods of poor recruitment. The timing and length of these strings has a great effect on population growth.

Historically, the northern subpopulation made wide-ranging migrations, moving as far north as British Columbia, Canada, in the summer months and as far south as northern Baja California, Mexico, in the fall. Northern movement increased with age. The migration was complex, with timing and movement affected to some degree by oceanographic conditions. The population is currently expanding, found primarily off central and southern California as well as Baja California, Mexico.

Estimates of sardine abundance from AD 280 to 1970 have been derived from the deposition of fish scales in sediment cores from the Santa Barbara basin. Significant sardine populations existed throughout this time period and varied greatly in size. The deposition record shows nine major recoveries and correlating collapses of the population during the 1700 year period. The average recovery time for those sardine populations was approximately 30 years. The current recovery is similar to past recoveries in terms of both rate and magnitude.

Status of the Population

The estimated spawning biomass of the Pacific sardine averaged 3.8 million short tons (3.5 million metric tons) from 1932 to 1934, and fluctuated from 3.1 to 1.3 million short tons (2.8 to 1.2 million metric tons) from 1935 to 1944. The population then steeply declined over the next two decades, with a few short reversals after periods of successful recruitment, to less than 100,000 short tons (90,719 metric tons) in the early 1960s. During the 1970s, spawning biomass was estimated to be as low as 5,000 short tons (4,536 metric tons). Since the 1980s, the sardine population has increased, and the total was thought to be greater than 1.2 million short tons (1.1 million metric tons) in 1998.

Stock biomass is estimated each year to calculate harvest specifications and is defined as the sum of the biomass for sardine age one and older. In July of 2011, the stock biomass was estimated to be 1,089,497 short tons (988,385 metric tons). From 2007 to 2010 there has been a decrease in the biomass estimates for sardine (Figure 6-5). This has been the cause of the lower HGs which has constrained the fishing efforts of sardine for the past four years.

Historically, the maximum sustainable yield of the fishery in the northern subpopulation was estimated to be 250,000 short tons (226,800 metric tons) or about 22 percent per year, which was far less than the catch of sardine during the height of the fishery. Although combined landings in Mexican and U.S. waters are still well below this level, landings had increased substantially up until 2007. In the absence of a bilateral management agreement between the United States and Mexico, their combined catches of Pacific sardine have the potential for contributing towards and accelerating the next population decline. Disagreement over whether the cause of the decrease in the sardine population was due to overfishing or due to natural events has continued for decades. It is now known that both are important factors. Following the total fishery closure, management of the fishery and the development of more favorable environmental conditions has allowed the sardine resource to recover.

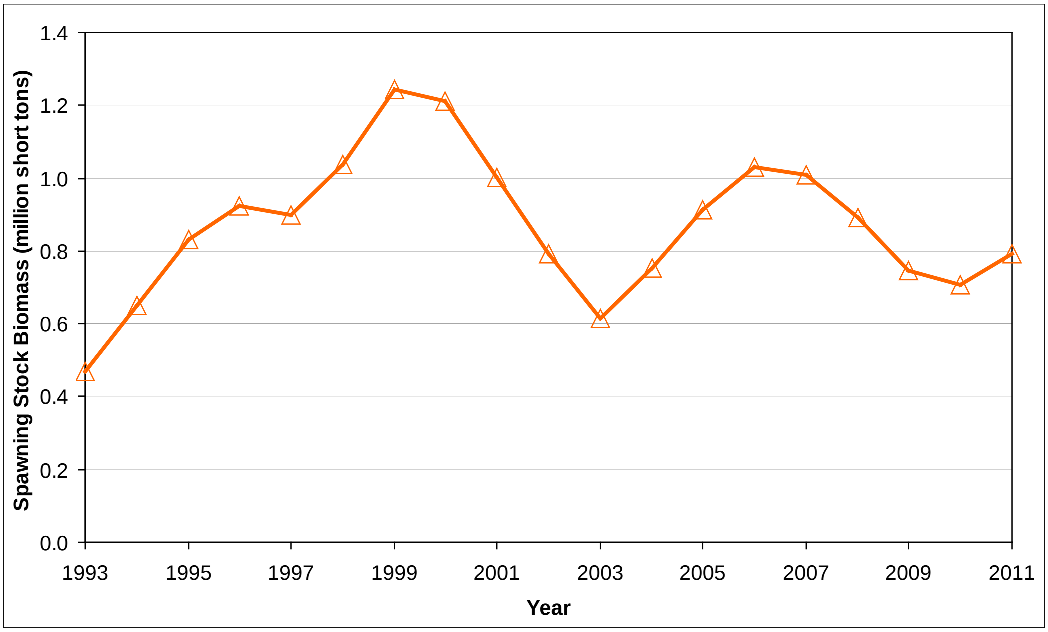

Figure 6-5. Pacific sardine spawning stock biomass, ages one and older, 1993-2011. Data source: Pacific Fishery Management Council (PFMC 2011) SAFE document.

Management Considerations

In 1999, a federal CPS FMP was established to help manage the Pacific sardine fishery as well as other coastal pelagic species along the west coast of the United States. The CPS FMP was implemented by the Pacific Fishery Management Council (PFMC), and was an expansion of the Northern Anchovy FMP which had been in place since 1978. The newly implemented plan transferred management responsibilities from the Department to the NOAA Fisheries Service. The elements of the CPS FMP consist of: 1) fishery management areas consisting of a limited entry (LE) zone and subareas; 2) specifications including a HG, quotas, and allocations; 3) requirements for closing directed fisheries when the HG is reached; 4) a dedicated fishing season for sardine from January 1 through December 31; 5) catch restrictions for incidental catch of sardine when the directed fishery is closed; 6) a federal LE program for the southern subarea; and, 7) authorization for NOAA Fisheries Service to issue exempted fishing permits for the harvest of CPS that otherwise would be prohibited.

The CPS FMP divides management into two categories: actively managed species and monitored species. Pacific sardine fall under the actively managed category and therefore have a HG. The CPS FMP and its operating regulations require NOAA Fisheries Service to set an annual HG for the Pacific sardine fishery based on the annual specifications framework in the CPS FMP. This framework includes a harvest control rule that determines what the maximum HG for the current fishing season will be based mainly on the stock biomass estimation for the year. The HG is allocated into three separate periods to extend fishing efforts throughout the year.

Initially, the U.S. sardine resource was allocated both spatially and temporally with two subareas divided at Point Piedras Blancas, California (north of Morro Bay), with the northern subarea and the southern subarea allocated 33 and 66 percent of the total allocation, respectively. After October 1, the remaining portion of the unused HG was split evenly between the two subareas. As the sardine resource expanded into Oregon and Washington, the line between the northern and southern subareas was changed to Point Arena, California (Mendocino County), with the allocation remaining the same. Beginning in 2006, the U.S. sardine resource allocation changed, moving to a coastwide allocation that was released at three separate times (January 1-35 percent, July 1-40 percent, and September 15-25 percent), to allow for a more equitable harvest opportunity between the three states.

In 2000, federal CPS LE permits were first issued when the CPS FMP went into effect for waters off the west coast of the U.S., with a total of 65 permits issued coastwide. In 2002, a capacity goal of 65 vessels with a calculated gross tonnage of 6229 tons (5650.9 metric tons) was adopted. Any CPS LE permit may be transferred to another vessel with restrictions on the harvesting capacity of the new vessel to which the permit is to be transferred to. These restrictions are as follows: 1) full transferability of permits to vessels of comparable capacity (vessel gross tonnage plus 10 percent allowance), and 2) allow permits to be combined (stacked) up to a greater capacity than the one from which the permit was transferred. At present, 56-57 permits are active in the fishery, with some of the reduction due to permit stacking.

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Further Reading

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Pacific sardine commercial landings, 1916-2011.

Year	Short tons	Year	Short tons	Year	Short tons	Year	Short tons
1916	7,824	**1940**	452,987	**1964**	6,569	**1988**	1,310
1917	52,052	**1941**	631,240	**1965**	962	**1989**	922
1918	78,826	**1942**	484,874	**1966**	439	**1990**	1,834
1919	76,939	**1943**	486,135	**1967**	74	**1991**	8,364
1920	59,260	**1944**	573,604	**1968**	62	**1992**	19,786
1921	29,666	**1945**	422,531	**1969**	53	**1993**	16,915
1922	46,700	**1946**	255,380	**1970**	221	**1994**	12,835
1923	79,080	**1947**	127,757	**1971**	148	**1995**	44,453
1924	121,343	**1948**	181,019	**1972**	186	**1996**	35,889
1925	157,647	**1949**	316,690	**1973**	76	**1997**	47,670
1926	143,371	**1950**	357,261	**1974**	7	**1998**	47,350
1927	171,138	**1951**	164,450	**1975**	3	**1999**	65,579
1928	210,135	**1952**	7,165	**1976**	8	**2000**	59,096
1929	325,886	**1953**	4,734	**1977**	2	**2001**	57,202
1930	251,031	**1954**	68,252	**1978**	1	**2002**	64,323
1931	182,176	**1955**	72,804	**1979**	57	**2003**	38,285
1932	211,305	**1956**	34,777	**1980**	23	**2004**	48,837
1933	313,199	**1957**	22,931	**1981**	38	**2005**	38,176
1934	559,966	**1958**	103,723	**1982**	2	**2006**	51,342
1935	547,879	**1959**	37,183	**1983**	1	**2007**	89,265
1936	731,772	**1960**	28,766	**1984**	1	**2008**	63,719
1937	535,745	**1961**	21,585	**1985**	6	**2009**	41,421
1938	511,695	**1962**	7,681	**1986**	428	**2010**	37,102
1939	580,397	**1963**	3,566	**1987**	484	**2011**	30,550

Data source: Department catch bulletins (1916-1986) and CFIS data (1987-2011), all gear types combined.

Pacific sardine commercial landings and harvest guideline for California, Washington, and Oregon, 2000-2011.			
Year	**WA & OR (short tons)**	**CA (short tons)**	**HG (short tons)**
2000	15,840	59,123	122,221
2001	26,353	57,280	148,840
2002	42,487	64,333	130,523
2003	40,981	38,288	122,221
2004	49,654	48,863	135,305
2005	57,134	38,251	150,069
2006	44,128	51,349	131,069
2007	51,597	89,320	168,269
2008	32,390	63,769	88,386
2009	32,526	41,510	65,291
2010	36,633	38,297	73,897
2011	20,979	30,550	52,718

Data source: CFIS data (California) and PacFIN data (Oregon and Washington).

Pacific sardine commercial landings by area (short tons) and value, 1990-2011.				
Year	**North**	**South**	**Total**	**Value**
1990	274	1,561	1,834	$292,105
1991	685	7,277	7,962	$1,321,779
1992	7,461	16,338	23,799	$2,711,654
1993	4,381	16,170	20,551	$2,186,223
1994	6,544	10,305	16,849	$2,099,411
1995	5,219	38,190	43,409	$4,827,484
1996	11,578	27,084	38,662	$4,197,653
1997	10,530	32,943	43,473	$5,811,814
1998	15,631	35,778	51,409	$4,685,478
1999	12,299	46,316	58,615	$6,505,387
2000	12,592	46,531	59,123	$6,825,665
2001	7,950	49,330	57,280	$7,676,322
2002	15,311	49,021	64,333	$7,027,996
2003	8,735	29,553	38,288	$3,382,044

Pacific sardine commercial landings by area (short tons) and value, 1990-2011.				
Year	**North**	**South**	**Total**	**Value**
2004	17,484	31,378	48,863	$4,528,278
2005	9,455	28,796	38,251	$3,485,958
2006	19,674	31,675	51,349	$5,465,840
2007	38,396	50,924	89,320	$8,557,934
2008	29,494	34,275	63,769	$7,718,091
2009	27,666	13,843	41,510	$5,596,508
2010	5,942	32,355	38,297	$4,369,846
2011	11,103	19,447	30,550	$5,390,048

Data source: CFIS data, all gear types combined.

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7 California grunion, *Leuresthes tenuis*

Male grunion, *Leuresthes tenuis*, swimming around a female buried in the sand. Photo credit: D Martin.

History of the Fishery

The California grunion, *Leuresthes tenuis*, is of minor commercial importance. Grunion are taken incidentally with encircling nets, for human consumption, and as bait. Grunion are usually caught with other small fish and are typically not reported separately, thus commercial catch records provide an incomplete account of commercial grunion landings.

Grunion provide an important, although limited, recreational fishery in southern California. Grunion are famous for their remarkable spawning habits; they are the only terrestrially spawning fish in California, actually leaving the water to spawn in wet beach sand. As the fish leave the water to spawn, they may be picked up while they are briefly stranded, providing a unique recreational fishery. Existing recreational fisheries surveys such as the California Recreational Fisheries Survey do not typically collect grunion catch data, because these surveys operate only during daylight hours, whereas grunion are vulnerable to recreational anglers during the nocturnal spawning runs.

Grunion spawning runs declined during the 1920s, and a regulation was passed in 1926 establishing a closed season for the recreational fishery during the months of April, May, and June. The spawning runs improved, and in 1948, the closure was shortened to April through May, where it remains. Grunion may be taken by recreational anglers using their hands only. No appliances of any kind may be used to catch grunion, and no holes may be dug in the sand to entrap them. Anglers sixteen years of age and older must posses a valid sportfishing license. There is no bag limit for grunion.

Status of Biological Knowledge

The California grunion is classified in the family of New World silversides, Atherinopsidae, along with the jacksmelt and topsmelt in California. Silversides differ from true smelts (family Osmeridae) by having two dorsal fins, while true smelts have one dorsal fin and one adipose fin. Grunion are small, slender fish with bluish-green backs, and silvery sides and bellies. Grunion are most common from Point Conception, California, to Point Abreojos, Baja California, Mexico, with a maximum range from Tomales Bay, California to Bahía Magdalena, Baja California, Mexico. The establishment of populations at the northern extent of the species range may coincide with El Niño Southern Oscillation (warm-water events). Adult grunion inhabit nearshore waters from the surf zone to a depth of 60 feet (18 meters). Grunion are non-migratory, although they do not necessarily return to spawn on the same beach where they hatched.

Grunion grow rapidly to approximately 5 inches (12.7 centimeters) in length by the time they are one year old, at which time they reach sexual maturity. Adult grunion normally range from 5-6 inches (12.7-15.2 centimeters) in length, with a maximum recorded size of 7.5 inches (19.0 centimeters). The normal life span is two or three years, with rare individuals living to four years. Growth ceases during each spawning season, causing noticeable annuli to form on the scales. These annuli can be used for ageing purposes.

Figure 7-1. Female grunion in the nest with male approaching. Photo credit: D Martin**.**

Grunion runs typically occur for four nights following the highest tide associated with each new and full moon. Spawning begins shortly after high tide and continues for one to three hours. As a wave breaks on the beach, the grunion swim as far up the beach as possible. The female excavates the sand with her tail, twisting her body and digging tail-first until she is buried up to the pectoral fins. After the female is in the nest, one to several males attempt to mate with her by curving around the female and releasing their milt as she deposits her eggs a few inches below the surface (Figure 7-1). Multiple paternity is common in grunion nests. After spawning, the males immediately retreat toward the ocean. The female twists free and then returns to the sea. The spawning act can happen in twenty seconds, but some fish remain on the beach for several minutes.

The major spawning season is from March through August, with spawning occasionally starting in late February or extending into early September. Peak spawning occurs during the months of April, May, and June. Individuals may spawn during successive spawning periods at approximately two-week intervals. Most females spawn about four to eight times during the season. Females produce approximately 1000 to 3600 eggs every two weeks, with larger females producing more eggs.

The eggs incubate in the damp sand above the level of subsequent waves, and do not hatch until the next high tide series reaches them. Grunion eggs can delay hatching if tides do not reach them, for up to several weeks. The mechanical action of the waves uncovers the eggs and triggers hatching. The larvae hatch within minutes of being stimulated by wave action, and enter the oceanic phase of their lives.

Grunion have no teeth, and feed primarily on mysid crustaceans. Predators upon adult grunion include humans, birds, marine mammals, and larger fish. Incubating eggs are subject to predation by sand-dwelling invertebrates. Disruptions of spawning habitat include beach erosion, beach grooming, coastal construction, and pollution.

Status of the Population

Despite brief local concentrations during spawning runs, the grunion is not an abundant species. Although no formal stock analyses have been undertaken, the population north of Los Angeles County is considered to be extremely limited. The majority of the population occurs along the coast of Los Angeles, Orange, and San Diego counties. Grunion runs in 2011 were weak in comparison to previous years.

The Grunion Greeters program coordinated by Pepperdine University researchers has collected the most comprehensive, long-term data set of grunion spawning activity. Data collected by volunteer observers include run locations, duration, and the relative strength of observed spawning runs. These data have been used to assess the effects of oil spills on grunion spawning habitat.

Management Considerations

Grunion are vulnerable to human and environmental impacts due to their restricted range, narrow critical spawning habitat, and because they are fished during the spawning season. While no take is allowed during the peak spawning months of April and May, and no gear is allowed during the open season, there is no limit to the number of grunion an individual may possess. Given the apparent popularity of the fishery, the growing human population in coastal California, and the paucity of grunion catch and effort data, the institution of a bag limit may warrant further consideration.

Protection of nest sites is an important management measure, as incubating embryos are subject to human perturbations including coastal construction, sand replenishment, beach grooming, and foot traffic, as well as terrestrial predators. Outreach to beach managers has led to changes in beach grooming practices in parts of southern California, so that beach grooming now remains above the highest tide line during the grunion spawning season, avoiding the intertidal zone where grunion nests may be located. The impacts of coastal construction and sand replenishment include crushing and burial of eggs by bulldozers grading or moving sand in the intertidal, as well as artificial lighting and turbidity affecting adult spawning behavior. Sand replenishment may result in the building of beach berms that are too steep for successful grunion spawning. Steep slopes may not allow the eggs to hatch if the next high tide cannot reach the area where eggs are incubating.

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8 Silversides, Atherinopsidae

Left: Jacksmelt, *Atherinopsis californiensis*. Right: Topsmelt, *Atherinops affinis.* Photo credit: NOAA Fisheries Service (both).

There are three species of silversides (family Atherinopsidae) in California ocean waters, jacksmelt, *Atherinopsis californiensis*, topsmelt, *Atherinops affinis,* and California grunion which is presented in a separate section of this report. Although jacksmelt and topsmelt have the name “smelt” incorporated into their common names, they are not true smelt. True smelt (family Osmeridae) are more closely related to trout and differ from silversides in that they have an adipose fin, one dorsal fin, and their pectoral fins are placed low on the bodies. Silversides, which are more closely related to mullet and barracuda, lack an adipose fin, have two dorsal fins, and their pectoral fins are placed high on their bodies. Silversides have a brilliant silver stripe running the length of their bodies which gives them their name.

History of the Fishery

The commercial fishery for silversides is not considered an important fishery and is of minor economic importance in California. The commercial fishery is primarily incidental to other fisheries. Historically silversides have been reported in California’s commercial landings as “smelt” and combined with the landings for true smelt species. Jacksmelt made up a majority of the historical landings for “smelt” and topsmelt contributed up to 25 percent. Since 1976, topsmelt and jacksmelt have been reported separately from true smelt species in annual landings published in California Department of Fish and Wildlife (Department) catch bulletins. According to landing receipt data from the Department’s Commercial Fisheries Information System (CFIS), the commercial landings for grunion and topsmelt have been sporadic and very low compared to those for jacksmelt and the generic landing category “silversides”. The commercial landings and ex-vessel values for the silversides (jacksmelt, topsmelt, grunion, and unspecified silversides) have varied sharply over time (Figure 8-1).

In 1994, the Department revamped the landing receipts, dropping “silversides” from the list of preprinted species. At present, jacksmelt is the only silverside species listed on Department landing receipts, the rest of the silversides (topsmelt, grunion, “silversides”) have to be written in by the fish buyer. Prior to the change in landing receipts, landings of jacksmelt and “silversides” accounted for most of the landings (43 and 57 percent, respectively). Since 1994, “silversides” show up occasionally in the landings and jacksmelt make up 98 percent of all silverside landings. This is likely due to the presence of jacksmelt on the landing receipt and not a change in the commercial catch.

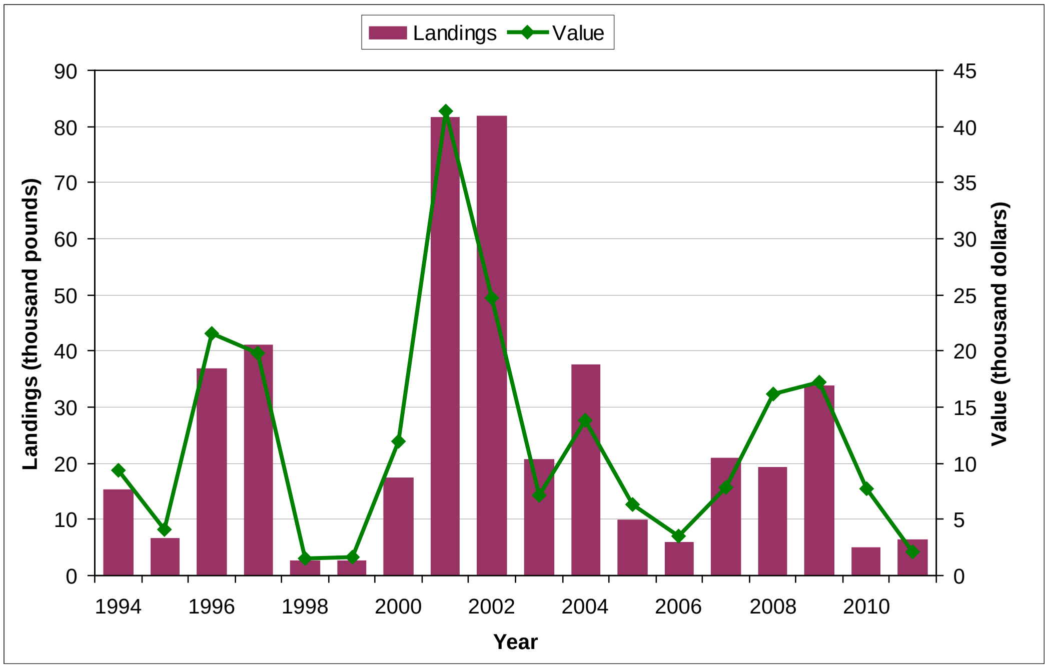

Figure 8-1. Silversides commercial landings and value, 1994-2011. Data source: CFIS data, all species combined including grunion.

Silversides have been caught using a variety of gear types such as encircling nets, hook-and-line, gill nets and beach seines. According to CFIS data, encircling nets such as purse seines, drum seines, and lampara nets have accounted for the majority of the landings. Starting in 1991, the use of hook-and-line gears increased. In 2010, hook-and-line gears contributed 95 percent of the total catch.

There is no commercial fishing season for silversides and they are landed throughout the year. There is no commercial take limit. The landings are largely made in San Francisco and ports to the south. According to CFIS data, the ports in Los Angeles County dominated commercial landings for jacksmelt from 1976 until 1999. However from 2000 on, a majority of the landings have been made in Monterey.

Recreational anglers catch silversides using hook-and-line gear from piers, beaches, and private and rental boats. A few silversides are taken by anglers on commercial passenger fishing vessels (CPFV). Anglers on piers catch silversides using fishing line with several small, shiny, bare hooks sometimes with colored yarn attached (typically yellow and red). Single baited hooks are also used from boats and piers. Juveniles of both jacksmelt and topsmelt can easily be taken by anglers chumming with bread crumbs and using nets to scoop up the feeding masses.

In California there are no seasons, size or bag limits for jacksmelt or topsmelt taken recreationally. The recreational catch of silversides has been highly variable ranging from a low of 315,000 fish caught in 1999 to a high of 1.08 million fish in 1993 according to data from the Marine Recreational Fisheries Statistics Survey (MRFSS) (Figure 8-2). During that period (1980-2003), jacksmelt accounted for 85 percent of the recreational catch, with topsmelt accounting for 15 percent. The catch of jacksmelt in southern California (Point Conception to the U.S./Mexico border) decreased from 53 percent to 33 percent, averaging 43 percent from 1980-2003 according to MRFSS data. Topsmelt were caught primarily in southern California and showed an increasing trend between 1980 and 2003, going from 90 percent (1980-1989) to 97 percent (1993-2003). Grunion were not sampled by MRFSS samplers because catch only occurs at night and samplers only sample during daylight hours.

In 2004, the California Recreational Fisheries Survey (CRFS) replaced MRFSS and while direct comparisons are not possible due to changes in sampling methodology, similar trends are seen in the silversides catch. CRFS samplers do not sample grunion catch. The recreational catch of silversides remained highly variable ranging from 350,000 fish in 2009 to 744,000 fish in 2006 (Figure 8-3). Jacksmelt continue to make up most of the silversides catch, averaging 82 percent between 2004 and 2011. More jacksmelt were caught in northern California than southern California (57 and 43 percent, respectively). Topsmelt were caught primarily in southern California, averaging 84 percent between 2004 and 2011 according to CRFS data.

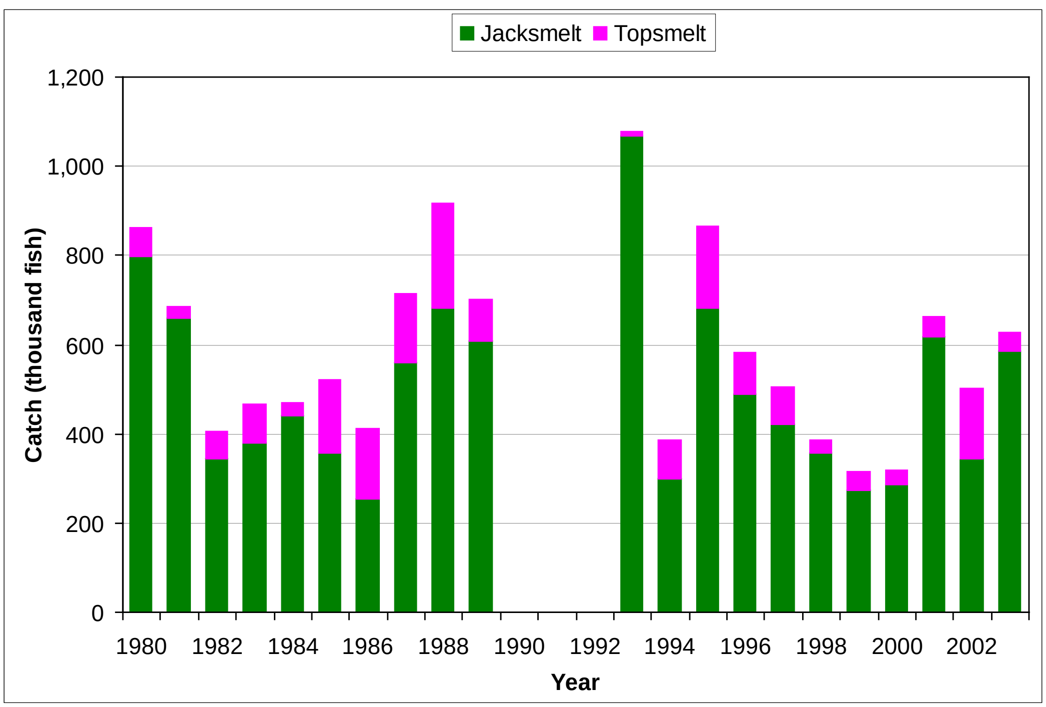

Figure 8-2. Silversides recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined, except grunion. Data for 1990-1992 are not available.

Figure 8-3. Silversides recreational catch, 2004-2011. Data source: CRFS data, all fishing modes and gear types combined, except grunion.

Status of Biological Knowledge

<u>Jacksmelt</u>

Jacksmelt range from Santa Maria Bay, Baja California, Mexico, to Yaquina, Oregon. Jacksmelt and topsmelt look similar to each other in that they are green to greenish-blue above, slivery on the sides with a blue midline stripe. Jacksmelt differ from topsmelt in that the anal fin originates between the two dorsal fins. The jacksmelt's teeth are not forked and are arranged in several bands on each jaw. Jacksmelt are reported to grow larger than topsmelt. The largest jacksmelt ever measured was 17.5 inches (44.5 centimeters) total length. Jacksmelt are schooling fish commonly found inshore and in bays near the surface.

Aging studies for jacksmelt were based primarily on length frequencies although annual growth rings on scales were used to ascertain maximum ages. Jacksmelt grow to an average length of 4.5 inches (11.4 centimeters) in their first year of life and 7.3 inches (18.5 centimeters) by the end of their second year, when most are sexually mature. Early research showed jacksmelt obtained a maximum age of nine or ten years, but in 1958, a 16 inch (40.6 centimeters) male taken off of Balboa pier was 11 years old.

Jacksmelt spawn in shallow waters between October and early April. Eggs range in size from 0.08-0.1 inches (2-2.5 millimeters) and are attached in masses by long filaments to submerged objects, usually kelp. Females can spawn several times during the breeding season. Jacksmelt larvae and juveniles are found in abundance in the surface canopy of kelp.

Studies of the digestive system of silversides show that jacksmelt are omnivores feeding on detritus and algal material, but mainly feeding on a variety of zooplankton. Jacksmelt are important forage species for many marine birds, fish, and mammals.

Topsmelt

Topsmelt range from the Gulf of California to four miles (6.4 kilometers) west of Sooke Harbour, Vancouver Island, British Columbia, including Guadalupe Island, Baja California, Mexico. As with the jacksmelt, topsmelt are green to greenish-blue above, silvery on the sides, and have a blue midline stripe. The topsmelt's anal fin originates directly below the posterior end of the first dorsal fin. Topsmelt have forked teeth arranged in one row on the jaw, unlike the jacksmelt which has multiple rows of teeth. The largest recorded topsmelt was 14.5 inches (36.8 centimeters). Although topsmelt from different locations and habitats were once thought to be different subspecies due to the variation in external characteristics, topsmelt has been recognized for more than a quarter of a century as a single species. Topsmelt are also schooling fish that are common in the surface waters of bays, sloughs, and kelp beds.

Topsmelt grow from 2.5 to 4 inches (6.4 to 10.2 centimeters) during their first year with another 2 inches (5.1 centimeters) added during their second year, in which most are sexually mature. Ageing studies on topsmelt were conducted using length frequencies and by counting annual growth rings on scales to determine age and growth rates. The longest fish are 7 to 8 years old. Larger fish usually occur in the northern extremities of their range.

Topsmelt spawning season runs from mid-May to early July, when females, accompanied by several males, enter shallow water to spawn. The eggs are attached to eel grass or low growing algae. Topsmelt larvae and juveniles are found in abundance in the surface canopy of kelp.

Topsmelt feeding habits reflect the different habitats they can occupy. Those found in estuaries are primarily herbivorous whereas those found in kelp forests are carnivorous. Topsmelt are important forage species for many marine birds, fish, and mammals.

Status of the Population

Stock sizes for jacksmelt and topsmelt have not been determined. At present, there are no indications that either species is being over harvested.

Management Considerations

The commercial and recreational fisheries for both species have no season, size or harvest limits. At present the silverside commercial fishery is incidental and of low economic importance, and therefore not foreseen to be over-exploited in the near future.

Because both species use bays and estuaries for spawning, they can be susceptible to adverse effects from pollution and habitat modification, especially the disturbance of eelgrass beds.

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Silversides commercial landings (pounds) and value, 1994-2011.						
Year	**Jacksmelt**	**Topsmelt**	**Grunion**	**Unspecified silversides**	**Total**	**Value**
1994	15,084	69		35	15,188	$9,403
1995	5,391			1,200	6,591	$4,100
1996	36,662			162	36,824	$21,612
1997	40,766	133		130	41,029	$19,773
1998	2,537			34	2,571	$1,466
1999	2,538			24	2,562	$1,687
2000	16,003	981	73	237	17,294	$11,969
2001	74,971	406		6,334	81,710	$41,458
2002	81,449			432	81,881	$25,424
2003	20,919	20			20,939	$8,516
2004	38,322			205	38,527	$18,432
2005	9,747				9,747	$6,382
2006	5,785	12		5	5,802	$3,671
2007	20,661			84	20,745	$7,837
2008	19,116			4	19,120	$16,160
2009	33,664			118	33,782	$17,269
2010	4,999				4,999	$7,708
2011	6,321	19			6,340	$2,125

Data source: CFIS data, all gear types combined.

Silversides recreational catch (number of fish), 1980-2003.							
Year	**Jacksmelt**	**Topsmelt**	**Total**	**Year**	**Jacksmelt**	**Topsmelt**	**Total**
1980	796,323	66,096	862,419	**1994**	297,852	87,263	385,115
1981	657,910	28,444	686,354	**1995**	683,621	181,722	865,343
1982	343,591	61,474	405,065	**1996**	489,128	92,023	581,151
1983	379,888	86,476	466,364	**1997**	422,594	81,650	504,244
1984	441,024	28,423	469,447	**1998**	357,115	29,116	386,231
1985	356,449	163,516	519,965	**1999**	272,223	42,876	315,099
1986	255,676	156,159	411,835	**2000**	287,792	30,926	318,717
1987	559,038	154,528	713,566	**2001**	616,173	48,100	664,272

Silversides recreational catch (number of fish), 1980-2003.							
Year	**Jacksmelt**	**Topsmelt**	**Total**	**Year**	**Jacksmelt**	**Topsmelt**	**Total**
1988	683,089	233,911	917,000	**2002**	343,084	160,256	503,340
1989	606,798	95,087	701,885	**2003**	585,303	42,222	627,525
1993	1,066,864	10,197	1,077,060				

Data source: MRFSS data, all fishing modes and gear types combined, except grunion. Data for 1990-1992 are not available.

Silversides recreational catch (number of fish), 2004-2011.			
Year	**Jacksmelt**	**Topsmelt**	**Total**
2004	513,679	101,682	615,361
2005	508,604	188,580	697,185
2006	586,557	157,460	744,017
2007	345,602	34,371	379,973
2008	582,153	82,907	665,060
2009	539,271	123,983	663,253
2010	303,125	47,514	350,639
2011	365,768	67,215	432,983

Data source: CFRS data, all fishing modes and gear types combined, except grunion.

9 California Corbina, *Menticirrhus undulatus*

California corbina, *Menticirrhus undulatus*. Photo credit: B Varney

History of the Fishery

The California corbina (*Menticirrhus undulatus*), also known as California king croaker or California whiting, is one of several species of croakers (family Sciaenidae) that inhabit the nearshore coastal waters of southern California. Fishing for corbina has remained a strictly recreational activity ever since the commercial fishery in California was shut down in 1915, though corbina can still be found in the commercial markets of Mexico. This fish is very popular with southern California anglers in part because of how challenging it is to catch one. They also put up a good fight and are good eating.

Fishing for corbina occurs year round, but the best fishing is in the summer and early fall. Corbina can be taken along sandy beaches, and off piers and jetties. According to California Recreational Fisheries Survey (CRFS) data, about 99 percent of the catch was estimated to come from shore modes, which includes beach and bank (BB) and manmade (MM) modes; corbina are rarely caught form the boat modes, including private/rental boats, and party/charter boats. Average annual catch estimates from 2004-2009 suggest this species is caught equally as often from beaches and banks as from a pier or jetty. CRFS reduced sampling levels for the BB mode in 2010 and BB and MM in 2011; therefore, the estimates for 2010 and 2011 are not comparable with the 2004-2009 estimates.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by CRFS, which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

The annual number of corbina caught by recreational anglers has been variable, with Marine Recreational Fisheries Statistics Survey (MRFSS) annual catch estimates for 1980-2003 ranged between a high of 53,000 fish in 1987 and a low of 2,000 fish in 2003, averaging 24,000 fish annually (Figure 9-1).

The CRFS annual catch estimates for 2004-2009 ranged between 5,800 and 38,000 fish in 2008 and 2006, respectively, with an average of 23,000 fish (Figure 9-2). Both surveys show a downward trend in catch over time. Some studies suggest that this trend, which is also characteristic of the majority of sciaenids in southern California, may be attributed to environmental factors such as changing sea surface temperatures and plankton biomass.

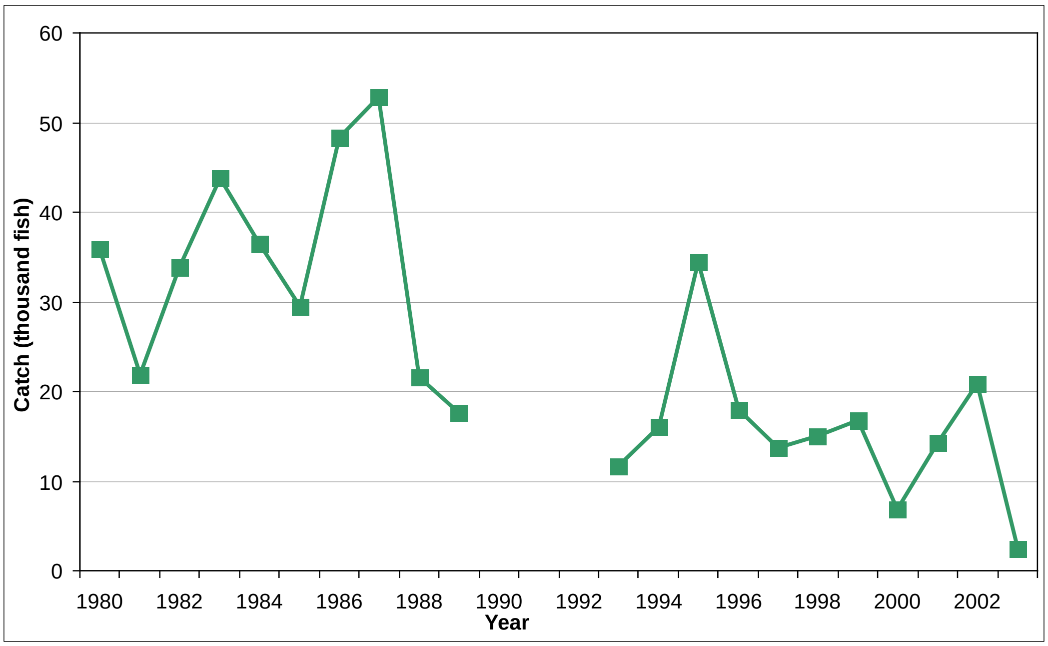

Figure 9-1. California corbina recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

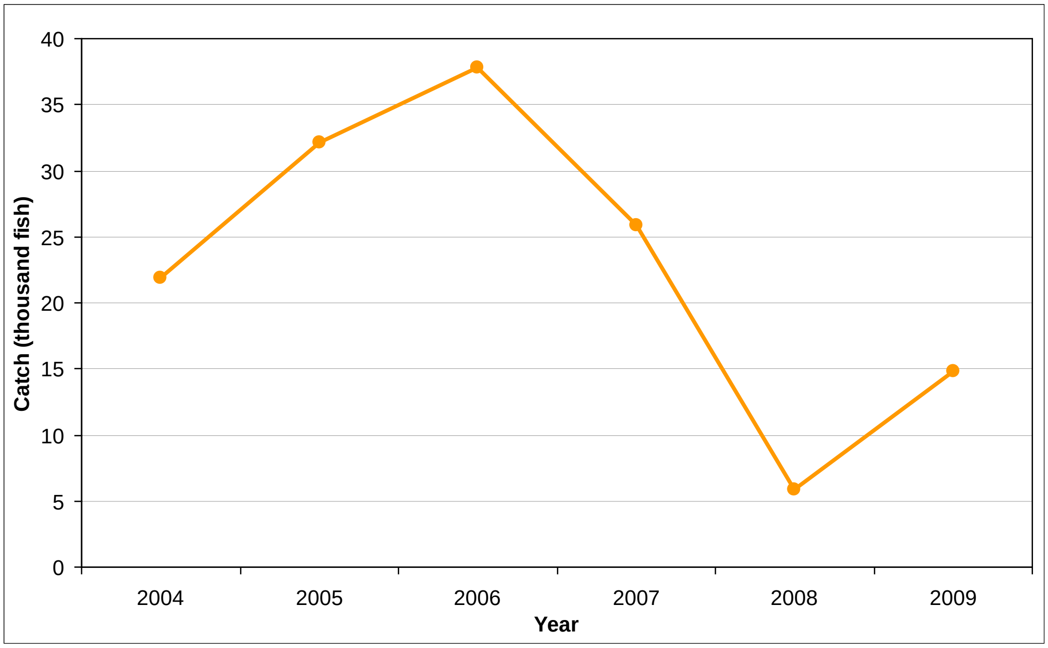

Figure 9-2. California corbina recreational catch, 2004-2009. Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

Status of Biological Knowledge

The California corbina are a slender croaker with a gray to bluish back and a white flattened belly. They have a short, stiff chin barbell and may have wavy oblique lines on their sides. Corbina range from Point Conception, California to the Gulf of California, Mexico. They can be found along sandy beaches and inside shallow bays in water anywhere from a few inches deep to 66 feet (20 meters), but are most commonly found shallower than 40 feet (12 meters). Corbina are usually solitary or in small loose groups, but occasionally occur in very large schools.

Corbina can grow to 30 inches (76 centimeters) and weigh up to 8.5 pounds (3.6 kilograms); the official sportfishing record for a corbina caught using hook-and-line is 7 pounds, 1 ounce (3.2 kilograms) and 24.5 inches (62 centimeters) total length. The oldest corbina sampled was a 23 inch (58 centimeter) female caught on the open coast that was estimated to be 11 years old. Spawning season takes place from April to October with peak activity occurring from June through August. The eggs are pelagic and fish that are only 1.5-3 inches long (40-76 millimeters) have been collected in the surf zone to 30 feet (9 meters) deep.

