STATUS OF THE FISHERIES REPORT- AN UPDATE THROUGH 2006

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

Prepared by
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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) and all the important plants and marine animals that dwell there. This report is available on the Department's website.

All the reviews in this report were done by Department biologists unless another affiliation is indicated. Author's names and e-mail addresses are provided with each review. All the contributors endeavored to make their reviews as accurate and up-to-date as possible.

Terry Tillman, marine economist, provided the 2006 commercial fishing revenue information for each of the reviews with the exception of Pismo clam, which may not be harvested commercially. Dave Ono and Brian Owens, marine biologists, assisted with formatting the text, tables and figures.

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INTRODUCTION

The Marine Life Management Act (MLMA) of 1998 changed the way the California Department of Fish and Game (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 sustainably and conserved. When species have been depleted or habitats degraded, restoration is the management goal. The Department is also 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. This *Status of the Fisheries Report- An Update Through 2006* continues the series and provides information on a different set of 15 species. 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 www.dfg.ca.gov/marine/status/index.asp.

Recognizing the increasing importance of economic value in evaluating fisheries, data other than ex-vessel price (what the fisherman was paid for his catch) was included in these species reviews. Small coastal communities and local economies that have little industrial diversity must import necessary goods and services from outside the area. The sale and delivery of commercial fishing products (exports) helps to offset expenditures for these imports.

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

- Commercial landing receipts. Every time a commercial fisherman lands his catch, a Department landing receipt is filled out documenting the species, poundage, gear, price paid to the fisherman, and other relevant information.

- Marine Recreational Fisheries Statistics Survey (MRFSS). This statewide survey provided estimates of the fish caught recreationally in California through interviews with anglers and onboard observations. The program was terminated in California on December 31, 2003.
- California Recreational Fisheries Survey (CRFS). This statewide survey provides estimates of the fish caught recreationally in California through interviews with anglers and onboard observations on a more geographically-based model than the previous survey. The CRFS program replaced MRFSS on January 1, 2004.
- Commercial Passenger Fishing Vessel (CPFV) logbooks. CPFV captains are required to submit a log for each day fished which documents the number of anglers aboard and the species and numbers of fish caught.

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 or academics using research methodology and technology.

1. CALIFORNIA MARKET SQUID

Review of the Fishery

One of the state's most valuable fisheries, the California market squid, *Loligo opalescens*, was first exploited commercially in Monterey Bay in the 1860s by Asian and European immigrants. They established successful fishing communities, many that still exist today, with multiple generations participating in the fisheries of their ancestors. Market squid has become the largest and most valuable California commercial fishery by volume with 54,200 tons (49,200 metric tons) landed in 2006. Fishing revenue from the 2006 commercial harvest of market squid was about $27 million (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $52 million. Likewise, total employment and wages from market squid is estimated to be the equivalent of 924 jobs and $24 million, respectively.

Market squid is an important international commodity with the majority of the export product being frozen and shipped to China, Japan, and Europe for human consumption. In 2006, 46 percent of the catch landed was exported for a value of $28.8 million. Domestically, market squid is canned or used fresh for human consumption, and is increasingly used live and frozen as bait by recreational fishermen.

When the fishery first developed in 1863, Chinese fishermen rowed small boats, called sampans, in the shallow waters of the bay at night using lighting techniques such as torches and wire baskets with burning pitchwood hung over the sides of their boats to attract spawning aggregations of market squid to their nets. They dried their catch and sold it for export to Asian countries as a food staple and as fertilizer. At the turn of the twentieth century, immigrating fishermen from Europe brought their methods from the old world and quickly adapted them to California waters. Italian fishermen from Sicily introduced the lampara net to Monterey which increased competition between the Chinese and Italian fishermen and led to the growth of market squid as a major product from Monterey Bay.

Purse seine fishermen from Yugoslavia and Italy settled the Santa Barbara and San Pedro areas to fish market squid and sardines. Lights and brail nets were used almost exclusively in southern California until the late 1970s. These boats were smaller and required smaller crews than the purse seine or lampara vessels. However, there was a shift in gear for the southern fleet, from brail to purse seine around 1977. Smaller brail vessels could not compete with the larger seine vessels that could easily meet increasing demands. An expansion of the southern California market squid fishery began in 1961 with a dramatic rise in landings in the Santa Barbara area ports.

Two distinct fisheries have emerged north and south of Point Conception due to the timing of peak spawning periods in each region. Historically, the fishery north of Point Conception, mainly around Monterey Bay, has operated from April through

September, while the southern fishery has been most active from October through March. However, spawning and fishing activities can occur in both areas throughout the duration of the fishing season, which runs from April 1 to March 31 of the following year.

The most common practice in today's fishery is to use two vessels and a skiff to capture market squid. As the majority of fishing takes place at night, light boats with high wattage bulbs are used to attract and concentrate market squid near the surface. A seine vessel then deploys a skiff that encircles an aggregation of market squid with round haul gear (Figure 1.1). The seine vessel then pumps the market squid onboard. A smaller volume of market squid may be taken by the light boats using brail gear, which is a large scoop net. From 1996 to 2006, approximately 95 percent of the vessels used either purse (69 percent) or drum (26 percent) seine nets, and 5 percent used brail nets.



Figure 1.1. Fishing operations: a) A light boat attracting market squid; b) a purse seine vessel with skiff deployed.

The market squid fishery is strongly affected by environmental and atmospheric conditions of the California current. California market squid are extremely sensitive to the warm water trends of El Niño, with overall catches decreasing, but then rebounding in cooler La Niña phases which bring increased upwelling. El Niño conditions hamper the southern fishery and market squid landings are minimal during these events, while landings in the northern fishery often increase, then decrease for several years after. During these warm water events with nutrient poor water, landings can disappear entirely in some areas.

Due to an increase in market demand, the commercial market squid fishery grew to an average annual catch of 10,000 tons (9,080 metric tons) by 1980. A significant expansion of fishing activity in southern California during the 1980s and 1990s was driven by a rapid expansion of the international export market, which helped the California market squid fishery emerge as one of the largest and most important in the state (Figure 1.2). Since 1985, the southern California fishery has dominated statewide landings and expanded its fishing areas, particularly in the Channel Islands and along the coast. In 1993, market squid became the largest California commercial fishery by volume with 47,100 tons (42,770 metric tons) landed, and by 1996 it had became the most valuable fishery resource valued at $33.3 million. Commercial landings of market squid in California increased almost 400 percent from the 1990/1991 season to the 1997/1998 season.

California market squid landings fluctuate as a consequence of demand that results from the volatile overseas markets and from the success of other international squid fisheries. During times of high resource abundance, demand may be the limiting factor in determining the amount of market squid landed. Local dealers often place daily trip limits on vessels, such as 30-tons (27-metric tons), as supply can sometimes exceed the demand. Market demand, resource availability, and the quality of the product all affect the price paid to fishermen. When resource volume is low, the markets pay a higher price per ton. During some months of the 1997/1998 El Niño when market squid was scarce, prices averaged $320 per ton. When resource volume is high the price is driven down, as in the year 2000 when prices averaged $257 per ton. A few prices were recorded as low as $100 per ton to some vessels bringing in full loads. Significantly higher prices are paid for market squid taken by brail gear, and for market squid purchased in lower volumes by smaller local dealers. Since 2005, prices have remained around $499 per ton due to the strong international demand for California market squid because of the collapse of other squid fisheries.

During the slower months in the northern fishery, many participating vessels will return to other ports in Oregon and Alaska to fish for sardines and salmon. Both the northern and southern fleets also participate in other coastal pelagic finfish fisheries targeting Pacific sardine, *Sardinops sagax*; Pacific mackerel, *Scomber japonicus*; and northern anchovy, *Engraulis mordax*.

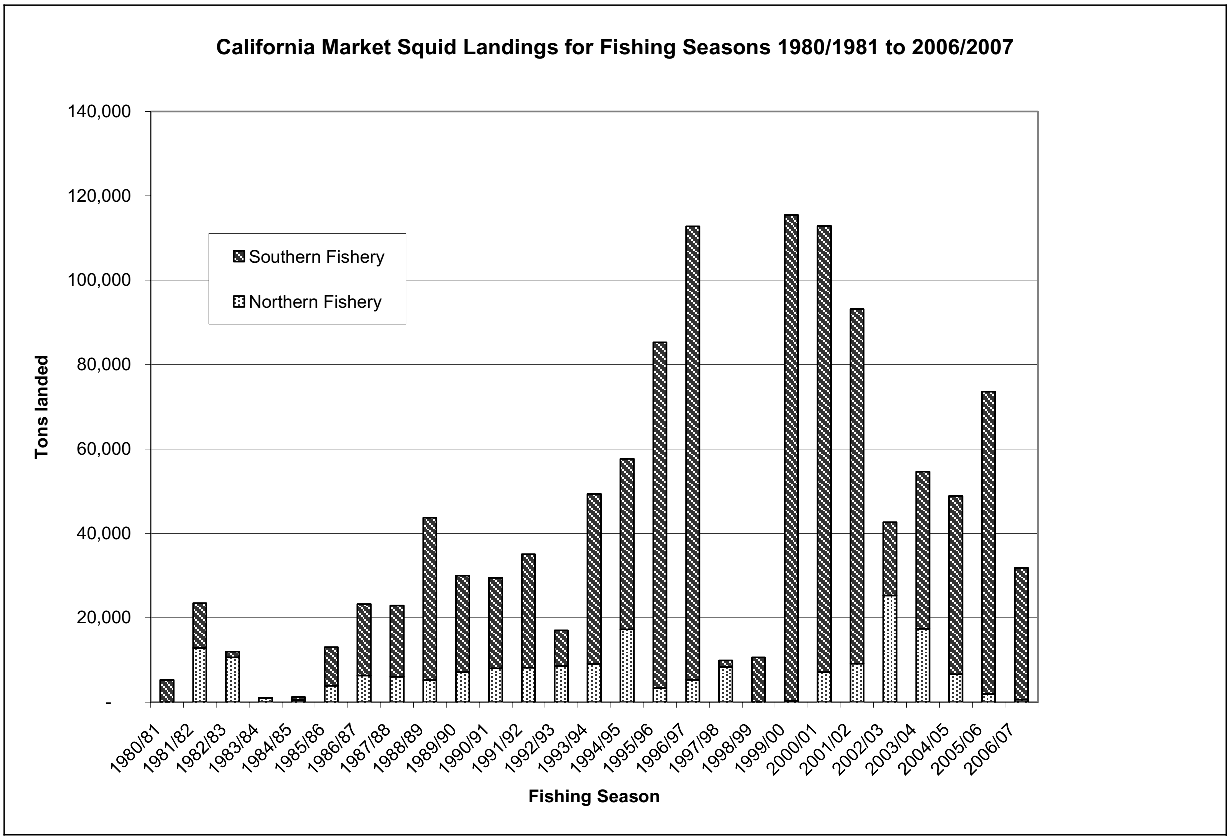

Figure 1.2. Market squid landings for northern and southern fisheries by fishing permit season (April 1 - March 31), from the 1980/1981 season to the 2006/2007 season.

Although substantial growth in the market squid fishery was concentrated in the Southern California Bight, questions were raised about the fisheries overall ecological and socioeconomic sustainability. Prior to 1997, regulations had been piecemeal and limited to Monterey Bay, with limits on the use of lights, the prohibition of round haul gear, and weekend closures that were imposed in 1983 to allow market squid a consecutive two-day period of non-interrupted spawning. As one of the West Coast's last open access fisheries in the late 1990s, the market squid fishery attracted fishermen facing declines in other fisheries. They were met with a willingness of the local markets to utilize their vessels in order to fill increasing demands for product. However, they faced opposition from local fishermen that felt their livelihoods might be jeopardized due to the over-expansion of the fishery.

The rapid increase in harvest and number of new vessels entering the fishery, especially from other states, prompted industry sponsored legislation in 1997, with Monterey Bay fishermen asking for a limited entry fishery. Beginning on April 1, 1998 new legislation placed a moratorium on the number of fishing vessels participating in the fishery, and a $2,500 annual permit fee was imposed for three years in order to fund resource assessment for conservation and management of the market squid resource. Interim measures also included mandatory biological port sampling, logbooks from light boats and round haul vessels, and an extension of the weekend closure to southern California. For the first market squid fishing season under the moratorium (1998/1999), 243 market squid vessel permits and 53 light boat permits were issued (Table 1.1).

Both shielding requirements and wattage restrictions for market squid-attracting lights were imposed in response to concerns raised in 1999 by the National Park Service that the abundance of vessels lighting for market squid may be responsible for the apparent increase in nest abandonment and chick predation among seabirds nesting at the Channel Islands. The Fish and Game Commission (FGC) placed a statewide wattage restriction on light boats and round haul vessels to 30,000 watts, and required these vessels to shield their lights to reduce impacts. Even with these restrictions, the landings increased to a record high in 2000 of 118,800 tons (107,870 metric tons), with an ex-vessel value of $36 million.

Table 1.1. The number of market squid permits sold since legislation was enacted to maintain the fishery at sustainable levels. A moratorium on the number of permits was enacted in 1998 and a restricted access program was enacted in 2005.

Season	Market Squid Vessel Permit	Market Squid Light Boat Permit	Transferable Market Squid Vessel Permit	Transferable and upgrade Market Squid Brail Permit	Non-transferable Market Squid Vessel Permit	Experimental Non-transferable Market Squid Vessel Permit	Total
1998/99	243	53					296
1999/00	219	52					271
2000/01	204	50					254
2001/02	197	44					241
2002/03	185	41					226
2003/04	176	39					215
2004/05	167	44					211
2005/06	-	64	77	14	14	1	170
2006/07	-	64	76	14	12	3	169

In 2004, the Market Squid Fishery Management Plan (MSFMP) was adopted by the FGC, and went into effect March 28, 2005. Goals of the MSFMP were developed to ensure sustainable long-term conservation of the resource, and to provide a management framework that would be responsive to environmental and socioeconomic changes. The four components of management include: 1) fishery control rules including a seasonal catch limit, various spatial and temporal constraints, and continued fishery-dependent monitoring programs utilizing logbooks and biological port sampling; 2) a restricted access program based on historical participation in the fishery was established to produce a moderately productive and specialized fleet of round-haul and light vessels; 3) an area closure to the use of lights to protect seabirds at the Farallon Islands; and 4) administrative items that allow the Director to establish an advisory committee composed of scientific, environmental and industry representatives. The 2005/2006 fishing season marked the inaugural year of implementation of the MSFMP.

Status of Biological Knowledge

The California market squid ranges from as far north as southeastern Alaska and as far south as Bahia Asunción Baja California, Mexico. It is a nearshore species that is found within 200 miles (322 kilometers) of shore. Although they are generally considered pelagic, market squid are found over the continental shelf from the surface to depths of 2,300 feet (700 meters). Adult market squid move into deeper water during the day, but return to surface waters at night within the upper 295 feet (90 meters) of the water column to feed. Adults and juveniles are most abundant at temperatures between 50 to 61˚ F (10 to 16˚ C). Market squid occupy the middle trophic level as active predators of copepods, euphausiids, and fish, and are a principal forage species preyed on by many fishes, birds and marine mammals.

The California market squid is a small mollusk with eight arms and two longer feeding tentacles, and an internal shell called a pen. Fishery-dependent samples indicate that market squid can grow to 7.9-inches (20-centimeters) in mantle length (ML) and can weigh up to 5-ounces (144-grams). Males are generally larger than females with longer and more robust arms and tentacles. Sex ratios are sometimes dominated by males or females but tend to be 1:1. The life cycle of market squid has four stages: eggs, hatchlings (paralarvae), juveniles, and adults. It is a short-lived species with a lifespan of 6 to 9 months. Adult market squid are semalparous (spawning only once) and spawn at the end of their lifespan. Although they are terminal spawners, market squid may spawn repeatedly over the last weeks of their lives.

When adults reach maturity, they move into shallow waters to spawn, usually over sandy habitat. In some areas, spawning may occur throughout the year. In Monterey, mass spawning events start around April and coincide with the upwelling season when water temperatures reach approximately 57˚ F (14˚ C). In southern California, spawning begins around November when there is less stratification of the water column and more mixing due to winter storms and colder air temperatures. While spawning, males grab the females and hold them in a vertical position while using a specially moified hectocotylized left ventral arm to transfer a bundle of spermatophores (sperm packets) into the female's mantle cavity near the oviduct. The female usually lays her eggs on sandy substrate, at depths of 49 to 164 feet (15 to 50 meters) in Monterey Bay and 66 to 295 feet (20 to 90 meters) in the Southern California Bight.

Eggs are laid within elongated finger-like capsules containing up to 300 eggs suspended in a gelatinous matrix that may protect against predation. The capsules are made up of many layers of protein and contain bacteria that may serve as an antibiotic to prevent fungal infection. Each female produces 20 to 30 egg capsules which she inserts into the sand with a sticky substance to anchor them in place allowing them to aerate in the surge. Groups of capsules are placed in masses creating clusters or "flowers" that can extend into vast egg beds covering more than 1,076 square feet (100 square meters) (Figure 1.3). Observations in Monterey Bay indicate that the rate of egg laying is slow, so egg beds may be built up over many days instead of in rapid spawning events occurring over one or two nights. The eggs are preyed on predominately by bat stars, brittle stars, sea urchins and rays; fish do not appear to eat them. Incubation time varies and is dependent on temperature. Eggs take between 3 to 5 weeks to hatch at average water temperatures of 52 to 57˚F (11 to 14˚ C). Warmer water temperature shortens the incubation time.

Figure 1.3. Cluster or "flower" of market squid egg capsules on sandy substrate.

Paralarvae hatch from the eggs resembling miniature adults (0.08- to 0.12-inches; 2- to 3-millimeters) ML and immediately begin swimming. They rapidly learn to hunt, eating copepods, krill, and other plankton in the first months of their lives. They perform a daily vertical migration in the water column from 98 feet (30 meters) depth during the day, up to 49 feet (15 meters) depth where they are found in greatest abundance at night. The daily migration and the zone created by tidal and nearshore currents often entrain the paralarvae within 1.9 miles (3 kilometers) of shore. At around two months, market squid reach 0.6-inches (15-millimeters) ML and are strong enough to swim in groups. These juveniles form large groups that hunt with tentacular strikes resembling the adults. Their sexual organs mature between 4 to 8 months and they are then considered adults.

Biological data collected through port sampling efforts include length, weight, sex, maturity, and age. Maturity is determined by the presence or absence of eggs and spermatophores. The age of market squid can be estimated by counting daily ring deposition on statoliths (Figure 1.4). Statoliths are calcareous structures secreted by the squid similar to the bony otoliths in fish. Since the fishery targets spawning market squid, statoliths collected should represent individuals approaching the end of their life span. Studies indicate the average age of harvested market squid is 188 days.

From 1999 to 2007, an overall decline in market squid length and weight has been observed with the exception of the 2005/2006 season in southern California (Figure 1.5, weight not shown). This has management implications for the resource since the fecundity of females increases with length, and the reproductive output of the population might be affected.

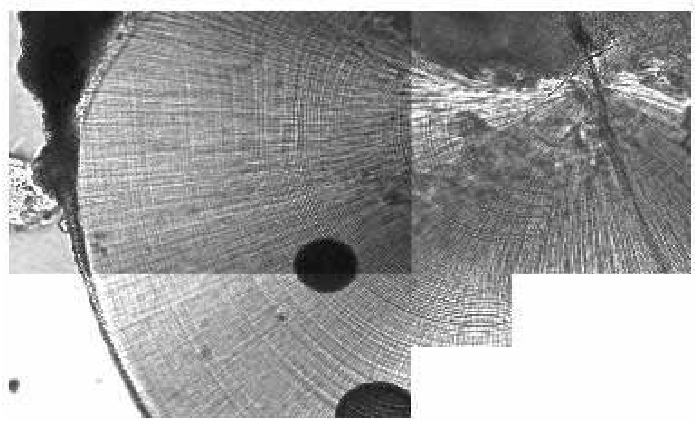

Figure 1.4. Multiple pictures overlayed of a cross-sectioned statolith showing daily ring deposition.

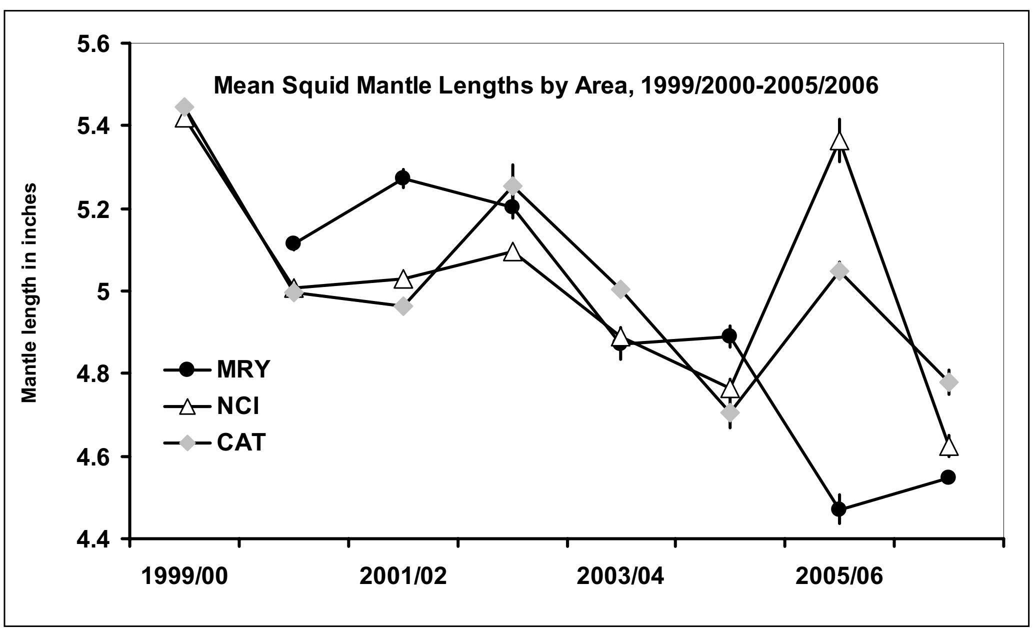

Figure 1.5. Mean squid dorsal mantle length by fishing season for fishery-dependent samples taken from Monterey (MRY), the northern Channel Islands (N CI), and Catalina Island (CAT).