The California corbina feeds primarily on benthic organisms. Individuals may be seen foraging in the very shallow waters of the surf zone - waters so shallow in fact that their backs are exposed. They feed by scooping up mouthfuls of sand and filtering the contents through their gill openings. Juveniles mainly consume clam siphons and small crustaceans, moving on to larger parts of clams and sand crabs as they grow. Because of its benthic feeding habits, corbina is exposed to contaminants in the sand and mud.

One Newport Bay study found corbina samples containing concentrations of DDTs and PCBs above the screening value for human fish consumption. Therefore, current health guidelines advise against eating more than 2 servings per week of California corbina caught from southern California waters between Ventura Harbor and San Mateo Point, just south of San Clemente.

Limited tagging studies suggest that corbina tend to be mainly sedentary and do not display any discernable migratory pattern. The greatest distance any tagged corbina has been known to travel is 51 miles (82 kilometers). Some studies indicate there may be some seasonal inshore-offshore movement. One study that analyzed entrainment data from several southern California power generating stations for 1977-1998 noticed that corbina densities were highest from January through March. The intakes for these stations were located offshore and in midwater depths between 13 and 20 feet (4 and 6 meters). Other studies looking at recreational catch data collected in the surf zone showed higher densities in the summer months and early fall. These data suggest corbina may move offshore in the winter months and move inshore in the summer months.

Status of the Population

Recruitment, population size, and mortality of California corbina are unknown. California Department of Fish and Wildlife (Department) beach seine hauls along the open coast in southern California from 2007 through 2009 yielded slightly higher but similar numbers of corbina to those obtained during two other previous similar Department studies from 1994-1997 and 1953-1956. These three studies also yielded similar catch-per-unit efforts, indicating that the population is sustaining itself under present recreational harvest levels.

California corbina ranked sixth in abundance during the most recent Department beach seine study (2007-2009), below other common surf fish species such as queenfish, yellowfin croaker, and walleye surfperch. When compared to the previous two Department studies in the 1990s and 1950s, corbina ranked second and ninth, respectively, in abundance. The most recent study sampled over a wide range of tidal conditions and found that corbina were more abundant during lower, incoming tides. Corbina catches consisted of fish ranging in size from young-of-the-year to adult, and were dominated by smaller size classes. Annual average weight estimates remained relatively constant over the past several decades (MRFSS and CRFS data) with an average of 1.2 pounds (0.5 kilograms) per fish. Annual average length estimates varied more than weight, with an average fork length of 14 inches (35.6 centimeters).

Management Considerations

Current recreational take of California corbina appears to be at sustainable levels, just as it has also been in the past decades. The current sport fish regulations and the ban on commercial take of California corbina appear to be effective management measures and should be maintained.

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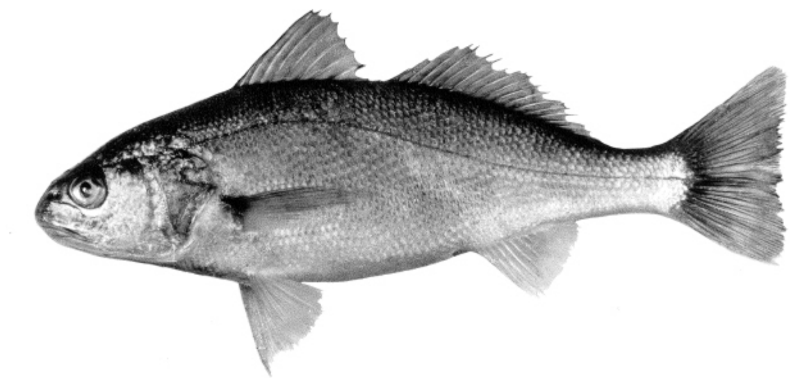
California corbina recreational catch, 1980-2003					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	35,926	**1988**	21,659	**1996**	17,989
1981	21,915	**1989**	17,654	**1997**	13,780
1982	33,864	**1990**	*no data*	**1998**	15,071
1983	43,788	**1991**	*no data*	**1999**	16,786
1984	36,476	**1992**	*no data*	**2000**	6,837
1985	29,457	**1993**	11,687	**2001**	14,322
1986	48,270	**1994**	15,989	**2002**	20,851
1987	52,823	**1995**	34,386	**2003**	2,467

Data Source: MRFSS data for all fishing modes and gear types combined. Data for 1990-1992 are not available.

California corbina recreational catch, 2004-2009	
Year	**Number of fish**
2004	21,857
2005	32,116
2006	37,810
2007	25,833
2008	5,868
2009	14,825

Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

10 White Croaker, *Genyonemus lineatus*



White croaker, *Genyonemus lineatus*. Photo credit: Department archives.

History of the Fishery

White croaker, *Genyonemus lineatus*, is one of several species of sciaenids that is commonly fished for in the nearshore waters of California. It has both a commercial and recreational fishery. Between 1996 and 2011 the main gear type used to catch white croaker in both of these fisheries has been hook-and-line. During this time period white croaker have been taken predominately in southern California.

According to California Department of Fish and Wildlife (Department) landings data, white croaker commercial landings averaged 154,000 pounds (70,000 kilograms) annually between 1996 and 2011. The largest annual landing occurred in 1996 at 529,000 pounds (240,000 kilograms) with an ex-vessel value of $305,000. Landings have steadily declined since that time to an all time low of 6000 pounds (2700 kilograms) in 2011 with an ex-vessel value of only $3400 (Figure 10-1). Part of the decline in landings may be due to the banning of gill nets in southern California waters (within 3 miles [4.8 kilometers] along the mainland coast and within 1 mile [1.6 kilometers] around the offshore islands) in 1994 (FGC §8610.3 (b)). In addition, since 1990 it has been illegal to commercially fish for white croaker in a specific area of water within 3 nautical miles (4.8 kilometers) of shore off of the Palos Verdes Peninsula in southern California due to contamination issues (FGC §7715; Title 14, CCR, §104). Since 1996, the majority of commercially-caught white croaker have been taken by hook-and-line and trawl gear, at 51 percent and 19 percent, respectively (Figure 10-2). Most of the commercial catch is sold in the fresh fish market, although a small amount is used for live bait. “Kingfish” is the most common name seen in markets.

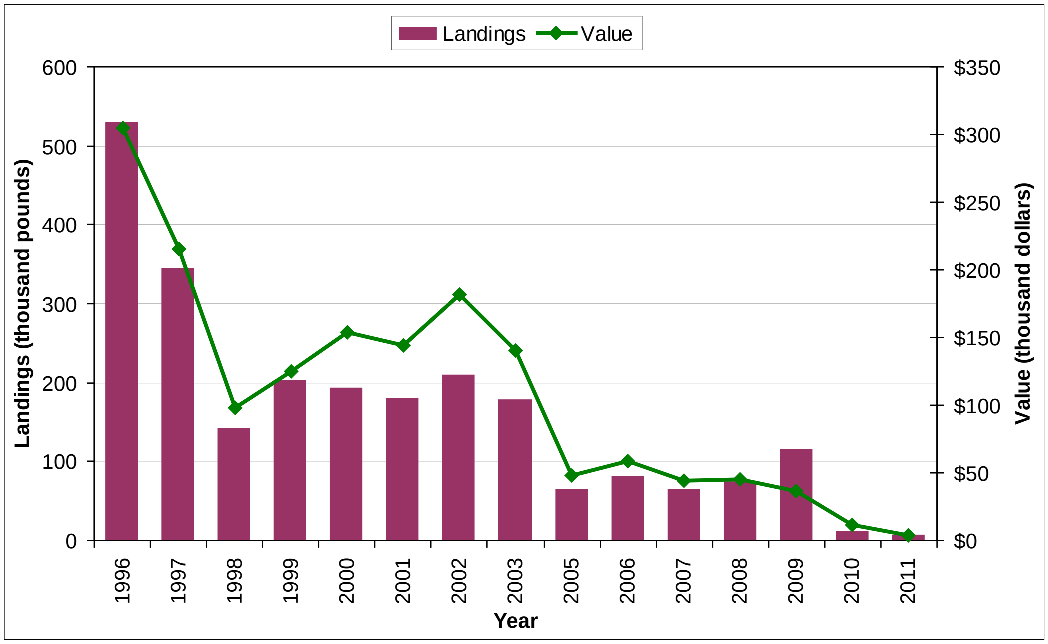


Figure 10-1. White croaker commercial landings and value, 1996-2011. Data Source: Commercial Fisheries Information System (CFIS) data, all gear types combined.

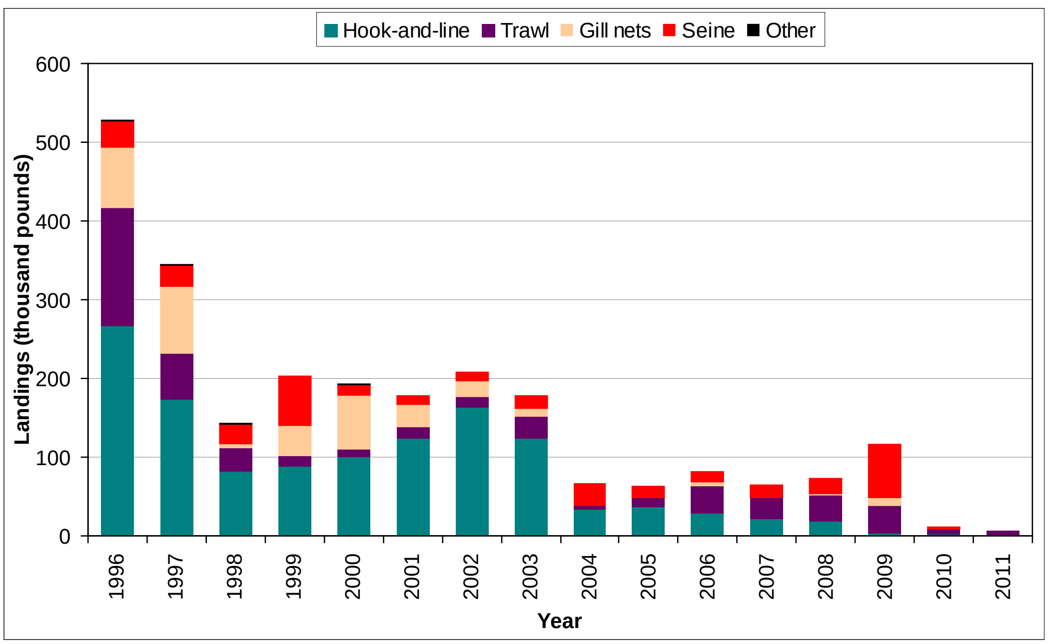


Figure 10-2. White croaker commercial landings by gear type, 1996-2011. Data source: CFIS data.

In the recreational fishery, white croaker were added to the list of species covered under the general recreational daily bag and possession limit regulation of 10 fish in 1998. This change in the regulations was due to concern that white croaker were being taken under the authority of a sport fishing license and subsequently sold in the commercial markets. Before this change, recreational anglers were allowed to take an unlimited number of white croaker.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by the California Recreational Fisheries Survey (CRFS), which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

White croaker is a very easy fish to catch with hook-and-line gear and for this reason they are a mainstay of pier and small vessel anglers. According to Marine Recreational Fishery Statistical Survey (MRFSS) estimates, landings of white croaker by recreational anglers between 1996 and 2003 averaged 520,000 fish per year; 42 percent taken by shore modes (beach/bank [BB] and manmade [MM]), 50 percent taken by private/rental mode (PR), and 8 percent taken by party/charter mode (PC) (Figure 10-3).

According to California Recreational Fisheries Survey (CRFS) estimates, landings of white croaker between 2004 and 2009 averaged 195,000 fish per year; 67 percent taken by the shore modes, 31 percent taken by PR mode, and 2 percent taken by PC mode (Figure 10-4). CRFS reduced sampling levels for the BB mode in 2010 and BB and MM in 2011; therefore, the estimates for 2010 and 2011 are not comparable with the 2004-2009 estimates.

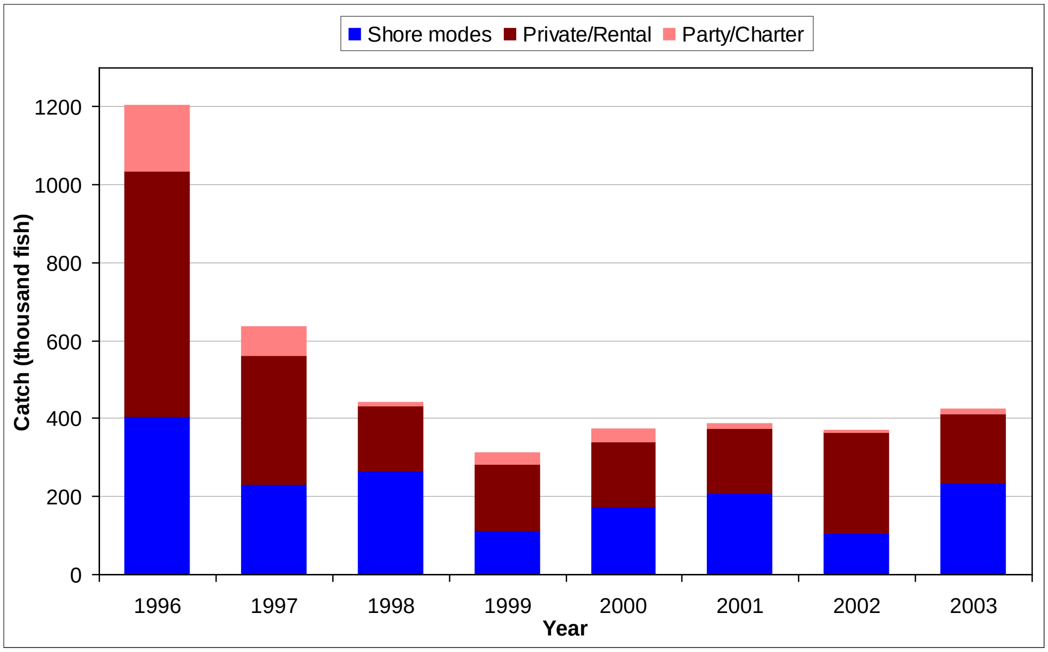


Figure 10-3. White croaker recreational catch by fishing mode, 1996-2003. Data source: MRFSS data, all gear types combined.

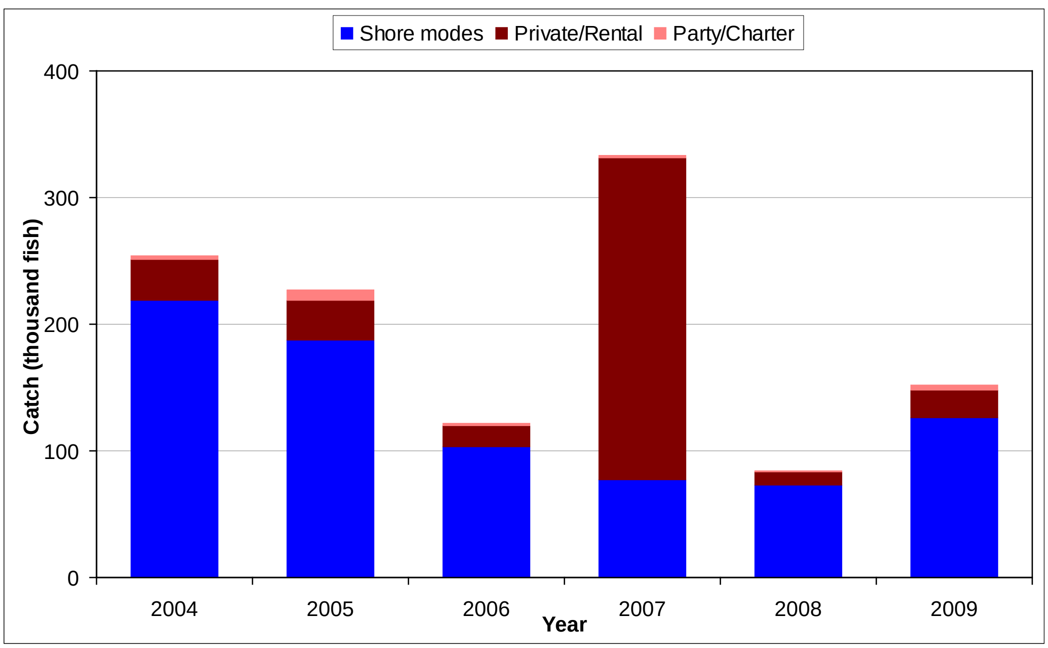


Figure 10-4. White croaker recreational catch by fishing mode, 2004-2009. Data source: CRFS data, all gear types combined. Data for 2010-2011 are not available.

Status of Biological Knowledge

White croaker is one of eight species of drums or croakers from the family Sciaenidae recorded off of California. *Genyonemus* is a combination of two Greek words, genys, meaning lower jaw, and nemus, meaning barbel. The species name lineatus is a Latin word meaning striped. White croaker are often sold in fish markets under the name kingfish, and they are also known as wongfa, chogy, tomcod, tommy, roncador, or ronkie by recreational anglers.

White croaker have subfusiform (spindle-shaped) compressed bodies, with the snout projecting beyond the mouth and the upper jaw extending beyond the lower. The pectoral are sickle-shaped, the pelvic fins are under the pectoral, and the caudal fin is truncate or straight. They are typically silvery to brassy colored, with a small, but prominent black spot at the base of each pectoral fin and a cluster of minute barbels on the membranes underneath the lower jaw.

White croaker is an abundant nearshore species in California, usually found over soft, sandy-mud substrate. They range from Barkley Sound, British Columbia, Canada, to Bahía Magdalena, Baja California, Mexico. They are reported to be common in Humboldt Bay in northern California, and are abundant from San Francisco southward to at least Bahía de Sebastian Vizcaino, central Baja California, Mexico. They usually swim in schools and are found from the surf zone to depths as great as 780 feet (240 meters) and in shallow bays, sloughs, and lagoons. Most of the time, they occupy nearshore areas at depths of 10 to 100 feet (3 to 30 meters), but sometimes are fairly abundant to a depth of 300 feet (90 meters).

The maximum recorded length for white croaker is 16.3 inches (41 centimeters) total length (TL); however, fish larger than 12 inches TL (30 centimeters) rarely occur. Fish up to 4 pounds (2 kilograms) have been reported, but those weighing over 2 pounds (1 kilogram) are extremely rare. White croaker live to about 15 years and over 50 percent of both sexes are sexually mature by 1 year. At 1 year, males are about 5.5 inches TL (14 centimeters) and females are about 6 inches TL (15 centimeters). By 3 or 4 years white croaker are about 7.5 inches TL (19 centimeters) and both males and females are mature.

In southern California, white croaker spawn mainly from November through May, with peak months being January through March. In central California, they spawn all year and may have winter and summer spawning peaks (ovary weights were found to be highest in January and September, and lowest in May). Females spawn 18 to 24 times each season with individual spawning events occurring about every 5 days, depending upon their size and age. Batches of eggs range from an estimated 800 eggs in a 6 inch TL (15 centimeter) female to 37,200 in a 10 inch TL (25 centimeter) female. The fertilized eggs are pelagic and occur in depth ranges from about 25 to 120 feet (8 to 37 meters). The larvae initially are pelagic and most abundant in ocean depth ranges from about 50 to 75 feet (15 to 23 meters). As the larvae grow, they descend toward the ocean floor and migrate towards shore. Juveniles occur near the bottom at ocean depths of 10 to 20 feet (3 to 6 meters). As they mature, they migrate to somewhat deeper water.

White croaker are omnivores; their diet may include a variety of worms, shrimps, crabs, squid, octopuses, clams, small fishes and other items, living and dead. They feed primarily at night and on the bottom, although some midwater feeding occurs during the day. They are preyed upon by Brandt's and double-crested cormorants, seals, sea lions, dolphins and many fish species (e.g., barred sand bass, California lizardfish, California halibut, giant sea bass, Pacific bluefin tuna, and various sharks).

White croaker that live near marine waste discharges may concentrate toxic materials such as pesticides (DDT, DDE, etc.), polychlorinated biphenyls (PCBs), metals (zinc, selenium, mercury, etc.), and petroleum products in their bodies at levels that are considered hazardous for human consumption. Some white croaker in these areas are diseased and malformed and some show reproductive impairment. Current health guidelines advise against human consumption of white croaker caught from southern California waters between the Santa Monica Pier and the Seal Beach Pier. It is recommended consumption of only one serving per week (skinless fillet) of white croaker caught between the Ventura Harbor and the Santa Monica Pier and the area from the Seal Beach Pier south to San Mateo Point (just south of San Clemente). Eating fish contaminated with pesticides and PCBs does not make people sick right away. The more contaminated fish you eat, the greater the amount of chemicals that build up in your body over time. Health problems associated with increased exposure to these chemicals include cancer, liver disease, and developmental effects, as well as effects on the immune and endocrine systems.

Status of the Population

The population size of white croaker is not known. A beach seine haul study by the Department along the open coast in southern California from 2007 through 2009 yielded a much lower catch-per-unit-effort than another similar Department study conducted from 1953 through 1956. Catch declines are also evident in other longer term datasets. Power plant entrainment studies have shown a declining trend in white croaker abundance since the late 1970s. This trend has primarily been influenced by warmer water and other associated environmental factors. White croaker egg hatching is also poor during very warm water years. However, white croaker catches have not increased during the more recent cooler water years. Many other variables may also be affecting catch rates such as regulation changes, pollutants affecting reproductive output, changes in angler attitudes/fishing effort, or changes in fishing locations.

Management Considerations

Future management considerations should include continual monitoring of the commercial and recreational fisheries, environmental factors, and the status of contaminant levels in areas of concern. Studies to determine population size of white croaker would aid fisheries managers in making more informed decisions regarding this species.

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White croaker commercial landings and value, 1996-2011.

Year	Pounds	Value	Year	Pounds	Value	Year	Pounds	Value
1996	528,786	$305,228	**2002**	209,309	$182,008	**2008**	73,469	$45,251
1997	345,034	$215,622	**2003**	178,037	$140,559	**2009**	116,042	$36,718
1998	142,441	$97,777	**2004**	67,261	$50,005	**2010**	11,846	$11,296
1999	203,161	$125,442	**2005**	63,669	$48,298	**2011**	6,833	$4,140
2000	192,764	$154,180	**2006**	81,057	$58,216			
2001	179,214	$143,899	**2007**	65,048	$43,965			

Data Source: CFIS data, all gear types combined.

White croaker commercial landings (pounds), by gear, 1996-2011.						
Year	**Hook-and-line**	**Trawl**	**Gill net**	**Seine**	**Other**	**Total**
1996	266,721	148,638	78,019	33,220	2,188	528,786
1997	174,080	58,248	84,030	27,958	719	345,034
1998	82,355	28,741	4,686	24,919	1,740	142,441
1999	89,018	12,527	38,353	62,930	333	203,161
2000	99,603	10,033	68,033	14,140	954	192,764
2001	123,875	15,327	27,088	12,580	344	179,214
2002	163,996	13,446	18,682	11,815	1,369	209,309
2003	122,506	29,198	8,745	17,588	0	178,037
2004	33,263	6,397	321	27,280	0	67,261
2005	36,827	11,199	652	14,992	0	63,669
2006	29,275	34,701	4,664	12,417	0	81,057
2007	22,129	26,786	26	16,107	0	65,048
2008	17,883	32,776	2,186	20,625	0	73,469
2009	3,197	35,856	9,955	67,035	0	116,042
2010	1,564	6,547	469	3,267	0	11,846
2011	56	6,077	35	98	65	6,331

Data Source: CFIS data.

White croaker recreational catch (number of fish), by fishing mode, 1996-2003.				
Year	**Shore modes**	**Private/Rental**	**Party/Charter**	**Total**
1996	404,600	631,019	170,391	1,206,010
1997	230,262	332,258	75,476	637,996
1998	263,774	166,961	13,005	443,740
1999	113,052	170,021	29,564	312,637
2000	172,538	168,055	34,353	374,946
2001	207,732	168,302	11,031	387,065
2002	105,469	258,575	6,225	370,268
2003	236,071	174,955	13,557	424,584

Data Source: MRFSS data, all gear types combined.

White croaker recreational catch (number of fish), by fishing mode, 2004-2009.				
Year	**Shore modes**	**Private/Rental**	**Party/Charter**	**Total**
2004	218,557	31,501	3,405	253,462
2005	187,743	30,672	7,799	226,215
2006	102,784	16,606	2,497	121,887
2007	77,370	254,411	2,256	334,036
2008	72,634	9,947	1,318	83,899
2009	126,325	22,022	4,373	152,721

Data Source: CRFS data, all gear types combined. Data for 2010 and 2011 are not available.

11 Spotfin croaker, *Roncador stearnsii*

Spotfin croaker, *Roncador sternsii*. Photo credit: B Varney

History of the fishery

Spotfin croaker were determined to be overexploited in the early 1900s and since 1915, it has been illegal to commercial take spotfin croaker. Today spotfin croaker are mostly targeted by recreational anglers fishing in bays and surf zones from beaches, jetties, and piers in southern California. Spotfin croaker may form small aggregations (usually fewer than 50 fish) in depressions or holes near shore and it has been reported that the best spotfin croaker fishing is when a “croaker hole” or a “croaker run” is found.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by the California Recreational Fisheries Survey (CRFS), which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

According to the Marine Recreational Fishing Statistical Survey (MRFSS) spotfin croaker catch has varied greatly between 1980 and 2003, from a high of 87,000 fish in 1981 to a low of 643 in 1989 (Figure 11-1).

Since 2004, the spotfin croaker catch has continued to be highly variable, ranging from 29,143 fish in 2005 to 58,123 fish in 2007 (Figure 11-2) according to California Recreational Fisheries Survey (CRFS) data. Ninety-seven percent of spotfin croaker were caught in shore modes (beach/bank [BB] and manmade [MM]) versus boat modes (party/charter boats and private/rental boats). The average estimated annual spotfin croaker catch from 2004 to 2009 was 40,197 fish per year with catch almost evenly divided between BB and MM modes. CRFS reduced sampling levels for the BB mode in 2010 and BB and MM in 2011; therefore, the estimates for 2010 and 2011 are not comparable with the 2004-2009 estimates. Currently there is no minimum size limit for spotfin croaker; however, there is a ten fish bag limit.

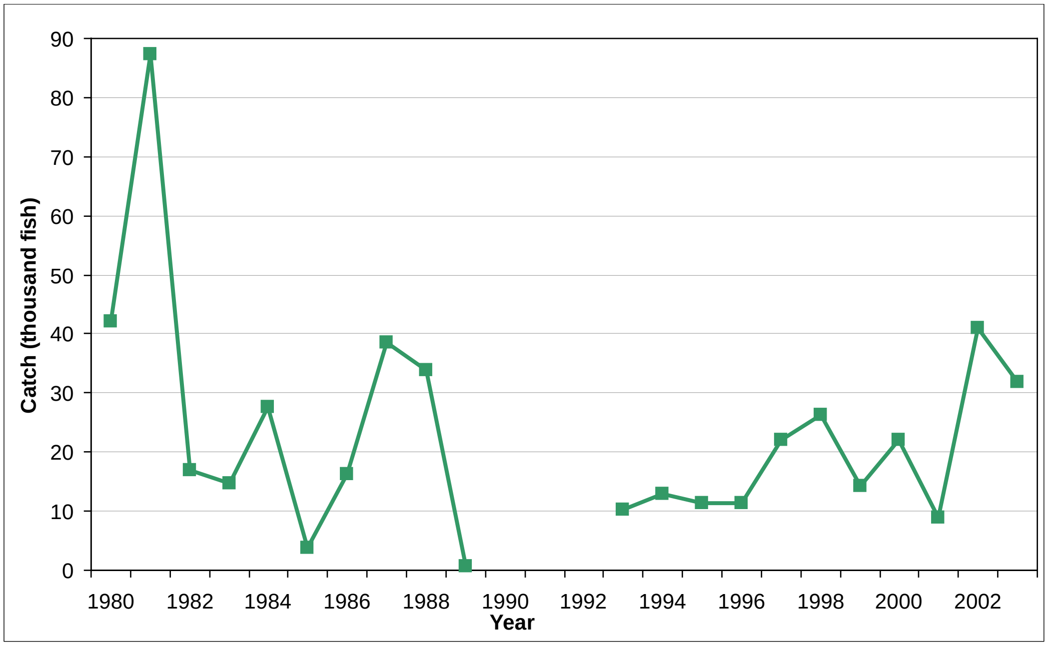

Figure 11-1. Spotfin croaker recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

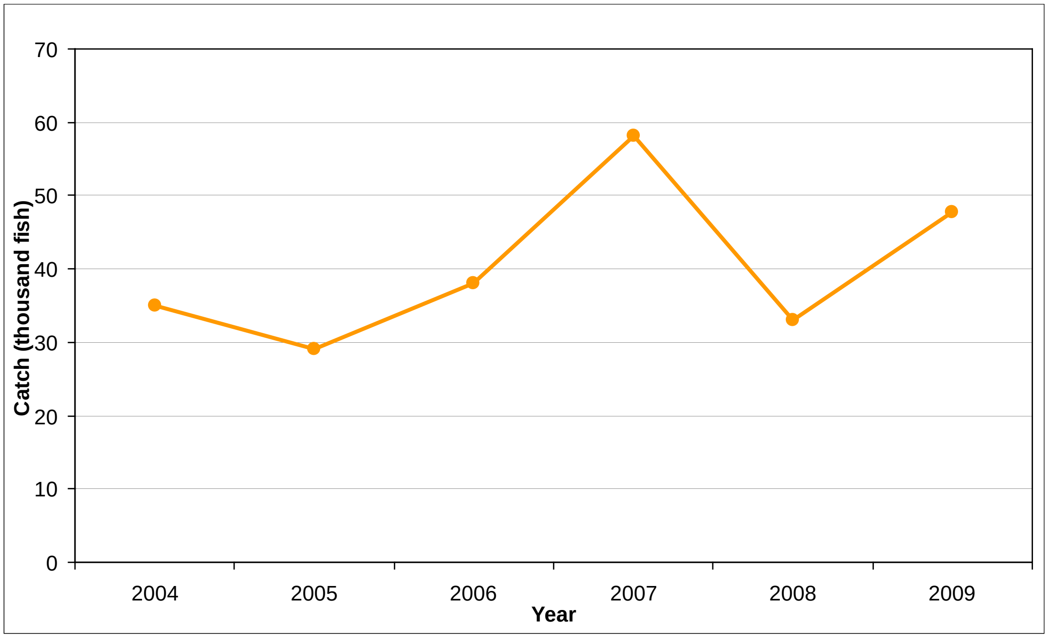

Figure 11-2. Spotfin croaker recreational catch, 2004-2009. Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

Status of the Biological Knowledge

Spotfin croaker range from Point Conception, California to the southern tip of Baja California, Mexico but are most commonly found from Los Angeles Harbor, California to central Baja California, Mexico. They are a heavy bodied fish named for the distinct black spot at the base of the pectoral fin. Spotfin croaker can grow to be at least 27 inches (69 centimeters) and live to be 24 years old. They are usually a bluish silver color on their backs with wavy lines on their sides and they have white bellies. During the summer spawning season, males may exhibit golden colored pectoral and pelvic fins and gold coloring on their backs. Spotfin croaker have pharyngeal tooth plates (modified gill arches with teeth) and feed on benthic invertebrates including clam siphons and small crustaceans.

Spotfin croaker can be found from the intertidal zone to 73 feet (22 meters). They are most commonly found in water less than 30 feet deep (9 meters), primarily over sand or mud bottoms; however, they may also be found less frequently in rocky reef habitats. Spotfin croaker may be sexually segregated during the spring and summer months. A study reported male spotfin croaker utilizing primarily soft bottom, nearshore habitat while during the same seasonal period, females dominated the population inside a bay and estuary site. Spotfin croaker also show sexual dimorphism in growth rates with females growing faster than males after age three.

A recent study conducted in 2004 captured larval spotfin croaker in May, July, and September, suggesting the spawning season for spotfin croaker is at least from April to September. This is longer than previously thought. Spotfin croaker are serial spawners and new research estimates that small spotfin croaker (8-12 inches; 20-31 centimeters) may spawn approximately 35,000-641,000 eggs in one batch depending on the size of the female. The larval duration for spotfin croaker is approximately 25 days and larval croaker spawned in May showed 30 percent slower growth rates than those spawned later in the season.

A limited tagging project conducted more than 50 years ago by the California Department of Fish and Wildlife (Department) found spotfin croaker moved extensively between Alamitos Bay and Newport Bay in southern California. Although the data showed no discernible patterns in spotfin croaker movements and only one percent of the tagged spotfin croaker were recaptured, spotfin croaker tagged in Los Angeles Harbor were recaptured as far south as Oceanside, California, a distance of 61 miles (98 kilometers). A more recent Department beach seine study conducted in southern California in 2007-2009 captured no spotfin croaker during the winter months; however, spotfin croaker were caught consistently throughout the rest of the year supporting speculation about seasonal movements. In addition, the most recent beach seine study found spotfin croaker are more abundant on lower incoming tides than at other times suggesting daily horizontal movements related to tidal flux.

Status of the Population

Data for estimating spotfin croaker abundance and density across southern California are limited. Historic impingement surveys at coastal power generating stations from 1977 to 1998 noted a declining abundance of spotfin croaker; however, a recent study found that the mean entrapment rate for spotfin croaker after 1998 was 295 percent higher than the mean annual entrapment rate for the period from 1972-1998.

Beach seine studies conducted by the Department also found increased spotfin croaker abundance in recent years. Relative to other species, spotfin croaker abundances ranked 26th in the 1960s, 17th in the 1990s, and 3rd in the 2000s. Currently there are no data to suggest the spotfin croaker population is in decline. In addition, recently restored wetlands at Bolsa Chica and Huntington Beach, in southern California may provide new habitat important for spotfin croaker.

Management Considerations

Based on the limited available data, the spotfin croaker stock does not appear to be in decline; however, a more complete understanding of the adult life history and ecology of spotfin croaker could help to refine management efforts. Spotfin croaker are rarely targeted by commercial passenger fishing vessels or private boaters, and most angler pressure is from shore based fishing modes limiting exploitation exposure. Spotfin croaker are most likely benefiting from the recent bay and estuary restoration at Bolsa Chica and Huntington Beach wetlands in southern California. These newly restored wetlands may provide increased habitat and protection for the species.

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Further Reading

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Spotfin croaker recreational landings, 1980-2003.

Year	Number of fish	Year	Number of fish	Year	Number of fish
1980	42,161	**1988**	33,877	**1996**	11,431
1981	87,321	**1989**	643	**1997**	22,074
1982	16,937	**1990**	*no data*	**1998**	26,364
1983	14,683	**1991**	*no data*	**1999**	14,233
1984	27,607	**1992**	*no data*	**2000**	21,944
1985	3,692	**1993**	10,319	**2001**	9,017
1986	16,198	**1994**	12,895	**2002**	40,967
1987	38,650	**1995**	11,428	**2003**	31,914

Data Source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

Spotfin croaker recreational landings, 2004-2009.	
Year	**Number of fish**
2004	35,066
2005	29,143
2006	38,129
2007	58,123
2008	32,971
2009	47,749

Data Source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

12 Yellowfin Croaker, *Umbrina roncador*

Yellowfin croaker, *Umbrina roncador*. Photo credit: P Gregory.

History of the Fishery

The yellowfin croaker, *Umbrina roncador*, is a nearshore fish caught exclusively by recreational anglers since being banned by the State of California for commercial sale in 1915. A majority of anglers catch these fish from sandy beaches, piers, jetties, harbors, and bays. They are most commonly caught from Santa Barbara to the U.S./Mexico border during summer months. About 80 percent of the catch occurs from May to September. Yellowfin croaker are popular with recreational anglers because they can be readily caught from shore with basic, light spinning gear. Common baits used to catch them include mussels, sand crabs, blood worms, ghost shrimp, artificial worms, and lures.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by the California Recreational Fisheries Survey (CRFS), which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

A review of the Marine Recreational Fisheries Statistics Survey (MRFSS) data from 1980-1989 showed an average annual catch of 76,433 yellowfin croaker (Figure 12-1). The average annual catch decreased by five percent to 72,622 fish from 1993-2003, but catch fluctuated greatly from year to year. The California Recreational Fisheries Survey (CRFS) data from 2004-2009 showed an average annual catch of 101,852 yellowfin croaker (Figure 12-2). CRFS reduced sampling levels for the beach/bank (BB) mode in 2010 and BB and man made (MM) modes in 2011; therefore, the estimates for 2010 and 2011 are not comparable with the 2004 to 2009 estimates. Between 2004 and 2009, yellowfin croaker catch reached a high of 159,502 fish in 2007 and a low of 64,980 fish in 2004.

According to MRFSS, from 1993-2003 anglers fishing from shore modes (BB and MM) accounted for two-thirds of the total recreational catch while boat modes (party/charter boats and private/rental boats) comprised the remaining third (Figure 12-3). That changed dramatically during 2004-2009, based on CRFS data, when boat modes only comprised 5 percent of the recreational catch (Figure 12-4). Yellowfin croaker are rarely caught by party/charter boats due to their affinity for shallow water and sandy habitats.

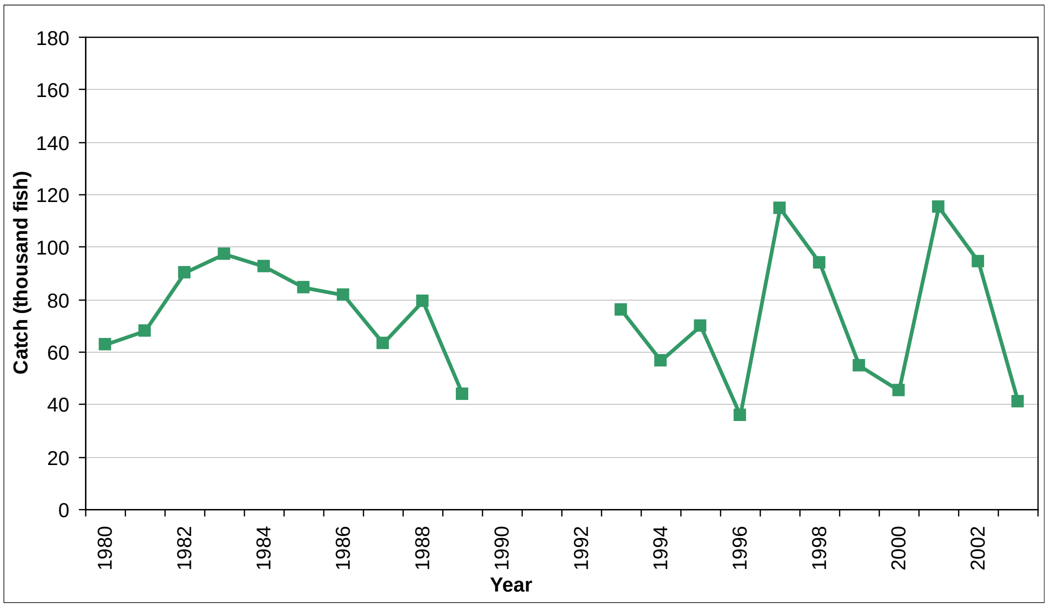

Figure 12-1. Yellowfin croaker recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

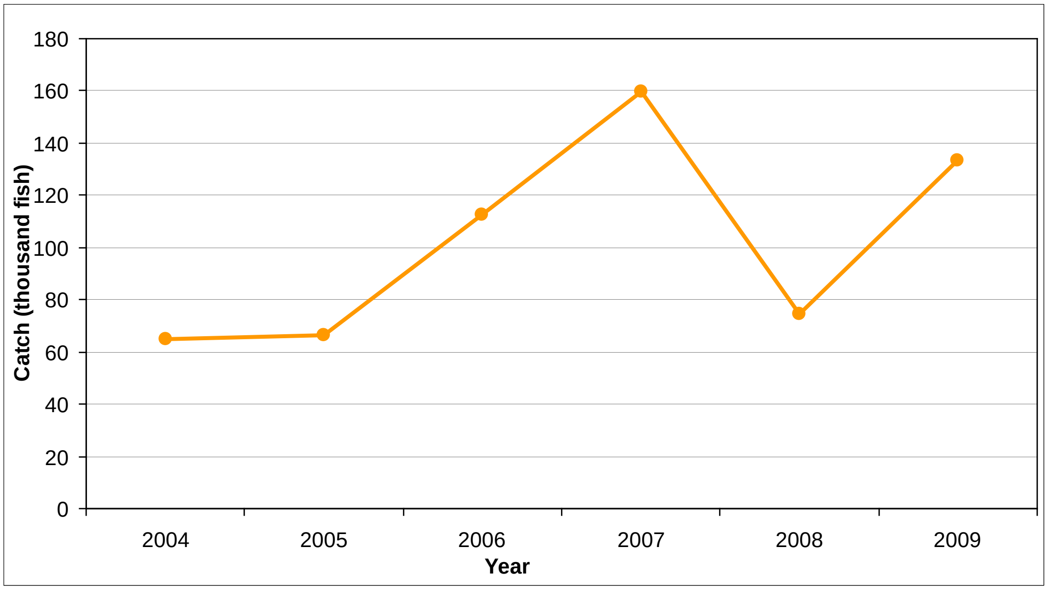

Figure 12-2. Yellowfin croaker recreational catch, 2004-2009. Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

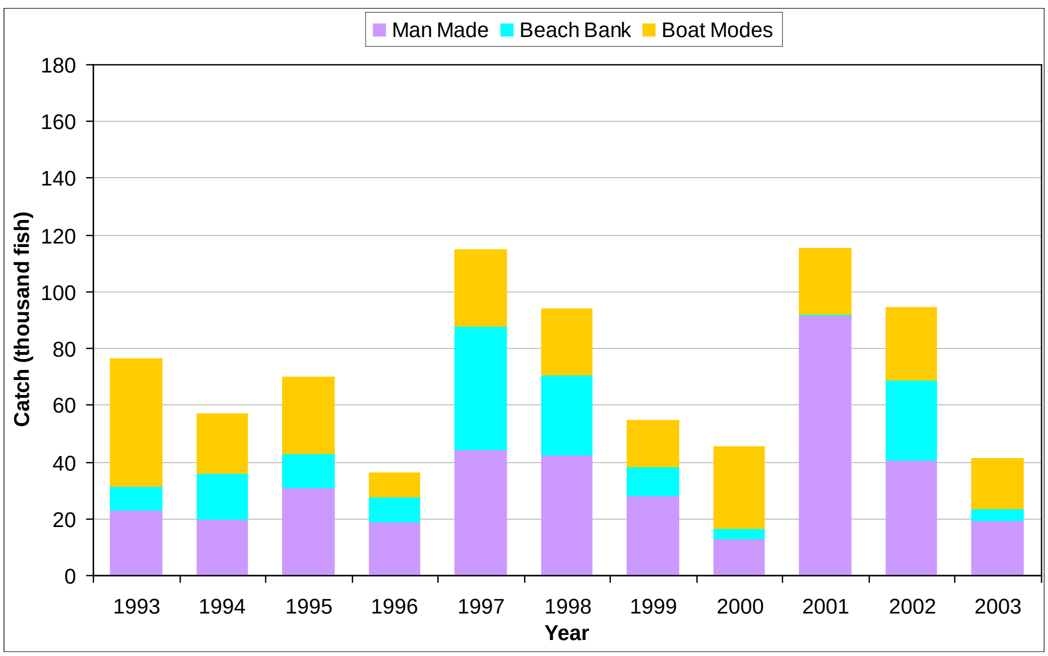

Figure 12-3. Yellowfin croaker recreational catch by fishing mode, 1993-2003. Data source: MRFSS data, all gear types combined.