Status of the Population

The status of the population is not fully understood because there is no reliable estimate of market squid biomass. However, evidence from studies on paralarvae, egg beds, behavior, genetics, and catch data suggest biomass is large, and at times, may constitute the largest population of any single marketable species in California's coastal environment. Since the California fleet targets spawning adults in limited geographic areas, it is not known if reduced landings indicate only a decline in availability to the fishery, or if overall stock size is diminished, since market squid have been commonly documented at greater depths not accessible to the fishery. Other spawning aggregations of market squid are also occasionally found as far north as British Columbia, and in the early 1980s, a short-term fishery developed along the coast of Oregon.

Historically, the market squid resource was considered by some to be underutilized. There are, however, few reliable estimates of the utilization of the market squid resource by other species. Although it is known that the resource supply can exceed demand, in some years the demand has exceeded the catch. The fluctuations in supply coincide with the environmental conditions. Because market squid are a short-lived and highly fecund species, it seems to be able to recover from dramatic decreases in the population from environmental fluctuations in a short period of time. However, other fishery-independent estimates of abundance are needed before the true status of the population can be determined.

The number of market squid stocks or subpopulations along the Pacific Coast is unknown at this time; and genetic analyses have had limited success in distinguishing stocks within a fishery. No significant differences were observed between the southern California and Monterey populations, suggesting that there are not two distinct stocks between the two fisheries.

Studies indicate that market squid endure very high natural mortality rates, and the adult population is composed almost entirely of new recruits made up of multiple cohorts. Even in the absence of fishing, the entire stock replaces itself semi-annually, so the stock is entirely dependent on successful spawning from each generation coupled with good survival of recruits to adulthood. Preliminary data indicate that the rate of eggs spawned prior to harvest varies between seasons. Because market squid are short lived, populations have been more effectively correlated with local oceanographic conditions than have pelagic fish species with longer life spans. Results indicate densities of paralarvae in February are correlated to catch-per-unit-effort (CPUE) of landings for the following November in southern California. Because market landings are driven by demand, it is difficult to use landing and vessel data to estimate an accurate CPUE or biomass.

Management Considerations

Since the implementation of the MSFMP, further issues affecting the management of this monitored species have been raised. The realized lifetime fecundity is a critical life history trait. Because the market squid fishery takes place above the spawning grounds, it is critical that management allows for an adequate number of eggs to be spawned prior to harvest. Allowing enough market squid to spawn before capture helps to ensure production for the next generation.

Biological sampling carried out by CDFG is designed to estimate the percentage of the population allowed to spawn before being captured by the fishery. The Pacific Fishery Management Council adopted the egg escapement method and an egg escapement threshold level of 30 percent as a proxy for maximum sustainable yield (MSY), since there is no reliable measure of annual recruitment success or biomass stock estimates beyond information obtained from the fishery. Fishery-dependent data presents difficulties in management of market squid because they are terminal spawners with short life spans, and fishing activity generally occurs only on spawning aggregations in shallow water. Use of egg escapement in determining if the stock is subject to overfishing, in lieu of a biomass estimate, should be considered a temporary solution while other fishery-independent methods are pursued to assess biomass and to collect essential fishery information. It is imperative to gather information on the extent and distribution of spawning grounds along the Pacific Coast, especially in deep water and areas north of central California not traditionally targeted by fishing vessels. Further information on fecundity, egg survival, impacts of different types of fishing gear on spawning grounds, and paralarvae density estimates is also needed from different spawning habitats and oceanographic conditions associated with the entire geographic range of the market squid population.

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Suggested Reading

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2. SPOT PRAWN

Overview of the Fishery

The fishery for spot prawn, *Pandalus platyceros*, originated in the early 1930s in Monterey when prawns were caught incidentally in octopus traps. It was a minor fishery with landings averaging around 2,000 pounds (0.9 metric ton) annually until the early 1970s. In 1974, trawl fishermen fishing out of Santa Barbara caught over 182,000 pounds (83 metric tons) of spot prawn. Trawl landings steadily grew as more fishermen entered the fishery and new areas were explored, reaching a peak of more than 375,500 pounds (170 metric tons) in 1981. Landings fell drastically in the next few years, causing concern among fishermen and Department biologists. A fishery closure was instituted between Point Conception and Point Mugu in southern California during the peak egg-bearing months of November, December and January in 1984. Following the implementation of this closure, trawl landings remained low through 1993, averaging about 54,000 pounds (25 metric tons) and 25 vessels annually. Some of these trawl vessels may have switched to other fisheries such as ridgeback prawn, sea cucumber, and groundfish.

In 1985, a trap fishery targeting spot prawn developed in the Southern California Bight. The trap fishery was concentrated around all of the Channel Islands and along coastal submarine canyons in water depths from 600 to 1,080 feet (183 to 329 meters). Trap fishing was occurring in areas of southern California that the trawl fleet did not have access to because trawling was not allowed within three miles (five kilometers) of the shore. The advent of the trap fishery also meant the start of a live prawn fishery for the Asiatic community locally and overseas. With traps, prawns could be brought on board in excellent condition and kept alive using holding tanks set at optimum water temperatures. Annual landings in the trap fishery grew from 8,800 pounds (four metric tons) in 1985 to over 247,000 pounds (112 metric tons) in 1991. During this period, trapping accounted for 75 percent of statewide landings; and trawling accounted for the remaining 25 percent.

Two years of declining landings in the trap fishery and the continued low landing levels by the trawl fleet led fishermen and biologists once again to address the management of California's spot prawn resource. In 1994, the Fish and Game Commission (Commission), with the support of the trap and trawl fishermen, expanded the November through January trawl closure to include the entire Southern California Bight. The Commission also instituted the first regulations for the trap fishery by requiring a 1-inch by 1-inch (25-millimeters by 25-millimeters) minimum mesh size for traps, limiting the number of traps per vessel to 500, and requiring a November through January fishing closure south of Point Arguello. Following these management measures, the spot prawn fishery underwent significant changes in composition and statewide growth. The spot prawn fishery was now comprised of four fishery components: northern California trawl, northern California trap, southern California trawl, and southern California trap, although some of the trawl vessels fished in both parts of the state. From 1994 until 1998, statewide landings nearly doubled from 444,000 pounds (201 metric tons) to a historic high of 780,000 pounds (354 metric tons). All of the fishery components showed increases in landings during this period. The northern trawl fishery experienced a 14-fold increase, the southern trawl and northern trap fisheries had a four-fold increase, and the southern trap fishery had almost a two-fold increase.

During this period, more than 50 trawl vessels made landings annually. The primary reasons for this growth in the fisheries were the following: increased market demand, which raised the average ex-vessel price for live prawns from $6 per pound to $8; new or increased effort by California and Washington trawl fishermen displaced from other fisheries; changes in gear design, specifically the use of large rollers (rock hopper gear) on the groundline of the trawl nets; and increased availability of the resource due to strong spot prawn recruitment in 1996 and 1997.

The advent of rock hopper gear allowed trawl fishermen to fish previously inaccessible, moderate-relief rocky habitat. Some of these areas had not been trapped before due to lower densities of spot prawn, but trawling was economically feasible. Thus, some of these areas had previously acted as de facto reserves, providing new recruits for adjacent areas traditionally worked by trawl and trap vessels. The use of this gear resulted in new conflicts between the trap and trawl fisheries in some areas.

The 1999 price for live prawns ranged from $6 to $10 per pound, whereas dead (heads-on) prawns brought only $4.50 to $5.50 per pound. Live prawns accounted for 95 percent of all trap and trawl landings. Trawl fishermen made adjustments in net design and tow duration to increase the survival of captured spot prawns, and they developed onboard refrigeration systems for multi-day trips at sea.

The rise in the number of participants, and a 21 percent decline in statewide 1999 landings prompted some spot prawn fishermen to ask for further regulation and the development of restricted access fisheries. An ad-hoc committee of trap and trawl fishermen and Department biologists developed a series of management recommendations for consideration by the Commission. In 2000, the Commission adopted a November through January trawl closure statewide, a May to August closure for the trap fishery north of Point Arguello, and retained the November through January closure for the trap fishery south of Point Arguello. While trap fishermen north of Point Arguello are permitted to catch prawns during the peak egg-bearing season in the winter, they are limited year-round to 300 traps within 3 miles (5 kilometers) of the mainland shore and 500 traps overall. Other regulations adopted by the Commission in 2000 for this fishery included a requirement for bycatch reduction devices on trawl nets, and a one-year observer program for all components of the spot prawn fishery. A control date for the establishment of restricted access trawl and trap fisheries was established, but other work was put on hold until 2001.

In 2001, the Department worked with northern and southern California trap fishermen to develop regulations for a two-tiered restricted access trap fishery.

Qualifying criteria consisted of a minimum number or weight of spot prawn landings utilizing traps during a three-year window period between 1997 and 1999. Tier-1 vessel permits were transferable, and no cap on annual landings was established. Tier-2 vessel permits were not transferable, and restrictions were placed on maximum annual landings, and the maximum allowable number of traps used was 150. The restricted access trap fishery was implemented in April 2002. A restricted access trawl fishery was never developed.

During the 2000-2001 fishing season, the Department conducted a one-year observer program to document bycatch, particularly rockfish in the spot prawn trap and trawl fisheries. Results from the observation of 86 trawl tows and 262 trap strings showed a significantly higher bycatch rate from trawls compared to that of traps. This, along with concerns about potential negative impact to hard bottom habitat, led the Commission to establish regulations in 2003 which prohibited the use of trawl gear for the targeted take of spot prawns.

The Commission also directed the Department to develop a trap permit for some of the trawl fishermen who were affected by the trawl ban. A Tier-3 trap vessel permit was adopted in 2004, with point-based qualifying criteria of spot prawn landings and poundage utilizing trawl nets encompassing a seven-year window period (1994-2001). Only eleven Tier-3 permits were issued, and the majority of the permits have not been used. Most Tier-3 permittees do not have the capital necessary to purchase traps and rig their trawl vessels for trapping.

The 2006 statewide spot prawn trap fishery in California consisted of 30 permits (17 Tier-1, 3 Tier-2, and 10 Tier-3), and 22 of the permittees were active. Annual landings from the trap fishery increased steadily from 2003, the year trawling was prohibited, to 2006, from approximately 167,600 pounds (76 metric tons) to 321,000 pounds (146 metric tons). However, the 2006 harvest levels were well below those of the mid- to late-1990s and appear to be sustainable (Figure 2.1).

Fishing revenue from the 2006 commercial harvest of spot prawn was about $3.6 million (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $6.9 million. Likewise, total employment and wages from the spot prawn catch is estimated to be the equivalent of 122 jobs and $3.2 million, respectively.

The spot prawn trap fleet operates from just north of Monterey Bay to southern California. Fewer than six vessels typically fish north of Point Arguello, and regional landings are significantly less than those of the southern California fishery. Spot prawn trap vessels range from 20 to 75 feet (6 to 23 meters) in length. Trap designs are limited either to oval or rectangular-shaped traps of mesh with a minimum inside measurement of 7/8-inch by 7/8-inch (22-millimeters by 22-millimeters). The dimension of the single chamber plastic traps is approximately 2.5-feet by 1.5-feet (0.8-meters by 1.5-meters) while the typical size of the wire traps is 3-feet by 1.5-feet by 1-foot (0.9-meters by 0.5-meters by 0.3-meters) with two chambers. Normally, a fisherman will set multiple trap strings, with 10 to 50 traps

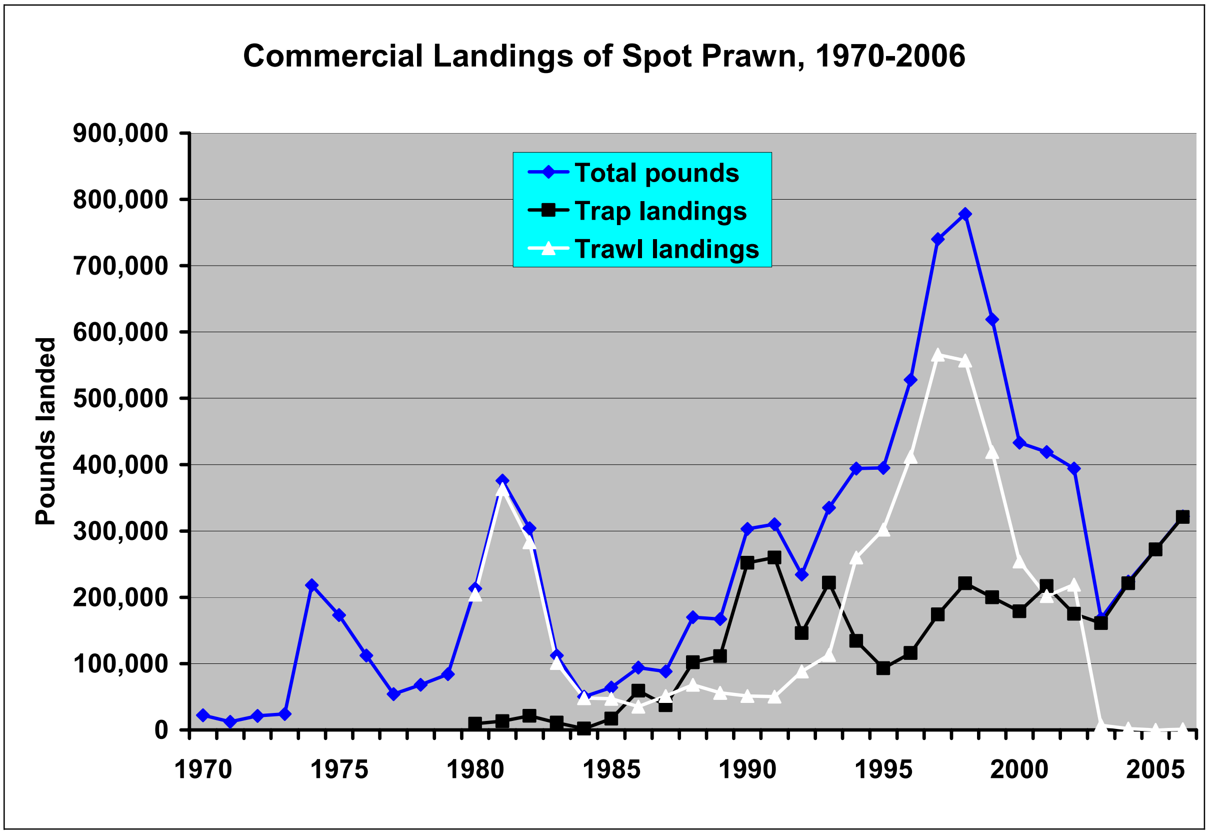

Figure 2.1. California spot prawn landings from 1970 through 2006 in pounds. Data source: CDFG commercial landing receipts.

attached to a common groundline with anchors and a buoy at one end or both ends. Traps are set at depths of 400 to 1,000 feet (122 to 305 meters) along submarine canyons or along shelf breaks. By law, all bycatch is returned to the water immediately.

Trap logbooks are required to be completed by all spot prawn fishermen after every day of trapping. These provide an informative historical data base of catch and effort by the Department fishing block which are areas of approximately 100 square miles (259 square kilometers); however, the spatial resolution is very broad.

It is legal to harvest spot prawns with a recreational fishing license, but practically speaking, it is difficult at best due to the depth range of the spot prawns. Although there is no season or limit on the number of traps that may be used, the recreational bag limit is 35 spot prawn per day. Given the depth at which the traps must be fished, and the bag limit of 35 prawn, there is little recreational fishing for this species.

Status of Biological Knowledge

Spot prawns range from Alaska to San Diego, California, in depths from 150 to 1,600 feet (46 to 488 meters). Areas of higher abundance in California waters occur off of the Farallon Islands, Monterey, the Channel Islands and most offshore banks. This species is a protandric hermaphrodite, beginning life as a male and changing into a female. Sexual maturity as a male is reached during the third year, with the carapace length (CL) averaging 1.5-inches (33-millimeters). By the fourth year, many males begin to change sex to the transitional stage. By the end of the fourth year, the transitionals become females averaging 1.75-inches (44-millimeters) CL. Maximum observed age is estimated at over 6 years, but there are considerable differences in age and growth of spot prawns between areas. Animals from Canada live no longer than 4 years, whereas, prawns from southern California can reach 6 years. Studies indicate that prawns grow faster in a temperate environment than in a cold environment.

Spawning occurs once a year, and each individual mates once as a male and once or twice as a female. Females spawn at a carapace length of 1.75-inches (44-millimeters). Spawning takes place at depths of 500 to 700 feet (152 to 213 meters). September appears to be the start of the spawning season, when the eggs are extruded onto the females' swimmerets. Female spot prawn carry eggs for a period of 4 to 5 months before they hatch. By April, only 15 percent of females still carry eggs.

Fecundity varies with size and age, ranging from approximately 1,400 to 5,000 eggs for the first spawning down to 1,000 eggs for the second spawning. Eggs hatch over a ten-day period and the first three or four larval stages are planktonic. During the third or fourth stage, spot prawn larvae begin to settle out at depths as shallow as 175 feet (53 meters). After completing larval stage six at a carapace length of approximately 0.3-inches (8-millimeters), spot prawns are considered to be juveniles and progressively move deeper as they reach adulthood.

Spot prawns feed on other shrimp, plankton, small mollusks, worms, sponges, and fish carcasses. They usually forage on the bottom throughout the day and night.

Status of the Population

Exploratory surveys conducted by the Department during the 1960s revealed the presence of prawns along the coast, but no estimates of population size have ever been made. During the 1980s, additional surveys were conducted in southern California to further define distribution and range. The development of the southern California trap fishery in the mid-1980s detected sizable aggregations of this species, which were previously unknown. The introduction of roller gear on trawl nets in the 1990s led to the exploration of even more areas and the location of additional habitat suitable for spot prawns. Anecdotal information on relative density and habitat associations of spot prawns has become available through the use of manned submersible observations conducted by National Marine Fishery Service (Santa Cruz, California facility) biologists in central and southern California from the early 1990s to the present.

Management Considerations

The small, restricted access trap fishery for spot prawn that currently exists in California is considered sustainable and environmentally friendly. Although traps can catch species of concern and disturb the bottom, bycatch is usually released alive with little harm, and lasting bottom impacts for traps are unknown. Population estimates would require trawl surveys to efficiently cover large areas of California's nearshore habitat, and are not economically feasible for the Department to undertake. Genetic work to determine whether there is one large population of spot prawn or a series of subpopulations along California's coast would also be helpful.

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3. PACIFIC OCEAN SHRIMP

Review of the Fishery

The commercial trawl fishery for Pacific ocean shrimp, *Pandalus jordani*, commonly referred to as pink shrimp, began in California in 1952 after commercial quantities were found in 1950 and 1951 by California Department of Fish and Game (CDFG) research vessels. The California Fish and Game Commission (Commission) established the first set of regulations for the new fishery in 1952, which included season, net type, and mesh size restrictions. At that time the state was also divided into three regulatory areas, designated A, B, and C. In 1956, Area B was divided into two areas: B-1 extending from False Cape to Point Arena and B-2 from Point Arena to Pigeon Point.

Ocean shrimp take was governed by catch quotas established in each regulatory area from 1952 to 1976. Quotas were based on recommendations of the CDFG and were set each year by the Commission. From 1952 to 1963, ocean shrimp fishermen were limited to the use of beam trawls with a minimum mesh size of 1½-inches (38-millimeters) between the knots. Following the1963 season, the use of otter trawls with the same size mesh was also permitted. In 1975, the mesh size was reduced to 1⅜-inches (36-millimeters) in Areas A, B-1, and B-2. The quota system was abandoned in 1976 and the following regulations were enacted in an effort to protect the resource: 1) a season closure from November 1 through April 14 to protect egg-bearing females; 2) a net mesh size of 1⅜-inches (36-millimeters) to allow for escapement of small zero- and one-year-old shrimp; 3) a count per pound of 170 or less intended to protect one-year-old shrimp; and 4) a minimum catch rate of 350 pounds (159 kilograms) per hour to protect shrimp when the population was at a low level.

In 1981, these regulations were changed based on an agreement with Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fisheries to establish uniform coastwide management measures. The resulting regulations, which are still in effect today, included an open season from April 1 through October 31, a maximum count per pound of 160, and a minimum mesh size of 1⅜-inches (36-millimeters) measured inside the knots (California waters only). Additionally, the state of Oregon has a “reciprocal landing law” which prohibits the landing of ocean shrimp taken in California waters using nets with a mesh size less than 1⅜-inches (36-millimeters). The ocean shrimp fishery off the United States west coast is managed by the states, but incidental groundfish catch limits, trip limits, size limits, a vessel monitoring system starting in 2008, and area restrictions protecting essential fish habitat for groundfish are enforced in the federal open access trawl fishery under Title 50 of the Code of Federal Regulations.

All shrimp boats in California pulled a single rig of one net and two doors prior to the 1974 season, when vessels towing a double rig from outriggers (one net on each side of the boat) entered the fishery. The double-rigged vessels are approximately 1.6 times more effective than single-rigged vessels. Double-rigged vessels made up approximately 25 percent of the California fleet in the late 1970s, and increased to nearly half the fleet during the 1980s and 1990s. Surveys conducted by ODFW researchers in the early 1990s on the Oregon fleet revealed that nearly 90 percent of the vessels were double-rigged. In recent years, nearly all of the ocean shrimp fishermen in California, Oregon, and Washington used a double-rigged vessel.