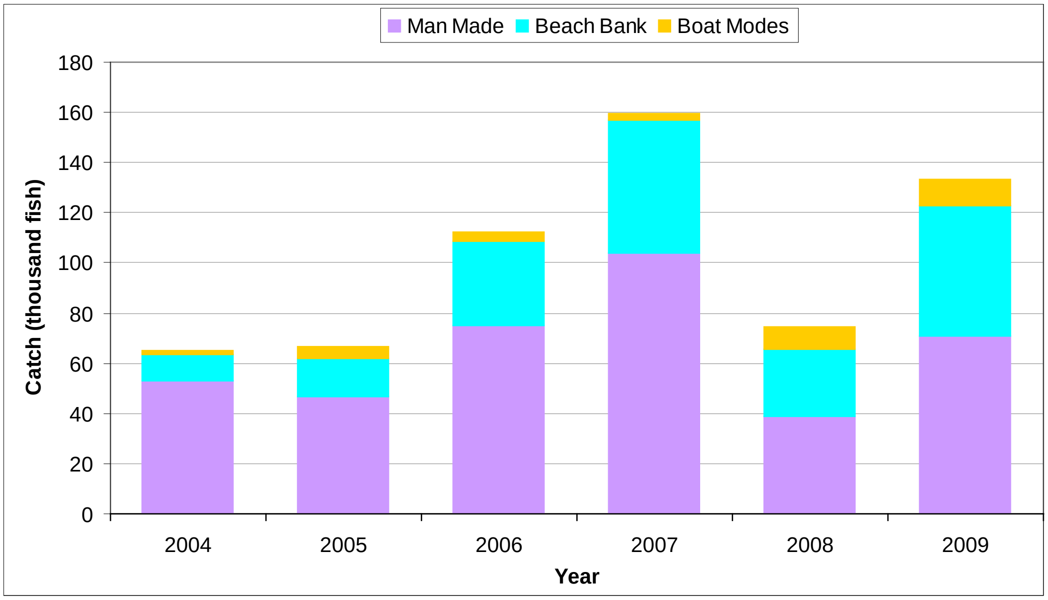

Figure 12-4. Yellowfin croaker recreational catch by fishing mode, 2004-2009. Data source: CRFS data, all gear codes combined. Data for 2010-2011 are not available.

Status of Biological Knowledge

Yellowfin croaker has an elliptical-elongate body with a series of dark brownish yellow stripes that run diagonally down their back, mostly yellow fins, and a short chin barbel. Yellowfin croaker range from Point Conception, California to southern Baja California, Mexico, but are rare north of Ventura. They typically occur in schools over soft bottom habitats from the surf zone out to 150 feet (46 meters), but are most abundant in waters less than 30 feet (10 meters). Yellowfin croaker are also common in harbors and bays as they tend to prefer calmer, more protected sites.

Research indicates that spawning occurs offshore during summer months. Spawning begins in June, peaks in July, and is completed by September. Females are batch spawners known to produce 99,000-405,000 eggs per batch and batch fecundity was found to rapidly increase with length. Fish are thought to reach sexual maturity around 2 years of age (~ 9 inches total length [TL]; 23 centimeters). Females grow faster and reach a larger size than males. Yellowfin croaker have been reported to reach 22 inches TL (56 centimeters) and weigh nearly 4 pounds (2 kilograms), but a fish over 2 pounds (1 kilogram) is uncommon. The current California state record is 3 pounds and 14 ounces (1.76 kilograms). Ageing studies indicate that a 10 inch fish (25 centimeters) is about 4 years old and a 15 inch fish (38 centimeters) is about 10 years old. The maximum observed age of a yellowfin croaker is 15 years old.

Yellowfin croaker appear to be opportunistic predators and have been observed schooling during the day and dispersing to feed at night. Their diet consists of California grunion eggs, polychaetes, amphipods, clams, and brittle stars. Yellowfin croaker eggs, larvae, and small juveniles are often preyed upon by a variety of fish while larger individuals are preyed upon by seals, sea lions, and bottlenose dolphins.

Status of the Population

The population appears to be healthy despite potential impacts associated with recreational fishing, contaminants from urban runoff, and shoreline habitat modifications. A fishery independent study done in 2007-2009 by the California Department of Fish and Wildlife found a greater abundance of yellowfin croaker within the surf zone of Los Angeles and Orange County beaches than similar studies done in the 1990s and 1950s. A stock assessment has not been done for yellowfin croaker so no population estimates exist and stock structure has not been examined. There is also a lack of larval abundance data.

Nearshore abundances are strongly correlated with sea surface temperatures. Increased sea surface temperatures caused by several El Niño events during the 1990s and 2000s have likely benefited yellowfin croaker since they are a warm temperate species. Power plant entrainment data collected along the southern California coastline for the past 38 years indicate dramatically increased population density for species with more southern distributions like yellowfin croaker in recent years, compared to historical records.

Management Considerations

Current regulations such as limiting harvest to recreational fishing only and retaining the existing 10 fish bag limit appear to be effective. Collection of more basic life history information and regular monitoring of catch and effort is necessary to accurately access the status of the fishery.

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Further Reading

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Miller EF, Pondella II DJ, Beck DS, Herbinson KT. 2011. Decadal-scale changes in southern California sciaenids under different levels of harvesting pressure. ICES J Mar Sci (68):2123-2133.

Pondella II DJ, Froeschke JT, Wetmore LS, Miller EF, Valle CF, Medeiros L. 2008. Demographic Parameters of Yellowfin Croaker, *Umbrina roncador* (Perciformes: Sciaenidae), from the Southern California Bight. Pac Sci. 62(4):555-568.

Yellowfin croaker recreational catch, 1980-2003.

Year	Number of fish	Year	Number of fish	Year	Number of fish
1980	62,977	**1988**	79,460	**1996**	36,126
1981	67,957	**1989**	44,038	**1997**	114,979
1982	90,443	**1990**	---	**1998**	94,079
1983	97,206	**1991**	---	**1999**	54,659
1984	92,574	**1992**	---	**2000**	45,168
1985	84,787	**1993**	76,139	**2001**	115,374
1986	81,749	**1994**	56,751	**2002**	94,418
1987	63,139	**1995**	69,900	**2003**	41,244

Data Source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

Yellowfin croaker recreational catch, 2004-2009.

Year	Number of fish	Year	Number of fish
2004	64,980	**2007**	159,502
2005	66,608	**2008**	74,375
2006	112,314	**2009**	133,330

Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

Yellowfin croaker recreational catch (number of fish) by fishing mode, 1993-2003.				
Year	**Manmade**	**Beach Bank**	**Boat Modes**	**Total**
1993	23,068	8,492	44,578	76,138
1994	20,056	16,198	20,497	56,751
1995	31,111	11,945	26,843	69,899
1996	19,061	8,674	8,391	36,126
1997	44,459	43,275	27,245	114,979
1998	42,457	28,209	23,413	94,079
1999	28,140	10,280	16,239	54,659
2000	12,858	3,665	28,646	45,169
2001	91,402	653	23,318	115,373
2002	40,938	27,893	25,587	94,418
2003	19,608	4,013	17,623	41,244

Data source: MRFSS data, all gear types combined**.**

Yellowfin croaker recreational catch (number of fish) by fishing mode, 2004-2009.				
Year	**Manmade**	**Beach Bank**	**Boat Modes**	**Total**
2004	52,838	10,838	1,305	64,981
2005	46,526	15,578	4,504	66,608
2006	74,948	33,687	3,679	112,314
2007	103,975	52,763	2,764	159,502
2008	38,938	26,897	8,540	74,375
2009	70,714	52,001	10,614	133,329

Data source: CRFS data, all gear types combined. Data for 2010-2011 are not available.

13 Surfperch, Embiotocidae

Barred surfperch, *Amphistichus argenteus*. Photo credit: K Oda. CDFW.

Overview of the Surfperch Family

The surfperch family, Embiotocidae, is composed of 23 species, 18 of which occur in California's coastal waters. Members of this family are commonly called surfperch, seaperch, and perch. While the former are generally considered to reside in or near the surf zone along sandy beaches, we also use the term "surfperch" throughout this chapter to describe all species collectively. Surfperch are found in temperate nearshore waters of the northeastern Pacific with the exception of three species in the Sea of Japan and the tule perch (*Hysterocarpus traski*) which occupy freshwater and estuarine habitats. The following 18 marine species in California waters are found in a variety of habitats, including adjacent to beaches, above rocky substrate, in the intertidal zone, and in subtidal kelp beds:

- barred surfperch, *Amphistichus argenteus*
- black perch, *Embiotoca jacksoni*
- calico surfperch, *Amphistichus koelzi*
- dwarf perch, *Micrometrus minimus*
- kelp perch, *Brachyistius frenatus*
- pile perch, *Rhacochilus vacca*
- pink seaperch, *Zalembius rosaceus*
- rainbow seaperch, *Hypsurus caryi*
- redtail surfperch, *Amphistichus rhodoterus*
- reef perch, *Micrometrus aurora*
- rubberlip seaperch, *Rhacochilus toxotes*
- sharpnose seaperch, *Phanerodon atripes*
- shiner perch, *Cymatogaster aggregata*
- silver surfperch, *Hyperprosopon ellipticum*
- spotfin surfperch, *Hyperprosopon anale*
- striped seaperch, *Embiotoca lateralis*
- walleye surfperch, *Hyperprosopon argenteum*
- white seaperch, *Phanerodon furcatus*

History of the Fishery

Surfperch support localized commercial fisheries from northern to south-central California. Landings in Del Norte and Humboldt counties are composed primarily of redtail surfperch. San Francisco Bay port landings are composed of black perch, shiner perch, striped seaperch, and white seaperch. Barred surfperch, calico surfperch, and walleye surfperch are landed in the Morro Bay area. Surfperch are sold live and dead for food, as well as for live bait to take game fish such as California halibut and striped bass. Shiner perch purchased as live bait bring $1.25 each to bait shops. Average price paid to commercial fishermen in 2011 was $2.35 per pound for surfperch.

The commercial fishery is dominated by fishermen using hook-and-line gear. This gear accounts for approximately 93 percent of surfperch landings, followed by A-frame dip nets, beach seine, round haul nets, and trawl gear; the latter two gear types take surfperch incidentally. Historically, gill and trammel nets also caught surfperch incidental to targeting other species (e.g., California halibut and white croaker) prior to the implementation of restrictions regarding the use of gill and trammel nets in nearshore waters in central and southern California.

Today, the surfperch fishery is conducted primarily by shore based hook-and-line fishermen targeting redtail surfperch in Humboldt and Del Norte counties, and barred surfperch in Monterey and San Luis Obispo counties. In central and south San Francisco Bay, a variety of species, including striped seaperch, rubberlip seaperch, black perch, and pile perch, are taken by fishermen operating skiffs fishing along rocky shoreline and manmade structures. Generally, shore based fishermen use traditional heavy surf rods. San Francisco Bay fishermen fish with light rods and baits such as cut market shrimp and grass shrimp.

Important commercial port areas for surfperch are Crescent City, Eureka, Fields Landing, Richmond, Morro Bay, and Avila/Port San Luis. These port areas account for 77 percent of all surfperch landings statewide since 1990. Barred surfperch and redtail surfperch dominated surfperch landings in the 1990s through the 2000s, comprising approximately 37 and 57 percent, respectively, of all specified surfperch landings.

Commercial fishery landings data are available from 1916 to 2011. Prior to 1927, “perch” landings included a combination of surfperch and perch-like species. Subsequently, landings for surfperch, blacksmith, halfmoon, opaleye, and sargo were reported separately; however, fish dealers on occasion have combined other species with surfperch on landing receipts. In addition, individual landing receipts frequently are not sorted to species. During the period 1990-1999, the percentage of landing receipts of unspecified surfperch appearing in the California Department of Fish and Wildlife’s (Department) Commercial Fisheries Information System (CFIS) database was approximately 58 percent. Following a concerted effort by Department staff to gain fish buyer cooperation in sorting species on receipts, the percentage of unspecified surfperch landings declined to about 19 percent statewide in 2010-2011.

Annual commercial landings have declined over time (Figure 13-1). Commercial landings have been heavily influenced by market demand, ocean conditions affecting abundance and distribution, and fisheries restrictions. Another change that impacted the fishery statewide was prohibiting the use of four-wheel drive vehicles on most beaches. Historically, fishermen were able to drive long sections of beaches to locate fish schools and transport their catches to market. Currently, vehicle access is limited to Oceano Dunes State Park in San Luis Obispo County, and several beaches in Humboldt and Del Norte counties. Some of the recently-implemented marine protected areas (MPAs), such as the Point Buchon State Marine Reserve (San Luis Obispo County), may have displaced some local commercial fishermen.

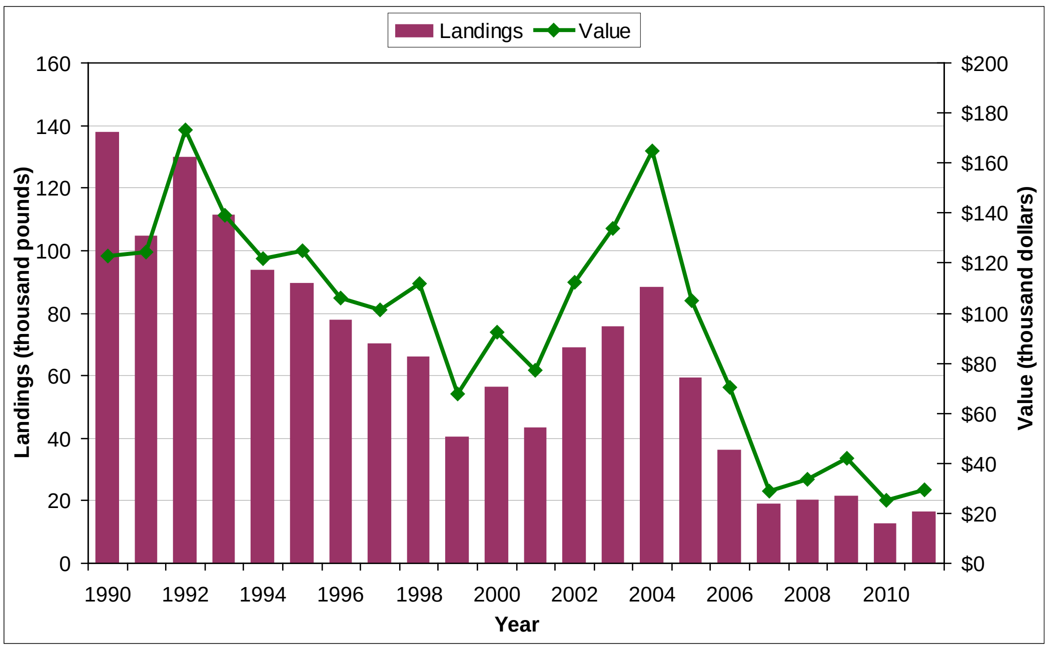

Figure 13-1. Surfperch commercial landings and value, 1990-2011. Data source: CFIS data, all species and gear types combined.

The general negative trend in landings since the 1980s reached a low in 1999, rebounded in the early 2000s, then declined to a historic low in 2010. Fishermen making 10 or more surfperch landings annually declined from 100 in 1992 to eight in 2008. Although commercial landings hit new lows recently, the average landing per receipt, which is a measure of catch-per-unit-effort (CPUE), has remained fairly steady since 2002 (Figure 13-2).

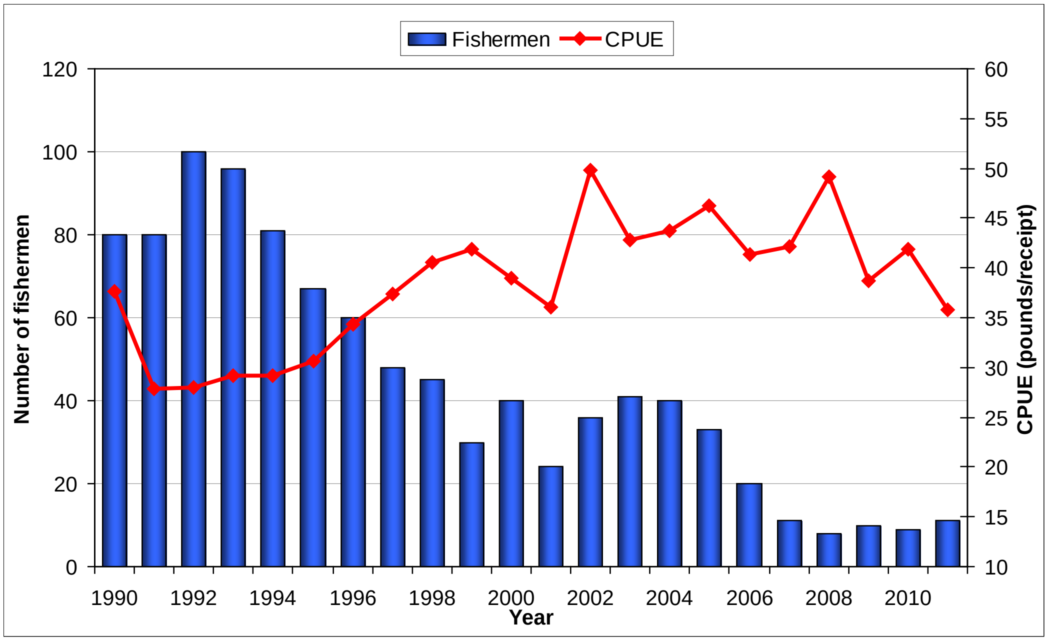

Figure 13-2 Surfperch commercial number of participants and CPUE (pounds/receipt), 1990-2011. Data source: CFIS data, all species and gear types combined.

Commercial fishery regulations include a seasonal closure for taking surfperch from May 1 through July 31 with the exception of shiner perch, which may be taken at any time. In 2002, the closure was extended from the original end date, July 14, to July 31 to further reduce the take of females and slow the fishery at a time when they are aggregated for parturition (i.e., giving birth). The take of barred surfperch, calico surfperch, and redtail surfperch for commercial purposes is prohibited south of Point Arguello (Santa Barbara County).

Surfperch are important to recreational anglers, with the vast majority of surfperch taken from sandy beaches and rocky banks (beach/bank mode [BB]) that are accessible from the shore. A smaller portion of the statewide catch is taken from manmade structures (manmade mode [MM]), an even smaller portion from private/rental boats (private/rental mode [PR]), and a negligible amount (i.e., less than 1 percent) from private/charter boats (private/charter mode [PC]).

Historically, surfperch were caught with a variety of natural baits including clams, mussels, polychaete worms, Dungeness crab backs, mackerel, Pacific mole crabs, and various species of shrimp by anglers using 10-14 foot (3-4 meter) heavy surf rods. Although many anglers enjoy bait fishing, there is a growing trend among anglers to fish with 7-10 foot (2-3 meter) lighter rods, used for steelhead and freshwater bass, and cast artificial baits, soft plastic “grubs”, and hard plastic minnows, as well as traditional baits.

Another growing trend in recreational saltwater fisheries is fly fishing for species traditionally targeted by other fishing methods. Fly fishing for surfperch was described by an outdoor writer in the early 1970s; however, anglers fly fishing on beaches was a rarity until the early 2000s. It is now a common sight along sandy beaches in central and southern California.

The recreational fishery for surfperch is substantial and estimated catches far surpass those of the commercial fishery. By weight, the most abundant surfperch species comprising the recreational take statewide are barred surfperch, black perch, redtail surfperch, walleye surfperch, and striped seaperch (in descending order). Recreational catch weight estimates are converted from number estimates based on length-weight regressions of sampled fish. Recreational catch estimates from 1990 through 2009 and commercial landings from 1990 through 2011 indicate that the annual recreational catch averaged approximately 320,000 pounds (145,000 kilograms), while the annual commercial catch averaged about 65,000 pounds (29,000 kilograms), about 20 percent of the total surfperch harvest.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by the California Recreational Fisheries Survey (CRFS), which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

MRFSS catch estimates indicate a decline in overall recreational surfperch take between 1981 and 2003 (Figure 13-3). Beginning in 1986 and for three years thereafter, the BB and MM modes were collectively designated the shore mode. This change on methodology may have been partly responsible for the huge single-year spike in estimated catch in 1986.

However, more recent estimates from CRFS indicate a generally stable level of catch from 2004 to 2009 (Figure 13-4). CRFS reduced sampling levels for the BB mode in 2010 and BB and MM in 2011; therefore, the estimates for 2010 and 2011 are not comparable with the 2004-2009 estimates. Although many surfperch species are caught statewide, barred surfperch comprised approximately 52 percent of the catch composition since 2004 (Figures 13-5 and 13-6). Black perch comprised 12.5 percent of the catch, followed by redtail surfperch at 10 percent, walleye surfperch at 7 percent, and striped seaperch at 6 percent. All other surfperch species each comprised less than 3 percent of the catch. The BB mode continues to provide the majority of the catch compared to the boat and MM modes (Figure 13-7 and 13-8).

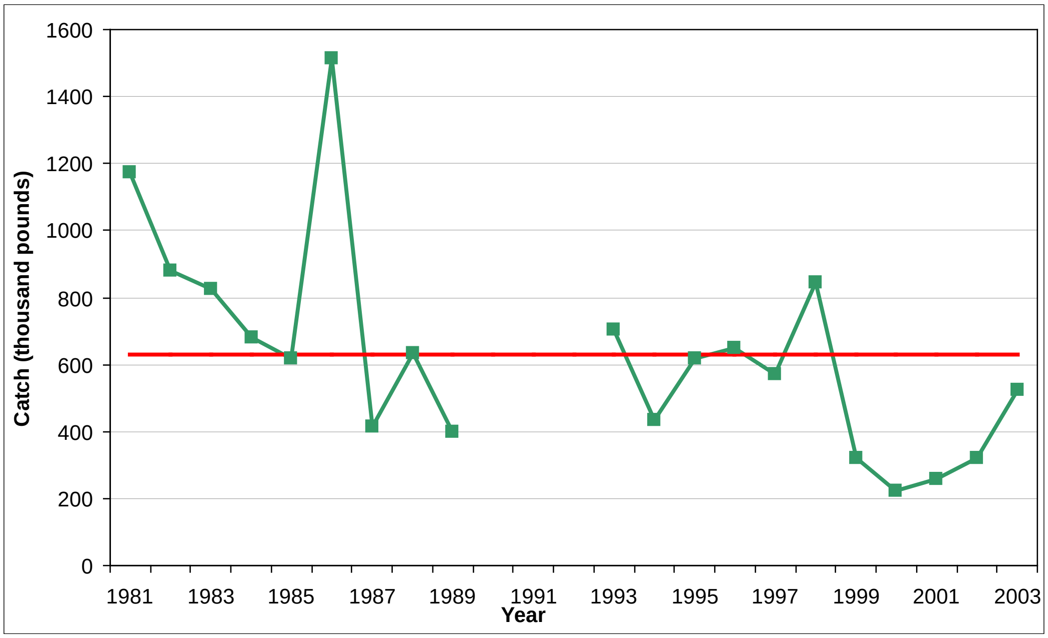

Figure 13-3. Surfperch recreational catch, all species combined, 1981-2003. Solid red line indicates the average catch across all years. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

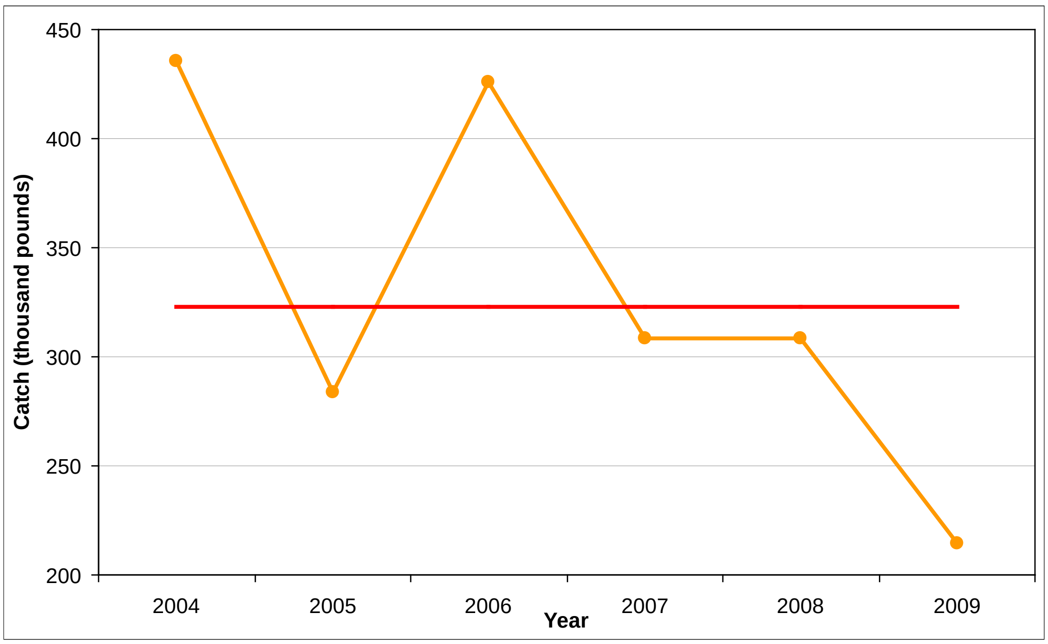

Figure 13-4. Surfperch recreational catch, all species combined, 2004-2009. Solid red line indicates the average catch across years. Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

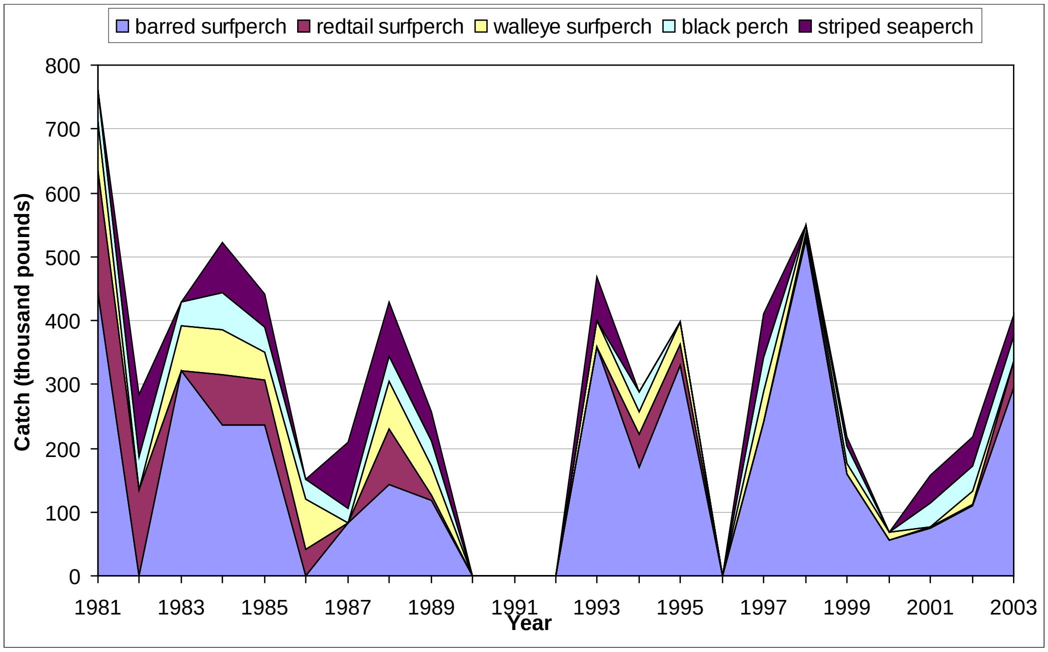

Figure 13-5. Surfperch recreational catch composition for the five most commonly caught species, 1981-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

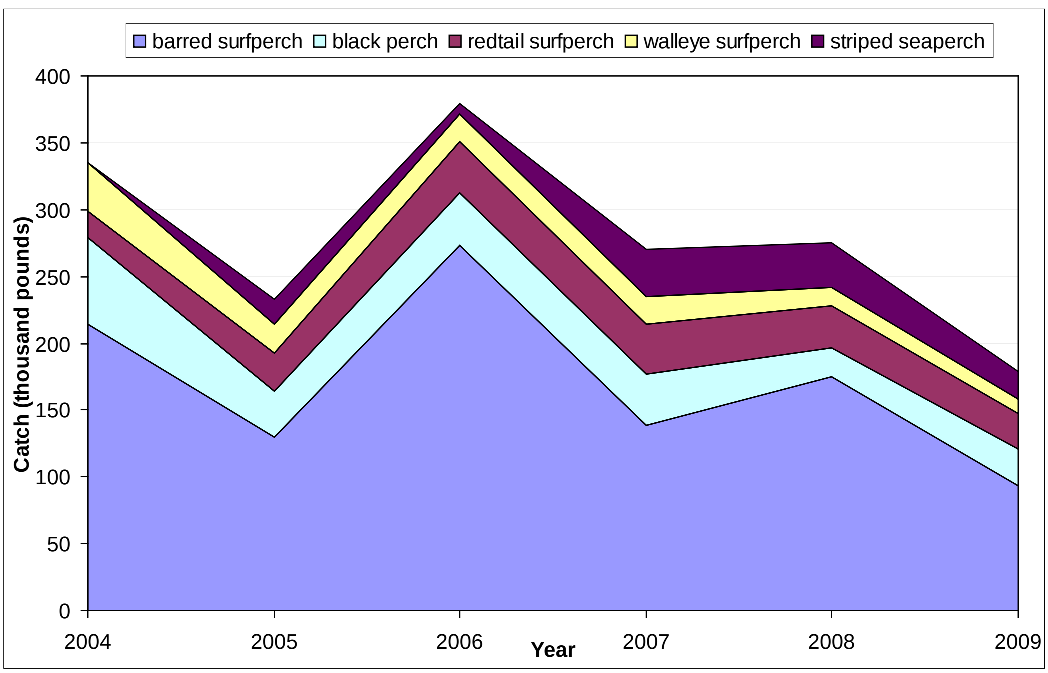

Figure 13-6. Surfperch recreational catch composition for the five most commonly caught species, 2004-2009. Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

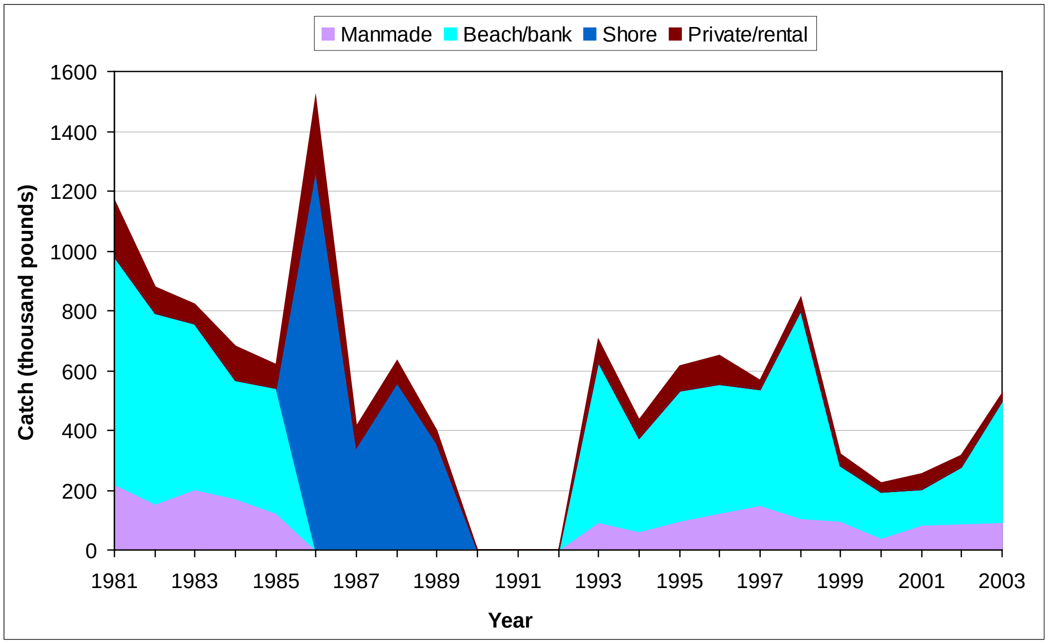

Figure 13-7. Surfperch recreational fishing mode composition, all species combined, 1981-2003. Data source: MRFSS data, all gear types combined. Between 1986-1989, the beach/bank and manmade modes were collectively designated ‘shore mode’. Data for 1990-1992 are not available.

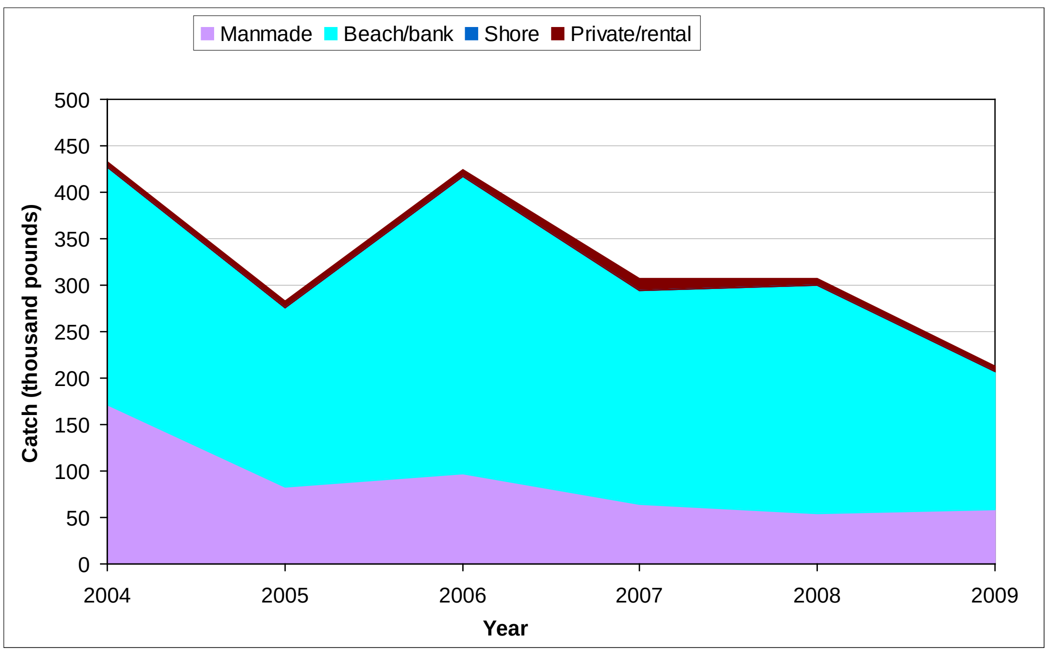

Figure 13-8. Surfperch recreational fishing mode composition, all species combined, 2004-2009. Data source: CRFS data. Data for 2010-2011 are not available.

Changes in CPUE and mean length at capture can be used to infer changes in population relative abundance and status. Since barred surfperch and redtail surfperch are common to both the recreational and commercial catch, the Department uses these species as indicators of the surfperch resource in general. A time-series of CPUE for barred surfperch in central California suggests that there is some inter-annual variation, but no long-term trend (Figure 13-9). A plot of mean annual length at capture for barred surfperch over the same time period also shows some inter-annual variation without a trend (Figure 13-10).

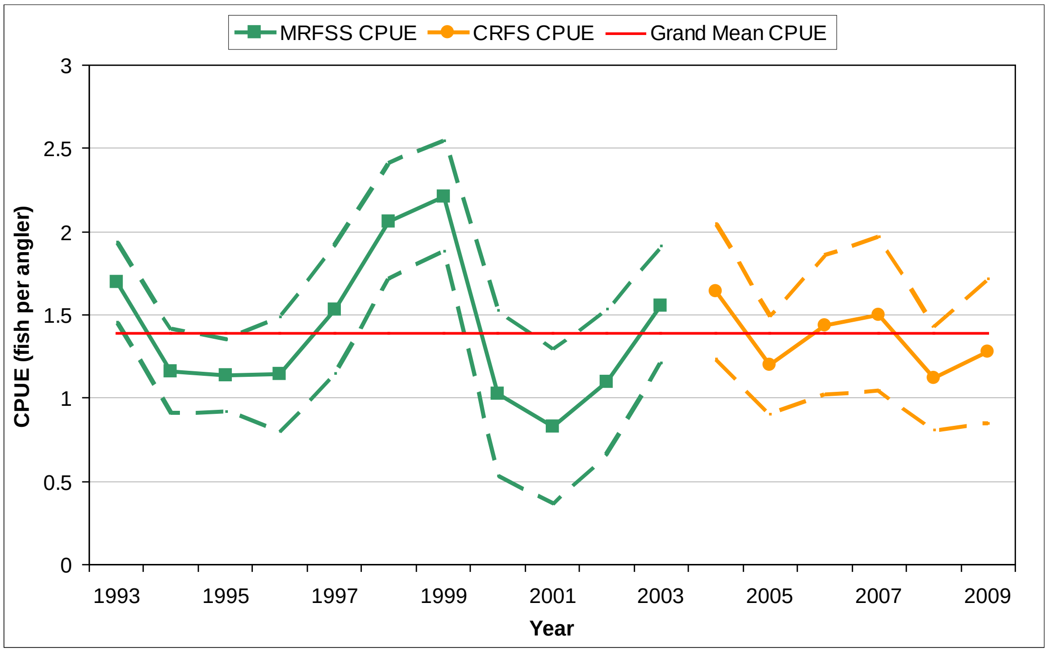

Figure 13-9. Barred surfperch recreational CPUE with dashed standard error bounds, 1993-2009. The solid red line represents the mean CPUE across all years. Data source: MRFSS data (1993-2003) and CRFS data (2004-2009), all fishing modes and gear types combined. Data for 2010-2011 are not available.