Annual landings for ocean shrimp in California are highly variable and have ranged from 140,000 pounds (64 metric tons) to 18,700,000 pounds (8,490 metric tons) in the 55 years of the fishery (Figure 3.1). Average annual landings increased each decade from the start of the fishery in the 1950s up to the end of the 1990s. However, there was a four-fold decrease in average annual landings from 2000 through 2006 compared to the 1990s. The number of active vessels mirrored the trends in annual landings. A record high of 121 active vessels were recorded in

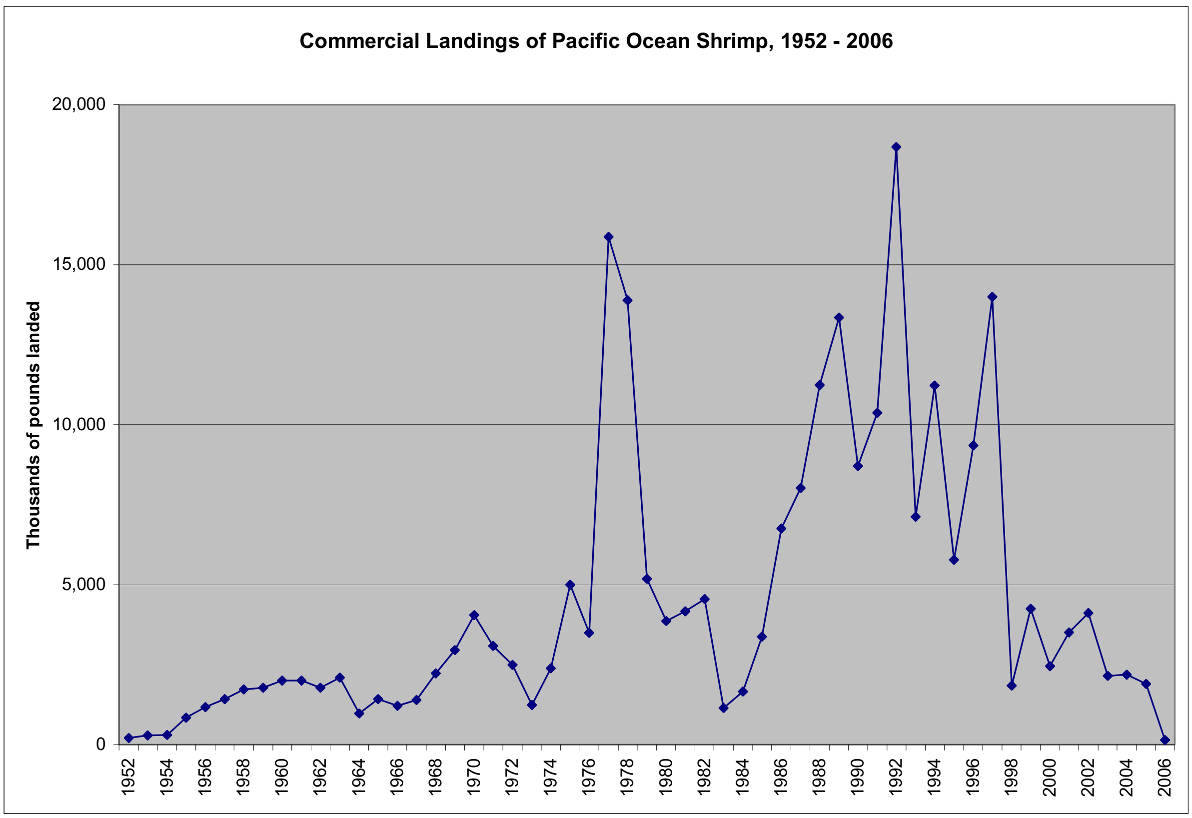

Figure 3.1. Pacific ocean shrimp commercial landings from 1952 to 2006. Data source: CDFG commercial landing receipts.

both 1994 and 1996. Since 2000, the number of active vessels has decreased nearly every year to only four vessels in 2006, which is the lowest mark in the history of the fishery.

The average total annual ex-vessel price increased each decade from the 1950s to the end of the 1990s. From 2000 through 2006, the average total annual ex-vessel price averaged $951,000, which is over a four-fold decrease from the average ex-vessel price of $4,470,000 in the 1990s. Fishing revenue from the 2006 commercial harvest of ocean shrimp was about $66,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $128,000. Likewise, total employment and wages from the harvest of ocean shrimp is estimated to be the equivalent of two jobs and $59,000, respectively.

The price per pound paid to fishermen has ranged from a low of $0.07 per pound in 1955 to a high of $0.87 per pound in 1987. The average price per pound from 2000 through 2006 was $0.42 per pound. The average price per pound paid to Oregon fisherman in the same period was $0.34 per pound. Total annual ex-vessel price for the fishery has also declined in recent years.

The majority of ocean shrimp landed in California are machine cooked and peeled (shell removed), and sold as individually quick-frozen meat, commonly referred to as salad shrimp or cocktail shrimp. A small amount is sold fresh as cooked picked meat or packed in vacuum cans. Most of California's shrimp catch was hand peeled until 1969 when large processing machines were introduced in the Eureka area. These machines have enabled the shrimp industry to process much smaller shrimp than was possible with hand peeling.

Recently, three additional regulatory changes have been implemented in the California ocean shrimp fishery. First, the State was divided into a northern and southern region in 2001, and fishing in each region requires a separate permit. The northern region was designated as a limited entry fishery from the California-Oregon border to Point Conception, and the southern region was designated as an open access fishery from Point Conception to the California-Mexico border. From 2001 through 2006, the average number of active vessels in the northern region was 24 compared to only 3 in the southern region. Additionally, over 99 percent of the annual landings from 2001 through 2006 occurred in ports located in the northern region, particularly the Eureka area, and no landings have been recorded in ports south of Morro Bay since 2003.

The second recent regulatory change was the requirement of an approved Bycatch Reduction Device (BRD) on all nets used in the ocean shrimp fishery in order to protect overfished groundfish species off the United States west coast. In California, this regulation was approved in 2001 and operative in 2002 under Title 14, Section 120 of the California Code of Regulations. In Oregon and Washington, BRDs were required inseason to minimize canary rockfish, *Sebastes pinniger*, catches on August 1, 2001 and July 1, 2002, and then permanently required in 2003. Several types of BRDs may be used in the California fishery, including the Nordmøre grate (rigid-grate excluder), soft-panel excluder, and fisheye excluder. However, rigid-grate BRDs are generally considered to be the most efficient in reducing fish bycatch with minimal ocean shrimp loss. The vast majority of current, active vessel operators in both California and Oregon have been using this type of BRD since 2003 (Figure 3.2).

A recent study conducted in Oregon by ODFW researchers indicates the use of BRDs resulted in a 66 to 88 percent reduction in total fish bycatch, and the use of rigid-grate BRDs is generally more effective at bycatch reduction of groundfish species than soft-panel BRDs. Furthermore, mandatory BRD use has changed the species composition of the bycatch from commercially important large fish species to primarily smaller fish species with little or no commercial value. Rigid-grate BRDs with 1¼-inch (32-millimeter) bar spacing have been the most commonly used BRD in recent years. However, recent experimentation suggests that ¾-inch (19-millimeter) bar spacing may further reduce bycatch rates to well below 5 percent of the total catch with minimal shrimp loss. Largely attributed to the use of BRDs, the ocean shrimp fishery in Oregon was recently certified in accordance with the Marine Stewardship Council (MSC) Principles and Criteria for Sustainable Fishing, which is the world's first sustainable shrimp certification under the MSC certification program. Both Monterey Bay Aquarium and Blue Ocean Institute have recently put ocean shrimp on their lists of good seafood choices for environmentally conscious consumers.

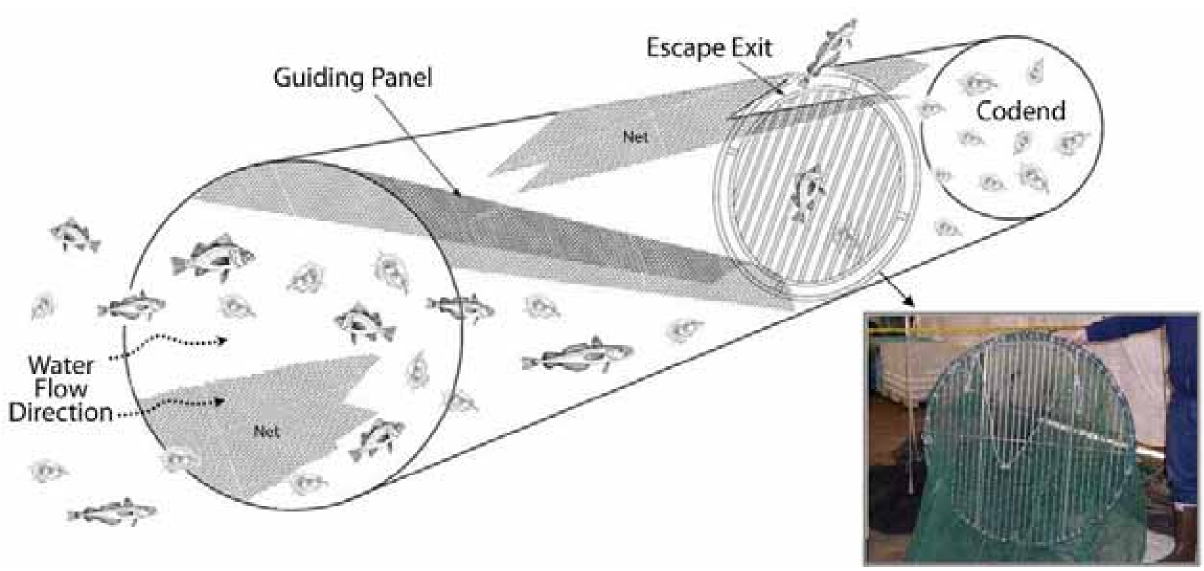

Figure 3.2. Diagram of a typical rigid-grate (double-ring) Bycatch Reduction Device (BRD) used in the ocean shrimp trawl fishery. The diagram depicts shrimp traveling through the BRD, and larger fish species deflected by the BRD and guided through the escape exit opening. The inset picture is a rigid-grate (single-ring) BRD with 1½-inch bar spacing. Credit: Diagram and inset picture modified from Robert W. Hannah, ODFW.

The third recent regulatory change in the California ocean shrimp fishery pertains to fishing in state waters off the north-central coast. In 2004, the State Legislature approved Senate Bill 1459, adding Fish and Game Code (FGC) Section 8841 to statute, and amending Section 8842. The new Section grants the Commission management authority over all state-managed bottom trawl fisheries not managed under a federal or state fishery management plan. It established that, commencing January 1, 2008, bottom trawling for ocean shrimp was prohibited in state waters between 2 and 3 nautical miles (3.7 and 5.6 kilometers) from the mainland on the north coast of California from Point Reyes to False Cape. These fishing grounds, often referred to as the pink shrimp trawl grounds (PSTG), produced an average of 21 percent of the annual ocean shrimp landings statewide from 2000 through 2006. According to FGC Section 8842, the Commission has the authority to open state waters to bottom trawling for ocean shrimp if it determines, based on the best available scientific information, that bottom trawling in those areas is sustainable, does not harm bottom habitat, and does not unreasonably conflict with other users.

Status of Biological Knowledge

Ocean shrimp are found in waters from Unalaska in the Aleutian Islands to San Diego, California, at depths from 150 to 1200 feet (45 to 366 meters). Off the coast of California, this species is generally found from depths of 240 to 750 feet (73 to 229 meters). Spawning may occur throughout the range, but commercial quantities are limited to the area between Queen Charlotte Sound, British Columbia and Point Arguello, California. High concentrations of ocean shrimp typically occur in well-defined areas from year to year, most commonly referred to as beds. Ocean shrimp beds are generally characterized by green mud or muddy-sand bottoms. Adult shrimp usually remain in one of ten localized beds along the coast. Previous studies suggest some horizontal, onshore-offshore transport may occur within the confines of a single bed due to prevailing currents and feeding activities. However, no convincing evidence exists to believe ocean shrimp exhibit large, coastwide migratory behavior. Nevertheless, larval transport may occur among beds since young-of-the-year shrimp live in the plankton for 7 to 8 months before settling to the bottom. Genetic stock identification work on this species has failed to isolate any genetic differences between ocean shrimp off the coasts of California, Oregon, Washington and British Columbia. It is therefore assumed that there are no genetically distinct subpopulations of ocean shrimp off the coast of western North America.

Ocean shrimp undergo diel vertical migration by inhabiting deeper waters near the bottom during the day and ascending in the water column during the night to feed. Stomach contents of shrimp taken at night consist of primarily smaller planktonic animals, such as euphausiids and copepods. Shrimp stomach contents taken during the day contained little food; identifiable food items included diatoms, sponges, polychaetes, amphipods, and isopods. Ocean shrimp have been reported as prey for many fish species, including Pacific hake, *Merluccius productus*; arrowtooth flounder, *Atheresthes stomias*; sablefish, *Anoplopoma fimbria*; petrale sole, *Eopsetta jordani*; spiny dogfish, *Squalus acanthias*; and several species of rockfish and skates.

Ocean shrimp are protandric hermaphrodites, functioning as males during the first year and a half of their life, then passing through a transitional phase to become females. During some years, a large percentage (up to 60 percent) of one-year-old shrimp become females and never mate as males. Mating takes place during September and October. During the winter, female shrimp produce eggs, usually between 1,000 and 3,000, which are fertilized by packets of sperm from males. Small individuals in their second year have been found bearing as few as 900 eggs, whereas larger shrimp in their third or fourth year of life have been found bearing up to 3,900 eggs.

The female carries the eggs attached to the posterior swimming appendages until the larvae hatch. The peak hatching period occurs during late March and early April. Ocean shrimp go through a larval period which lasts 2 to 3 months. The developing juvenile shrimp occupy successively deeper depths as they grow, and often begin to show up in commercial catches by late summer. Ocean shrimp grow in steps by molting or shedding their carapace. Growth rates vary according to region, sex, age, and year class. There is a clear pattern of seasonal growth despite the variations mentioned, with very rapid growth during spring and summer and slower growth during the winter.

Growth rates of ocean shrimp off the coast of Oregon increased markedly after 1979, suggesting a density-dependent growth response to fishing. During the first, second, and third winters of life, ocean shrimp generally range from 0.5- to 0.7-inches (13- to 17-millimeters) in mean carapace length after one year of life, 0.7- to 1- inches (18- to 25-millimeters) after two years, and 1- to 1.1-inches (25- to 29-millimeters) after three years (Figure 3.3); and survival between fishing seasons (over winter) is estimated to be 46, 76, and 43 percent, respectively. In California, few shrimp survive beyond their fourth year. Natural mortality rates may also change in response to the abundance of predator stocks, such as Pacific hake.

Status of the Population

Population estimates of the various ocean shrimp beds were obtained by CDFG sea-surveys from 1959 to 1969. Catch quotas were set at one quarter of the estimated population. Since the cost of sea-surveys was quite high, another method of estimating the population was needed. A mathematical population model, designed by CDFG statisticians, was used to estimate the population size. The population model set the quota from 1969 until 1976, but it was subsequently dropped the following year because of the variable recruitment, growth, and natural mortality rates associated with ocean shrimp. No further attempts to estimate the population have been made in California.

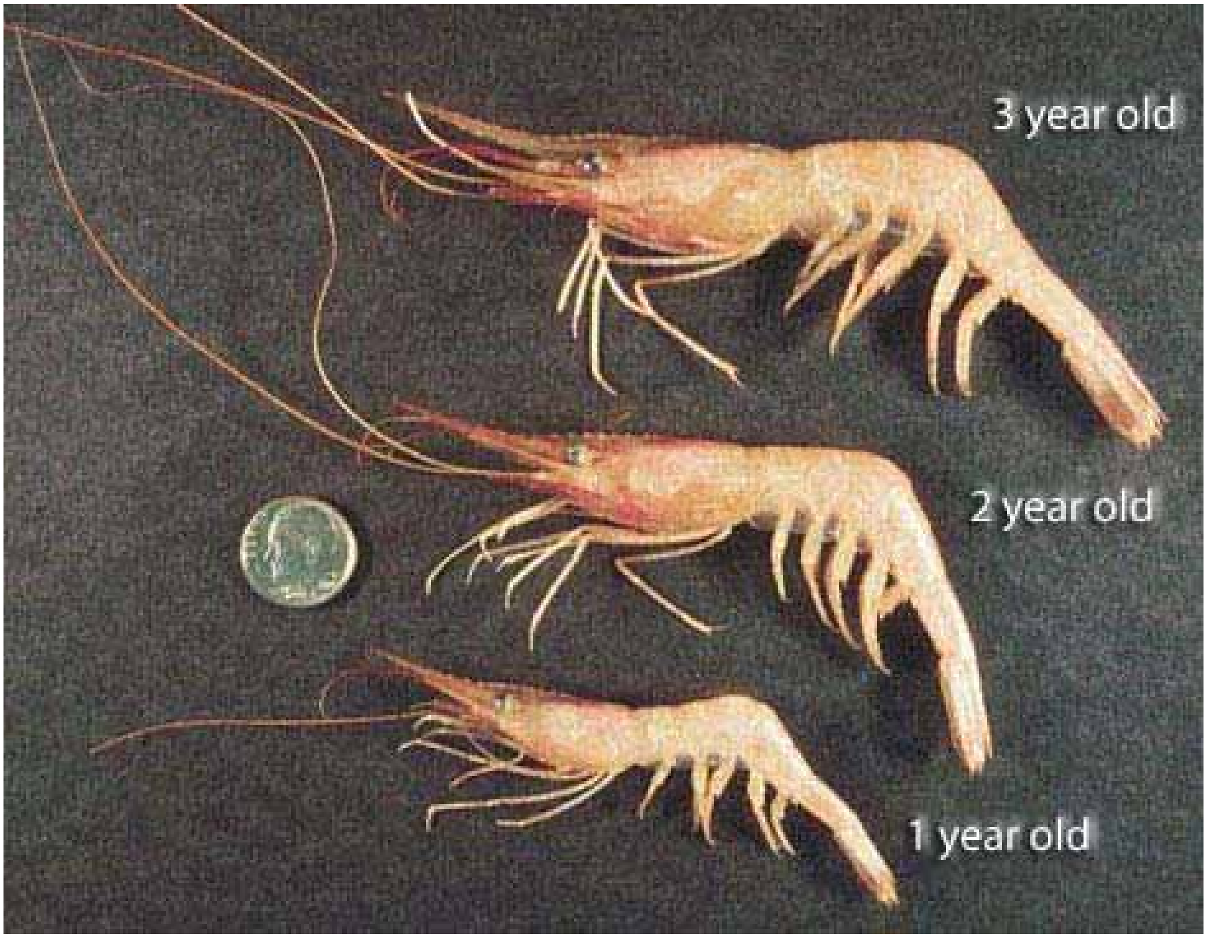

Figure 3.3. Three size (age) classes of Pacific ocean shrimp, *Pandalus jordani*. Credit: Robert W. Hannah, ODFW.

Ocean shrimp abundance off California varies substantially from year to year, which is largely attributed to environmental factors causing natural fluctuations in recruitment. Annual recruitment success has been linked to the strength and timing of the “spring transition.” The spring transition refers to the seasonal change from northward winter winds to southward summer winds which force a shift in coastal currents just following larval release. An early, strong transition is necessary to produce a large year class. Shrimp are short-lived and exhibit flexible rates of sex change that act to maintain a roughly balanced sex composition, despite highly variable mortality rates. Other evidence also suggests that shrimp exhibit a density-dependent growth response to fishing. Nevertheless, the importance of environmental factors on ocean shrimp recruitment and distribution suggests fishing pressure may have relatively less influence on stock status. However, overfishing may be possible if intensive fishing were to be directed at a failed year class. This is considered very unlikely because the low ex-vessel value of small ocean shrimp makes it very difficult to fish profitably on low standing stocks.

Annual landings in California have been exceptionally low since 2003, marked by a record low in 2006 (Figure 3.1). Similarly, annual Oregon landings were below average from 2003 through 2006. A combination of factors may explain the recent reduction in landings, such as a weak market attributed to competition from other warm water and cold water shrimp fisheries, competition from aquaculture production of warm water species worldwide, increased fuel prices, limited shrimp processors available on the U.S. west coast, and environmental conditions negatively affecting recruitment. Moreover, the federal groundfish fishing capacity reduction program, or vessel buyback program, was implemented by the National Marine Fisheries Service in 2003 in an effort to increase productivity, promote economic efficiency, and to help conserve and manage the resources in the groundfish fishery. The program involved a reduction in the fishing capacity of both the Dungeness crab, *Cancer magister*, and ocean shrimp fisheries. As a result, 85 ocean shrimp permits were relinquished coastwide: 31 from California, 40 from Oregon, and 14 from Washington.

For the last several years, fishable concentrations of ocean shrimp in waters off Oregon have been almost exclusively off the northern half of the state. If recruitment off southern Oregon recovers, ocean shrimp in California waters may bounce back as well.

Management Considerations

The mandatory requirement of BRDs on nets used in the ocean shrimp trawl fishery (FGC Section 8841) has proven to be a highly successful method of reducing bycatch. Three types of BRDs are currently allowed in the statewide California ocean shrimp fishery, including rigid-grate, soft-panel, and fisheye excluders; however, the Commission is currently considering changes to BRD regulations in the California ocean shrimp fishery. Recent experimentation by ODFW in Oregon waters has demonstrated that rigid-grate BRDs are the most effective in reducing groundfish bycatch of the three allowable BRD types. A phone survey conducted by CDFG in 2007 on active, ocean shrimp fishermen in California concluded that the majority of vessels in the northern region are double-rigged and use rigid-grate BRDs. The fishermen surveyed also reported the most common bar spacing on rigid-grate BRDs in recent years was 1¼-inches (32-millimeters) to 1½-inches (38-millimeters). Recent experimentation by ODFW in Oregon waters indicated that ¾-inch (19-millimeter) bar spacing on rigid-grate BRDs may further reduce bycatch rates to well below 5 percent of the total catch with minimal shrimp loss. Therefore, reducing the bar spacing on rigid-grate BRDs to ¾-inch (19-millimeter) or less should be considered by managers.

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4. Ridgeback Prawn

Review of the Fishery

During the early 1960s, bottom trawlers operating in the Santa Barbara Channel noticed incidental catches of ridgeback prawn, *Sicyonia ingentis*, in their groundfish catch. By 1967, a directed bottom trawl fishery was operating under the authority of a prawn trawl permit and was regulated with area restrictions, gear specifications, and incidental catch limits for non-target species. However, it was a minor fishery until 1978 due to low market demand. An increase in demand in 1979 resulted in 356,700 pounds (162 metric tons) being landed (Figure 4.1). Since then, landings have fluctuated with two major peaks; one in 1985 of 896,500 pounds (406 metric tons) and a record high in 2000 of 1,565,000 pounds (710 metric tons). By 2004, landings declined to their lowest level in 25 years and have remained flat since then. This fishery is characterized as being low in volume and high in value when compared to the California fishery for Pacific ocean shrimp, *Pandalus jordani*.