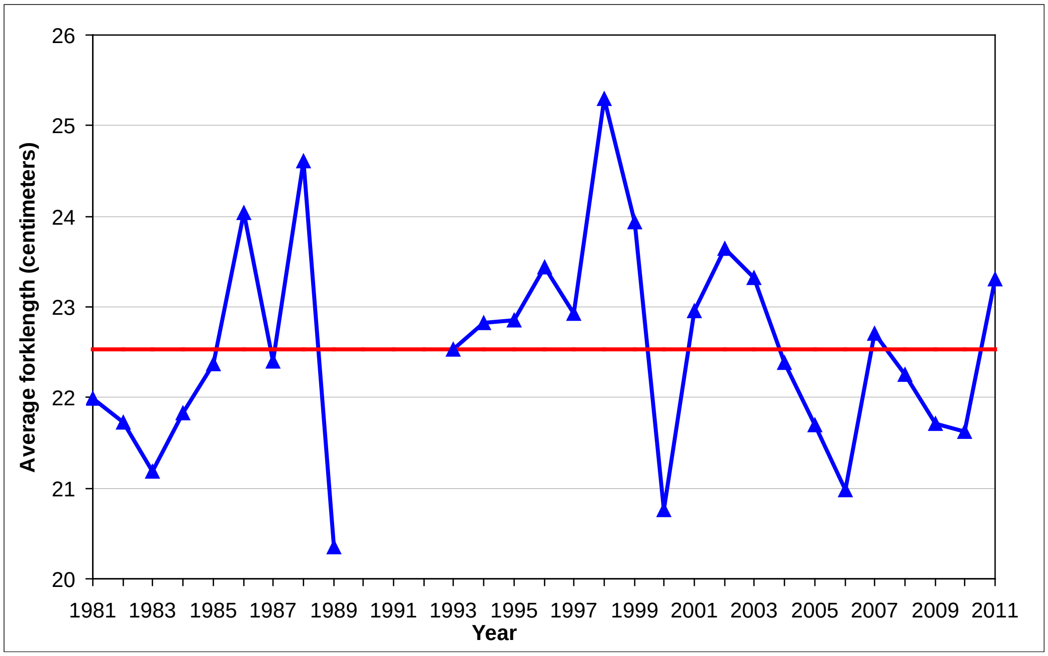

Figure 13-10. Barred surfperch recreational average fork length, 1981-2011. The solid line represents the mean length of sampled fish across all years. Data source: MRFSS (1981-2003) and CFRS (2004-2009), all fishing modes and gear types combined. Data 1990-1992 are not available.

Redtail surfperch CPUE from northern California exhibit inter-annual variation yet appears to have a slight positive trend (Figure 13-11). The time series of average length at capture also exhibits a slight increasing trend, based on observations from recreational surveys (Figure 13-12). However, the annual percentage of redtail surfperch released by recreational anglers appears to have increased after the imposition of a minimum size limit [10.5 inches total length (TL) (26.7 centimeters); 9.5 inches fork length (FL) (24.0 centimeters)] for this species in 2002 (Figure 13-13), likely contributing to the observed increase in average fish length in recent years.

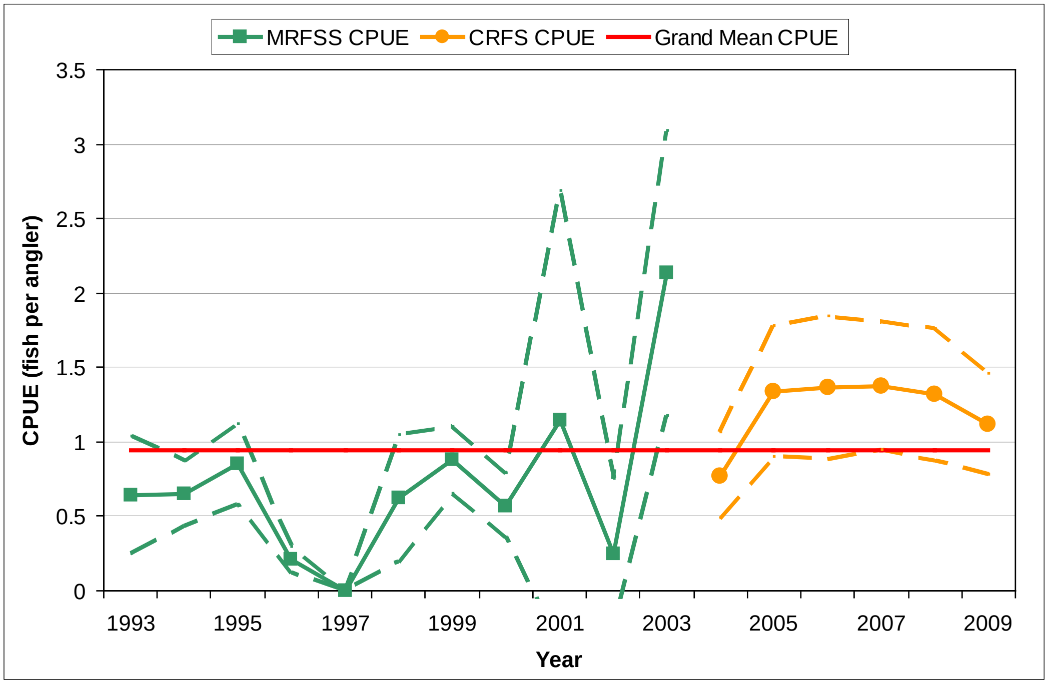

Figure 13-11. Redtail surfperch recreational CPUE (captured fish/number of anglers) with dashed standard error bounds, 1993 – 2009. The solid red line represents the mean CPUE across all years. Data source: MRFSS (1993-2003) and CRFS (2004-2009), all fishing modes and gear types combined. Data for 2010-2011 are not available.

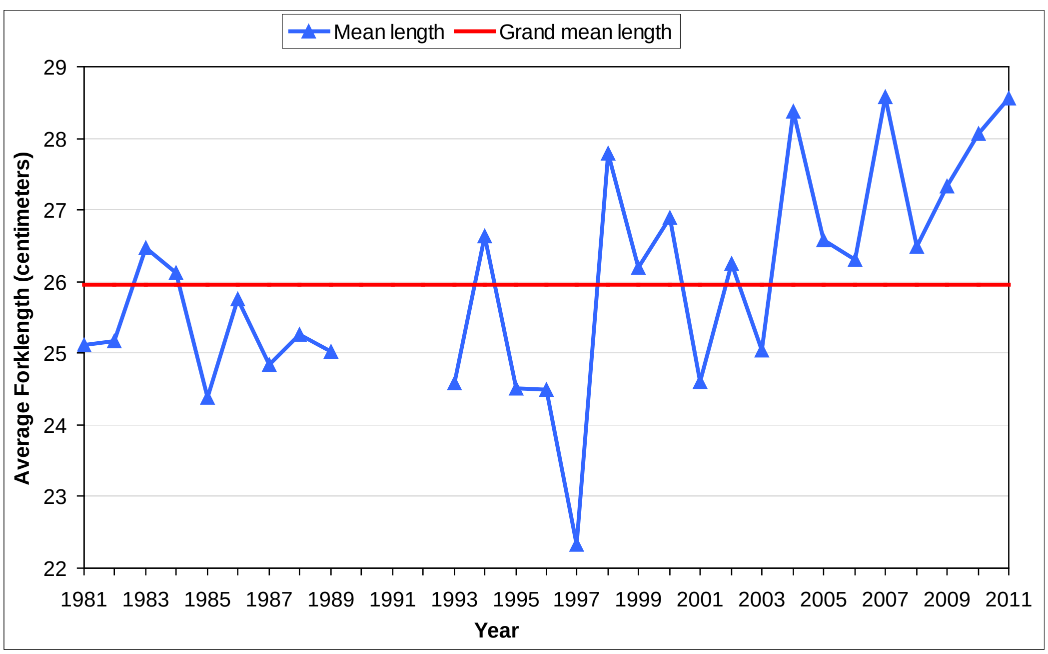

Figure 13-12. Redtail surfperch average fork length for the recreational fishery, 1981-2011. The solid red line represents the mean length of sampled barred surfperch across all years. Data source: MRFSS (1981-2003), and CRFS (2004-2011), all fishing modes and gear types combined. Insufficient data for 1996, 1997, 2001, and 2002 are available. Data for 2010-2011 are not available.

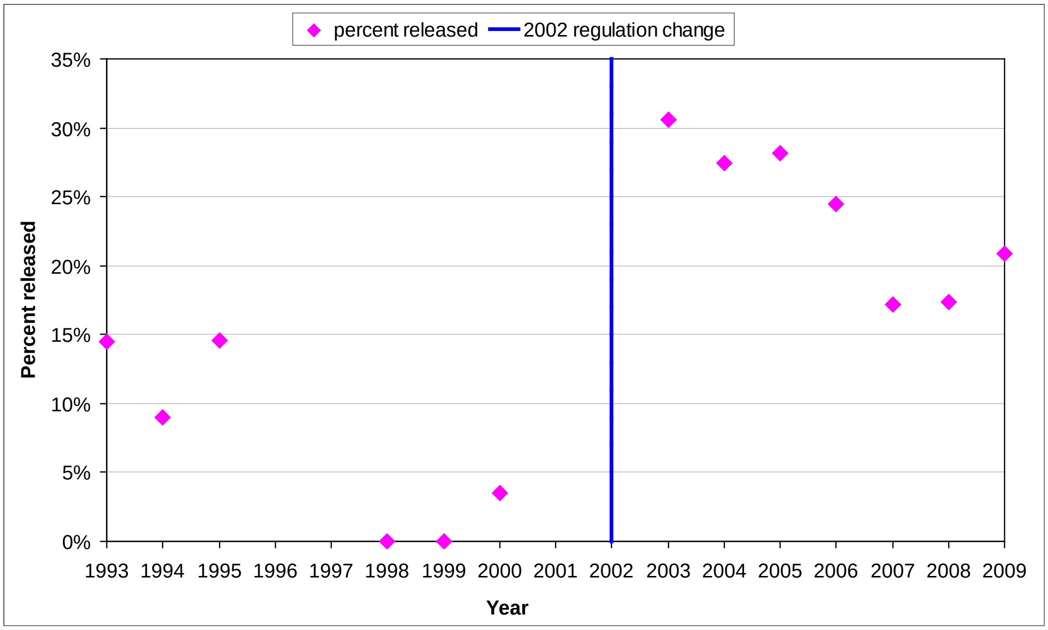

Figure 13-13. Percent redtail surfperch released by recreational anglers, 1993-2009. The blue line indicates the 2002 implementation of a minimum size limit (10.5 inches TL) for redtail surfperch. Data source: MRFS (1993-2003) and CRFS (2004-2009), all fishing modes and gear types combined. Insufficient data available for 1996, 1997, 2001, and 2002. Data for 2010-2011 are not available.

Status of Biological Knowledge

Surfperch can be identified by their compressed, elliptical outline with a furrow along either side of the dorsal fin, continuous spinous and soft dorsal fin, and forked tail. The dorsal fin has 9-11 spines and 19-28 soft rays, and the anal fin has three spines with 15-35 soft rays. The lateral line canal is continuous and located high on the side. Scales are cycloid, meaning thin, rounded, and smooth-edged.

Surfperch are viviparous, meaning they produce fully developed live young. Mating for most species initiates in the fall months, and females store the sperm for a few months until the eggs are ready for fertilization. The gestating females retain the young for 3-6 months before giving birth in the spring and summer. Barred surfperch have been found with full-term embryos earlier in the year south of Point Arguello. Many surfperch move in proximity to river mouths, bays, and estuaries for mating and parturition. The number of young produced by a single female varies by species from less than 10 to over 100, and is approximately proportional to the size of the female. Surfperch newborns are fully developed and free swimming, ranging in size from 1.5 to 3 inches (3.8-7.6 centimeters) depending upon the species, and have been observed in large schools.

The maximum age and size vary with species. Maximum age ranges from 2 to at least 14 years. The largest surfperch, as documented by angling and spear fishing records maintained by the Department, were both rubberlip seaperch: a 5 pound, 17.9 inch (2.3

kilogram, 45.5 centimeter) fish and a 4 pound 10 ounce, 19 inch (2.1 kilogram, 48.3 centimeter) fish, respectively.

The surfperch family ranges from subtropical Baja California, Mexico to southeastern Alaska. They are absent along the Aleutian Island chain but several species reappear off of Japan and Korea. The center of abundance for most species is central California, with 11 of the marine species found in California's waters also occurring north of the California-Oregon border, and 7 species found only in California to Baja California, Mexico. The occurrence of redtail surfperch south of Monterey Bay is considered rare, although recent reports indicate that surf anglers in northern Baja California, Mexico land redtail surfperch regularly.

Surfperch are found in a variety of habitats including adjacent to beaches (sand and/or cobble), over rocky substrate, and in kelp beds and estuaries. A number of species are found in multiple habitats including barred surfperch, redtail surfperch, walleye surfperch, pile perch, rubberlip seaperch, shiner perch, and white seaperch; and, a few species occupy a single habitat type. Silver surfperch and spotfin surfperch are most commonly found adjacent to sandy beaches. Black perch, dwarf perch, kelp perch, rainbow seaperch, reef perch, sharpnose seaperch, and striped seaperch tend to be associated with rocky substrate and kelp beds. The pink seaperch is found in relatively deeper waters than other surfperch.

The diets of surfperch species vary widely but most feed on small crustaceans such as the Pacific mole crab, gammarid and caprellid amphipods, and isopods, as well as polychaete worms, juvenile market squid, fish eggs, and small fish. Some species such as black perch, kelp perch, pile perch, rainbow seaperch, sharpnose seaperch, and white seaperch, can act as "cleaners", removing external parasites from other fish.

Surfperch are forage for a variety of species including game fish, marine mammals, and birds. Predatory fish include striped bass, California halibut, Pacific bonito, lingcod, salmon, rockfishes, kelp bass, barred sand bass, and leopard shark. Surfperch also fall prey to harbor seals, river otters, and birds such as great blue heron, least tern, Caspian tern, Forster's tern, cormorants, loons, osprey, and various gulls.

Surfperch population sensitivity to environmental conditions has been suggested by studies and inferred from recreational and commercial data analyses. Poor catches were linked to periods associated with the El Niño Southern Oscillation (ENSO) resulting in warming sea surface temperatures, poor upwelling, and low productivity. Warm seawater temperatures were indicated to shorten gestation and parturition periods of redtail surfperch in laboratory studies.

Status of the Populations

There are no formal population estimates for any species of surfperch in California, although CPUE, length at capture, and fishery independent surveys can be used to infer changes in population abundance. Commercial landing receipt analyses indicate conflicting trends. Landings declined from an average of 92,000 pounds (41,700 kilograms) during the 1990s to 43,000 pounds (19,500 kilograms) in the 2000s, representing a 53 percent drop, including an all-time low in 2010 of 12,600 pounds (5,700 kilograms). The number of fishermen landing fish 10 or more times per year declined from a high of 100 in 1992 to 8 in 2008. The total CPUE (total pounds/number of receipts) for hook-and-line gear has been relatively stable over the past two decades with inter-annual variation ranging from 21-38 pounds (9.5-17.2 kilograms)/receipt, showing a modest positive trend in recent years.

Commercial fishery trends, historically, have also been impacted by factors beyond fish behavior and abundance. Market demand for surfperch declined from 1938 to 1942 and resulted in low prices offered by fish buyers. A landings peak in the early 1990s was associated with increased demand for surfperch to partially fill a market void left by reduced availability of rockfish due to regulatory actions. Regulations were implemented prohibiting nearshore gill nets, resulting in displaced fishermen exploring alternative fisheries such as the hook-and-line surfperch fishery.

Unlike commercial landings, the recreational catch has not shown a sharply declining trend during the last two decades. In spite of a general decline in overall recreational and commercial harvest, our analyses of indicators such as mean length and CPUE suggest that populations of barred surfperch have remained relatively stable during this period, and that redtail surfperch populations may have even slightly increased. However, population level inferences for redtail surfperch based on changes in average annual length are confounded by the imposition of a recreational minimum size limit of 10.5 inches TL (26.7 centimeters) in 2002. The proportion of the catch released increased dramatically in 2003 for redtail surfperch, likely motivated by the new regulatory change.

Since CPUE also appears to be increasing for redtail surfperch, this may indicate that stock size is increasing. It is plausible that the benefits to the resource from the establishment of a minimum legal size are being manifested in terms of CPUE, now that several generations of redtail surfperch have passed since the regulation was imposed.

Management Considerations

Surfperch are very important to recreational anglers, providing Californians with fishing opportunities coastwide, and have supported historically important localized commercial fisheries. Commercial and recreational catches peak during the mating and parturition seasons when surfperch are aggregated in the late fall through early summer. Barred surfperch and redtail surfperch are the two most important surfperch species to recreational and commercial fisheries.

The ecological value of surfperch is well documented. They are an important trophic component of many nearshore habitats statewide including sandy and rocky shallow subtidal areas, kelp forests, bays and estuaries, and areas adjacent to manmade structures. Surfperch consume small invertebrates, small fish, and fish eggs. Surfperch have been identified as forage items as juveniles and adults for a wide variety of fish, marine mammals, river otters, and sea birds.

Surfperch have been managed by the Department through regulations adopted by the State Legislature and the California Fish and Game Commission (Commission). Recent regulation changes included the following: 1) a 10.5-inch TL (26.7 centimeter) minimum size limit for recreationally caught redtail surfperch in 2002; 2) an April through July 31 recreational closure within San Francisco and San Pablo Bays in 2002; 3) a reduction in bag limit from 10 to 5 surfperch in 2002; 4) a shiner perch bag limit of 20 fish and an exemption from the closure in 2002/2003; 5) an extension of the commercial fishery closure from July 15 to July 31 in 2004; and 6) an increase back to a 10 surfperch bag limit, with the exception of San Francisco Bay and San Pablo Bay which remained at 5 surfperch in the aggregate, in 2006. In addition the implementation of significant numbers of MPAs in California within the past 5 years should assist surfperch populations in maintaining sustainability, particularly in kelp beds and other shallow subtidal rocky habitats.

Formal stock assessments have not been conducted for any surfperch species, although life history features indicate that surfperch may be susceptible to overfishing. As a group, they have a relatively low reproductive potential and are vulnerable to fishing when aggregated during mating and parturition periods. There is a trend, however, indicating that direct fishing mortality may be decreasing due to changing angler behavior. More recreational anglers are practicing catch and release fishing. The average daily angler catch for barred surfperch and redtail surfperch is less than three each. The number of active fishermen in the commercial fishery has declined to approximately 10 percent of the 1990s level. The number of fish buyers has declined as well.

Surfperch habitats have been, and will continue to be, areas of conflict with losses due to shoreline development and pollution. In addition, rising sea level heights over the past several decades have reduced sandy beach habitat important to surfperch species and opportunity for both recreational and commercial fishermen. Recent research has indicated that ENSO can be a cause of potential declines in surfperch abundances.

Continuing to monitor the commercial and recreational catch, collection of life history data, and analyzing fishery trends will facilitate successful management of this diverse yet unique species assemblage.

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Surfperch commercial landings, all species combined, 1980-2011.

Year	Pounds	Value	Year	Pounds	Value
1980	162,952	$103,540	**1996**	77,867	$105,992
1981	182,675	$130,475	**1997**	70,038	$101,186
1982	367,704	$209,833	**1998**	65,866	$111,905
1983	211,556	$169,986	**1999**	40,448	$67,853
1984	182,120	$140,674	**2000**	56,235	$92,543
1985	122,078	$99,414	**2001**	43,300	$77,376
1986	124983	$97,676	**2002**	68,707	$112,526
1987	145566	$118,556	**2003**	75,499	$133,691
1988	107,071	$101,910	**2004**	88,248	$164,618
1989	118,201	$106,735	**2005**	59,373	$105,086
1990	137,648	$122,734	**2006**	36,173	$70,221
1991	104,746	$124,581	**2007**	18,715	$29,019
1992	129,662	$173,257	**2008**	19,990	$33,412
1993	111,261	$139,088	**2009**	21,432	$41,944
1994	93,672	$121,571	**2010**	12,643	$25,045
1995	89,643	$124,998	**2011**	16,534	$29,537

Data source: CFIS data, all gear types combined.

Surfperch recreational catch (pounds), all species combined, 1981-2003.						
Year	**Manmade**	**Beach/Bank**	**Shore**	**Party/Charter**	**Private/Rental**	**Total**
1981	220,180	761,525	--	2,779	187,437	1,171,921
1982	152,819	636,456	--	585	91,689	881,549
1983	203,831	550,459	--	4,040	67,353	825,683
1984	172,874	393,644	--	1,281	114,262	682,061
1985	124,999	416,729	--	842	76,750	619,320
1986	--	--	1,268,466	0	244,679	1,513,145
1987	--	--	342,471	3,223	68,740	414,434
1988	--	--	558,427	625	73,220	632,272
1989	--	--	355,688	794	43,234	399,716
1990	--	--	--	--	--	--
1991	--	--	--	--	--	--
1992	--	--	--	--	--	--
1993	91,479	536,844	--	2,049	73,186	703,558
1994	63,704	308,933	--	812	61,796	435,245
1995	94,579	436,459	--	0	86,293	617,331
1996	124,478	428,963	--	0	96,429	649,870
1997	150,600	384,152	--	1,789	33,056	569,597
1998	104,961	695,003	--	776	44,260	845,000
1999	96,355	186,465	--	2,115	36,978	321,913
2000	40,196	151,881	--	585	30,863	223,525
2001	82,620	119,939	--	2,120	54,403	259,082
2002	89,056	185,873	--	1,053	42,909	318,891
2003	92,817	403,297	--	1,110	28,556	525,780

Data source: MRFSS data, all fishing modes and gear types combined. Between 1986 and 1989, the beach/bank and manmade modes were collectively designated ‘shore’ mode. Data for 1990-1992 are not available.

Surfperch recreational catch (pounds), all species combined, 2004-2009.						
Year	**Manmade**	**Beach/Bank**	**Shore**	**Party/Charter**	**Private/Rental**	**Total**
2004	171,290	256,406	--	2,361	5,512	435,569
2005	82,711	192,854	--	1,398	6,623	283,586
2006	96,507	320,711	--	1,116	7,703	426,037
2007	63,934	230,308	--	877	13,514	308,633

Surfperch recreational catch (pounds), all species combined, 2004-2009.						
Year	**Manmade**	**Beach/Bank**	**Shore**	**Party/Charter**	**Private/Rental**	**Total**
2008	54,427	245,101	--	1,235	7,928	308,691
2009	58,738	147,994	--	1,058	6,715	214,505

Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

Surfperch recreational catch (pounds) for the five most commonly caught species, 1981-2003.					
Year	**Barred**	**Redtail**	**Walleye**	**Black**	**Striped**
1981	443,941	18,972	77,204	49,628	0
1982	0	133,843	0	53,050	97,676
1983	320,239	0	72,123	35,677	0
1984	236,655	77,651	71,971	58,009	77,674
1985	237,205	69,450	43,983	39,502	50,486
1986	0	41,235	78,034	32,578	0
1987	83,272	0	0	22,636	102,683
1988	142,033	87,852	74,149	40,721	83,361
1989	117,295	9,546	45,810	38,243	45,229
1990	--	--	--	--	--
1991	--	--	--	--	--
1992	--	--	--	--	--
1993	358,991	0	41,974	0	66,581
1994	169,497	51,616	35,597	32,127	0
1995	330,370	32,715	35,734	0	0
1996	0	0	0	0	0
1997	240,503	0	47,138	53,939	68,006
1998	526,620	9,190	12,812	0	0
1999	158,920	0	17,150	26,568	15,270
2000	56,148	0	12,740	0	0
2001	73,586	2,841	0	38,311	42,036
2002	109,754	2,356	19,612	39,823	46,487
2003	293,413	41,868	0	39,499	34,463

Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

Surfperch recreational catch composition (pounds) for the five most commonly caught species, 2004-2009.					
Year	**Striped**	**Black**	**Walleye**	**Redtail**	**Barred**
2004	0	64,221	35,726	20,245	214,715
2005	19,026	34,231	21,447	28,352	130,165
2006	7,571	39,486	21,389	37,645	273,310
2007	35,281	37914	20,565	37,635	138,566
2008	33,526	21,234	13,568	32,228	174,955
2009	20,187	27,836	11,636	26,067	93,079

Data source: CRFS data, all fishing modes and gear types combined. Data for 2010-2011 are not available.

14 Garibaldi, *Hypsypops rubicundus*

Juvenile garibaldi, *Hypsypops rubicundus*. Photo credit: D Porzio, CDFW.

History of the Fishery

In the late 1800s, garibaldi, *Hypsypops rubicundus*, was a minor commercial species commonly taken at Santa Catalina Island with gill nets for Los Angeles fish markets. There has never been any significant sport fishery for garibaldi. In 1995, garibaldi was designated California's state marine fish, and a prohibition on commercial take was implemented on January 1, 1996. Prior to the commercial ban, garibaldi was one of the main targets of the commercial marine aquarium trade.

Adult garibaldi are a brilliant orange color while juveniles are orange with iridescent blue spots. Because of their brilliant colors, both adult and juvenile garibaldi were harvested for the commercial marine aquaria trade, which supplies specimens for live pet, hobby, and display purposes. The take of marine aquaria species occurs statewide primarily in nearshore waters by commercial divers. Methods used to take garibaldi and other finfish for the aquarium trade include traps gear, hook-and-line but primarily consist of dropnets and slurp guns used by divers. Commercial laws governing the marine aquarium trade were first implemented in 1993 which established a Marine Aquaria Collectors Permit for commercial fishermen and a Marine Aquaria Receiver's License for commercial fish businesses. These laws put restrictions on where fish may be taken, and created a listed of prohibited species (FGC §8596 et seq.). Before 1993, only a general commercial fishing license was required to land fish destined for the aquarium trade.

According to California Department of Fish and Wildlife (Department) commercial landing receipt data reported by fish businesses, there were little to no reported garibaldi landings before 1981 (Figure 14-1). In 1982, 38 landings were reported, totaling 133 pounds (60 kilograms) of garibaldi, and landings increased each year until peaking in 1990 at 520 pounds (236 kilograms) with 85 reported landings (Figure 14-1). The number of reported landings decreased to 10 in 1992, totaling just 39 pounds (18 kilograms). The ex-vessel value of garibaldi increased from $3,700 in 1982 to a high of $14,100 in 1990, with the price per pound ranging from a high of $32.40 ($71.28 per kilogram) in 1983 to a low in 1991 of $7.69 ($16.91 per kilogram). The catch during this period mostly originated from the front side of Santa Catalina Island near the Isthmus, and at Palos Verdes and Laguna Beach along the mainland coast (Figure 14-2a). Before 1993, all landing receipts required landings to be reported in pounds; however most garibaldi (and other fish in the aquarium trade) were sold by the individual and as a result, landing receipts typically only contained an estimate of pounds landed. Due to this discrepancy, some landing receipts did not accurately capture pounds landed. Therefore, while the trends in catch are likely valid, landings before 1993 likely do not reflect true values.

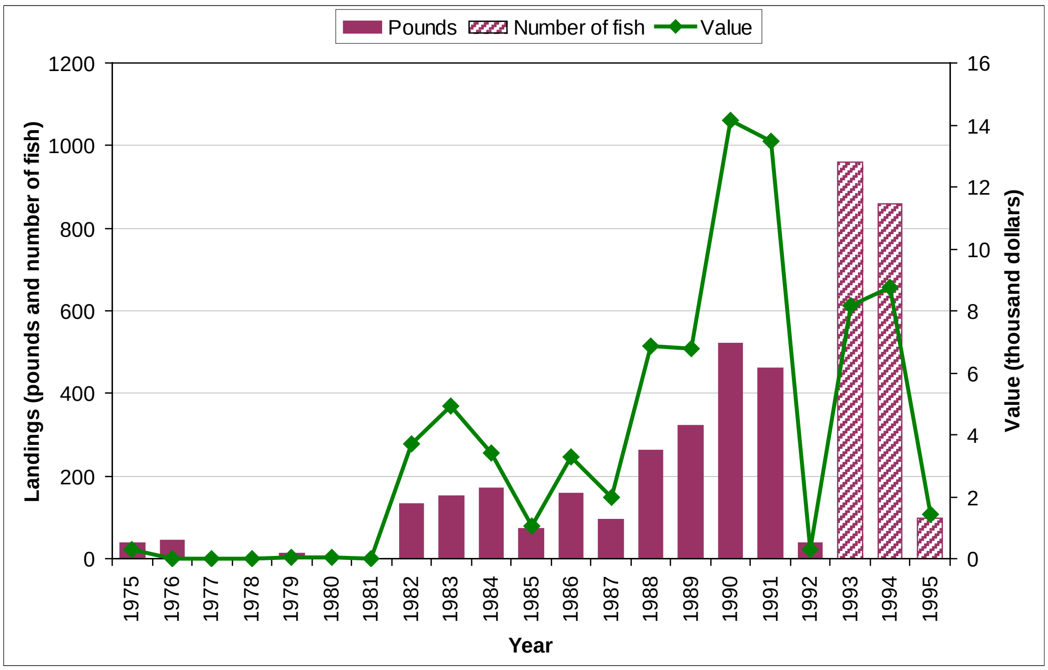

Figure 14-1. Garibaldi commercial landings and value, 1975-1995. Data source: Commercial Fisheries Information System (CFIS) data, all gear types combined. Data prior to 1975 are not available. From 1975-1992 actual pounds (solid bars) were recorded on commercial landing receipts. Landings after 1992 were reported in numbers of individuals landed (slashed bars) due to new landing receipts and regulations instituted in 1993 for the commercial aquarium trade. The commercial fishery was closed in 1996.

In 1993, a Marine Aquaria Collectors Permit was required for landing species for the aquarium trade (FGC §8598.3) and new landing receipts were created for this fishery requiring landings to be reported as numbers of individuals with price paid per individual. During this first year of new reporting requirements, 20 landings were reported totaling 959 garibaldi with an average price of $8.50 each and an ex-vessel value of $8,157 (Figure 14-1). From 1994 to 1995, landings decreased from 859 to 99 individuals with only 8 and 4 landings reported; however, the price paid per individual increased from $10.20 to $14.50, respectively. After 1992, garibaldi catch shifted from Santa Catalina Island to the front side of San Clemente Island and the Laguna Beach area due to a restriction implemented in 1993 (FGC §8598) on commercial aquarium trade collecting at Santa Catalina Island (Figure 14-2).

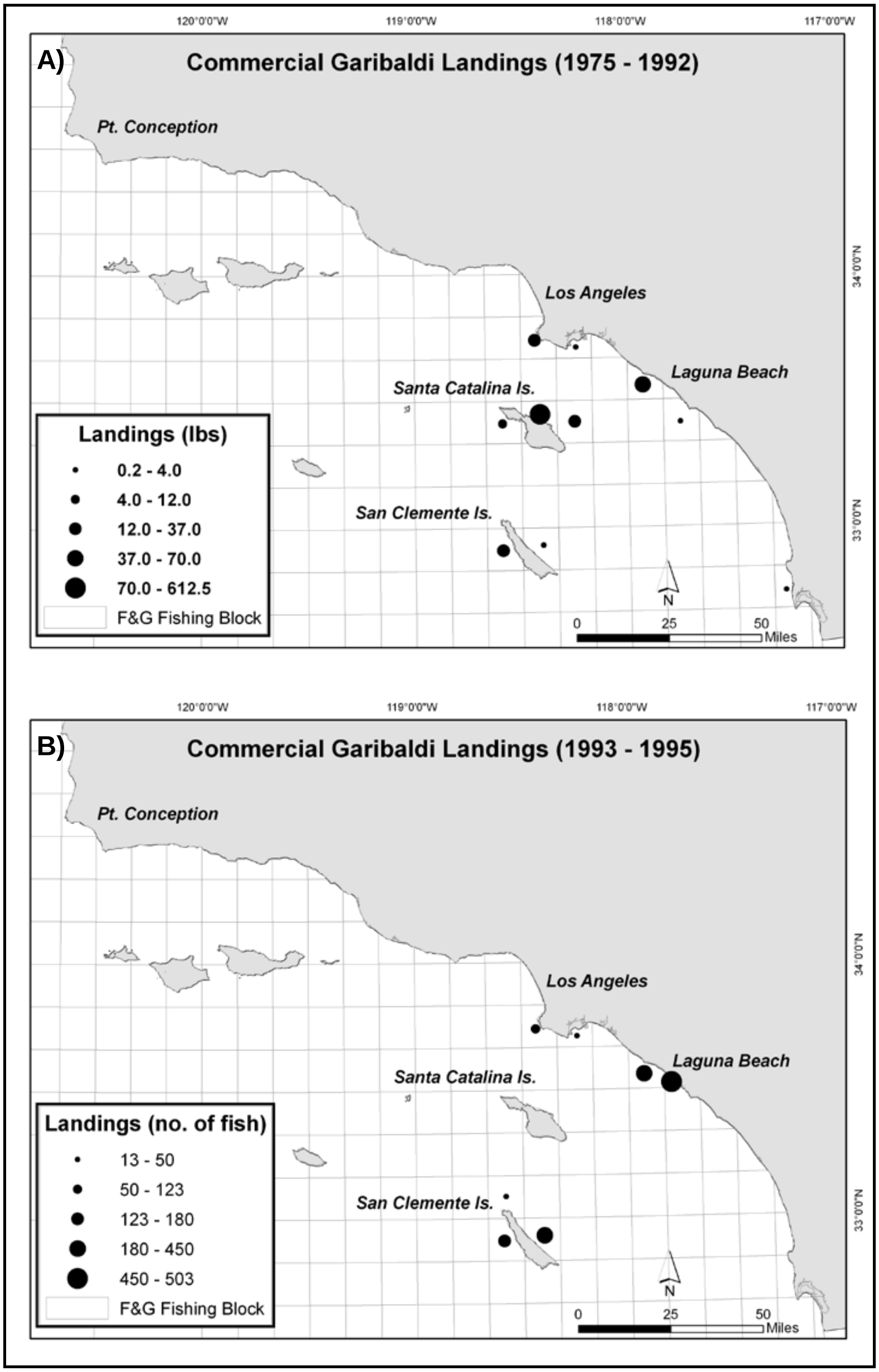

Figure 14-2. Origin of commercial garibaldi landings. A) pounds landed, and B) numbers of fish landed. Data source: CFIS data, all gear types combined. Data prior to 1975 are not available. The commercial fishery was closed in 1996.

During the early 1990s, a commercial aquarium trade developed for juvenile garibaldi. Although not substantial in terms of weight, because the fish were juveniles, these landings represented a large number of individuals. Because most of this take focused on one area, Santa Catalina Island, there was concern for localized depletion. Likely a result of concerns for garibaldi populations, Assembly Bill 77 (Morrow, 1995) was signed into California State law effective January 1, 1996 suspending the commercial fishery for garibaldi. This bill declared garibaldi the State marine fish (Government Code §425.6) and imposed a 3 year ban on its commercial collection "unless a study, the methodology of which is approved by the Department of Fish and Game shows a less than significant impact on the population of the resource." Three years later in 1999, FGC§ 8598 was amended removing the exception clause on the 3 year commercial ban and added garibaldi to the list of no-take species without exceptions. The prohibition on the commercial take of garibaldi continues today and garibaldi are now imported from Mexico where the commercial fishery continues.

Historically, garibaldi was never an important component of the recreational fishery in southern California and no reliable catch data exists, but some reports indicate that they were easy targets for novice spearfisher. In, *How to Fish the Pacific Coast*, published in 1953, the author states that garibaldi are taken in swirling waters along rocky shores but are very difficult to tempt. The author goes on to say, "This fish is of such beauty in the water it should be left there". According to the California Fish and Game Commission (Commission) meeting notes from January 2, 1953, the Department presented potential sportfishing regulation changes that included a recommendation to "prohibit skin diving fishing along the waterfront of Avalon, Santa Catalina Island" as proposed by the Santa Catalina Island Company. This proposed regulatory change was met with opposition because the public wanted to continue to spearfish near Avalon and the main concern was take of garibaldi. So the proposed regulation was modified to a statewide prohibition on the recreational take of garibaldi. At the January 30, 1953 Commission meeting, the prohibition against the take or possession of garibaldi, by either angling or diving was adopted (Title 14, CCR, §28.05). This prohibition on the recreational take of garibaldi is still in place.

Status of Biological Knowledge

The garibaldi, a member of the damselfish family (Pomacentridae), ranges from Monterey Bay, California to southern Baja California, Mexico. In California, they are rare north of Point Conception, but larvae and juveniles are transported to the north during El Niño events. Adult garibaldi have a conspicuous bright orange color, which is a unique characteristic in the rocky reef fish assemblage of southern California. They inhabit rocky habitat from the shallow intertidal to a depth of 125 feet (39 meters) but can also be found on shallow crossbeams of offshore oil platforms. Garibaldi are rarely found more than 3 to 6 feet (1 to 2 meters) above the bottom and prefer moderate to high relief rocky habitat that provides large holes and crevices for shelter. Their diet consists mainly of small benthic invertebrates such as sponges, bryozoans, anemones, and polychaete worms.

Adult male and female garibaldi are territorial year round, occupying a territory of about 54-108 square feet (5-10 square meters) which typically includes an area for forage, shelter, and for adult males, a benthic nest. Adults will aggressively defend their territory and attack or chase most invaders including individuals many times their size. For example garibaldi have been observed to attack kelp bass, California scorpionfish, and broomtail grouper but will tolerate juvenile garibaldi up to 8 inches (20 cm), and plankton eating species like blacksmith, and some flatfish species. The only animal reported to cause an adult to seek shelter are harbor seals. Individuals are only active during the day and seek shelter at night in crevasses that may include other species like California spiny lobster, moray eels, and, sometimes, other adult garibaldi.

Garibaldi spawning occurs between May and October when water temperatures reach at least 59°F (15°C). In March, males will start to attract females by cultivating a nest of red turf algae, which they defend aggressively. Courtship takes about 10-15 minutes with females laying thousands (34,000 to 190,000) of eggs that are externally fertilized on the male-tended red algal nests. Males actively defend the nest during the day until the eggs hatch. Nests typically contain more than one clutch as males will spawn with multiple females within a season. Some males may not spawn while others will spawn up to 7 times per season. Females likely only produce one clutch per season and preferentially spawn with males that are already guarding eggs. Newly deposited eggs are yellow in color, become grey as they develop, hatching in 12 to 20 days at dusk over a period of several days. Nests are reoccupied each year by the same male for many years, with later generations taking over after the male dies.

After a 21 day pelagic larval period young of the year garibaldi 0.7-1.0 inches (18-26 millimeters) settle out in shallow (<15 feet; 3 meters) rocky reefs from July to November. Individuals spend about three years as juveniles and two years as sub adults with males and females reaching sexual maturity at approximately 5-6 years of age and just over 8 inches (21 centimeters). Visibly there is no way to distinguish between males and females although behaviorally only males guard nests and attain a slightly larger size on average. Garibaldi attain a maximum size of 14 inches (35.6 centimeters) with a lifespan of 12-13 years and maximum reported age of 15-17 years.

Status of the Population

Garibaldi populations have rebounded from the local effects of commercial take and are in good condition throughout their range in southern California. While regulations prohibit the commercial and recreational take of garibaldi some individuals are taken under the auspices of a Department issued Scientific Collecting Permit, for research and educational purposes. Some garibaldi are also caught incidentally in the recreational fishery and may be subject to catch and release mortality; however, this mortality is likely very low.

Management Considerations

Recently implemented marine protected areas, particularly no-take state marine reserves, should reduce catch and release mortality of garibaldi in the recreational fishery. Similarly, reserves would protect habitats valuable to garibaldi from a variety of potential fishing activity related impacts. Some larval transport to distant areas would be expected, however this would not be expected to have significant impacts on populations as the garibaldi is already protected and at good population levels. Recent studies in San Diego County using diver surveys estimate that garibaldi densities range up to 0.32 individuals per square meter depending upon the location and availability of quality habitat.

The value of garibaldi is likely in its aesthetics and as an iconic species in its natural habitat, and not within a fishery. Garibaldi are commonly viewed by recreational scuba divers and snorkelers in California along La Jolla, Laguna Beach, Palos Verdes, and offshore Islands, and in some areas via glass bottom boat tours.

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Further reading

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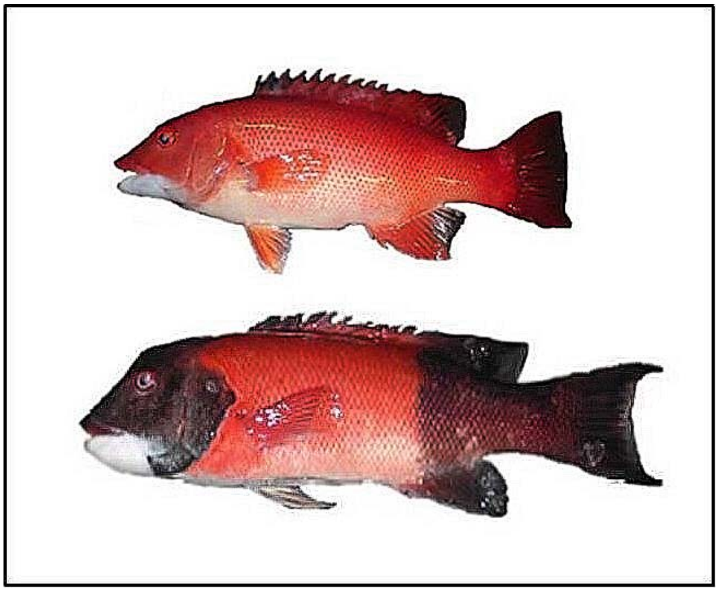
Garibaldi Commercial Landings, 1975-1995.								
Year	**Pounds**	**Value**	**Year**	**Pounds**	**Value**	**Year**	**Number landed**	**Value**
1975	38	$276	**1984**	170	$,3398	**1993**	959	$8,157
1976	45	$0	**1985**	72	$1,071	**1994**	859	$767
1977	0	$0	**1986**	158	$3,300	**1995**	99	$,1434
1978	0	$0	**1987**	95	$1,988			
1979	12	$27	**1988**	261	$6,864			
1980	2	$30	**1989**	322	$6,797			
1981	0	$0	**1990**	520	$14,144			
1982	133	$3,715	**1991**	462	$13,461			
1983	152	$4,914	**1992**	39	$300			

Data Source: CFIS data, all gear types combined. Data prior to 1975 are not available. The commercial fishery was closed in 1996.

15 California sheephead, *Semicossyphus pulcher*



California sheephead, *Semicossyphus pulcher*. Female top, male bottom.
Photo credit: KA Loke-Smith, CDFW.

History of the fishery

California sheephead, *Semicossyphus pulcher*, have been part of the commercial catch in California since the late 1800s. Commercial landings records show that the fishery has experienced two booms since 1916. During the first boom from 1925 to 1951, sheephead landings averaged 139,500 pounds (63,276 kilograms) per year and reached a historical high of 373,000 pounds (169,190 kilograms) in 1928. For nearly four decades from 1952 to 1989, sheephead catch declined and average landings were less than 16,000 pounds (7,258 kilograms) per year. Then in the 1990s, a boom in landings occurred again, driven in part by a live fish commercial market and a jump in the market price from an average of $0.57 per pound ($0.26 per kilogram) in the 1980s to $2.34 per pound ($ 1.06 per kilogram) in the 1990s. This accounted for a five-fold increase in the value of the fishery (Figure 15-1). The live fish fishery is primarily a trap fishery which is size selective for “plate-size” individuals. The average commercial landings for sheephead in the 1990s were 234,000 pounds (106,141 kilograms) per year. With the implementation of catch limits and size restrictions since 1999, annual landings have decreased; however, the average landings for sheephead from 2000-2011 were 97,000 pounds (43,998 kilograms) per year, well above the pre-boom average in the 1950s-1980s of 16,000 pounds (7,258 kilograms) per year. The market price for California sheephead has increased steadily since the 1990s reaching an average high price of $4.34 per pound ($1.97 per kilogram) in 2008. Most commercially landed sheephead are caught by trap but some are caught by hook-and-line, and also as bycatch in the gill net fishery (Figure 15-2).

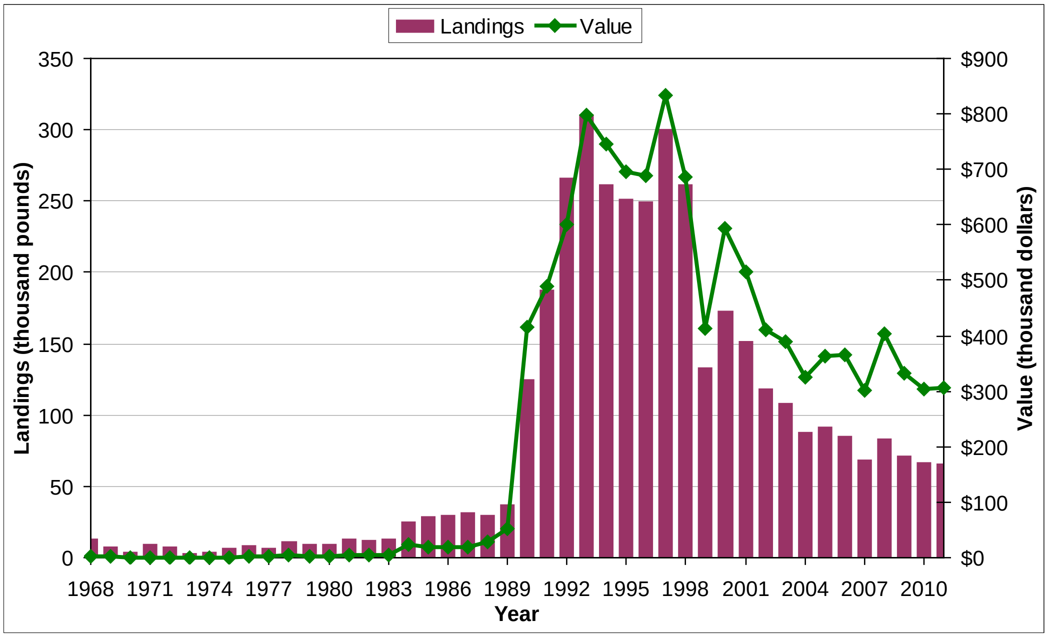


Figure 15-1. California sheephead commercial landings and value, 1969-2011. Data source: Commercial Fisheries Information System (CFIS) data, all gear types combined.

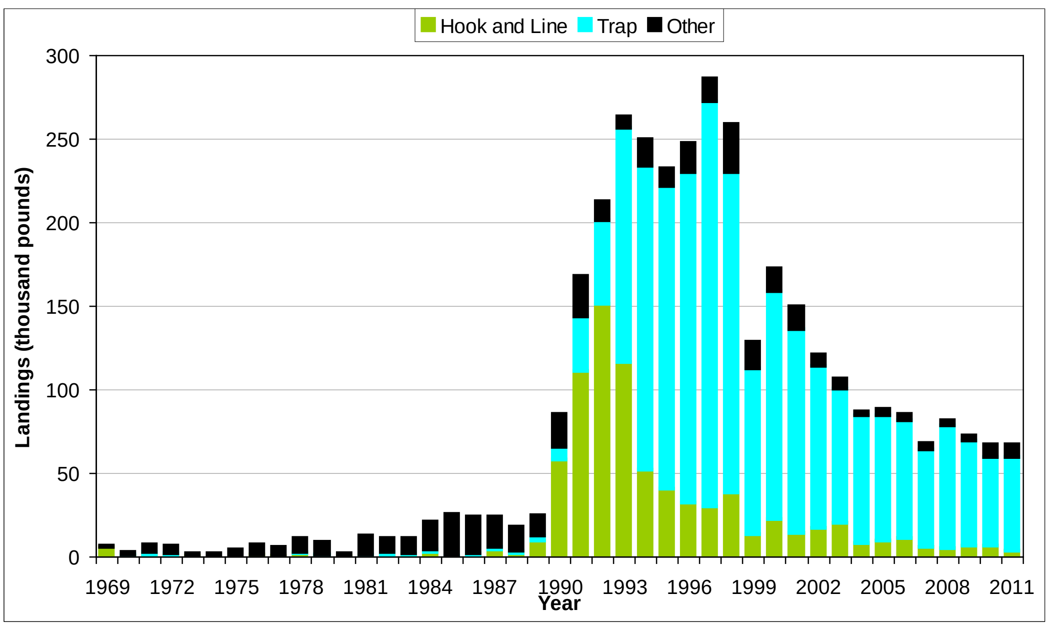


Figure 15-2. California sheephead commercial landings by gear type, 1969-2011. Data source: CFIS data.

California sheephead are one of 19 species listed in the State's Nearshore Fishery Management Plan and are regulated by the California Fish and Game Commission. The commercial fishery for sheephead is part of the nearshore restricted access program that applies to 10 of the 19 nearshore species, and a Nearshore Fishery Permit is required to take California sheephead with hook-and-line gear. A trap endorsement is also needed to use trap gear. The minimum size limit for sheephead was first set at 12 inches (30.5 centimeters) total length in 1999 for the commercial fishery, but the size limit was increased to 13 inches (33 centimeters) in 2001. Also in 2001, state quotas for sheephead based on optimum yield estimates were first set and to avoid surpassing the quotas, the commercial fishery was closed early every year from 2001 to 2007. Current regulations for sheephead still include 12 inch (30.5 centimeters) and 13 inch (33 centimeters) minimum size limits for the recreational and commercial fisheries, respectively, along with a five-fish bag limit for the recreational fishery. The commercial fishery has bimonthly trip limits of 2000 pounds (907 kilograms) for January-February, and 2400 pounds (1088 kilograms) for May-June, July-August, September-October, and November-December; the commercial fishery is closed in March and April. The recreational fishery south of Point Conception is closed in January and February to boat-based anglers. Divers and shore based angler can fish year round. The current statewide total allowable catch for California sheephead is 205,000 pounds (92,986 kilograms), with 130,300 pounds (59,103 kilograms) allocated to the recreational fishery and 75,200 pounds (34,110 kilograms) allocated to the commercial fishery.

Recreational anglers target large trophy California sheephead by spear and by hook-and-line. Since the late 1970s, sheephead have been a consistent part of the recreational catch although it has decreased in recent decades. The average number of California sheephead landed annually by commercial fishing passenger vessels (CFPVs) has decreased from 36,047 in the 1980s to 29,022 in the 1990s, and 27,564 in 2000-2011 (Figure 15-3). The decrease in recreational landings may be in part due to increased competition for fish from the commercial fishery in the 1980s and the introduction of minimum size limits and catch limits in the early 2000s. Previous publications on sheephead biology have estimated biomass landed by CPFVs using an average weight of 2 pounds (0.9 kilogram) per fish; however, new research indicates that spatial and temporal differences in sheephead biological parameters exist (including growth rates and average size) such that using an average weight for all populations over time may be inaccurate and may under or over estimate the biomass landed from year to year.

For the recreational fishery, a minimum size limit was set in 2001 at 12 inches (30.5 centimeters) total length and the recreational bag limit for sheephead was reduced from 10 fish to 5. In 2003, the Rockfish Conservation Areas (RCAs) were established and recreational bottom fishing was limited to waters less than 30 or 60 fathoms (55 or 110 meters), depending on the month. Depth limits for the Southern RCA (Point Conception to the U.S./Mexico border) varied until 2006, when they were set at 60 fathoms (110 meters) for all months. The Cowcod Conservation Area was established in 2007 and limited bottom fishing to waters less than 20 fathoms (37 meters). In 2002 and 2003, the recreational fishery for California sheephead closed early. Beginning in 2004, the recreational fishery for sheephead has been closed in January and February along with cabezon, greenlings and rockfish. Since the two-month closure went into effect there has been no need to close the sheephead recreational fishery early.

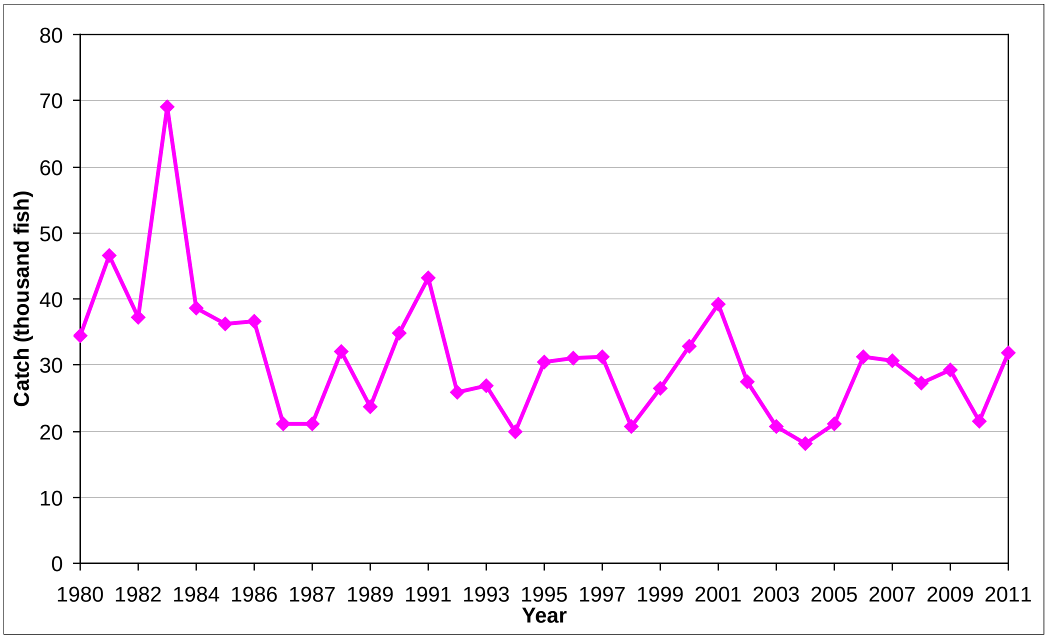


Figure 15-3. California sheephead CPFV catch, 1980-2011. Data source: CPFV logbook data.

Status of the Biological Knowledge

California sheephead, like other wrasses in the family Labridae are monandric protogynous hermaphrodites, meaning that they all begin life as females and may change sex to become male. California sheephead range from Monterey, California to southern Baja California, Mexico and the Gulf of California. Sheephead have been reported to reach sizes of 36.5 pounds (16.6 kilograms) and three feet (0.9 meters) in length. They are sexually dimorphic, with most females having uniformly pink color pattern, a gently sloping forehead and a slight chin, while most males have a distinctive black and red color banding pattern, and a pronounced nuchal hump (enlarged forehead). In spite of the distinctive differences in typical female and male appearance, morphology may not be an accurate indicator of sex in all populations. California sheephead have protruding canine-like teeth and crushing pharyngeal plates and they are a generalist predator whose diet varies geographically and developmentally. As sheephead grow they shift their prey from small filter feeders to larger invertebrates including sea urchins. Sheephead predation may play a role in controlling urchin grazing; however, recent studies indicate that this predation may only have a significant effect in altering urchin populations at certain locations and on small scales.

Sex change in sheephead is thought to be triggered by social cues; specifically, the absence or removal of a dominant male in a population triggers the next dominant female to change sex. California sheephead spawn almost every day during the summer months. New estimates of fecundity indicate the relationship between length and number of eggs increases exponentially (to the power of 5.5), showing the importance of large females to the overall reproductive potential of the sheephead stock.

Sheephead have been reported from shallow subtidal depths to 280 feet (85 meters) and are typically associated with rocky reefs and kelp forests. Tracking studies at Santa Catalina Island have found that California sheephead have relatively small home ranges of 0.23 to 20.26 acres (938 to 82000 meters^2) and they show a high degree of site fidelity. They use hard and soft substratum in equal proportions during the day, but use primarily hard substratum when refuging at night. They also show a very strong association with ecotone habitat (where habitat changes from one type to another). On offshore oil platforms, sheephead exhibited daily vertical migrations from shallow water during the day to deeper water at night.

There is wide spatial variation in the demography and life history of California sheephead populations in southern California. New research indicates that California sheephead in four southern populations (Santa Catalina Island, San Clemente Island, Palos Verdes, and Point Loma) attain smaller maximum sizes (for females and males), reach maturity, and undergo sexual transition at smaller sizes and younger ages than five northern populations within southern California (Santa Cruz Island, Santa Rosa Island, Anacapa Island, Santa Barbara Island, and San Nicolas Island). The growth rate of sheephead was also slower in the southern populations than in the northern populations. Plasticity (ability to change) in biological traits is commonly seen in fishes to increase fitness and may be affected by environmental conditions including temperature and diet composition as well as manmade conditions including fishing. Indeed, temperature and diet vary significantly across southern California populations and size selective fishing by the commercial and recreational fisheries across southern California has been shown to have significant effects on population size structure, growth rate, size/age at maturation, and size at sex change of California sheephead.

Status of the Population

A stock assessment of California sheephead conducted in 2004 estimated the stock was approximately 20 percent of the unfished level, well below the target level of 50 percent estimated as sustainable. Unfortunately, most of the biological data used in the stock assessment were collected before the boom in the fisheries that began in the 1990s and before the effects of size limits and catch limits set between 1999 and 2001 could be fully observed. Since the 2004 stock assessment, new research shows the variability in life history parameters of sheephead populations across southern California depends on the population’s exposure to environmental conditions and fishing pressures.

The data available to estimate temporal changes in sheephead populations are sparse because long term historic and current data are only available for two populations: Santa Catalina and San Nicolas Islands. Since 1970, a decrease in size at maturity, size at sex change, and maximum size of both females and males have occurred for the sheephead population at Santa Catalina Island. Since smaller females produce exponentially fewer eggs than larger females, a small reduction in the maximum size of females indicates a large loss in the number of eggs produced. In addition, two separate studies conducted on opposite sides of Santa Catalina Island found approximately 25 percent of the population undergoing sexual transition in the summer breeding season. Sex change involves a period of reproductive inactivity and until 2005, this had never been reported in California sheephead during the summer breeding season. The temporal changes in the Santa Catalina Island population and the change in the timing of sexual transition suggest a reduction in the reproductive potential in that population. In contrast, the temporal data for San Nicolas Island shows a decrease in the maximum sizes of females and males from 1980 to 1998; however, by 2007 the population structure was very similar to the structure observed in 1980 suggesting that the San Nicolas population may be recovering.

Although the data from San Nicolas Island shows the potential for California sheephead populations to recover, this may be due to the unique conditions at the island. The island’s sheephead population may have benefited due to increased recruitment during the 1998 El Niño followed by decreased fishing pressure. San Nicolas Island is located 62 miles (100 kilometers) from any mainland port making travel to the island an expensive endeavor with the increased fuel prices over the last decade. In addition, the island is owned by the U.S. Navy and since September 11, 2001, the island has been periodically closed to fishing without warning making it an unattractive fishing destination.

If the observed temporal changes in life history at Santa Catalina Island are more indicative of temporal changes in life histories across the range, then there has likely been an overall decrease in the reproductive potential of California sheephead relative to the unfished condition of the stock.

Management Considerations

As a sex changing species, California sheephead present a unique challenge for fisheries managers. Further confounding sheephead management is the geographic variation in sheephead life history parameters with populations in the northern part of their California range having faster growth rates, maturing at larger sizes and achieving larger maximum sizes for females and males than their more southern California counterparts. For populations of sheephead in the most southern populations in California, the current minimum size limit of 12 inches (305 millimeters) preserves some mature females and males allowing them to spawn at least once before they are recruited to the fishery; however, in the more northern populations, sheephead are still immature at 12 inches (30 centimeters) and individuals may not get to spawn before they are recruited to the fishery.

A new modeling study for sheephead made estimates of fishery yields under different minimum size limits. Models indicate that a statewide increase in the minimum size limit by at least 2 inches (5 centimeters) would allow more individuals in northern populations to spawn at least once and may increase fishery yield by up to 15 percent. Models also highlight the potential for increasing fishery yield by dividing the management area into northern and southern management zones with unique size limits.

Alternative management considerations also include slot limits which would preserve both males and females of the species; however, variability in life history parameters across California may limit the effectiveness of a statewide slot limit option.

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Further Reading

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California sheephead commercial landings, 1969-2011.

Year	Pounds	Value	Year	Pounds	Value	Year	Pounds	Value
1969	13,285	$1,432	**1984**	25,085	$23,245	**1999**	129,598	$412,832
1970	3,805	$419	**1985**	28,486	$18,476	**2000**	173,615	$593,155
1971	8,419	$932	**1986**	29,228	$17,805	**2001**	150,118	$516,488
1972	7,084	$947	**1987**	32,865	$19,385	**2002**	121,470	$411,830
1973	3,072	$472	**1988**	29,314	$29,122	**2003**	108,552	$390,191
1974	3,721	$599	**1989**	33,019	$54,169	**2004**	87,213	$328,138
1975	6,031	$1,104	**1990**	123,539	$414,701	**2005**	89,228	$361,852
1976	8,325	$1,813	**1991**	191,705	$491,588	**2006**	85,599	$367,214
1977	6,409	$1,611	**1992**	258,502	$600,719	**2007**	67,869	$300,861
1978	11,139	$5,233	**1993**	314,151	$800,644	**2008**	81,479	$402,661
1979	8,813	$3,039	**1994**	259,099	$745,063	**2009**	72,374	$335,491
1980	9,102	$3,274	**1995**	253,658	$697,687	**2010**	67,256	$308,121
1981	12,900	$4,960	**1996**	252,123	$690,037	**2011**	68,040	$312,167
1982	11,761	$4,800	**1997**	301,878	$835,471			
1983	12,620	$5,317	**1998**	261,640	$687,697			

Data source: CFIS data, all gear types combined.

California sheephead commercial landings by gear type, 1969-2011.							
Year	**Hook-and-line**	**Trap**	**Other**	**Year**	**Hook-and-line**	**Trap**	**Other**
1969	5,732	746	6,807	**1991**	191,705	32,510	111,781
1970	555	767	2,483	**1992**	258,502	49,666	151,864
1971	1,548	1,591	5,280	**1993**	314,151	140,171	117,146
1972	940	1,776	4,368	**1994**	259,099	182,069	54,225
1973	630	34	2,408	**1995**	253,658	181,335	54,075
1974	263	106	3,352	**1996**	252,123	197,777	44,346
1975	181	107	5,743	**1997**	301,878	241,830	45,660
1976	1,584	127	6,614	**1998**	261,640	192,145	50,827
1977	425	48	5,936	**1999**	129,590	99,486	23,898
1978	2,043	1,062	8,034	**2000**	173,615	135,847	33,022
1979	505	974	7,335	**2001**	150,118	121,903	23,916
1980	453	578	8,071	**2002**	121,470	96,367	22,555
1981	794	795	11,311	**2003**	108,552	79,762	25,798
1982	969	1,788	9,004	**2004**	87,213	76,720	9,493
1983	1,792	696	10,131	**2005**	89,228	74,574	13,288
1984	3,421	1,156	20,509	**2006**	85,599	70,790	14,044
1985	331	763	27,392	**2007**	67,869	58,526	6,852
1986	666	1,563	26,999	**2008**	81,479	73,667	6,481
1987	4,250	1,593	27,022	**2009**	72,374	62,638	9,548
1988	3,286	1,277	24,752	**2010**	67,256	52,667	13,665
1989	9,795	3,234	19,990	**2011**	68,020	56,686	10,922
1990	58,451	7,471	57,616				

Data source: CFIS data.

California sheephead CFPV landings, 1980-2011.					
Year	**Number of Fish**	**Year**	**Number of Fish**	**Year**	**Number of Fish**
1980	34,368	**1991**	43,158	**2002**	27,396
1981	46,479	**1992**	25,785	**2003**	20,781
1982	37,242	**1993**	26,910	**2004**	18,192
1983	68,972	**1994**	19,922	**2005**	21,124
1984	38,522	**1995**	30,430	**2006**	31,316
1985	36,267	**1996**	30,976	**2007**	30,696
1986	36,707	**1997**	31,195	**2008**	27,286
1987	21,146	**1998**	20,610	**2009**	29,175
1988	21,146	**1999**	26,498	**2010**	21,440
1989	32,058	**2000**	32,780	**2011**	31,834
1990	23,612	**2001**	39,156		

Data source: CPFV logbook data, all gear types combined.

16 California Halibut, *Paralichthys californicus*

California halibut, *Paralichthys californicus*. Photo credit: O Horning, CDFW.

History of the Fishery

California halibut, *Paralichthys californicus*, is an important flatfish species to the commercial fisheries in central and southern California. The highest recorded annual landings from California waters were an estimated 3.5 million pounds (1588 metric tons) in 1917. This was followed by another high year of 2.7 million pounds (1225 metric tons) in 1918. Following the high of 1917, the fishery was subject to increasing exploitation. In the years following World War I, the overall volume of landings decreased, possibly a result of increased fishing pressure. Annual landings declined sharply until 1926 and more gradually to a low in 1942 at 0.57 million pounds (258 metric tons). The fishery rebounded during and after World War II (1944 to 1949). From 1942 to 2011, the annual landings average was 780,000 pounds (354 metric tons) with six peaks: 1945 (1.6 million pounds; 717 metric tons), 1946 (1.7 million pounds; 762 metric tons), 1981 and 1985 (1.3 million pounds; 572 metric tons), 1997 (1.3 million pounds; 603 metric tons), and 1999 (1.3 million pounds; 594 metric tons) (Figure 16-1).

The commercial fishery may occur statewide and was historically centered off southern California ports, and the waters of northern Baja California, Mexico. Catch from Mexican waters peaked in 1916 at an estimated 2.5 million pounds (1134 metric tons). Landings from Mexican waters were variable, but steadily decreased after a high in 1925 of 1.5 million pounds (694 metric tons). In recent history, landings have shifted to central California, with the majority of landings occurring in the San Francisco port area. The majority of fishing in southern California occurs in the legislatively-defined California Halibut Trawl Grounds (CHTG) and over shallow, sandy habitat around the Channel Islands.

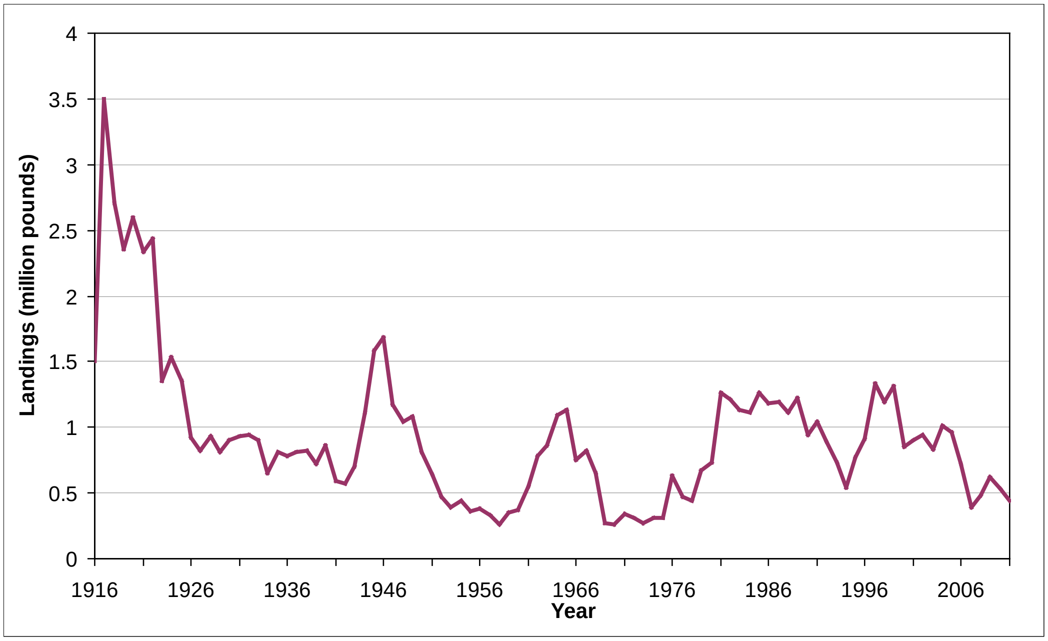

Figure 16-1. California halibut commercial landings, 1916-2011. Data source: California Department of Fish and Wildlife (Department) catch bulletins (1916-1983) and Commercial Fisheries Information System (CFIS) data (1984-2011), all gear types combined**.**

The three principle commercial gears used to catch California halibut are otter trawl, set gill net, and hook-and-line. The trawl fishery began in 1876 with the introduction of the paranzella net in the San Francisco Bay area. This early trawl net was towed by two sail boats. Eventually wind-powered vessels were replaced by steam, then combustion engines. The two-vessel method of towing a net remained until the 1940s, when single vessels began towing and hauling their own nets. The current California halibut trawl fleet ranges from small (29 feet; 9 meters) to larger (71 feet; 22 meters) vessels with a typical crew size ranging from one to three.

Various prohibitions on bottom trawling within state waters have been in effect since 1915 with some exceptions, one of these being the CHTG. Created in 1971, the CHTG by definition encompass an area 1 to 3 nautical miles (1.8 to 5.6 kilometers) from shore between Point Arguello (Santa Barbara County) and Point Mugu (Ventura County). The CHTG are closed to trawling from March 15 through June 15, and are subject to special trawl gear restrictions. In addition to the seasonal closure and gear restrictions, several areas within the CHTG are permanently closed to trawling. In 2004, Senate Bill 1459 prohibited trawling in all State waters except those in the CHTG. Within the CHTG, vessels are required to use “Light Touch Trawl Gear” with a minimum cod-end mesh size of 7.5 inches (19 centimeters) (Title 14 CCR §124(b)). A California Halibut Bottom Trawl Vessel Permit (CHBTVP) issued by the Department is required to target California halibut with trawl gear and to fish in the CHTG. Fishermen with a federal groundfish trawl permit who do not have a CHBTVP may land up to 150 pounds (68 kilograms) of California halibut caught during a groundfish trip in federal waters.

As a result of Senate Bill 1459, trawl fishing in Monterey Bay, which is entirely within state waters, was prohibited. This area, particularly the northern section, was historically trawled for at least 75 years, and the new closure has been enforced since 2006.

Gill net or entangling nets were introduced in the mid 1880s for use statewide. Since introduction of these nets, regulations for their use have gone through several changes including bans, ban overrides with limited use, and area or depth closures. As of 1989, gill nets used for California halibut must have a minimum mesh size of 8.5 inches (21.6 millimeters). In 1994, legislation was enacted prohibiting gill net use within 3 nautical miles (5.56 kilometers) of shore south of Point Conception, and within 1 nautical mile (1.8 kilometers) from shore or 420 feet (128 meters) around the Channel Islands. A limited entry General Gill/Trammel Net Permit is required for this fishery.

The gill net fishery from Point Reyes to Point Arguello, in waters 360 feet (110 meters) or less, was closed beginning in 2000 as an emergency measure to protect seabirds and marine mammals. This emergency closure was enacted through a series of smaller closures. Two closures prohibited the use of gill nets in less than 360 feet (110 meters) from Point Reyes (Marin County) to Yankee Point (Monterey County). The other closure was from Point Sal (Santa Barbara County) to Point Arguello. A third closure was enacted to close the entire area between Point Reyes to Point Arguello. The closure from Point Reyes to Point Arguello became permanent in 2002.

Hook-and-line gear, when compared to the other two principle gears, historically comprised a minor portion of the commercial fishery. Hook-and-line landing trends have been relatively stable, with a slight increase in the past 20 years (Figure 16-2). During this period, hook-and-line gear averaged less than 20 percent of total commercial California halibut landings. A majority of these landings occur in the San Francisco Bay fishery. The commercial hook-and-line fishery is nonrestrictive, meaning that no special permits are required.

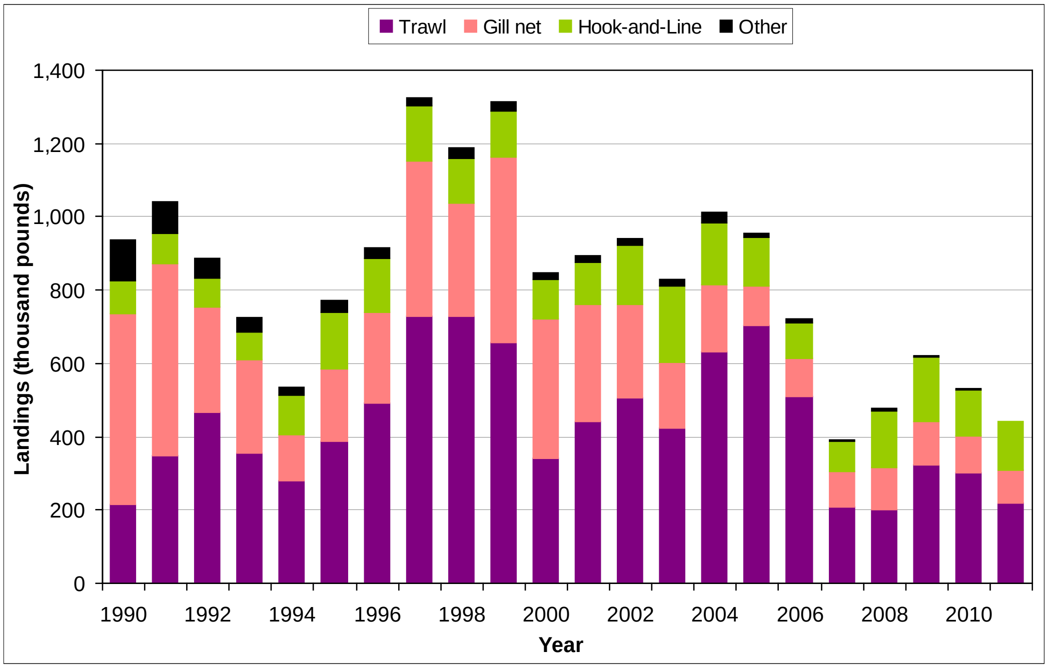

Figure 16-2. California halibut commercial landings by gear type, 1990-2011. Data source: CFIS data.

California halibut is a valuable fish, sold fresh whole or as fillets to fish markets and local restaurants, or in some cases, in live condition. Prior to 1990, California halibut supplied a fresh/dead market. In 1990, one fish receiver began buying and selling live California halibut. After a few years, other markets began requesting that fishermen land their catch in live condition. Live California halibut fetch a higher price, thus changing fishing habits and increasing the value of each fish caught (Figure 16-3). Fish buyers, primarily from the Los Angeles area, would travel as far north as Moss Landing (Monterey County) to buy trawl-caught, live California halibut. Since the closure of Monterey Bay to trawling in 2006, the live California halibut industry primarily occurs in the Santa Barbara/Ventura port complex. Short trawl tow times and a large mesh size codend help ensure that California halibut can be caught and landed live. Set gill net and hook-and-line are other gears used in the live California halibut fishery.

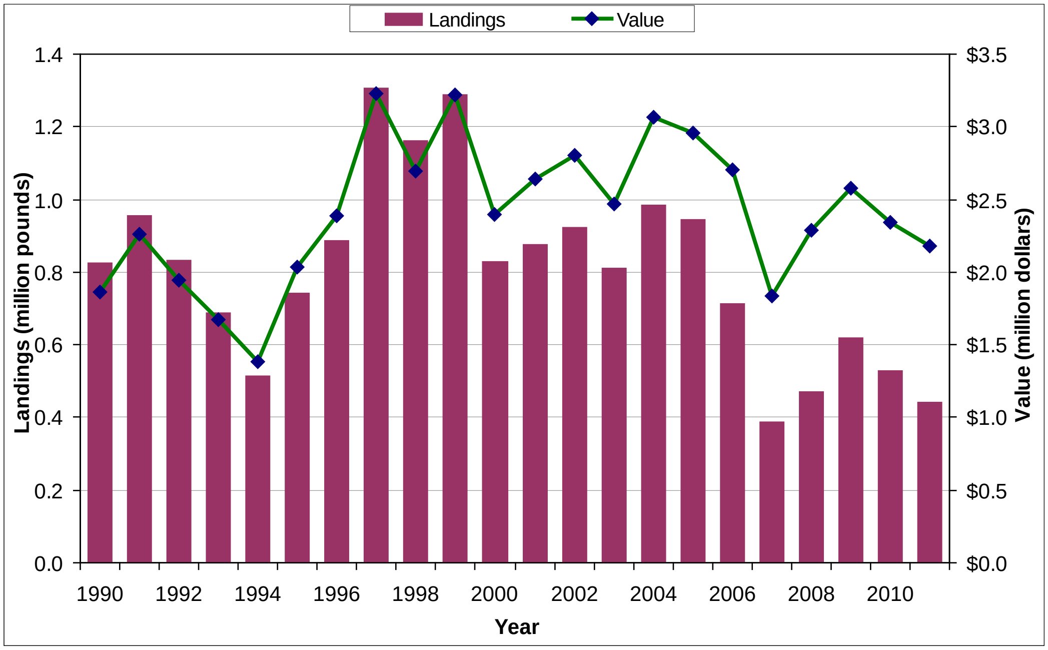

Figure 16-3. California halibut commercial landings and value, 1990-2011. Data source: CFIS data, all gear types combined.

The commercial California halibut minimum size limit is 22 inches (56 centimeters) total length (TL), established in 1979. Prior to that there was a minimum weight limit of 4 pounds (1.8 kilograms) in the round, established in 1915. This was changed in 1931 to 3.5 pounds (1.6 kilograms) for dressed, head-on fish or 3 pounds (1.4 kilograms) for dressed, head-off fish.

California halibut serve as an important game fish for recreational anglers. Recreationally, California halibut are typically caught using hook-and-line gear (troll or drift/mooch) or by spear. California halibut are mostly taken from vessels, with some fish caught from piers or taken from sandy beaches.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by the California Recreational Fisheries Survey (CRFS), which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

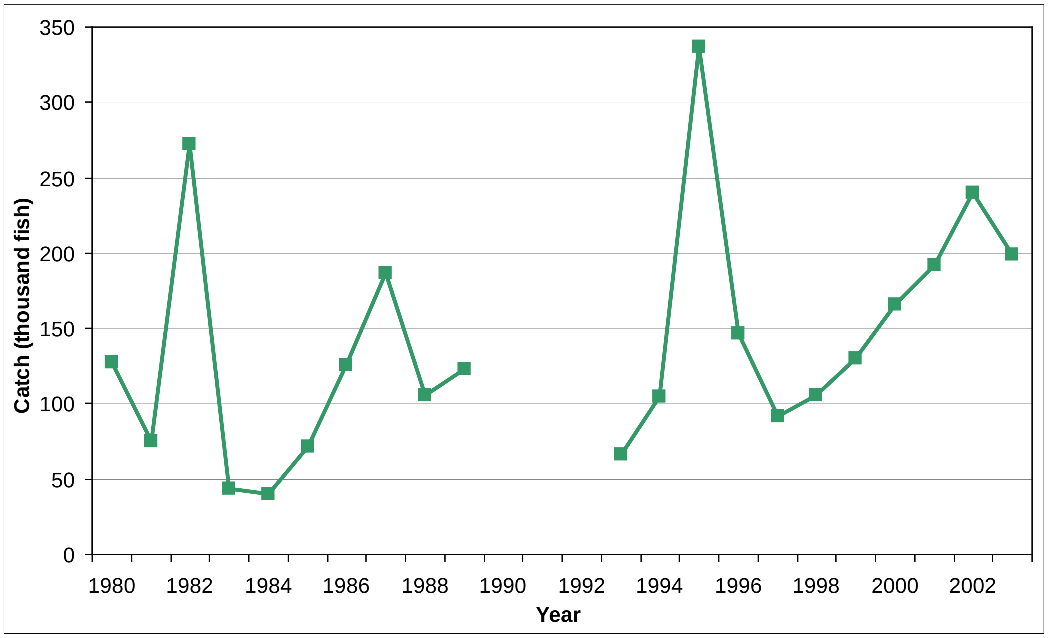

Figure 16-4. California halibut recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

Since 2004, the recreational catch of California halibut has been sampled and the total catch estimated through CRFS (Figure 16-5). The CRFS program samples California halibut caught from private/rental boats, commercial passenger fishing vessels (CPFVs), public piers, and sandy beaches. While the data from MRFSS and CRFS are not comparable, there were several peaks (1982, 1995, 2002, and 2008) in recreational halibut catch. These peaks are possibly due to successful recruitment events resulting from prior El Niño events which provide favorable conditions by keeping larvae near shore where they can settle out. The success of the 2008 fishing season was likely the result of a large year class moving through the San Francisco Bay fishery. These fish were most likely spawned during the 2002-03 El Niño. The 2008 season was also closed to ocean salmon fishing, causing recreational fishermen to target other species, mostly halibut. The decline in the recreational catch since 2008 may have been due to a reduction of individuals from the 2005 year class and poor recruitment conditions since 2003.

Figure 16-5. California halibut recreational catch, 2004-2011. Data source: CRFS data, all fishing modes and gear types combined.

Since 1936, CPFV operators have been required by law to submit accurate logs of their fishing activity, providing an important source of recreational data. The CPFV logbook dataset is one of the Department's most comprehensive datasets documenting recreational California halibut catch. During World War II, many CPFVs were put into military service, thus no logs were submitted or recorded during this period.

There are two major peaks in the CPFV fishery for California halibut with the first occurring in 1948 (143,462 fish) and second in 1964 (141,465 fish) (Figure 16-6). Following World War II, fishing operations resumed at normal capacity with recreational anglers taking up to 10 fish per day with no minimum size. This level of take contributed to record total landings recorded in the1948 season. However, due to the high level of take, total catch following 1948 decreased significantly. Several restrictions, including reducing the bag limit to two fish and establishing a temporary minimum size limit of 22 inches TL (56 centimeters), coupled with good recruitment, resulted in an increase in catch. In 1963 the California halibut bag limit was increased to five fish and the minimum size limit was lifted. The CPFV fishery peaked again in 1964. After the peak in 1964, the total number of fish landed decreased sharply, most likely due to reasons leading to the previous decline and has remained relatively stable for the past four decades. In 2008, the number of California halibut landed by the CPFV fleet increased, mostly due to an excellent fishing season in San Francisco Bay. The San Francisco Bay CPFV fleet also had excellent fishing in 1995 and 2003 (Figure 16-7). As an indicator of the fishery, these three peaks correspond to the three most recent peaks in successful recruitment events for 1- and 2-year old California halibut in San Francisco Bay, with an appropriate lag time for fish to reach minimum legal size (Figure 16-8).

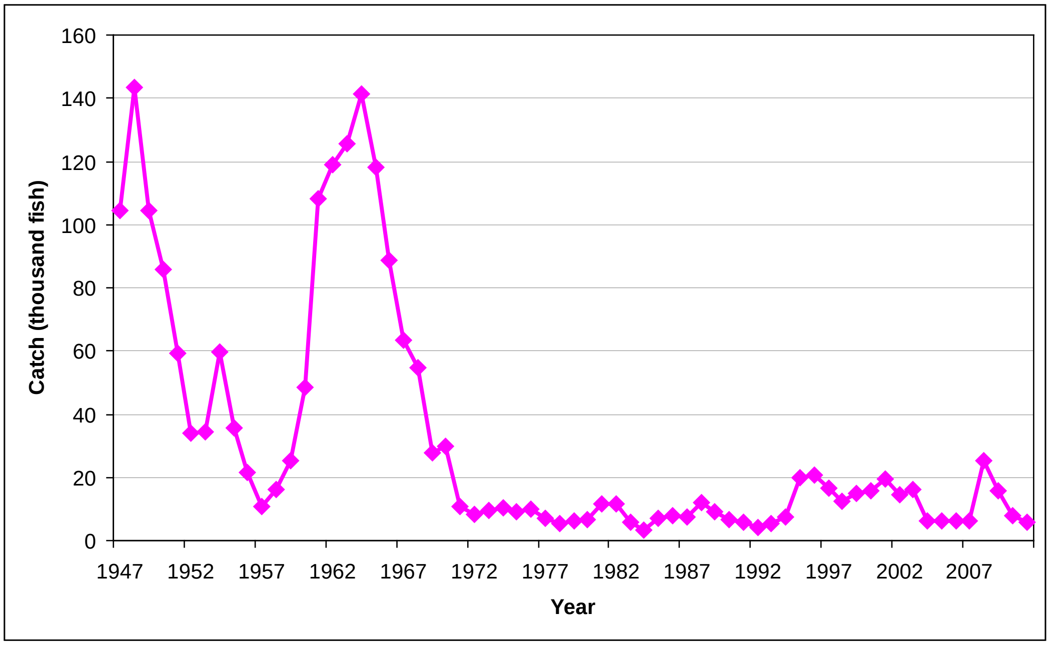

Figure 16-6. California halibut CPFV catch, 1947-2011. Data source Department catch bulletins (1947-1986) and CPFV logbook data (1987-2011).