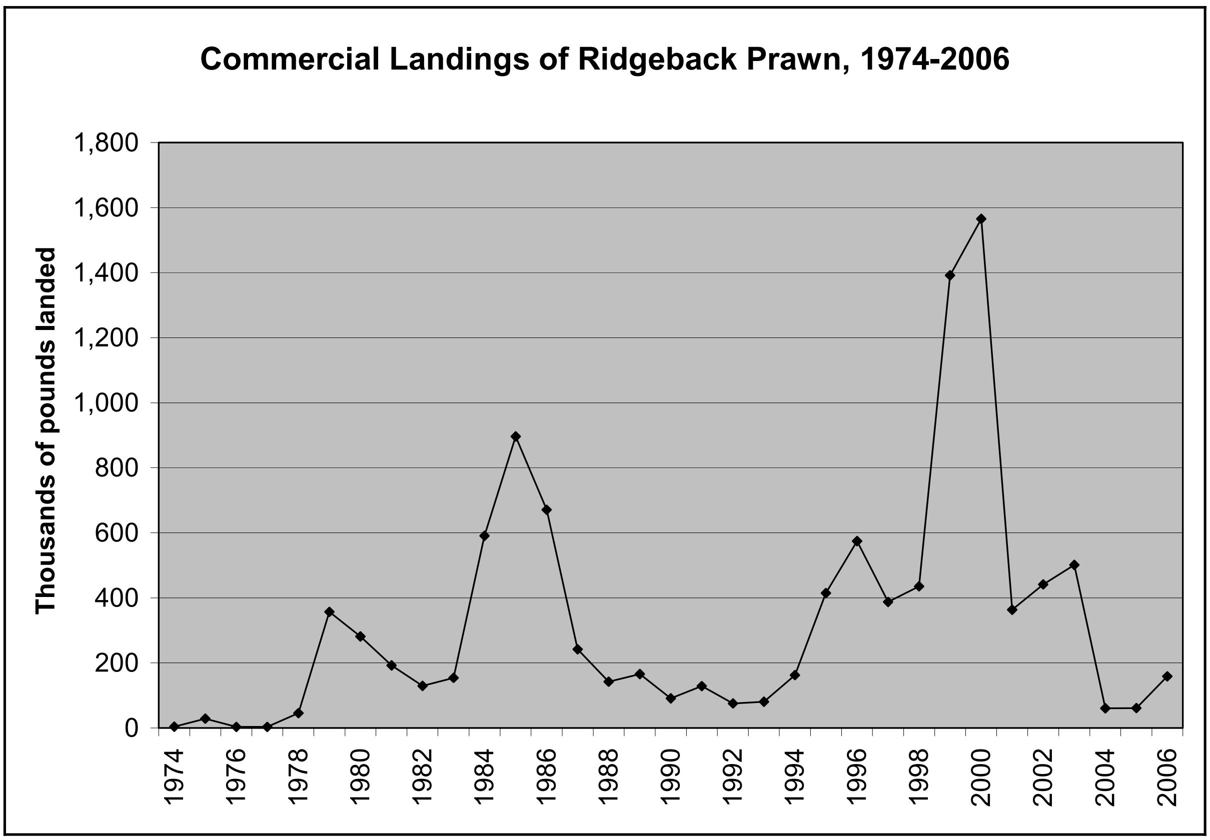

Figure 4.1. Annual California commercial landings (pounds) of ridgeback prawn, 1974-2006. Data source: CDFG commercial landing receipts.

Marketing this product was difficult in the early years of the fishery due to an enzymatic breakdown of the prawn flesh after death, causing an unappealing, “blackening” discoloration (Figure 4.2). Since the 1980s, new handling techniques were developed, such as keeping the prawn chilled or selling the prawn live, which enabled the product to expand beyond the Santa Barbara and Ventura ports to markets throughout southern California. The average annual ex-vessel price increased from $0.60 per pound in the 1970s to $1.00 per pound in the 1980s and peaked at $2.80 per pound in 1992. Since 1992, the annual ex-vessel price has averaged $1.70 per pound. In 2006, the average ex-vessel price was $2.01 per pound for live and dead prawn.

Figure 4.2. Ridgeback prawn, *Sicyonia ingentis*. The “blackening” discoloration, as observed in the head region, occurs after death. It is a byproduct of enzymatic activity that breaks down the color pigment. Photo credit: CDFG.

Since the species does not freeze well, it is primarily sold live or as fresh whole prawns. The live market is considered the best way to prevent discoloration and generates the highest ex-vessel value. Since 1995, live landings have been an important component of the fishery, averaging $2.11 per pound. In 2004, the live landings hit a peak of 71 percent of the total reported catch but dropped to only 7 percent in 2006. The decrease in market deliveries of live ridgeback landings resulted in market prices ranging from $1.50 to $4.00 per pound in 2006.

Fishing revenues from the 2006 commercial harvest of ridgeback shrimp were about $332,000 (ex-vessel 2006 dollars). The contribution to total business output for the State from the 2006 commercial harvest is estimated to be $641,000 and total employment and wages from ridgeback shrimp is estimated to be the equivalent of 11 jobs and $295,000 respectively.

The Santa Barbara Channel is considered the center of the fishery, and ports within Ventura and Santa Barbara counties receive the majority of the ridgeback prawn landings from year to year. In 1981, Morro Bay became the first port to record landings north of Santa Barbara. These vessels were most likely fishing in the Santa Barbara Channel and landing their catch in Morro Bay. The total landings were relatively low and they have been insignificant since then. By 1984, the fishery expanded south of Santa Barbara into waters adjacent to Los Angeles County, with most of the activity occurring in Santa Monica Bay. A nominal amount of effort also occurred in San Diego County in the 1980s and 1990s, but no catch has been recorded there since 2000.

Vessels participating in the current fishery range from 29 to 63 feet (9 to19 meters) in length. The primary gear used in the fishery is a single-rig shrimp trawl with a single-walled net with mesh sizes ranging from 1¾- to 2¼ -inches (4.5- to 5.7-centimeters). Vessels deploying double-rigs are generally larger than vessels using single-rigged nets. Catch efficiency of a double-rigged vessel is as much as 60 percent higher than a single-rigged vessel. However, double-rigged gear is not preferred in this fishery because they are too costly to operate when the harvestable biomass is not available in high concentrations.

A season closure from June 1 through September 30 was adopted in 1983 by the Fish and Game Commission (Commission) to protect the ridgeback during their peak spawning months (Title 14, Section 120.3). During the closed season, incidental take of ridgeback prawns is allowed while fishing for other species, however, no more than 50 pounds (23 kilograms) or 15 percent of the weight of the load of fish is allowed to be taken. During the open season, no more than 1,000 pounds (454 kilograms) per trip of any non-groundfish including no more than 300 pounds (136 kilograms) of groundfish may be possessed on any vessel operating under provisions of the permit. Any amount of sea cucumbers may be landed with ridgeback prawn, as long as the vessel owner/operator has a valid sea cucumber permit. Trawling for ridgeback prawn has not been allowed in state waters (0 to 3 nautical miles from mainland shore, and off shore islands), since the development of the fishery. In 1983, a depth restriction was implemented to prevent trawling in any waters less than 150 feet (25 fathoms). Recent area/depth closures implemented to protect overfished groundfish stocks have further restricted trawling effort for ridgeback prawn.

Status of Biological Knowledge

The ridgeback prawn gets its name from its hard stony exoskeleton. It is the only species of rock shrimp that can be found along the west coast of the United States. This species ranges from Monterey Bay, California, to Isla Maria Madre, Mexico, including the Gulf of California. Major concentrations occur in the Santa

Barbara Channel which is considered to be the most suitable habitat, as well as Santa Monica Bay, and ocean waters off Baja California, Mexico. They are distributed between the inner to outer continental shelf between 16 and 984 feet (5 and 300 meters) but they are most abundant between 131 and 525 feet (40 and 160 meters). The species occurs primarily on soft bottom habitat composed of green mud, shell and sand, and can tolerate temperature and salinity gradients ranging from 39 to 86 ºF (4 to 30 ºC) and 33-35 ^{0}/00, respectively.

This species is the largest in its genera with the females attaining larger sizes than the males. The maximum length for females is 1.8-inches (4.6-centimeters) carapace length (CL) and the maximum length for males is 1.5-inches (3.8-centimeters) CL. Length-weight ratios for both sexes are equivalent. They typically recruit into the fishery after one year, although a majority of the catch is documented to be composed of two and three year olds. They have a maximum life span of five years and are dioecious (having separate sexes) unlike ocean shrimp which are protandrous hermaphrodites that change from male to female during their life cycle.

Ridgeback prawns are broadcast spawners, as opposed to other shrimp that carry their fertilized eggs. Females store packets of sperm (spermatophores) deposited by the males and release both the eggs and sperm into the water column where fertilization and embryonic development occurs. Spawning can occur after the first year of growth, but a majority of the spawning occurs upon reaching 1.2-inches (3.1-centimeters) CL in their second year of growth. The spawning season takes place from June through October, and individuals can spawn multiple times during this period. Females are known to produce 86,000 eggs on average during the spawning season. Observations of spawning events indicate that ridgeback prawn spawn in the water column at night during a new moon. Both sexes molt prior to and after the spawning season in the spring and late fall. A majority of females display synchronous molting right after the spawning season, but molting patterns of males are less discernable through out the year. Molting is rarely observed in either sex during the summer months.

This species is a benthic omnivore that feeds on organic surface sediments, diatoms, infaunal polychaetes, gastropods, and crustaceans. In Baja California, the ridgeback prawn is preyed upon by several species of searobins (Family Triglidae). Observations made in southern California found California scorpionfish, *Scorpaena guttata*, also feed on this species and it is presumed that rockfishes also feed on them. Other groundfish, such as lingcod, *Ophiodon elongatus*; sharks, rays and skates; as well as California halibut, *Paralichthys californicus*; and potentially octopus, may also prey on this species.

Status of Population

There have been no formal studies in recent years to determine the population status of the ridgeback prawn. However, there have been bottom trawl surveys performed by several city and county water quality agencies within the

Southern California Bight (SBC) that provide anecdotal information on the population. Results from these surveys from 1971 to 1985 showed that the ridgeback prawn was the second most abundant invertebrate species in the northern and central regions of the SBC on the outer shelf and upper slope of the continental shelf (148 to 1,033 feet (45 to 315 meters)). Another series of large scale bottom trawl surveys in SCB conducted by the Southern California Coastal Water Research Project in 1994 and 2003 found ridgeback prawn to be the second most abundant species on the middle shelf (85 to 328 feet (26 to 100 meters)); and it was the third most abundant macro-invertebrate species caught in the outer shelf (331 to 656 feet (101-200 meters)).

California has required ridgeback prawn trawl logbooks since the inception of the fishery in 1967. Since then, the reported Catch-per-Unit-Effort (CPUE) has varied and three major peaks have occurred; a high of 254 pounds (115 kilograms) per tow/hour during the 1984/1985 fishing season (33 active vessels); 161 pounds (73 kilograms) per tow/hour during the 1994/1995 season (35 active vessels); and 202 pounds (92 kilograms) per tow/hour during the 1999-2000 season (38 active vessels). The CPUE trend following the 1999/2000 season has been one of decline, averaging 63 pounds (30 kilograms) per tow/hour (Figure 4.4). The number of vessels also decreased from 38 vessels in the 1999/2000 season to 11 vessels by the 2005/2006 season.