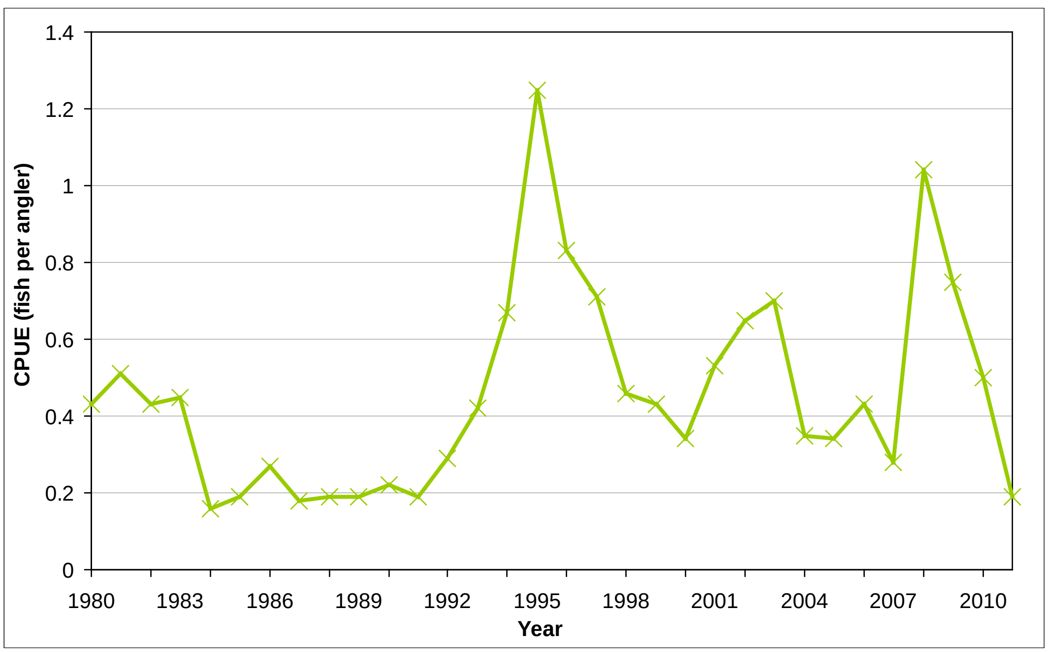

Figure 16-7. California halibut recreational catch per unit effort in San Francisco Bay, 1980-2011. Data source: CPFV logbook data.

The recreational minimum size limit is 22 inches TL (56 centimeters). This basic regulation has been in effect since 1971. When filleted at sea, California halibut fillets must be cut lengthwise and be at least 16.75 inches (42.5 centimeters) long. The recreational season is open year round, with a daily bag/possession limit of three

California halibut north of Point Sur (Monterey County) and five California halibut south of Point Sur.

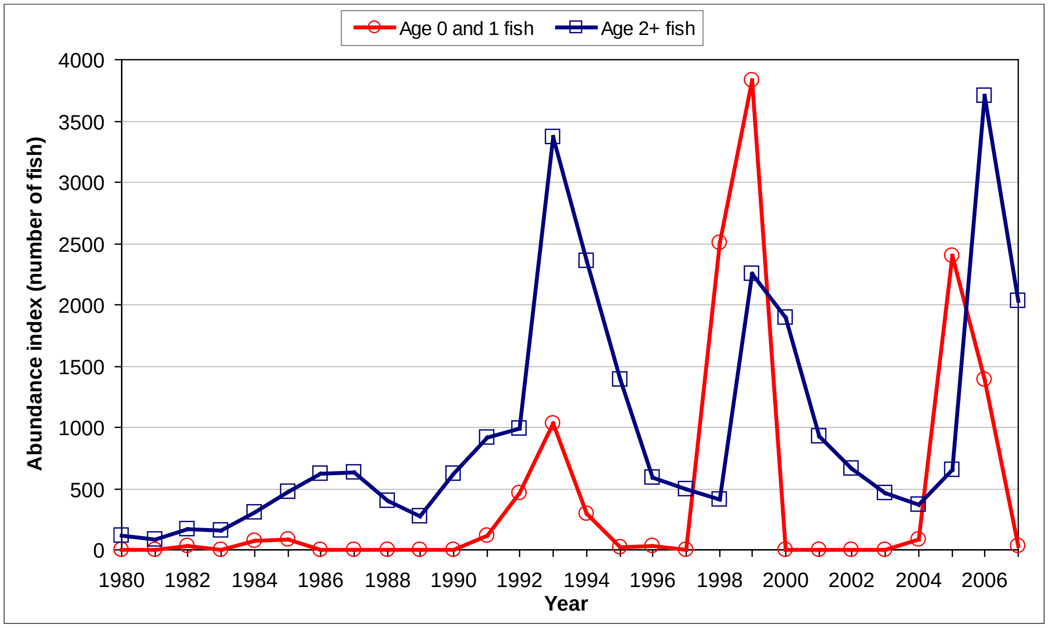

Figure 16-8. California halibut abundance index (number of fish) from San Francisco Bay, 1980-2007. Data source: Department Bay Study data, 1980-2007. Data are composed of summed regional totals that are averaged over the index period (February-October).

Status of Biological Knowledge

Adult California halibut may be found in shallow, sandy nearshore habitats on the west coast of North America from Almejas Bay, Baja California, Mexico to the Quillayute River, Washington, with the species most common south of Bodega Bay. California halibut may be caught in water depths out to 300 feet (91 meters), but are more common in depths less than 100 feet (30 meters). Individual fish can grow up to 5 feet (1.5 meters) in total length and weigh as much as 72 pounds (33 kilograms). The current recreational record is 67 pounds (30 kilograms). California halibut are sexually dimorphic with females growing at a faster rate than males and attaining a larger maximum size. Based on an extensive study conducted in southern California, males mature between 1 and 3 years of age, or 7.5 inches (19 centimeters) and 12.6 inches (32 centimeters), respectively. Females mature between 2 and 7 years of age with 50 percent of females maturing at 4 years. Corresponding lengths at maturity for females begin at 14 inches (36 centimeters), with 100 percent being mature at 23 inches (59 centimeters). California halibut have been aged up to 30 years using otoliths. Ageing of otoliths continues at present by Department staff, and individuals greater than 15 years of age are rare in the sampled catch. The majority of California halibut aged from fishery sampling by the Department have been in the 5- to 8-year old range; this is true for historic samples from the late 1980s as well as those aged from 2007 to 2011.

California halibut fecundity is considered high with mature female California halibut producing up to one million eggs per spawning event. Spawning occurs year round, but based on larval presence in the water column, major spawning events typically occur mid-winter (January/February), summer (June/July), and fall (September/October). As a broadcast spawner, eggs and larvae are subject to direction and intensity of ocean currents. While in the drifting state (around 30 days), larvae tend to be concentrated in the upper 100 feet (30 meters) of the water column. Larval or juvenile California halibut will settle out along the open coast, but survival rate is better in protected bays and estuaries. El Niño events provide better conditions for recruitment by promoting conditions which keep eggs and larvae closer to shore where they may settle out. Annual recruitment to the fishery is dependent upon environmental conditions and is independent of overall stock size.

Several tagging studies have been completed documenting California halibut movement. These studies tagged California halibut from Tomales Bay, central California to Bahía Sebastian Viscaíno, Baja California, Mexico, with the majority of tagging effort in central and southern California. Studies indicate that California halibut tend to not travel great distances, since many tag recoveries were in the same geographic location of capture. For those California halibut that moved, most moved in a southerly direction, especially smaller fish. Some studies indicated that larger fish moved north. California halibut that traveled north tended to do so faster and swam further. In general there has been a direct relationship between total length and movement distance with larger fish traveling greater distances.

California halibut are predatory fish eaters, often hiding themselves such that only the eyes and outline of the fish are visible. Juvenile California halibut eat mostly small crustaceans and some finfish. As California halibut grow, larger finfish, such as Pacific sardine and northern anchovy, and market squid become the dominant food items.

Status of the Population

In 2011, the Department, through the use of a private contractor, completed the first statewide stock assessment of California halibut with separate assessments for areas north and south of Point Conception. The period assessed was 1971-2010. An independent peer review panel concluded that the documents were acceptable, but required additional sampling information before the next assessment. It was suggested that the Department increase gender-specific sampling of the fished population, continue ageing studies, divide southern California into smaller sampling regions to increase precision in analysis, and examine the possible link between the north and south through larval abundance. In addition to the peer review, Department staff conducted an evaluation of the stock assessment using methods learned at a Sea Grant-sponsored workshop in 2008 to evaluate data-poor fisheries. None of the Department’s findings countered the results of the stock assessment.

The stock assessment concluded that the population estimate and status north of Point Conception was considered well above the biomass associated with maximum sustainable yield. This high biomass may be associated with several recent recruitment events, especially in the San Francisco Bay area (Figure 16-8). Favorable environmental conditions, such as El Niño events, appear to be driving recruitment success and fishing was not thought to be a factor in controlling abundance.

South of Point Conception, the California halibut population was estimated to be depleted to 14 percent of historic levels, characterized by a lack of significant recruitment due to poor environmental conditions during the past decade, but population appears sustainable at current levels of harvest. In general flatfish are highly resilient marine finfish with high fecundity, and can respond relatively quickly to favorable environmental conditions with episodes of good recruitment. Southern California halibut stocks were considered depleted by the start of the evaluation period in 1971 due to sustained exploitation; furthermore, it was stated that the southern population was considered exploited since 1916. In response to the assessment, the California Fish and Game Commission (Commission) and the Department agreed that the best current course of action would be to increase monitoring of the fishery (both for catch level and total participation), investigate environmental bottlenecks, fill data gaps through fishery independent survey work, and to revisit the assessment process in 5 years. The assessment did not take into account any benefits from a recently-implemented series of marine protected areas (MPAs), especially those with California halibut habitat. The new southern California MPAs, adopted by the Commission in 2011 and effective January 1, 2012, account for 14 percent of soft bottom habitat within the depth range of California halibut in this region.

There have been limited studies attempting to identify the stock structure of California halibut through the use of genetic information and to evaluate if California halibut are subject to geographic boundaries such as Point Conception. Traditional logic dictates that the environment and fish populations north and south of Point Conception are different, and the contrary results from the recent stock assessments in these areas tend to support that. In addition, the average historical length of sampled California halibut is larger north of Point Conception, which may also indicate differences in population or differences in the level of exploitation. However, a recent study indicated that California halibut, genetically, may be one homogeneous population with migration occurring in a north to south direction. The study found that California halibut had no evidence of genetic differences north or south of Point Conception.

Management Considerations

California halibut has long been an important finfish species to the recreational and commercial fishing interests in California. Since the beginning of the fishery, the California halibut population has been subject to oscillations in abundance, but with a downward trend in southern California. This downward trend is related to poor recruitment coupled with a high exploitation rate. As cited in the 2011 stock assessment, in central California fishing is not a controlling factor, as opposed to environmental and habitat conditions. Since successful recruitment is linked to environmental conditions along with the health and availability of suitable bay/estuary habitat, additional management attention should be paid to these relationships in southern California. It is unlikely that the trend in substantial loss of estuarine habitat over the last century in southern California can be reversed, but water quality improvements during the last four decades will help ensure that the remaining estuarine habitats are viable and productive. While environmental factors are considered in the assessment of any fished species, fishery management actions generally target the users of a resource, thus controlling take. No regulatory changes are suggested at this time, but future management strategies for consideration may include:

- Continue to monitor the fisheries and the status of the stock through sampling, life history, and ageing studies.
- Monitor new shallow, soft-bottom MPAs in southern California to determine if they are effective in protecting mature California halibut in localized areas.
- Increase consultation between Department environmental review and biological staff regarding proposed estuarine projects.
- Explore environmental bottlenecks that influence recruitment.
- Increase fishery-independent survey work to fill data gaps not addressed by fishery-dependent monitoring.

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Further Reading

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For more information on the California halibut stock assessment documents are available on the Department's web site at: http://www.wildlife.ca.gov/marine/sfmp/halibut-assessment.asp.

California halibut commercial landings, 1916-2011.

Year	Pounds	Year	Pounds	Year	Pounds	Year	Pounds
1916	1,500,000	**1940**	861,908	**1964**	1,092,068	**1988**	1,107,207
1917	3,500,000	**1941**	592,911	**1965**	1,128,348	**1989**	1,219,321
1918	2,708,514	**1942**	569,245	**1966**	749,555	**1990**	938,572
1919	2,362,520	**1943**	701,219	**1967**	824,919	**1991**	1,040,864
1920	2,602,043	**1944**	1,111,880	**1968**	649,425	**1992**	885,346
1921	2,340,428	**1945**	1,582,150	**1969**	272,331	**1993**	726,550
1922	2,437,966	**1946**	1,675,280	**1970**	256,398	**1994**	535,018
1923	1,347,243	**1947**	1,172,638	**1971**	336,416	**1995**	771,641
1924	1,528,399	**1948**	1,041,124	**1972**	309,003	**1996**	914,236
1925	1,352,248	**1949**	1,079,501	**1973**	272,466	**1997**	1,325,175
1926	916,794	**1950**	806,279	**1974**	306,290	**1998**	1,187,503
1927	818,517	**1951**	643,279	**1975**	307,785	**1999**	1,314,501
1928	932,289	**1952**	473,620	**1976**	627,574	**2000**	848,411
1929	811,427	**1953**	387,739	**1977**	467,862	**2001**	895,341
1930	896,062	**1954**	444,543	**1978**	441,440	**2002**	941,210
1931	929,306	**1955**	363,834	**1979**	665,546	**2003**	829,214
1932	939,001	**1956**	382,006	**1980**	726,852	**2004**	1,012,791
1933	904,829	**1957**	332,584	**1981**	1,262,265	**2005**	956,303
1934	648,516	**1958**	256,075	**1982**	1,214,375	**2006**	722,873
1935	810,291	**1959**	345,286	**1983**	1,130,363	**2007**	391,666
1936	776,634	**1960**	366,191	**1984**	1,107,019	**2008**	475,903
1937	812,365	**1961**	545,472	**1985**	1,255,966	**2009**	620,720
1938	822,447	**1962**	776,077	**1986**	1,184,296	**2010**	530,422
1939	722,084	**1963**	855,092	**1987**	1,188,596	**2011**	440,906

Data source: Department catch bulletins (1916-1979) and CFIS data (1980-2011), all gear types combined.

California halibut commercial landings (pounds) and value, by gear type, 1990-2011.						
Year	**Hook-and-Line**	**Trawl**	**Gill net**	**Other**	**Total**	**Total value**
1990	87,162	216,168	520,906	114,336	938,572	$1,867,389
1991	81,973	349,252	522,810	86,829	1,040,864	$2,261,386
1992	78,891	465,015	287,638	53,802	885,346	$1,941,747
1993	77,601	356,400	253,111	39,438	726,550	$1,670,242
1994	108,415	279,137	126,313	21,153	535,018	$1,386,484
1995	153,880	388,631	197,395	31,735	771,641	$2,035,167
1996	145,748	491,859	248,138	28,491	914,236	$2,383,535
1997	153,533	728,962	422,072	20,608	1,325,175	$3,228,951
1998	123,326	728,225	308,649	27,303	1,187,503	$2,692,093
1999	124,220	656,099	508,332	25,850	1,314,501	$3,219,251
2000	108,730	339,843	380,971	18,867	848,411	$2,396,974
2001	115,229	442,092	318,644	19,376	895,341	$2,639,996
2002	160,950	506,572	255,420	18,268	941,210	$2,800,037
2003	207,722	422,253	181,513	17,726	829,214	$2,469,477
2004	170,099	631,475	182,849	28,368	1,012,791	$3,067,213
2005	132,524	703,660	106,558	13,561	956,303	$2,958,756
2006	97,875	510,044	103,392	11,562	722,873	$2,700,874
2007	82,023	207,592	97,455	4,596	391,666	$1,832,296
2008	156,307	202,691	112,000	4,905	475,903	$2,286,311
2009	175,516	322,717	119,633	2,854	620,720	$1,867,389
2010	126,681	301,803	98,612	3,326	530,422	$2,261,386
2011	131,209	217,460	91,496	741	440,906	$2,182,099

Data source: CFIS data.

California halibut recreational catch, 1980-2003					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	126,652	**1988**	105,517	**1996**	146,921
1981	75,286	**1989**	123,249	**1997**	91,942
1982	272,473	**1990**	-----	**1998**	106,220
1983	44,224	**1991**	-----	**1999**	129,975
1984	39,922	**1992**	-----	**2000**	166,415

California halibut recreational catch, 1980-2003					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1985	72,016	**1993**	66,145	**2001**	192,115
1986	125,715	**1994**	105,318	**2002**	239,865
1987	187,130	**1995**	337,231	**2003**	199,086

Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1002 are not available.

California halibut recreational catch, 2004-2011.			
Year	**Number of fish**	**Year**	**Number of fish**
2004	45,962	**2008**	74,531
2005	49,225	**2009**	61,676
2006	48,575	**2010**	48,701
2007	35,378	**2011**	25,496

Data source: CRFS data, all fishing modes and gear types combined.

California halibut commercial passenger fishing vessel (CPFV) catch, 1947-2011.					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1947	104,436	**1969**	27,634	**1991**	5,984
1948	143,462	**1970**	29,968	**1992**	4,343
1949	104,639	**1971**	10,598	**1993**	5,335
1950	85,935	**1972**	8,140	**1994**	7,528
1951	59,295	**1973**	9,622	**1995**	19,957
1952	34,158	**1974**	10,292	**1996**	20,619
1953	34,292	**1975**	9,118	**1997**	16,480
1954	59,674	**1976**	10,075	**1998**	12,332
1955	35,802	**1977**	6,982	**1999**	14,939
1956	21,661	**1978**	5,409	**2000**	15,854
1957	10,795	**1979**	6,329	**2001**	19,298
1958	16,192	**1980**	6,517	**2002**	14,668
1959	25,365	**1981**	11,440	**2003**	16,349
1960	48,310	**1982**	11,804	**2004**	6,115
1961	108,011	**1983**	5,682	**2005**	6,174

California halibut commercial passenger fishing vessel (CPFV) catch, 1947-2011.					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1962	118,956	**1984**	3,209	**2006**	6,051
1963	125,669	**1985**	7,090	**2007**	6,026
1964	141,465	**1986**	7,848	**2008**	25,306
1965	118,213	**1987**	7,572	**2009**	15,715
1966	88,726	**1988**	12,001	**2010**	7,810
1967	63,582	**1989**	9,113	**2011**	5,679
1968	54,663	**1990**	6,678		

Data source: Department catch bulletins (1947-1986) and CPFV logbook data (1987-2011), all gear types combined.

17 Groundfish Highlight: Update on the New Federal Individual Fishery Quota Program

Photo: Crew members of the F/V San Giovanni haul in a bottom trawl net near Monterey, California.
Photo Credit: MK Parker, CDFW.

Overview

A new federal West Coast Individual Fishery Quota (IFQ) program began in January 2011 for the groundfish trawl fishery after eight years under development. Limited entry (LE) trawl permit holders are allocated quota shares (fixed portion of the commercial allocation) of groundfish species and can fish their corresponding quota pounds (quota share multiplied by the commercial allocation) or lease them to others--quota shares are not yet eligible for sale or transfer. Landings from 2011 were compared with the past seven years of the fishery to preliminarily identify how the IFQ program may be changing the fishery in California.

Overall in 2011, fewer LE trawl permits were active and landings decreased by more than one third compared to 2010. However, the value of landings in 2011 did not decrease compared to previous years because many Pacific whiting, *Merluccius productus* (also known as hake), fishermen traded their quota shares for higher value sablefish, *Anoplopoma fimbria*, shares. Landings of Pacific whiting decreased by almost 100 percent because these permit holders leased their quota pounds and did not fish in California—only 10,500 pounds (5 metric tons) of Pacific whiting were landed in California in 2011 compared to an average of 8,244,000 pounds (3,740 metric tons) from 2004-2010.

Landings were made in port complexes from Crescent City south to the Morro Bay area; there is no LE trawl fishery in southern California (south of Point Conception). About 42 percent of the 38 participating vessels engaged in gear switching and made landings almost exclusively using non-trawl gears. Many of the vessels that fished using non-trawl gears were in the Morro Bay port complex, which also gained in number of active permits/vessels, number of landings, weight of catch landed and ex-vessel value of landings compared to the previous seven years.

Groundfish

There are over 90 species of marine finfish included in the Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP) that was adopted by the Pacific Fishery Management Council (PFMC) in 1982. Since that time, these species have been jointly managed by the states of California, Idaho, Oregon and Washington, coastal tribes, NOAA Fisheries Service, and the PFMC. In general, the Groundfish FMP guides management of many finfish species found within 200 miles (322 kilometers; Exclusive Economic Zone) of the U.S. Pacific coast off Washington, Oregon, and California.

Many species of groundfish are long-lived and slow growing, which makes them vulnerable to heavy fishing pressure. Prior to the late 1990s, management was much less complex; there were fewer regulations pertaining to groundfish in the commercial and recreational fisheries. Since then, many management changes have occurred in the groundfish fishery. For more joint management information on the groundfish fishery in California, including stock status and the recreational fishery, please see the Status of the Fisheries Report Through 2008, Groundfish Overview section (http://www.wildlife.ca.gov/marine/status/index.asp).

Overcapacity (too many participants competing to catch a limited amount of fish) has been a recurring problem in the commercial groundfish fishery. During the last 20 years, several management programs were implemented to reduce overcapacity in sectors of the fishery.

- In 1994, the groundfish trawl and sablefish fixed gear fisheries became LE fisheries. Vessels qualified for permits using qualifying criteria that capped effort and reduced capacity in the fleet. However, this did not result in a large enough reduction to the fleet and additional actions were taken in subsequent years to further address overcapacity.

- In 2001, a permit stacking program was implemented for the sablefish fixed gear fishery that allows an individual to own and fish multiple permits on a boat.

- In 2003, the PFMC and NOAA Fisheries Service developed and implemented a trawl vessel buyout program to further reduce capacity in the LE trawl sector. Coastwide, 92 trawl vessels sold their permits/vessel as part of the buyout program, representing one third of the fleet.

- In 2008, a LE program was created for all sectors of the Pacific whiting fishery (motherships, catcher-processors, and catcher vessels). The Pacific whiting trawl fishery is another sector of the groundfish fishery that continues to be over-capitalized. The program was implemented as an interim measure until the IFQ program (under development for the entire LE trawl sector) could be implemented.

- In 2009, the West Coast IFQ program was adopted by the PFMC and was implemented in January 2011 through the regulatory authority of NOAA Fisheries Service.

Individual Fishery Quota Program

Individual Fishing Quota (IFQ) programs are limited access privilege programs which control catch levels by granting the privilege to catch a specified portion of the total allowable catch to an individual fisherman, community, or other entity. IFQ programs have been developed in many countries across the globe for more than 250 species. Goals of IFQ programs can be to decrease, or eliminate derby-style fisheries, provide fishery participants with more control over when or where they fish, and to decrease the amount of discarded bycatch of non-target species.

There are 15 IFQ programs currently operating in the United States, and more programs are under development. While most IFQ programs cover only one or a few species, the West Coast IFQ program covers 65 species (Table 17-1), making it the most complex IFQ program in the world currently in operation. Because the program covers many Groundfish FMP species throughout the West Coast, some species on the list are not landed in California in great numbers or at all.

Final adoption of the IFQ program occurred in 2009 and included an IFQ system for the shore based Pacific whiting and non-Pacific whiting fisheries, and a co-op provision for the at-sea (catcher vessel and mothership) Pacific whiting sector. Implementation of the program began in January 2011, and fishing commenced January 11, 2011. Holders of LE trawl permits were allocated quota shares based upon past trawl sector fishery participation and corresponding annual quota pounds for various groundfish species. West Coast IFQ program quota shares are not available for sale or transfer until 2013. The sale/transfer provision will allow current participants to leave the fishery if they desire, and for new entrants to the fishery to purchase their own quota shares. Quota pounds are assigned to a vessel and may be leased to individuals/entities for use.

The West Coast IFQ program for federal groundfish was developed through a lengthy and complex process which began in 2003 to find a more efficient way to prosecute the LE trawl fishery while reducing impacts to overfished species (Table 17-1). Overfished groundfish species, such as yelloweye rockfish and cowcod, are the primary drivers of management restrictions in the federal groundfish fishery—including the LE trawl fishery—their populations will be rebuilding for decades. Of the species covered by the West Coast IFQ program, seven are currently designated as overfished by the PFMC. These seven rebuilding species can only be caught and retained if permittees hold enough shares and corresponding quota pounds for the overfished species caught. Lack of quota shares for overfished species, such as rebuilding rockfishes, can shut down a permittee until additional costly, quota can be leased—so individual permittees typically avoid catching rebuilding species.

Table 17-1. List of federally managed groundfish species and species complexes included in the trawl IFQ program.
Roundfish
Lingcod (*Ophiodon elongatus*) Pacific cod (*Gadus macrocephalus*) Pacific whiting (*Merluccius productus*) Sablefish (*Anoplopoma fimbria*)
Flatfish
Dover sole (*Microstomus pacificus*) English sole (*Parophrys vetulus*) **Petrale sole (*Eopsetta jordani*)**[1] Arrowtooth flounder (*Atheresthes stomias*) Starry flounder (*Platichthys stellatus*) Other flatfish stock complex[2]
Rockfish
Pacific ocean perch (*Sebastes alutus*) north of 40°10' N. lat Widow rockfish (*S. entomelas*) **Canary rockfish (*S. pinniger*)** Chilipepper rockfish (*S. goodei*) south of 40°10' N. lat **Bocaccio (*S. paucispinus*)** south of 40°10' N. lat Splitnose rockfish (*S. diplopora*) south of 40°10' N lat Yellowtail rockfish (*S. flavidus*) north of 40°10' N. lat Shortspine thornyhead (*Sebastolobus alascanus*) Longspine thornyhead (*Sebastolobus altivelis*) north of 34°27' N. lat **Cowcod (*S. levis*) south of 40°10' N. lat** **Darkblotched rockfish (*S. crameri*)** **Yelloweye rockfish (*S. ruberrimus*)** Minor Rockfish shelf complex[3] Minor Rockfish slope complex[4]
[1]Species listed in **bold** are considered overfished under the Groundfish FMP.
[2] Other flatfish includes butter sole (*Isopsetta isolepis*), curlfin sole (*Pleuronichthys decurrens*), flathead sole (*Hippoglossoides elassodon*), Pacific sanddab (*Citharichthys sordidus*), rex sole (*Glyptocephalus zachirus*), rock sole (*Lepidopsetta bilineata*), and sand sole (*Psettichthys melanostichtus*).
[3] Minor rockfish shelf complex includes bronzespotted (*Sebastes gilli*), chameleon (*S. phillipsi*), dusky (*S. ciliatus*), dwarf-red (*S. rufinanus*), flag (*S. rubrivinctus*), freckled (*S. lentiginousus*), greenblotched (*S. rosenblatti*), greenspotted (*S. chlorostictus*), greenstriped (*S. elongatus*), halfbanded (*S. semicinctus*), harlequin (*S. variegatus*), honeycomb (*S. umbrosus*), Mexican (*S. macdonaldi*), pink (*S. eos*), pinkrose (*S. simulator*), pygmy (*S. wilsoni*), redstripe (*S. proriger*), rosethorn (*S. helvomaculatus*), rosy (*S. rosaceus*), shortbelly (*S. jordani*), silvergrey (*S. brevispinus*), speckled (*S. ovalis*), squarespot (*S. hopkinsi*), starry (*S. constellatus*), stripetail (*S. saxicola*), swordspine (*S. ensifer*), tiger (*S. nigrocinctus*), and vermilion (*S. miniatus*) rockfishes.
[4] Minor rockfish slope complex includes aurora (*Sebastes aurora*), bank (*S. rufus*), blackgill (*S. melanostomus*), redbanded (*S. babcocki*), rougheye (*S. aleutianus*), sharpchin (*S. zacentrus*), shortraker (*S. borealis*), and yellowmouth (*S. reedi*) rockfishes.

Development of the IFQ program included input from state and federal governments, non-governmental organizations, the fishing industry and fishing communities, and individuals. The West Coast IFQ program regulations are included within the Groundfish FMP as Amendment 20 and implemented through the Federal Register, 50 CFR, Part 660. Due to the complex nature of the West Coast IFQ program, several trailing actions to Amendment 20 have been developed through the PFMC to address unforeseen and emerging issues within the new fishery. These include exemptions for state-managed trawl fisheries, allowing stacking of multiple LE trawl sector permits on one vessel, providing flexibility in sector set-asides to redistribute unharvested allocations to the fleet, and forming risk pools for overfished species so that individuals and communities can work together to share quota pounds for overfished species and allow greater amounts of target species to be taken.

Total Statewide Landings

In this report, "landings" refers specifically to those landings attributed to LE trawl sector groundfish landings. Landings from 2011 were compared with the past seven years of the fishery to preliminarily identify how the IFQ program may be changing the fishery. Fishing activity and landings information was compiled from January through December of each year from 2004-2011. Landings information are not provided prior to 2004 due to large differences in fishery management before and after that year (e.g., vessel buyout program, implementation of Rockfish Conservation Areas) which make comparisons of landings and fishery behavior before and after that year inappropriate.

Total Statewide Landings (including Pacific whiting)

Total statewide pre-IFQ (from 2004-2010) landings made by LE trawl permits averaged just under 20.5 million pounds (9298 metric tons) and showed a negative trend (Figure 17-1). Landings from 2011 totaled 11.2 million pounds (5091 metric tons), a decrease of 47 percent compared to the average yearly pre-IFQ landings—mainly due to a lack of substantial Pacific whiting landings. However, total ex-vessel value of pre-IFQ landings showed a positive overall trend (Figure 17-1) which continued in 2011. While the average price per pound for Dover sole and sablefish had been increasing in recent years, a drastic increase of $0.12 and $0.40 respectively, occurred in 2011 compared to average prices from 2010. The increased price per pound for Dover sole and sablefish, combined with an increased domestic and international demand for U.S. west coast groundfish catch, resulted in landings with an ex-vessel value of more than $10 million in 2011; this was a 13 percent increase in total sector value compared to the average yearly value of pre-IFQ LE trawl sector landings

In 2011, 38 vessels and 39 permits actively fished under the IFQ system in California, compared to an average of 49 vessels and permits that participated in the LE trawl sector fishery each year from the pre-IFQ time period. This represents a 22 percent decrease in permit and vessel participation for 2011. The vessels and permits active in California in previous years, but not active during 2011, were almost exclusively those which historically harvested Pacific whiting and were based out of Oregon.

Figure 17-1. Federal groundfish LE trawl fishery landings and value, 2004-2011. Data source: PacFIN data, all species combined including Pacific whiting.

Landings of Pacific Whiting

From 2004-2010, annual landings of Pacific whiting ranged between about 4 and 12 million pounds (1,800-5,430 metric tons), averaging 8.25 million pounds (3740 metric tons). Landings of Pacific whiting fluctuated from year-to-year, but showed an overall negative trend from 2004-2011 (Figure 17-2). Stock assessments showed a decreasing abundance of Pacific whiting and, consequently, annual catch limits were reduced. The large decrease in landings during 2009 was due to a “stand down” within the fleet; as the fishery approached overfished species bycatch limits, fishery participants stopped fishing and did not extract the entire optimum yield for the year. In 2011, landings of Pacific whiting in California decreased sharply to just over 10,500 pounds (about 5 metric tons) because the holders of Pacific whiting quota shares in California traded their Pacific whiting quota pounds for more valuable sablefish quota pounds. The lack of Pacific whiting landings during 2011 accounts for almost all of the decrease in total groundfish landings that year. However, no decline in overall groundfish ex-vessel value occurred because Pacific whiting is a high volume, low value fishery. The average annual pre-IFQ ex-vessel value of the Pacific whiting fishery in California was about $500,000; during 2011 the total ex-vessel value of Pacific whiting landings in California was $83.

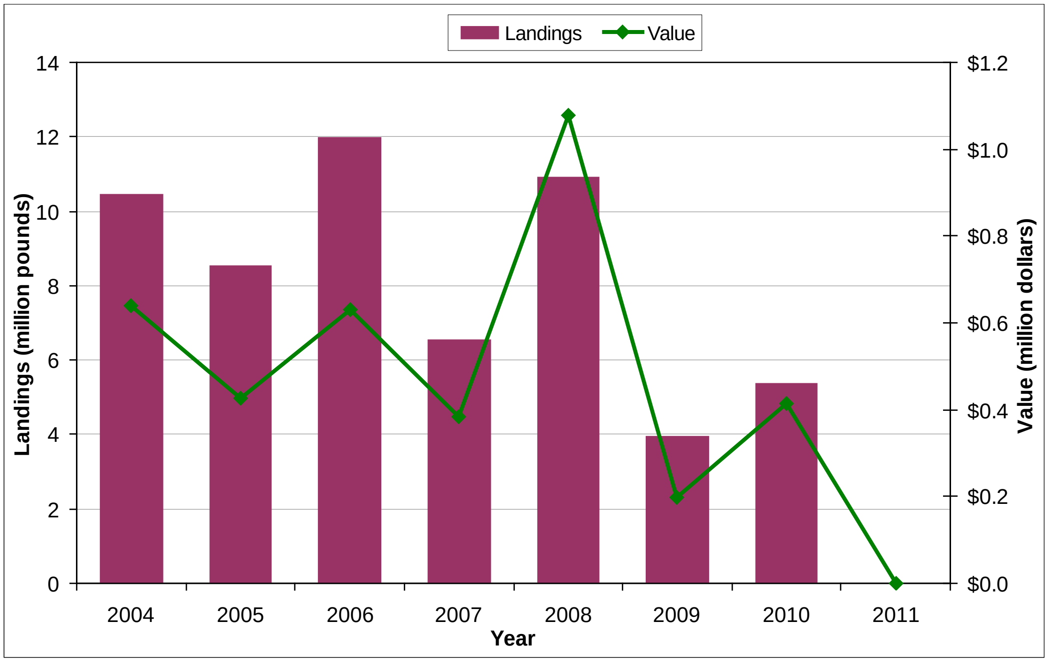

Figure 17-2. Pacific whiting LE trawl landings, 2004-2011. Data source: PacFIN data.

<u>Landings of Non-Whiting Groundfish</u>

Approximately 11,213,000 pounds (5087 metric tons) of non-Pacific whiting landings were reported for 2011. This is a 15 percent decrease compared to the average pre-IFQ landings (Figure 17-3) but within the pre-IFQ period range. However, there was an eighteen percent increase in ex-vessel value in 2011, compared to the average pre-IFQ ex-vessel value, mostly due to the increased value of Dover sole and sablefish.

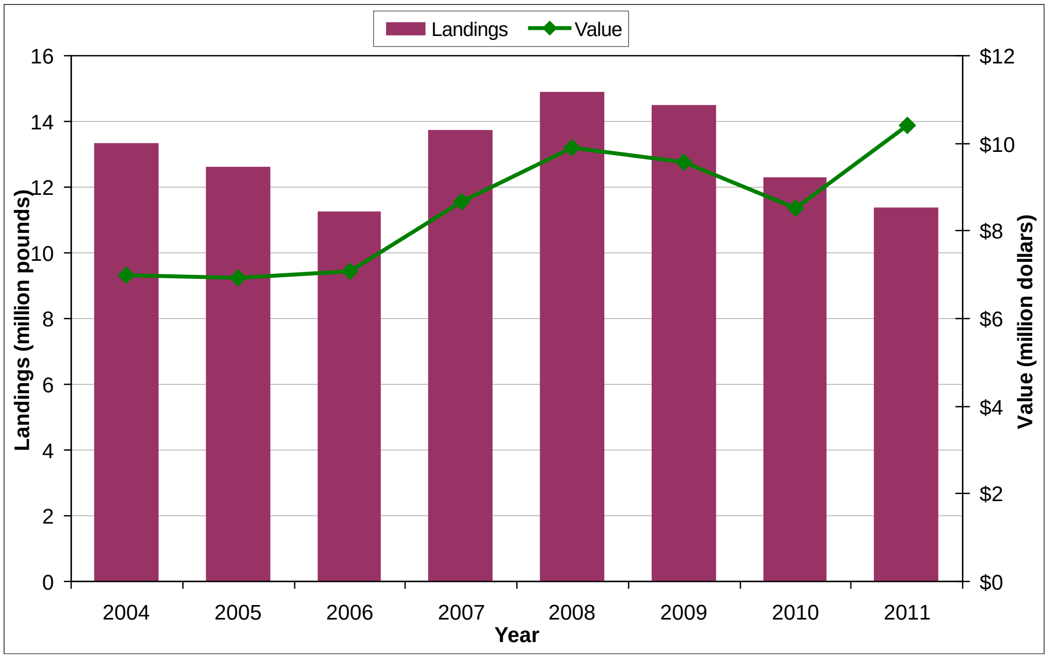

Figure 17-3. Non-whiting federal groundfish LE trawl landings and value, 2004-2011. Data source: PacFIN data, all species combined except Pacific whiting.

<u>Landings by Month</u>

Landings from the LE trawl fishery were slow to accumulate during the first half of 2011 due to: 1) the fishery participants still learning how to operate their businesses within the IFQ program, and, 2) the strong Dungeness crab fishery, which delayed changing both gears and fishing activities from crab to groundfish. June 2011 was the first month of the year during which non-Pacific whiting landings were comparable to the average pre-IFQ landings [Figure 17-4; approximately 1.1 million pounds (520 metric tons)]. From August through December 2011, the monthly non-Pacific whiting landings exceeded the average pre-IFQ monthly landings (Figure 17-4) by as much as 470,000 pounds (213 metric tons) and in December exceeded the average pre-IFQ landings by 40 percent. The ex-vessel value and landings of non-Pacific whiting in 2011 display a similar trend; the ex-vessel value from 2011 exceeded the average pre-IFQ monthly value from June through December (Figure 17-4), and exceeded the average pre-IFQ monthly ex-vessel value by $725,000 in September.

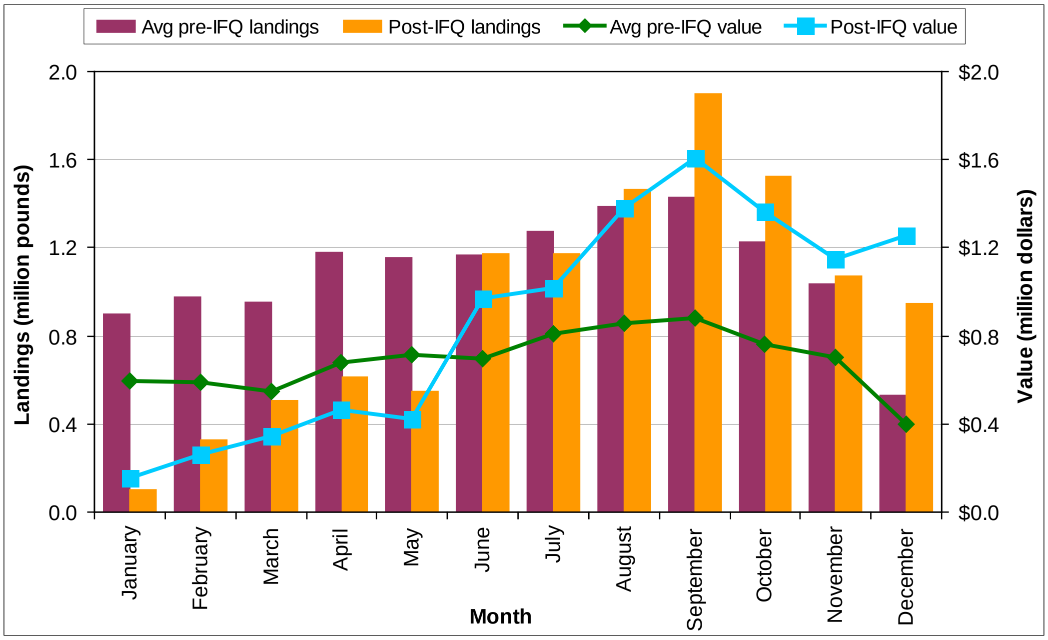

Figure 17-4. Non-whiting federal groundfish LE trawl fishery monthly landings and value, pre-and post-IFQ implementation. Data source: PacFIN data, all species combined except Pacific whiting.

Landings by Port Complex

Effort in the LE trawl sector in California is focused primarily north of Fort Bragg (Figure 17-5). Since 2006 there have been no landings attributable to LE trawl permits south of Morro Bay. Average pre-IFQ landings in the Eureka and Crescent City port complexes ranged from 5 million to just under 10 million pounds (2267 to 4540 metric tons) landed per year. Much of the effort in these port complexes during the pre-IFQ period focused on the Pacific whiting fishery. A large drop occurred in landings in these port complexes in 2011, due to the lack of Pacific whiting landings. The large drop in landings during 2011 in the San Francisco port complex is due, in large part, to reductions in landings of Petrale sole and other co-occurring species (see Species Composition above). Conversely, landings and value of landings in the Morro Bay port complex increased during 2011, compared to the pre-IFQ landings average; more vessels were fishing than in previous years due to the high market value of sablefish.

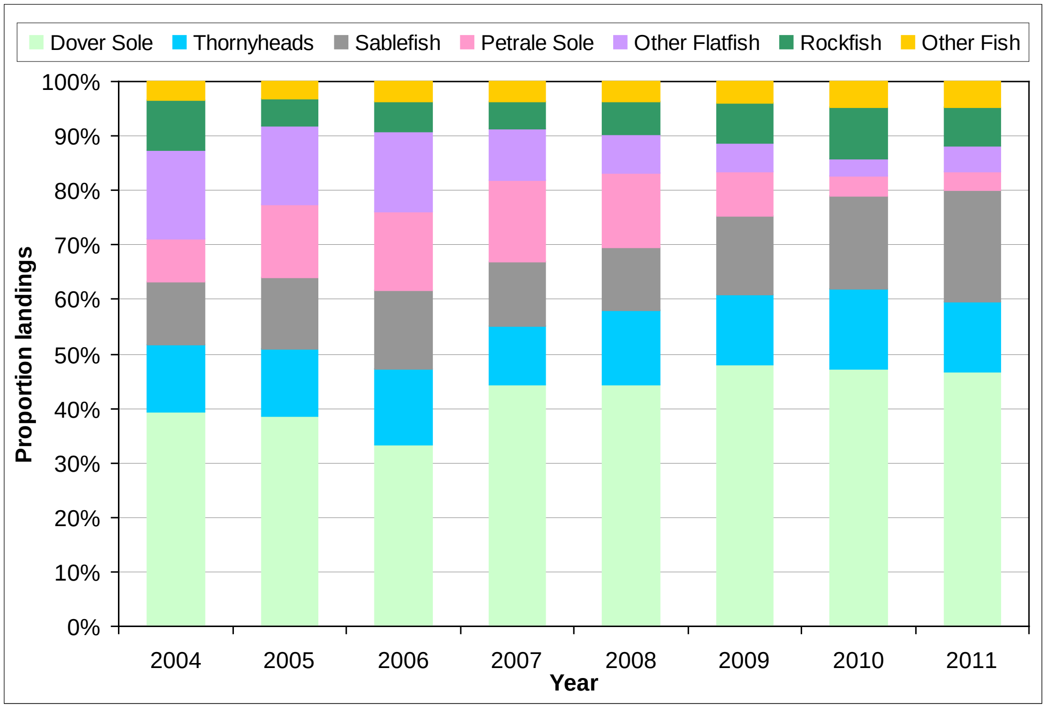

Figure 17-5. Non-whiting federal groundfish LE trawl fishery landings by species, 2004-2011. Data source: PacFIN data, all species combined except for Pacific whiting.

Gear Switching

Part of the IFQ program is referred to as gear switching and it allows IFQ pounds to be harvested using fixed gear (also known as non-trawl, which includes trap and hook-and-line gears). Gear-switching from trawl to fixed gear is allowed once in the same calendar year per permit and landings continue to count against one's quota allowance. The use of trawl and fixed gears on the same trip is not allowed. The purpose of gear switching is to promote the development and use of innovative gears and fishing techniques, particularly the use of fishing gears that are considered to be less detrimental to the ocean environment, specifically the sea floor. In 2011, 10 percent of the weight of non-Pacific whiting landings from the IFQ program were made using non-trawl gear and 16 of the 38 vessels (or 42 percent) participating in the fishery made landings that counted against their quota using fixed gears. Of the species covered by the IFQ program, sablefish was the most frequently landed species using fixed gears during 2011. That year, 2.2 million pounds (1010 metric tons), or 48 percent, of the sablefish IFQ landings were made using fixed gears, which generally command higher market prices than fish caught using trawl gears.

Species Composition

Landings of all species and species groupings decreased in 2011, except for sablefish, which experienced a 20 percent increase in landings compared to the average pre-IFQ period. Dover sole, thornyhead, and sablefish (DTS) complex landings increased approximately 15 percent from 2004-2011, accounting for 80 percent of non-whiting landings (Figure 17-6) in 2011. Landings of DTS complex species accounted for $6.9 million, or 88 percent, of the total 2011 LE trawl revenue. Conversely, landings of Petrale sole and other flatfish, besides Dover sole, declined sharply beginning in 2009 due to the overfished status determination for Petrale sole (2009) and subsequent management restrictions adopted to reduce landings of Petrale sole (for more information, see the section on Petrale Sole in this report). Since multiple species of flatfish are often caught together in the trawl sector, restrictions to Petrale sole landings also affected landings of other flatfish species, other than Dover sole.

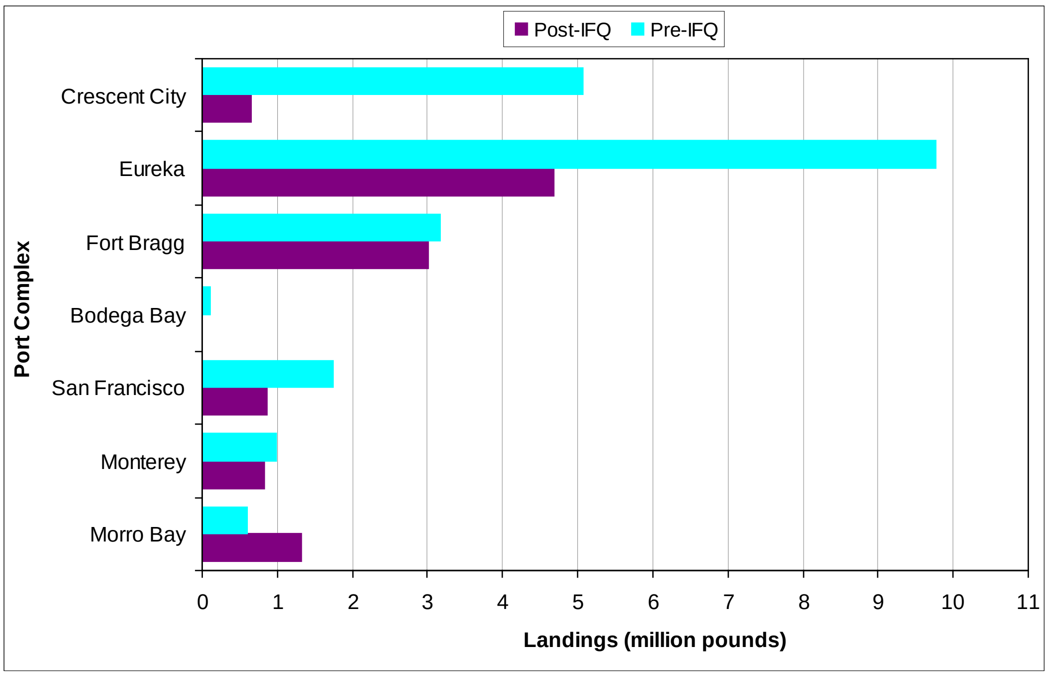

Figure 17-6. Federal groundfish LE trawl fishery landings, pre- and post-IFQ implementation. Data source: PacFIN data, all species combined including Pacific whiting. Pre-IFQ data are averaged from 2004-2010, post-IFQ data are from 2011. No LE trawl landings were made south of Morro Bay.

Catch of Overfished Species

Historically, accounting for bycatch of overfished species has been complicated and, as a result, initially distributing limited quota shares for overfished species was challenging. Retention of overfished species was prohibited, so few landings were available with which to distribute catch shares based upon past fishing effort. In addition, obtaining information at a state level can also be challenging. Overfished species quota shares are very limited, but often necessary to prosecute the fishery, so their use has significant importance to IFQ program development and success.

The IFQ program requires 100 percent observer coverage for all LE trawl trips, and all catch of overfished species is accounted for, even though much is still discarded at sea. Cowcod landings provide some indication of whether overfished species bycatch knowledge is improving because cowcod are only caught in California and have a very low bycatch quota. During the pre-IFQ period, landings of cowcod were only reported in 2004 (65 pounds; 29 kilograms) and 2007 (758 pounds; 344 kilograms). Cowcod were likely encountered more often than that, but were discarded at sea and therefore not in reported landings. West Coast Groundfish Observer Program data provides more complete overfished species catch data than landings alone, but prior to the IFQ program's implementation, not all LE trawl trips had a West Coast Groundfish Observer onboard. During the first year of the IFQ program and full observer coverage, 39 pounds (18 kilograms) of cowcod were caught in California and counted against the overfished species quota pounds; landings records report only 32 pounds (15 kilograms) of cowcod landed during the same period. This 100 percent tracking will provide better information for future management decisions as total catch amounts will be known.

Catch Per Unit Effort

Catch-per-unit-effort (CPUE), measured as the average number of pounds of fish landed per trip, can be an indicator of the efficiency of the fleet and/or the health of the fishery resource. The overall CPUE of the LE trawl fishery fluctuated from year to year and was heavily influenced by Pacific whiting landings. Years when more Pacific whiting were landed had higher CPUE values than years with less Pacific whiting (Figure 17-7). Total LE trawl sector CPUE was 15,188 pounds (6.89 metric tons) during 2011, which is only 560 pounds (0.25 metric tons) less than the average pre-IFQ CPUE.

The largest decrease in CPUE for Pacific whiting landings (Figure 17-8) occurred between 2010 and 2011 which would be expected since landings during 2011 decreased by almost 100 percent compared to pre-IFQ years. Prior to the decline of Pacific whiting landings during 2011, Pacific whiting generally had a high CPUE—often more than 100,000 pounds (45 metric tons) per trip, because of the high volume nature and limited season length of the Pacific whiting fishery.

When Pacific whiting are removed from the overall landings (Figure 17-7), a positive trend of increasing CPUE is seen in the non-Pacific whiting landings. While fewer vessels participated in the fishery during 2011, and fewer trips were made, the average per trip weight of non-Pacific whiting landings increased 27 percent compared to 2010. The CPUE for non-Pacific whiting landings in 2011 was 15,174 pounds (6.88 metric tons), which is 5,392 pounds (2.45 metric tons) more than the pre-IFQ period average non-Pacific whiting CPUE – meaning the fleet was more efficient.

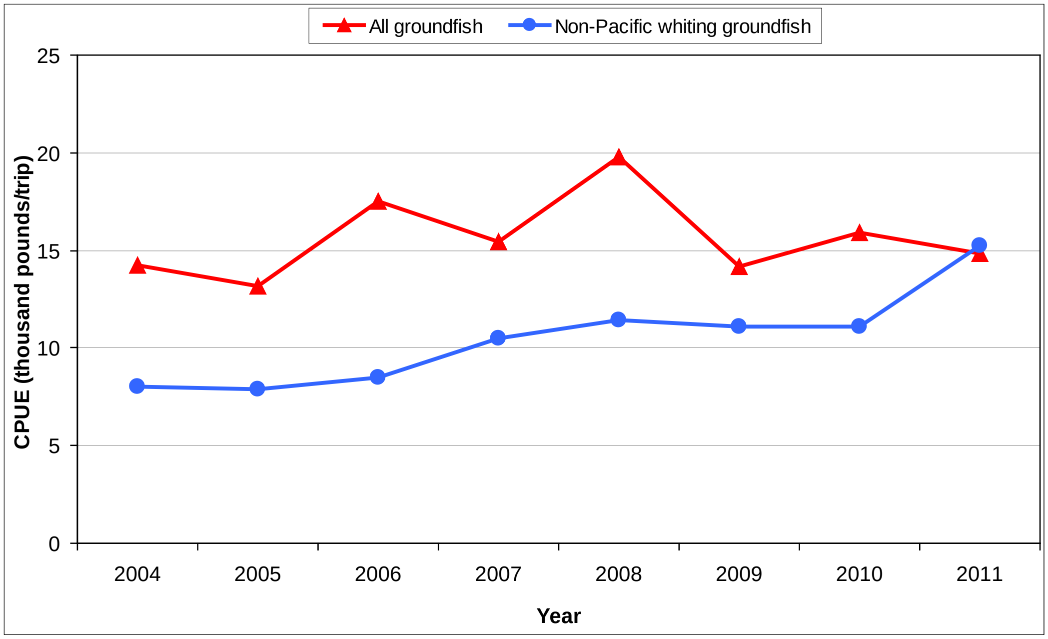

Figure 17-7. Federal groundfish LE trawl fishery CPUE (pounds per trip), 2004-2011. Data source: PacFIN data.

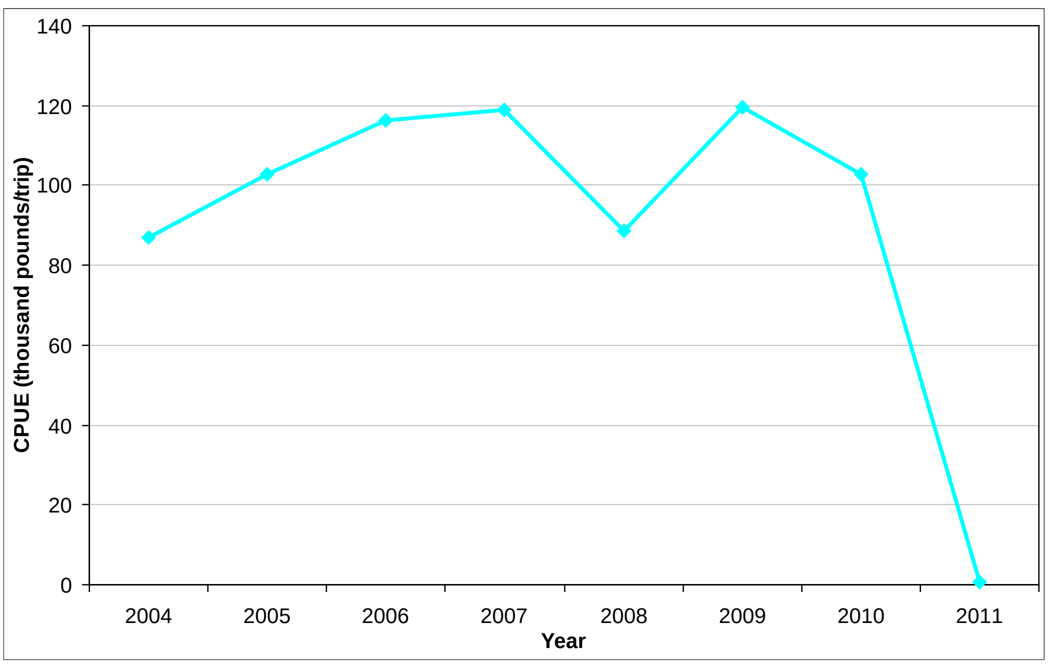

Figure 17-8. Pacific whiting federal LE trawl CPUE (pounds per trip), 2004-2011. Data source: PacFIN data.

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Further Reading

Branch TA. 2009. How do individual transferable quotas affect marine ecosystems? Fish and Fisheries 10(1):39–57.

Chu C. 2009. Thirty years later: the global growth of ITQs and their influence on stock status in marine fisheries. Fish and Fisheries 10(2):217-230

Sanchirico JN, Holland D, Quigley K, Fina M. 2006. Catch-quota balancing in multispecies individual fishing quotas. Marine Policy 30(6):767-785

For more information on the federal IFQ program go to the PFMC's website at: http://www.pcouncil.org/groundfish/fishery-management-plan/fmp-amendment-20/

or visit the NOAA Fisheries Service website at:

http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Trawl-Program/index.cfm

For more information on groundfish and groundfish management in California go to the California Department of Fish and Wildlife's Groundfish Central website at:

http://www.wildlife.ca.gov/marine/groundfishcentral/index.asp.

Groundfish LE trawl landings and value, 2004-2011.

	Non-Pacific whiting groundfish		Pacific whiting		All groundfish	
Year	**Pounds**	**Value**	**Pounds**	**Value**	**Pounds**	**Value**
2004	13,325,265	$6,989,275	10,453,874	$640,860	23,779,139	$7,630,136
2005	12,596,050	$6,928,066	8,543,526	$427,176	21,139,576	$7,355,243
2006	11,259,883	$7,089,111	11,968,718	$630,709	23,228,601	$7,719,820
2007	13,719,101	$8,682,936	6,541,721	$384,667	20,260,822	$9,067,603
2008	14,887,327	$9,893,611	10,900,438	$1,079,336	25,787,764	$10,972,948
2009	14,460,122	$9,583,530	3,950,314	$197,083	18,410,436	$9,780,612
2010	12,281,157	$8,507,844	5,351,328	$413,995	17,632,485	$8,921,839
2011	11,351,343	$10,398,366	10,504	$83	11,361,847	$10,398,449

Data source: PacFIN data, all species including Pacific whiting.

Non-Pacific whiting groundfish LE trawl landings by month, 2004-2011.				
	Pre-IFQ		Post-IFQ	
Month	**Pounds**	**Value**	**Pounds**	**Value**
January	899,217	$595,292	98,464	$155,778
February	976,863	$589,645	329,403	$261,366
March	952,048	$545,227	508,251	$346,877
April	1,177,161	$681,538	613,623	$466,256
May	1,155,913	$715,934	545,404	$420,318
June	1,164,067	$696,046	1,172,392	$968,007
July	1,275,913	$807,716	1,174,770	$1,017,883
August	1,389,426	$857,341	1,461,428	$1,383,311
September	1,431,008	$883,761	1,901,029	$1,609,726
October	1,228,824	$764,760	1,525,949	$1,365,346
November	1,037,941	$702,637	1,071,491	$1,148,894
December	530,034	$399,297	949,139	$1,254,602

Data source: PacFIN data, all species combined except for Pacific whiting. Pre-IFQ data are averaged from 2004-2010, post-IFQ data are from 2011.

Groundfish LE trawl landings by port complex, 2004-2011.		
Port complex	**Pre-IFQ Pounds**	**Post-IFQ Pounds**
Crescent City	5,073,206	656,936
Eureka	9,763,915	4,673,853
Fort Bragg	3,172,106	3,012,512
Bodega Bay	110,168	5,733
San Francisco	1,748,154	866,239
Monterey	982,009	819,131
Morro Bay	601,713	1,327,442

Data source: PacFIN data, all species combined including Pacific whiting. Pre-IFQ data are averaged from 2004-2010, post-IFQ data are from 2011. No LE trawl landings were made south of Morro Bay.

18 Longnose skate, *Raja rhina*

Longnose skate, *Raja rhina*. Photo credit: Department archives

History of the Fishery

There is no directed commercial fishery for longnose skate in California; however, longnose skate is taken incidentally as bycatch and sold when fishing for other groundfish species, primarily sablefish and Dover sole. The skate fishery in California is exclusively commercial due to their deep water habitat and plays a moderate role in the seafood industry. Landings in the commercial skate fishery in California have been documented by the California Department of Fish and Wildlife since 1916. Despite historical record keeping, it is difficult to determine what proportion of these landings were composed of Longnose skate (*Raja rhina*) because a general “unspecified” skate category was used when recording landings rather than individual market categories to distinguish between various skate species. In addition to longnose skate, the general “unspecified” skate category is also comprised of Big skate (*Raja binoculata*), California skate (*Raja inornata*), shovelnose guitarfish (*Rhinobatos productus*), and thornback skate (*Platyrhinoidis triseriata*). These combined commercial skate landings varied widely in the past due to a combination of fluctuations in market demand and changes to fishing regulations. From 1916-1989, the skate catch ranged from a low of 50,419 pounds (23 metric tons) in 1944 to a high of 631,420 pounds (286 metric tons) in 1981. Throughout the last two decades, landings of all skates peaked in 1997 at 2.9 million pounds (1315 metric tons) with an ex-vessel value of $575,000 (Figure 18-1).

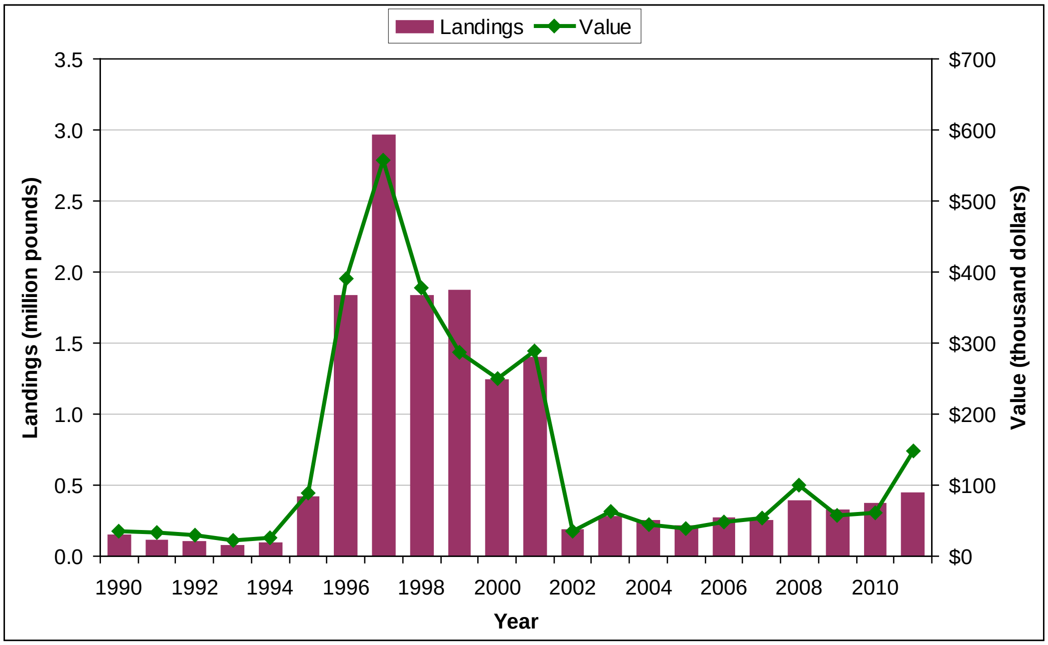

Figure 18-1. Skate commercial landings and value, 1990-2011. Data source: Commercial Fisheries Information System (CFIS) data, all species and gear types combined.

Longnose skate are easily distinguishable from other skate species, although it is still commonly reported on landing receipts as “unspecified skate”. Over the last several years, changes in management resulted in better information on longnose skate landings. Regulatory sorting requirements were implemented requiring longnose skate to be separated. In addition, dockside sampling protocols were expanded to include sampling of all skate species, resulting in increased identification and separation of species. As a result of these changes, it is apparent that longnose skate is the dominate skate species caught in California (Figure 18-2), while the other skate species are landed to a much lesser extent (Figure 18-3).

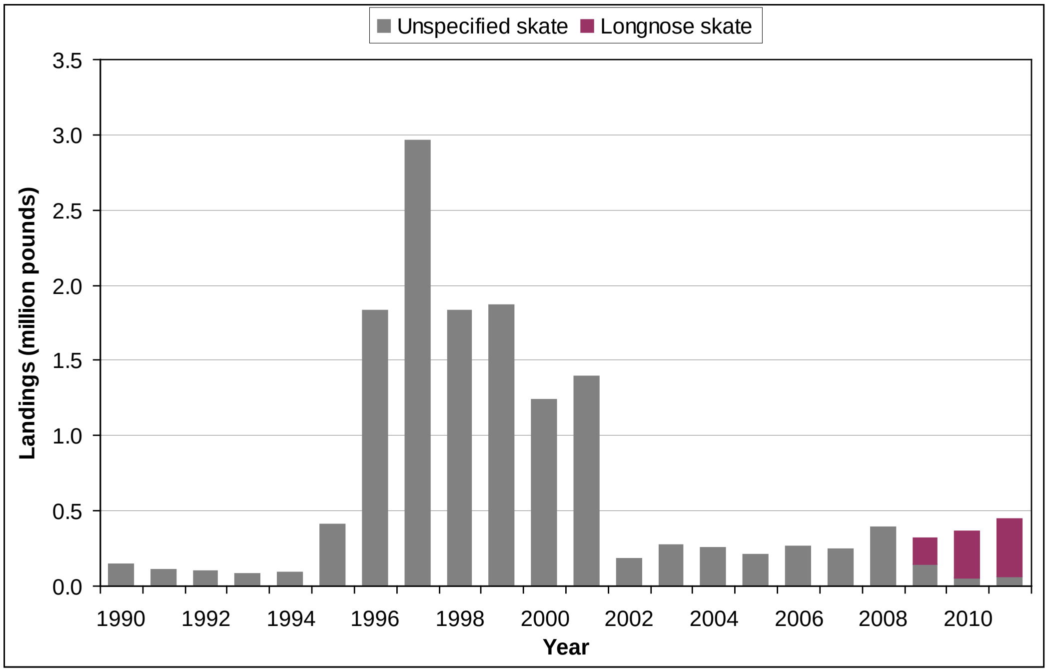

Figure 18-2. Longnose skate and unspecified skate commercial landings, 1990-2011. Data source: CFIS data, all gear types combined.

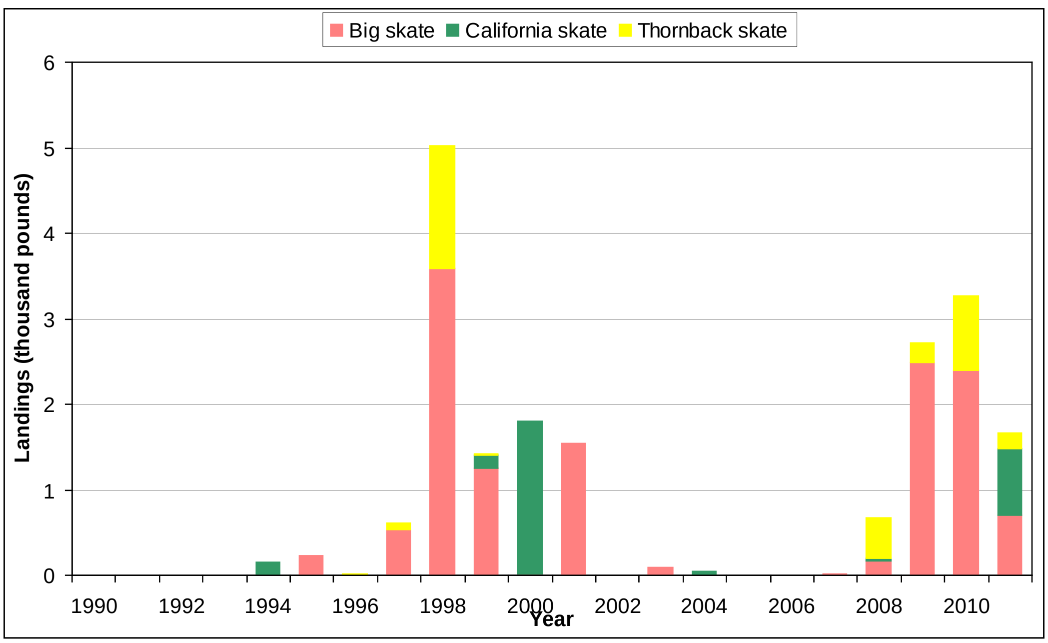

Figure 18-3. Big, California, and thornback skate commercial landings, 1990-2011. Data source: CFIS data, all gear types combined**.**

Longnose skate is incidentally taken while vessels are targeting other deep water groundfish species such as sablefish and Dover sole. As a result of their large size and wing span, it has been a common practice for vessel crews to “wing” skates by removing the marketable pectoral fins and discarding the carcass in order to save space onboard rather than storing skates in a whole condition. This practice contributed to the difficulty of identifying and recording landings of skates by correct species. Beginning in 2009, existing regulatory authority was enforced to disallow the practice of "winging" in order to more accurately record species composition and estimate life history parameters. There was initial concern that landing large whole skates, in addition to mandatory sorting, would impose time and safety constraints on industry and groundfish sampling staff that would prevent compliance, and possibly encourage maximal discarding at sea. Despite these concerns, landings are being separated; now the majority of receipts record the longnose skate market category rather than the unspecified skate category, and sampling information has been safely obtained from both market categories (Figure 18-2). Accordingly, industry now spends some extra time sorting, but overall landings were not negatively impacted by this requirement. Smaller vessels were moderately impacted because they could not accommodate the onboard space necessary to separate and land longnose skate whole. However, these smaller vessels were rarely encountering skates species, so the overall amount of discard was negligible.

From 1990 to 2011, skates were almost exclusively caught with trawl gear (96 percent average), while minimal amounts were taken with hook-and-line and gill net gears. When market demand peaked from 1995 to 2001, an average of 75 percent of skates were landed in northern California—in the Crescent City and Eureka port complexes. In 2010 and 2011, there was a southern shift in landings with the majority coming from Eureka and Fort Bragg (Figure 18-4). This was likely due to changes in the trawl fishery and market demand.

Longnose skate are considered an incidental species within the groundfish fishery in that they have never been individually targeted in California waters. Instead, they are caught in the process of targeting other groundfish species with high market demand and value, such as sablefish. Despite being taken incidentally, the commercial fishing industry has utilized longnose skate rather than discarding at sea, often at substantially lower market value than other more lucrative and targeted groundfish species. In 2010 and 2011, the median price for longnose skate was $0.40 per pound ($ 0.18 per kilogram). In 2010, longnose skate total ex-vessel value was $48,829, with an average price of $0.16 per pound ($0.07 per kilogram). In 2011, the total ex-vessel value was $130,000 with an average price of $0.34 per pound ($0.15 per kilogram). The increase in ex-vessel value resulted from a combination of increased landings of longnose skate with a corresponding decline in the unspecified skate category, and likely changes in market demand.

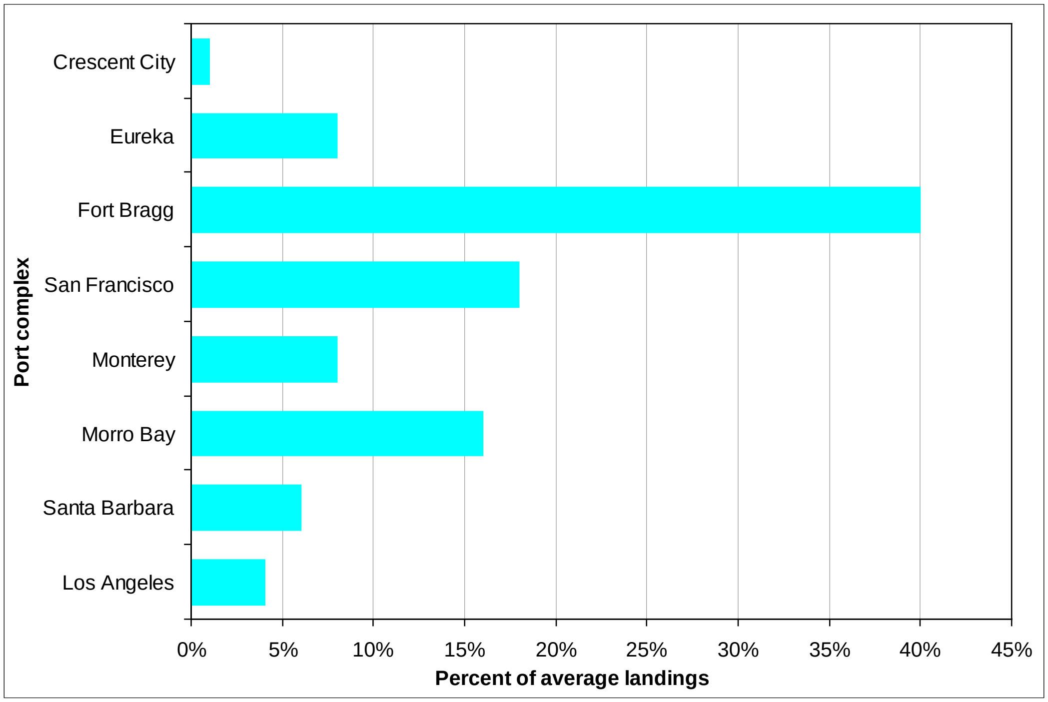

Figure 18-4. Skate average commercial landings by port, 2010-2011. Data source, CFIS data, all species and gear codes combined.

A recreational fishery for longnose skate does not exist in California. Anglers rarely fish at depths where longnose skate are likely to occur and, if encountered, their large wing span size would be a challenge for recreational anglers.

Status of the Biological Knowledge

The longnose skate is generally distinguishable from other skate species found in California because of a long and sharply pointed snout. It ranges from the southeastern Bering Sea to southern Baja California, Mexico. Although found over a wide range of habitats, they are most common over mixed cobble and sandy sediment on the sea floor, ranging from 164-656 feet in depth (50-200 meters). Very little information exists on the reproductive cycle of longnose skate. They are oviparous and egg cases are deposited onto the sea floor. Egg cases may be deposited on daily to weekly intervals for a period of several months or longer. Females grow larger than males and reach maturity around 28-39 inches (70-100 centimeters) while males reach maturity around 24-29 inches (62-74 centimeters). Longnose skate may live to at least 30 years and age at maturity can range from 5-14 years. They prey on smaller fishes, crustaceans, squid and octopus. They are preyed upon by larger marine mammals such as sea lions and sperm whales.

Status of the Population

In general, skates are vulnerable to overfishing due to sensitive life history parameters such as slow growth, late age maturation, low fecundity and relatively long life span compared to other fishes. Because the cumulative landings equate to a significant fishery along the entire U.S. west coast, the first longnose skate stock assessment was conducted in 2008. The results revealed a healthy west coast stock estimated at 66 percent of the unfished spawning stock biomass. However, the assessment relied on critical assumptions regarding species composition of the skate catch in California, which resulted in uncertainty in the model. Future research was recommended in order to reduce uncertainty in the population model for successive stock assessments. Reducing uncertainty in the model will facilitate the development of effective management measures to maintain a sustainable population in the future.

Management Considerations

In 1982, big skate, California skate and longnose skate were adopted as part of the federal Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP). These skate species were managed in the "Other Fish" complex, which is an aggregate of species that are un-assessed and generally considered underutilized. As a result of the healthy stock assessment outcome in 2008, adequate information was provided to set an optimum yield contribution for longnose skate of approximately 2.9 million pounds (1349 metric tons) to the "Other Fish" complex in 2009 and 2010. In addition, the Pacific Fishery Management Council (PFMC) decided on a mandatory sorting requirement for longnose skate beginning in 2009. The requirement was intended to provide more species-specific catch data to inform future stock assessments, which minimizes the need to take more precautionary management measures for the sake of protecting sensitive skate species. In addition, with the implementation of the Groundfish FMP's Trawl Rationalization and Individual Fishing Quota Program in 2011, all trawl fishing has 100 percent observer coverage and greater catch accounting, assuring further catch accuracy for all skates. It will not be necessary to re-assess the stock for several years until sufficient new data can be collected to significantly inform the population model, due to the healthy outcome of the initial longnose skate assessment. The preliminary preferred Annual Catch Limit (formerly referred to as the optimum yield) for longnose skate was set at approximately 4.4 million pounds (2000 metric tons) for the 2011 and 2012 regulatory cycle and it was removed from the "Other Fish" complex to be separately managed.

Fish and Game Code Section 5508 requires that longnose skate be landed in the whole condition (the fish cannot be cut up). A conversion factor which calculates the weight of the whole fish based on the weight of the wings would need to be developed to remedy the necessity of landing longnose skate in whole condition. Until then, it is anticipated that the landings will continue to be determined by market conditions rather than regulatory obligations.

Further Reading

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Skate commercial landings (pounds), 1990-2011.

Year	Big skate	California skate	Longnose skate	Thornback skate	Unspecified skate	Total landings
1990					143,732	143,732
1991					113,144	113,144
1992					103,469	103,469
1993					78,070	78,070
1994		155			93,236	93,391
1995	230				413,048	413,278
1996				18	1,830,076	1,830,094
1997	534			70	2,964,740	2,965,344
1998	3,592			1,427	1,831,148	1,836,167
1999	1,257	141		24	1,867,897	1,869,319
2000	19	1,782			1,271,691	1,273,491
2001	1,540				1,409,386	1,410,925
2002					180,794	180,794
2003	90				275,362	275,452
2004		47		1	251,892	251,940
2005					210,418	210,418
2006				2	269,709	269,711
2007	12				250,334	250,346

Skate commercial landings (pounds), 1990-2011.						
Year	**Big skate**	**California skate**	**Longnose skate**	**Thornback skate**	**Unspecified skate**	**Total landings**
2008	167	26		479	391,649	392,321
2009	2,493		172,747	226	144,779	320,245
2010	2,399		312,288	871	52,742	368,300
2011	705	776	376,516	190	65,435	443,622

Data source: CFIS data, all gear types combined.

Skate commercial landings and value, 1990-2011.		
Year	**Pounds**	**Value**
1990	143,732	$34,661
1991	113,144	$32,419
1992	103,469	$29,624
1993	78,070	$21,814
1994	93,391	$26,756
1995	413,278	$88,452
1996	1,830,094	$390,010
1997	2,965,179	$557,836
1998	1,837,518	$377,868
1999	1,872,075	$286,439
2000	1,243,827	$250,552
2001	1,399,493	$289,377
2002	180,794	$35,444
2003	275,469	$62,088
2004	251,893	$44,343
2005	209,266	$39,337
2006	268,288	$47,579
2007	247,495	$54,015
2008	392,313	$99,607
2009	320,245	$57,853
2010	368,300	$60,449
2011	444,350	$148,416

Data source, CFIS data, all species and gear types combined.

19 Petrale Sole, *Eopsetta jordani*

Petrale Sole, *Eopsetta jordani*. Photo credit: Department archives.

History of the Fishery

Petrale sole (*Eopsetta jordani*) is a larger flatfish found throughout the state of California and it is among the most valuable commercial flatfish species. Because they are caught in deep, offshore waters, the fishery has remained almost entirely commercial. Historically, petrale sole landings have been documented in California as far back as the late 1800s, with official documentation beginning in 1916. In early records from 1916-1931, petrale sole was recorded as "sole" which was an aggregate category additionally composed of English sole, rex sole, Dover sole and, to a lesser extent, with rock sole, sand sole, and other various flatfish species. During this period, average "sole" landings averaged 8.0 million pounds (3629 metric tons) per year. The California Department of Fish and Wildlife (Department) estimated that petrale sole comprised approximately 20 percent or 1.6 million pounds (726 metric tons) per year of the entire "sole" landings. Trawl gear dominated the entire composition of flatfish landings during this time period, and the majority were landed from San Francisco north to the California/Oregon border.

Beginning in 1931, petrale sole was officially recorded under an individual market category so that more accurate accounting of total individual harvest was possible. Despite high landings throughout most of the mid 1900s with a peak of almost 5.1 million pounds (2310 metric tons) in 1948, the fishery has landed 2 million pounds (907 metric tons) or less each year since 1980 (Figure 19-1).

From 1990-2009, annual landings of petrale sole had an average ex-vessel value of $1.2 million followed by an annual drop in 2010 and 2011 (due to regulation changes—see Management Considerations section below) to an ex-vessel value of $557,350 and $534,500, respectively (Figure 19-2).

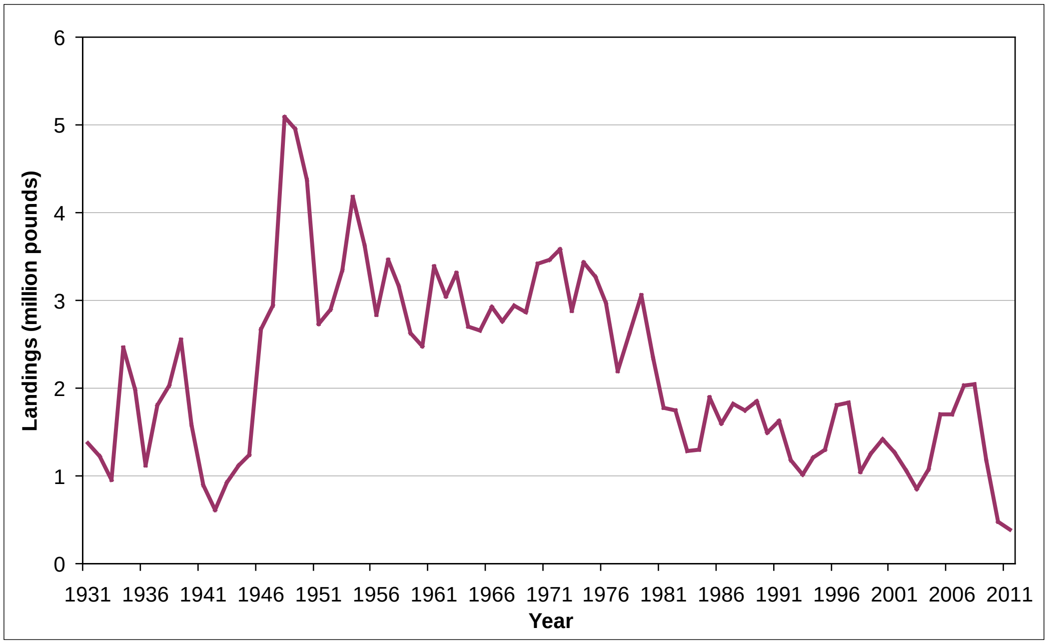

Figure 19-1. Petrale sole commercial landings, 1931-2011. Data source: Department catch bulletins (1931-1968) and Commercial Fisheries Information System (CFIS) data (1969-2011), all gear types combined. Data prior to 1931 are not available.

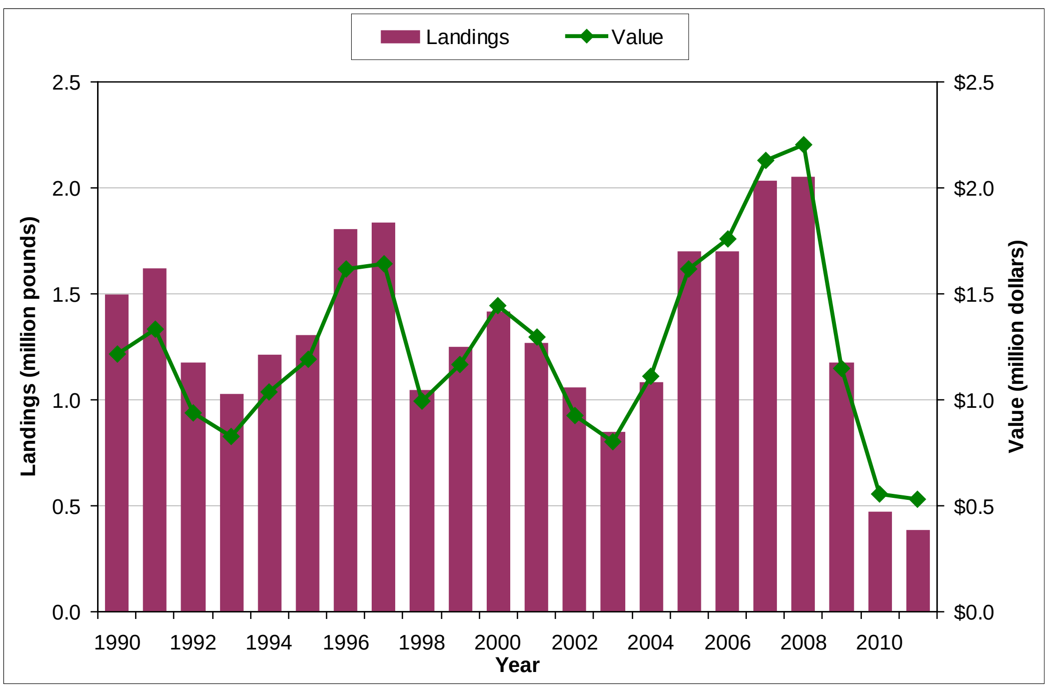

Figure 19-2. Petrale sole commercial landings and value, 1990-2011. Data source: CFIS data, all gear types combined.

Petrale sole is primarily trawl-caught, with 98 percent taken using trawl gear since 1990. From 1990-2011, a significant shift occurred in the composition of the trawl fleet which affected the catch-per-unit-effort (CPUE). The CPUE, measured by average landings per trip, has significantly increased since 2004 (Figure 19-3) as a result of multiple factors. These factors included: federal government buy back programs, continued restrictions on the entire groundfish fishery, higher fuel expenses, and the development of the federal trawl Individual Fishing Quota (IFQ) program that was implemented via Amendment 20 of the Federal Groundfish Fishery Management Plan (Groundfish FMP) (see Groundfish Highlight section in this report). The result is a more efficient fleet that has fewer vessels landing the same if not slightly more pounds than previous years, except for 2010 and 2011 when fishing regulations were severely constrained due to stock decline (see Management Considerations section below).

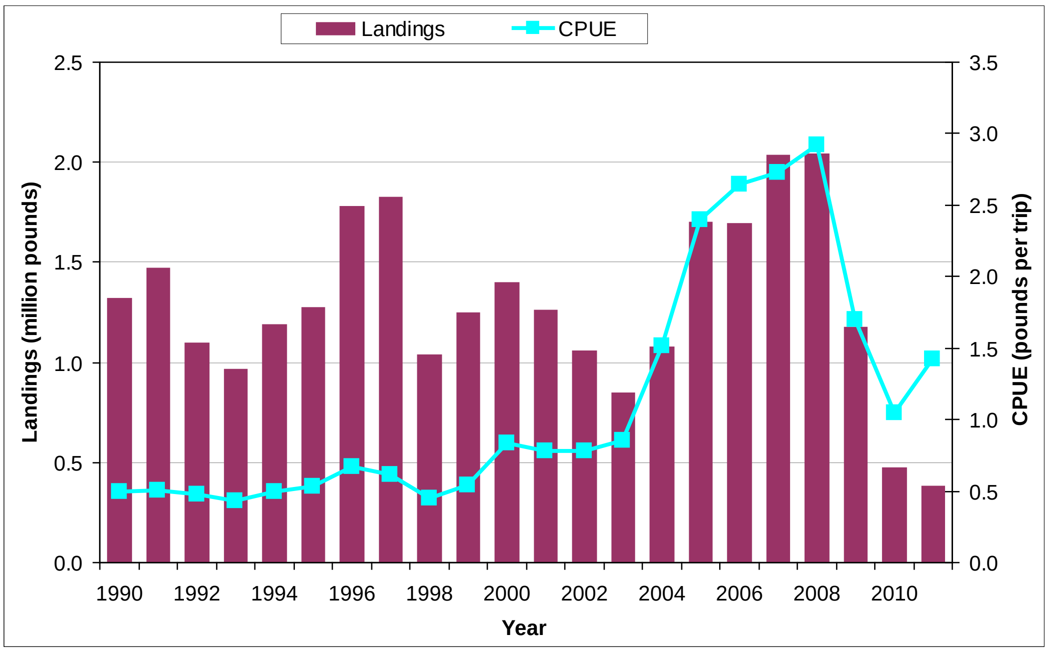

Figure 19-3. Petrale sole commercial trawl landings and CPUE, 1990-2011. Data source: CFIS data.

This fishery is characterized by strong winter and summer seasonality. During winter months, petrale sole aggregate in deep water for spawning and the trawl fleet harvests greater volume with less landings of associated groundfish species (such as chilipepper rockfish). Conversely, during spring and summer, petrale sole are found in shallower water. At this time they are spread out over the continental shelf where they are harvested with a large mixture of various rockfish species. Petrale sole are commonly caught with sablefish, Dover sole and other flatfishes throughout the year.

During the last decade, the majority of petrale sole were landed in the Eureka port complex, followed by the San Francisco and Fort Bragg port complexes (Figure 19-4). In Southern California, (south of Point Conception), petrale sole landings are minimal and do not amount to more than a few thousand pounds per year.

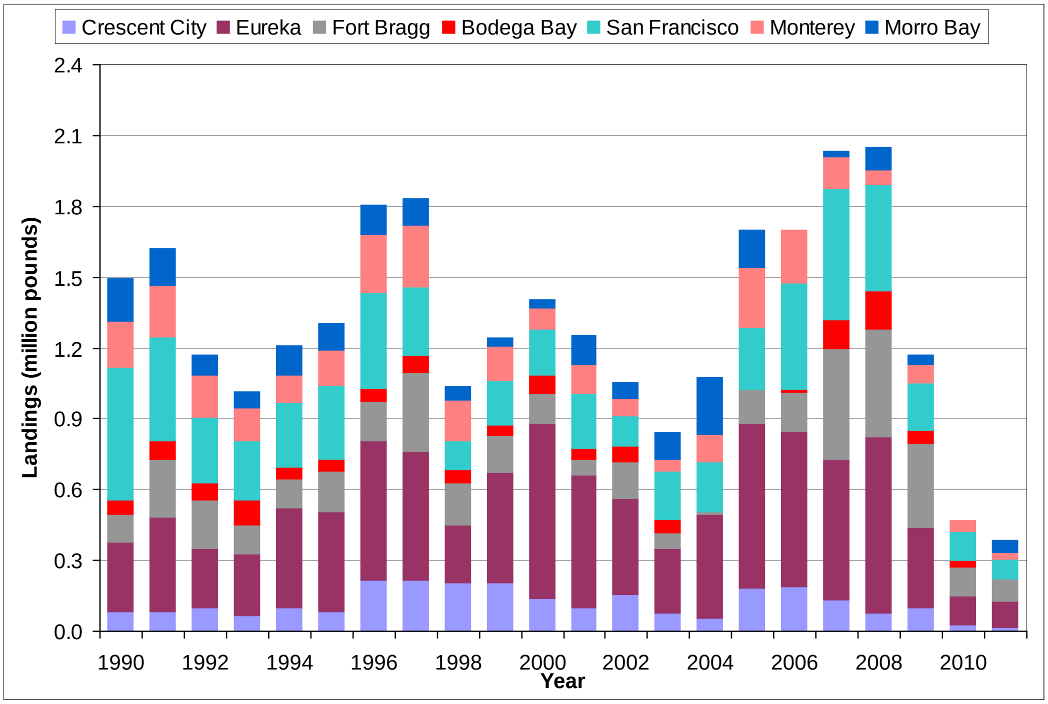

Figure 19-4. Petrale sole commercial landings by port, 1990-2011. Data source: CFIS data, all gear types combined.

Estimates of recreational catch were generated by the Marine Recreational Fisheries Statistics Survey (MRFSS) from 1981 to 1989 and from 1993 to 2003. From 2004 to the present, catch estimates are produced by the California Recreational Fisheries Survey (CRFS), which benefits from an improved sampling design. Both surveys rely on an angler-intercept method to determine species composition and catch rates, coupled with a telephone survey to estimate fishing effort. Though similar methodology in general was used for each, the two sampling designs are sufficiently different that catch estimates generated from MRFSS and CRFS are not considered comparable and will be provided in separate graphs and tables below.

Petrale sole is a very minor component of the recreational fishery. It is not a targeted species, but it is taken while fishing for other species such as rockfishes and other bottomfish. A review of the Marine Recreational Fisheries Statistical Survey (MRFSS) data (Figure 19-5) shows estimated annual recreational petrale sole catch averaged 3477 fish. Recent recreational data collected by the California Recreational Fisheries Survey (2004-2011) shows that since 2004 the petrale sole recreational catch averaged 685 fish annually (Figure 19-6). The recent decline in petrale sole catch is likely due to increased restrictions on recreational catch, including implementation of the Rockfish Conservation Areas that limit the depths at which recreational anglers can fish for bottomfish, including petrale sole. Depth restrictions vary by region, ranging from 20-60 fathoms (37-110 meters).

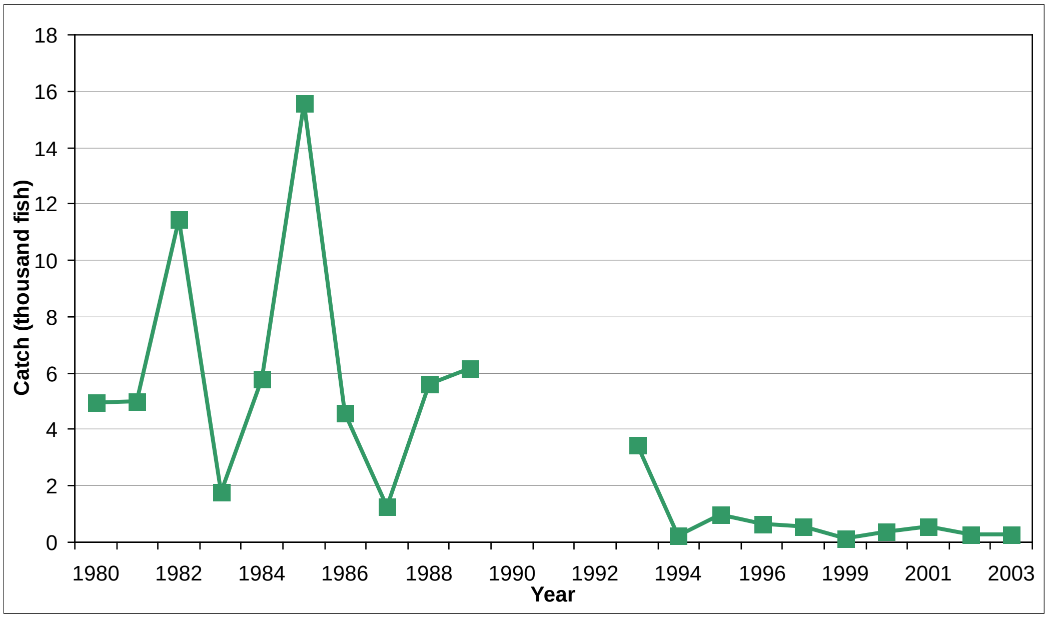

Figure 19-5. Petrale sole recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

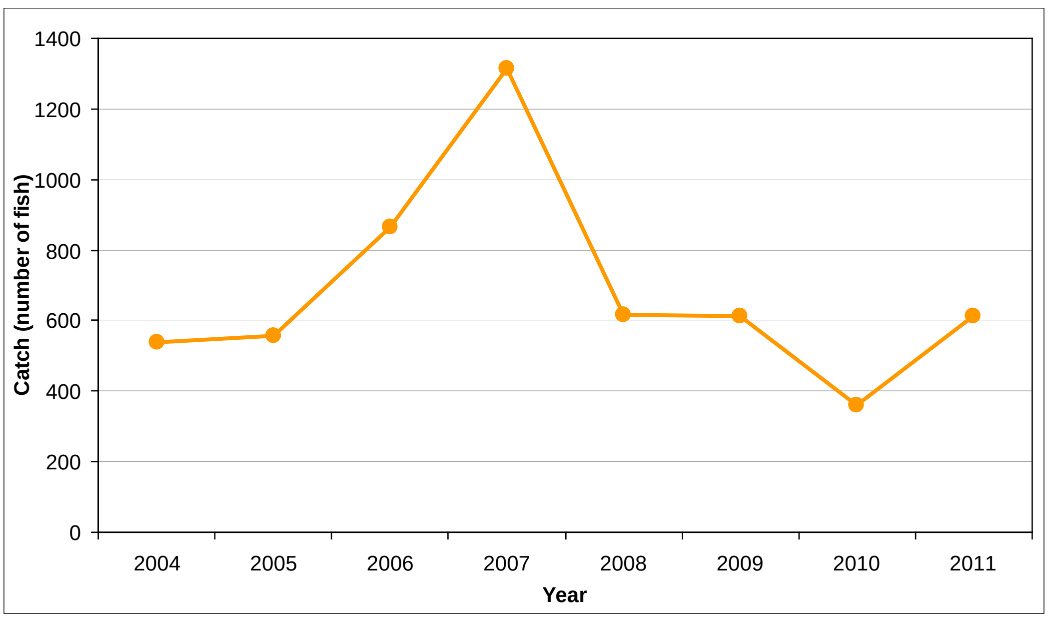

Figure 19-6. Petrale sole recreational catch, 2004-2011. Data source: CRFS data, all fishing modes and gear types combined.

Status of the Biological Knowledge

Petrale sole, a right-eyed and large-mouthed flatfish, are distributed from the western Gulf of Alaska to northern Baja California, Mexico. Planktonic larvae are found in water depths up to 295 feet (90 meters), ranging in size from approximately 0.12-0.79 inches

(3-20 millimeters), and begin settling in spring and fall. Females grow larger than males, and growth and age at maturation can be variable with location and year. Females reach maturity between approximately 11-17 inches (28-44 centimeters) and males reach maturity between approximately 10-15 inches (26-39 centimeters), when both sexes range between 4-8 years of age. Petrale sole can reach a maximum length of 28 inches (70 centimeters) and can live up to 25 years. Petrale sole are found over sandy or muddy bottom and spawn in deep water ranging from 890-1500 feet (270-460 meters) during winter, and then they return to shallower water during summer. They have a diverse diet which begins, as larvae or juveniles, with a variety of invertebrates such as amphipods and shrimp, transitioning to larger invertebrates (crabs, octopi, squid) and fishes (anchovy, herring, small rockfish) as they grow into adults. In turn, they are preyed upon by larger fishes, marine mammals, and sharks.

Status of the Population

Because of the economic and biological importance of petrale sole, periodic stock assessments are conducted by NOAA Fisheries Service scientists. In 2009, the Pacific Fishery Management Council (PFMC) adopted a new full stock assessment for one stock along the Pacific west coast of Washington, Oregon, and California. The outcome indicated the stock was at 11.6 percent of its unfished biomass, and was officially declared "overfished" (under NOAA Fisheries Service newly revised reference point for flatfish of 12.5 percent of unfished biomass). The most recent assessment (2010) included CPUE data from the winter trawl fisheries and accounted for a strong 2007 recruitment; a more optimistic stock status was the result at 18 percent of the unfished biomass.

Management Considerations

Current management of petrale sole is largely driven by the stock status. As a result of the "overfished" status of the 2009 stock assessment, the Council recommended immediate action to decrease the fishing pressure on petrale sole in the 2010 season by limiting access to winter fishing grounds and reducing trip limits. The effect of reducing trip limits led to a 60 percent decrease in petrale sole landings and a 51 percent decrease in ex-vessel value from 2009 to 2010, a trend that continued into 2011 (Figure 19-2). To offset this lost opportunity, the PFMC also recommended increased trip limits for other healthy, actively managed groundfish species such as sablefish, longspine and shortspine thornyheads, slope rockfishes and Dover sole, in an attempt to balance some of the petrale sole losses. This restriction on petrale sole continued into 2011 based on the outcome of the results of the 2010 stock assessment. The fishery continues to be constrained to allow the stock to fully rebuild, although the 2010 assessment had an improved outlook. An additional benefit to the fishery was the implementation of the federal trawl fishery IFQ program which began in 2011. As anticipated from this program, establishing trawl allocation limits in combination with 100 percent observer coverage enabled all trawl-caught groundfish species to stay within established catch limits.

All groundfish stocks declared overfished are held to a standard of 10 years to rebuild and require strict management measures in both state and federal waters, including conservative annual catch limits, to achieving the rebuilding goal. Because petrale sole grow relatively quickly and reach maturity at a young age, the recommended management changes coupled with a more optimistic stock assessment outcome project petrale sole to be fully rebuilt by 2016, well within the 10 year goal.

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Further Reading

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Love MS. 2011. Certainly more than you want to know about the fishes of the Pacific coast. p 565-566. Santa Barbara (CA): Really Big Press.

Petrale sole commercial landings, 1931-1989

Year	Pounds	Year	Pounds	Year	Pounds
1931	1,375,353	**1951**	2,726,304	**1971**	3,468,973
1932	1,227,223	**1952**	2,893,619	**1972**	3,575,245
1933	953,424	**1953**	3,350,163	**1973**	2,876,989
1934	2,456,989	**1954**	4,171,901	**1974**	3,430,685
1935	1,988,325	**1955**	3,619,530	**1975**	3,269,998
1936	1,126,527	**1956**	2,830,158	**1976**	2,977,557
1937	1,802,721	**1957**	3,456,709	**1977**	2,200,713
1938	2,026,166	**1958**	3,157,678	**1978**	2,634,039
1939	2,558,461	**1959**	2,632,451	**1979**	3,061,802
1940	1,575,489	**1960**	2,475,661	**1980**	2,350,504
1941	893,426	**1961**	3,390,739	**1981**	1,775,031
1942	611,580	**1962**	3,041,164	**1982**	1,745,597
1943	918,925	**1963**	3,317,948	**1983**	1,287,243

Petrale sole commercial landings, 1931-1989					
Year	**Pounds**	**Year**	**Pounds**	**Year**	**Pounds**
1944	1,123,986	**1964**	2,697,670	**1984**	1,301,895
1945	1,232,801	**1965**	2,662,257	**1985**	1,888,385
1946	2,666,285	**1966**	2,927,190	**1986**	1,600,379
1947	2,947,177	**1967**	2,768,537	**1987**	1,815,848
1948	5,089,684	**1968**	2,946,605	**1988**	1,752,935
1949	4,952,156	**1969**	2,866,769	**1989**	1,853,223
1950	4,366,598	**1970**	3,415,708		

Data source: Department catch bulletins (1931-1968), CFIS data (1969-1989), all gear types combined. Data prior to 1931 are not available.

Petrale sole commercial landings and value, 1990-2011.					
Year	**Pounds**	**Value**	**Year**	**Pounds**	**Value**
1990	1,495,649	$1,215,895	**2001**	1,266,702	$1,294,250
1991	1,620,124	$1,331,758	**2002**	1,055,574	$925,658
1992	1,172,949	$936,961	**2003**	843,418	$804,247
1993	1,021,859	$825,470	**2004**	1,080,285	$1,109,432
1994	1,211,845	$1,037,028	**2005**	1,700,169	$1,619,795
1995	1,305,154	$1,192,797	**2006**	1,700,151	$1,761,209
1996	1,803,639	$1,614,530	**2007**	2,031,027	$2,132,347
1997	1,836,090	$1,639,034	**2008**	2,048,686	$2,204,953
1998	1,042,122	$995,772	**2009**	1,172,154	$1,145,958
1999	1,247,391	$1,164,994	**2010**	470,348	$557,352
2000	1,411,037	$1,444,220	**2011**	383,328	$533,556

Data source: CFIS data, all gear types combined.

Petrale sole commercial landings (pounds) by port area, 1990-2011.									
Year	**Crescent City**	**Eureka**	**Fort Bragg**	**Bodega Bay**	**San Francisco**	**Monterey**	**Morro Bay**	**Southern California**	**Statewide total**
1990	86,167	291,535	117,610	62,963	563,663	190,991	179,857	2,864	1,495,649
1991	85,326	398,446	245,350	75,840	443,455	218,751	150,656	2,301	1,620,124
1992	97,810	252,299	208,754	72,089	277,634	178,513	83,750	2,101	1,172,949
1993	65,489	264,076	121,612	104,410	250,632	137,816	71,306	6,519	1,021,859
1994	98,528	423,903	120,831	52,820	272,832	116,334	121,987	4,609	1,211,845

Petrale sole commercial landings (pounds) by port area, 1990-2011.									
Year	**Crescent City**	**Eureka**	**Fort Bragg**	**Bodega Bay**	**San Francisco**	**Monterey**	**Morro Bay**	**Southern California**	**Statewide total**
1995	84,544	419,402	175,326	50,959	309,244	152,124	112,177	1,377	1,305,154
1996	216,782	591,510	166,701	55,481	404,386	245,568	121,012	2,199	1,803,639
1997	218,789	546,344	330,459	75,689	290,202	258,513	111,854	4,240	1,836,090
1998	207,474	244,657	179,686	54,728	123,294	168,013	59,849	4,422	1,042,122
1999	208,254	463,631	156,631	46,129	188,514	145,379	35,715	3,139	1,247,391
2000	141,691	736,028	128,940	78,980	192,325	93,564	34,035	5,475	1,411,037
2001	99,575	562,685	67,508	45,649	230,384	124,921	124,508	11,472	1,266,702
2002	153,760	410,613	154,547	64,664	129,024	73,752	67,223	1,991	1,055,574
2003	79,696	273,679	63,382	58,027	202,828	53,381	110,958	1,466	843,418
2004	55,775	438,031	13,287	173	211,161	119,309	239,338	3,211	1,080,285
2005	182,862	699,371	141,168	834	264,692	251,406	159,745	90	1,700,169
2006	188,018	660,462	162,769	15,571	449,746	221,389	2,167	29	1,700,151
2007	132,879	598,832	464,265	123,532	558,127	130,455	22,837	99	2,031,027
2008	80,047	746,347	452,961	164,918	448,090	62,560	92,750	1,013	2,048,686
2009	101,806	339,322	356,219	52,424	203,350	76,354	42,651	27	1,172,154
2010	25,867	121,980	124,291	29,191	124,289	44,370	39	321	470,348
2011	15,067	112,842	96,139	882	79,383	30,045	48,525	205	383,088

Data source: CFIS data, all gear types combined.

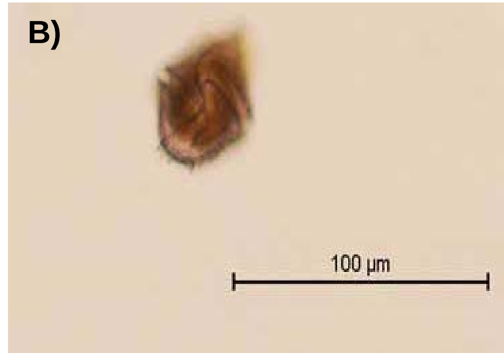
Petrale sole recreational catch, 1980-2003.			
Year	**Number of fish**	**Year**	**Number of fish**
1980	4,970	**1992**	---
1981	4,988	**1993**	3,437
1982	11,455	**1994**	217
1983	1,766	**1995**	977
1984	5,794	**1996**	665
1985	15,560	**1997**	542
1986	4,582	**1999**	145
1987	1,245	**2000**	351
1988	5,609	**2001**	547
1989	6,161	**2002**	274
1990	---	**2003**	273
1991	---		

Data source: MRFSS data, all fishing modes and gear types combined. Data for 1990-1992 are not available.

Petrale sole recreational catch, 2004-2011.			
Year	**Number of fish**	**Year**	**Number of fish**
2004	538	**2008**	616
2005	558	**2009**	613
2006	867	**2010**	361
2007	1,315	**2011**	612

Data source: CRFS data, all fishing modes and gear types combined.

20 Harmful Algal Blooms (HABS)



A) A live (left) and dead abalone (right) in the ocean. Photo credit: D Stein, CDFW. B) A microscope photo of the dinoflagellate *Gonyaulax spinifera.* Photo credit: A Paquin.

Introduction

Marine phytoplankton populations can undergo periods of explosive growth due to favorable environmental conditions. These instances are called algal blooms. Marine phytoplankton are microscopic, single celled plants that live in the ocean. They are vitally important to the marine ecosystem and play a crucial role in providing food to the base of the food web. Similar to plants on land, phytoplankton use energy from the sun and carbon dioxide to produce sugar and oxygen through the process of photosynthesis. Some species of phytoplankton can produce potentially harmful toxins. Others can be harmful due to the size of the bloom along with other environmental conditions through depletion of oxygen levels or by creating large oily mats of foam. When algal blooms are harmful to humans and or biological resources, they are called Harmful Algal Blooms (HABs). These harmful algae are generally present year round in the water column in very small amounts, but only become a problem for humans and animals when the phytoplankton species populations reach particularly high levels. Algal blooms and HABs are often visible due to pigments produced by the phytoplankton and are often referred to as “Red tides”.

Harmful algal blooms are not new to the California coast, with records of paralytic shellfish poisoning (PSP) dating back to historical Native California Tribal knowledge. “From time immemorial it has been the custom among coastal tribes of Indians, particularly the Pomo, to place sentries on watch for *Kal ko-o* (mussel poison),” wrote Karl F. Meyer, H. Sommer and P. Schoeholz in a 1928 issue of *the Journal of Preventative Medicine*. “Luminescence of the waves, which appeared rarely and then only during very hot weather, caused shellfishing to be forbidden for two days; those eating shellfish caught at such times suffered sickness and death”.

The presence of a HAB can cause significant effects to biological resources. A snapshot of effects to biological resources is seen in a timeline of HAB events in Monterey Bay compiled by the Central and Northern California Ocean Observing

System (CeNCOOS). The timeline illustrates the effects of major HAB events on both biological resources and the economy in one specific area. The first recognized toxic algal bloom involving domoic acid (DA) from *Pseudo-nitzschia* occurred in Monterey Bay in 1991 resulting in the deaths of pelicans and cormorants that had consumed sardines containing high levels of DA. In 1998, a *Pseudo-nitzschia* bloom in Monterey was followed by over 400 sea lion carcasses appearing on shore that showed signs of neurological damage from eating infected sardines. A harmful red tide event in 2007 caused by *Cochlodinium* killed abalone at the Monterey Abalone Company, costing almost $60,000 in damage. Slimy foam that caused birds' feathers to stick together and ultimately caused a huge bird die-off was created by a red tide (*Akashiwo sanguinea*) in 2007. The slimy foam was created by a combination of the large bloom, large waves, and onshore winds.

Status of the Biological Knowledge

Phytoplankton species that can cause HABs occur worldwide, including along the entire California coast. The population of each species and toxin levels in the water change with time and environmental conditions. The California Department of Public Health (CDPH) monitors the populations of these species, and the Southern California Coastal Ocean Observing System (SCOOS) and CeNCOOS compile additional data from research laboratories along the coast.

Major Causes of Harmful Algal Blooms

It is not known exactly what causes any individual phytoplankton bloom to become a HAB event or what the exact cause of a particular algal bloom may be. It is known that high nutrient levels, bright sunlight, water temperature and salinity, time of year, number of grazers and/or predators, and calm waters with low wind circulation patterns all play a role in predicting blooms and HAB events. Nutrient rich and dynamic upwelling zones, such as the California coast, are particularly prone to blooms and HAB events for this very reason.

Algal blooms can often be visible, but not always; in fact HABs can occur when the water is perfectly clear. The reddish pigment called peridinin, most often in dinoflagellates, generally causes "Red tides" which give the ocean a reddish hue during an algal bloom. Green tides are generally caused by *Phaeocystis* which is an algae found throughout the world. Water discoloration is not an accurate way to predict if an algae bloom is toxic or dangerous because HABs can occur in clear water, and there are numerous species of phytoplankton that cause visible algal blooms, both harmful and non-harmful.

Also unknown is what causes a species of phytoplankton to release toxins during a HAB event, although CeNCOOS reports multiple hypotheses. One hypothesis is that the phytoplankton are acquiring or detoxifying nutrients in the environment. Another hypothesis is the toxins are produced to protect the algae from grazers, such as krill and anchovies. A third hypothesis is that the toxin prevents or minimizes the growth of other algae competing for the same resources.

Not all algal blooms are HAB events, meaning they do not all cause harmful effects. During a phytoplankton bloom, researchers commonly look for the presence of the organisms through cell counts and DNA sampling, presence of a toxin, and harm or impact on the ecosystem, economy and/or human health. The information researchers gather during a bloom helps in identifying whether or not a particular bloom is a HAB event or has the potential of becoming a HAB event.

Common Species in California

Listed below are the most common species of HAB-forming phytoplankton on the California Coast. Current information on the populations of these species can be found on the SCOOS and CeNCOOS websites.

Akashiwo sanguinea

Akashiwo sanguinea (formerly called *Gymnodinium sanguineum* or *Gymnodinium splendens*) does not produce a known toxin. Blooms have been observed in summer and early fall; and have been reported to kill invertebrates, fish, and birds. Mortalities are most likely due to clogging of gills, the production of surfactants (foam leading to shorebirds' inability to keep warm and dry), and to oxygen depletion when blooms decay.

Alexandrium spp.

Alexandrium catanella (formerly *Gonyaulax catanella/catenatum*) is a dinoflagellate that produces a highly potent neurotoxin, saxitoxin. When consumed, saxitoxin, causes paralytic shellfish poisoning (PSP). PSP in humans is caused primarily through eating shellfish and can result in numbness, uncoordinated muscle movement, incoherence, and, in extreme cases, respiratory paralysis and death. Now recognized as one of the most deadly algal toxins, saxitoxin was first discovered in 1927 following a poisoning event that affected over a hundred people in central California.

Cochlodinium spp.

The dinoflagellate, *Cochlodinium*, has been observed in California waters for at least 80 years. Recent blooms have been reported from San Diego to Monterey Bay. The 2007 outbreak at an abalone farm caused gill damage to the abalone as well as lowered the amount of dissolved oxygen in the seawater. *Cochlodinium* has been implicated in the deaths of salmonids and other finfish, but the toxin or mechanism which causes the harmful effects is currently unknown.

Dinophysis spp.

Dinoflagellates within the genus *Dinophysis* have been found to produce okadaic acid which can cause diarrhetic shellfish poisoning (DSP). The primarily mild gastrointestinal disorder produces symptoms including: nausea, vomiting, diarrhea, and abdominal pain accompanied by chills, headache, and fever. Okadaic acid is produced by multiple species of *Dinophysis* that occur in California and the toxin has been documented in California waters.

Lingulodinium polyedrum

The common dinoflagellate *Lingulodinium polyedrum* (formerly *Gonyaulax ployedra*) prefers warmer temperate waters and frequently produces "red tides" along the coast of southern California. During the summer and fall of 2005, a large bloom of *Lingulodinium polyedrum* extended from San Diego to Ventura. This species may produce a toxin called yessotoxin that shares numerous similarities with DSP and the species was once included in the DSP group. Subsequently, the yessotoxins are now in a separate group due to distinct differences in chemistry and toxicology.

Phaeocystis spp.

Phaeocystis can be found as a colony of cells encased within a mucus layer or as single cells. The colonies of cells can produce large blooms that create white or colored foam that can cover beaches and shallow water areas. The blooms produce dimethylsulphide (DMS), an aerosol, which is thought to possibly contribute to cloud formation and acid rain.

Prorocentrum spp.

This dinoflagellate genus contains several toxic and harmful species. One of the most common species in the genus is *Prorocentrum micans* which occurs in cold temperate waters and produces red tides world wide. Despite being considered harmless in our region due to the lack of observed toxins, this species continues to be monitored due to the production of red tides as well as toxins produced in other regions.

Pseudo-nitzschia spp.

Nine species of *Pseudo-nitzschia* produce Domoic Acid (DA) worldwide. *Pseudo-nitzschia australis* and *Pseudo-nitzschia multiseries* are the most common species in California. Naturally occurring and rare, DA is an amino acid that is toxic to marine mammals, seabirds, and humans. Domoic Acid generally causes gastrointestinal disorders and neurological problems. Amnesic shellfish poisoning is a symptom of DA with the primary symptom being amnesia. First recognized in California when the deaths of more than 100 brown pelicans and cormorants were linked to DA in September 1991 in Monterey Bay; the toxin has since been implicated in other deaths of marine mammals and seabirds between Monterey Bay and San Diego.

Status of the Population

HABs and the species listed above are tracked throughout the year by the CDPH. Information on algal blooms and toxin levels can be found in the Marine Biotoxin Monitoring Reports on the CDPH website. The toxin levels surveyed by the CDPH are obtained from mussel tissue samples. Additional information and tracking of the current status of common HAB-causing phytoplankton species can be found on the SCOOS and CeNCOOS websites. University of California, California State University, and private research stations submit regularly collected and real time data to the SCOOS and CeNCOOS data portals. The SCOOS and CeNCOOS websites allow the use and comparison of data collected in the field.

2011 Significant HAB Event

During 2011, there were multiple algal bloom events on the California coast with one significant HAB event. The HAB event occurred off Sonoma County in August 2011 and continued into September 2011. Coinciding with a large bloom event located nearshore from Bodega Bay (Sonoma/Marin counties) north to Anchor Bay (Mendocino County) and probably extending beyond, a large die-off of marine invertebrates occurred predominantly in the vicinity of Fort Ross State Park north to Salt Point State Park. Invertebrate deaths were observed from many taxa including mollusks, echinoderms, and crustaceans. Marine mammals and fish did not appear to be affected by the event. Water samples were collected; the dominant phytoplankters were dinoflagellates belonging to the *Gonyaulax spinifera* species complex. Tissue samples from affected animals were tested for toxins and trace levels of yessotoxin were present. Marine scientists investigating the HAB have not been able to directly attribute the deaths to the presence of *G. spinifera* and associated toxin, but the general consensus is that the HAB is connected to the die-off. The vector responsible for potentially transferring toxins produced by phytoplankton to the herbivores that died in this event remains unknown. Water born toxins including viruses and bacteria may also be involved, but further investigation is needed. Based on the widespread die-off as well as the unknown source and ocean residence time of the toxin responsible, the California Fish and Game Commission voted on Sept. 15, 2011 to close the recreational abalone fishery in Sonoma County for the rest of the year. Research into the event is continuing and results will be released to the public as soon as available.

Management Considerations

Harmful algal blooms create numerous management considerations for the health and safety of humans and marine animal populations. Federal and State agencies, along with public-private partnerships, are working to establish predictive models for HAB occurrences and improve response time for affected marine resources.

California's Shellfish

Annually, the CDPH's Preharvest Shellfish Protection and Marine Biotoxin Monitoring Program (formerly called Mussel Watch) places a quarantine on sport harvesting of mussels for food from May 1 through October 31. During this time of year, mussels are most likely to accumulate toxins due to increasing phytoplankton populations and potential HAB events. The mussel quarantine provides protection to humans from DA and PSP. Should monitoring activities indicate unsafe levels of toxins, the quarantine can be expanded beyond or prior to the annual timeframe and include additional shellfish. Local health officers post signs advising people of the quarantine. The signs also warn people that clams and scallops may contain toxins. During the quarantine, people should remove the viscera from clams and scallops, the siphons from Washington clams, and eat only the remaining white meat.

CDPH monitors marine toxins in sport and commercial seafood year round. This program allows CDPH to follow changes in toxin levels and to alert the public and local health agencies if necessary. If CDPH finds unsafe toxin levels in seafood, they do not allow the affected species to be commercially harvested or sold; at the same time, they will also issue public warnings for sport harvesters of these species. The annual mussel quarantine does not apply to companies licensed by the State as certified shellfish harvesters. Mussels may be harvested and sold for bait at any time.

Marine Mammals

The neurotoxin DA affects marine mammals each year in California. The neurotoxin was first identified by the Marine Mammal Center in 1998 after a large HAB event. Marine mammals are affected when they eat prey, like anchovies, that have been feeding during HAB events. The effect of DA on marine mammals depends on the amount they eat and the amount of toxin accumulated in the prey. Symptoms include severe cases of seizures and other central nervous system problems, as well as hippocampal degeneration and amnesiac shellfish poisoning. Diagnoses are difficult to establish definitively due to unknown toxicity levels of algal blooms and the unpredictable timing of DA outbreaks. The Marine Mammal Center has been studying the effects of DA on California sea lions, including the effects on memory and learning, to hopefully better understand how DA affects the human population.

In 2007, deaths of southern sea otters from Monterey Bay were linked to a new type of HAB. "Super-blooms" of cyanobacteria, normally a freshwater species, that produce potent and environmentally persistent biotoxins (microcystins) were linked to the deaths of 21 sea otters. The sea otters were found near the mouths of rivers where freshwater was released to the ocean. Additionally, bioaccumulation of the toxins was found in nearby clams, mussels, and oysters. A recent paper by Miller et al. (2010) suggests that this discovery points to the possibility that humans could be at risk from harvesting shellfish near the freshwater marine interface when high levels of cyanobacteria are present in the freshwater source.

HAB Monitoring in California

It is widely accepted that the key to management of HABs is through a statewide and regional HAB monitoring network and forecast system. A February 2009 Working Draft White Paper "Harmful Algal Blooms in the West Coast Region: History, Trends, and Impacts in California, Oregon, and Washington" strongly recommends the need for a regional network. The list of reasons for a regional network include: improving the timeliness of HAB warning by interstate dissemination of current HAB data, improving the efficiency and decreasing the cost of HAB monitoring, improving the development and validation of forecast models, improving the accuracy of data for resource managers, improving public education, and improving the predictive models on factors promoting HABs. A California Current regional network is still being created and will most likely include the efforts of the individual states (California, Oregon, and Washington), plus monitoring efforts by SCOOS, CeNCOOS, and the Northwest Association of Networked Ocean Observing Systems (NANOOS).

Currently, the greatest strides have been made at the state level for creating a HAB Monitoring Network. The California Harmful Algal Bloom Monitoring and Alert Program (HABMAP) is an effort initiated by the National Oceanographic and Atmospheric Administration (NOAA), the California Ocean Science Trust (CA OST), and the Southern California Coastal Water Research Project (SCCWRP) to develop a state-wide Harmful Algal Bloom (HAB) alert network system for researchers and end user committees. HABMAP is the culmination of multiple expert level workshops exploring the need for increased HAB monitoring. In November of 2011, NOAA awarded $4 million for a five year project to the SCOOS and CeNCOOS systems to collaborate on creation of the HABMAP monitoring network that will include real time data from multiple federal, state, and private research stations. The data will allow for a better understanding of HABs on the California coast and ultimately lead to improved management strategies for California's resources. "This new effort will help us address a critical gap in past research, namely understanding the conditions leading to toxic blooms before they become a problem." said Raphael M. Kudela, professor at the University of California, Santa Cruz and project lead. "We are particularly excited because the project combines expertise from research and state public health managers in California with the developing national observing network established by NOAA."

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Further Reading

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For more information on the Southern California Coastal Ocean Observing System – SCOOS, go to the SCOOS website at:
http://www.sccoos.org/data/habs/abouthabs.php

For more information on the Central and Northern California Ocean Observing System – CeNCOOS, go to the CenCOOS website at:
http://www.cencoos.org/sections/conditions/algal_blooms.shtml

For more information on the California Department of Public Health (DPH) – Marine Biotoxin Monitoring Reports, go to the DPH website at:
http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Shellfishreports.aspx

For more information on the California Department of Public Health (DPH) – Preharvest Shellfish Protection and Marine Biotoxin Monitoring Program, go to the DPH website at:
http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Shellfish.aspx

For more information on the Seafood Network Information Center – Sea Grant Extension, go to their website at:
http://seafood.ucdavis.edu/Pubs/natural.htm

For more information on the Marine Mammal Center, go to their website at:
http://www.marinemammalcenter.org