The El Niño Southern Oscillation (ENSO) appears to play a major role in the population structure of the ridgeback prawn. This species' biological productivity is greatest during warm water years and is depressed during the cooler water regimes. An examination of both the commercial landing receipts and the trawl logbook data suggests a positive correlation between ENSO conditions and catch success. After the two biggest ENSO events of the past 30 years, the 1982-1983 and the 1997-1998 events, ridgeback prawn landings, along with CPUE, dramatically increased one to two years following these events. Since ridgeback prawn recruit into the fishery at around age one or two, it seems apparent that the oceanographic conditions, during very warm water ENSO years, have resulted in relatively successful reproductive seasons in the SCB.

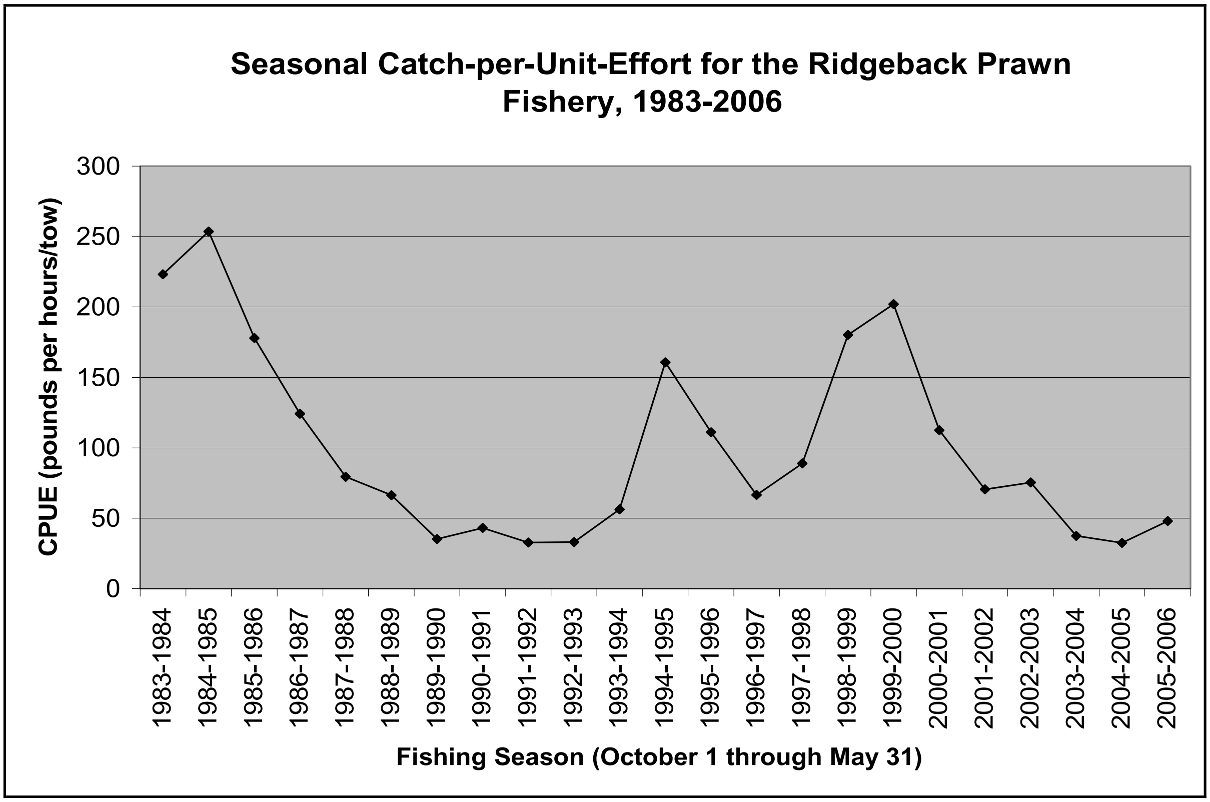

Figure 4.4. Catch-per-Unit-Effort for ridgeback prawn by fishing season (October 1 through May 31) from 1983-2006. Data source: CDFG commercial trawl logbooks.

Management Considerations

Since April 2006, bottom trawlers targeting ridgeback prawn have been required to use a rigid-grate fish excluder device to minimize bycatch (Fish and Game Code Section 8841). Section 8841 authorizes the Commission, the Pacific Marine Fishery Management Council, or the National Marine Fisheries Service to approve another type of fish excluder device if it is equal to or more effective in reducing bycatch. The current rigid-grate is not preferred by the fishery's participants because it becomes damaged when wrapped on the net reel. Future management considerations could explore alternative bycatch reduction devices that provide for the sustainable harvest of ridgeback prawn, reduces bycatch below current levels, and meets the needs of the industry.

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5. SEA CUCUMBERS

Overview of the Fishery

Sea cucumbers have been harvested in parts of the western Pacific for hundreds of years, and more recently the fisheries have expanded worldwide, involving the harvest of nearly 50 species. Two species of sea cucumbers are fished in California: the California sea cucumber, *Parastichopus californicus*, also known as the giant red sea cucumber, and the warty sea cucumber, *P. parvimensis*. The warty sea cucumber is fished almost exclusively by divers, while the California sea cucumber is caught principally by trawling in southern California, but is also occasionally targeted by divers in northern California. There is an artisanal dive fishery for warty sea cucumbers in Baja California, Mexico, and commercial dive fisheries are conducted for California sea cucumbers in Washington, Oregon, Alaska, and the coast of British Columbia, Canada.

The first recorded commercial landings of sea cucumbers in California were made in 1978 at Los Angeles area ports (Figure 5.1 and Table 5.1). Divers fishing warty sea cucumbers at Santa Catalina Island were the first to make landings, but they were soon joined by trawl vessels. Combined annual landings remained under 100,000 pounds (45 metric tons) until 1982, when the principal fishing area shifted to the Santa Barbara Channel. In that year, 140,000 pounds (64 metric tons) were landed with an ex-vessel value of about $25,000. Recorded landings fluctuated from 52,000 to 160,000 pounds (24 to 73 metric tons) over the next eight years, and in 1991 reached more than 577,000 pounds (262 metric tons). Through the first 18 years of the fishery, trawl landings composed an average of 75 percent of the annual sea cucumber harvest, but between 1997 and 2002, sea cucumbers landed by divers accounted for 70 to 88 percent of the combined dive and trawl landings. During that time period, trawl effort declined substantially, primarily due to court cases pursued by the Department of Fish and Game, which ruled that 16 trawl fishermen had fraudulently obtained their sea cucumber permits. Those fishermen were subsequently excluded from the fishery.

Diver effort and landings, in contrast, increased markedly from 1997 on, driven by a 1997 moratorium of the abalone fishery, a sea urchin fishery depressed by El Niño conditions, and a poor Japanese export market. Beginning in 1997, many commercial sea urchin or abalone divers, who also held sea cucumber permits, targeted sea cucumbers more heavily than before. In 2002, combined trawl and dive sea cucumber landings reached an all time high of 944,700 pounds (429 metric tons) with an ex-vessel value of $797,748. In the four years since 2002, the trawl catch has remained relatively stable, while the dive fishery has declined, averaging 300,000 pounds (136 metric tons) of warty sea cucumber annually. Part of the drop in the diver catch can be attributed to a shift in diver effort from warty sea cucumber to red sea urchin harvesting, especially at the northern Channel Islands, where a substantial segment of the fishery for both species occurs. Fishing revenue from the 2006 commercial harvest of sea cucumber was about $188,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $363,000. Likewise, total employment and wages from sea cucumber is estimated to be the equivalent of 7 jobs and $167,000, respectively.

Most of the California and warty sea cucumber product is shipped overseas to Hong Kong, Taiwan, mainland China, and South Korea. Asian markets within the United States also purchase a portion of California's sea cucumber catch. The majority are boiled, dried, and salted before export, while lesser quantities are marketed as a frozen, pickled, or live product. The processed sea cucumbers can sell wholesale for up to $20 per pound. In Asia, sea cucumbers are claimed to have a variety of beneficial medicinal or health enhancing properties, including lowering high blood pressure, aiding proper digestive function, and curing impotency. Studies of the biomedical properties of various sea cucumber chemical extracts, such as saponins, and chondroiton sulfates, are being conducted by western medical researchers investigating the efficacy of these substances for pharmaceutical products used in the treatment of arthritis, and as nutritional supplements.

Sea cucumbers are placed on outdoor drying racks after having been, slit, eviscerated, and boiled.
Credit: Dave Ono

There is no significant sport fishery for sea cucumbers in California. Sea cucumbers fall under the general 35 count bag limit for the sport take of many invertebrate species. Additionally, sport fishing regulations prohibit the take of sea cucumbers within 1,000 feet (305 meters) of the high tide mark, and few sport divers have shown an interest in harvesting sea cucumbers as a food item.

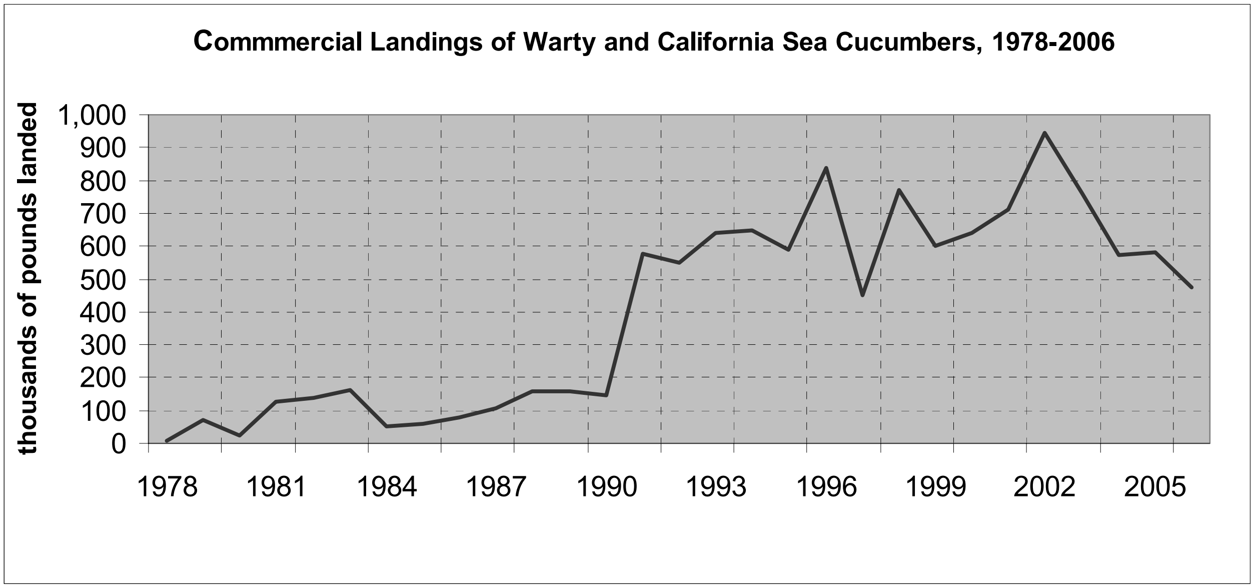

Figure 5.1 Annual combined commercial landings (pounds) of warty and California sea cucumbers from 1978 to 2006. Data from California Department of Fish and Game (DFG) Catch Bulletins (1978-1983) and the DFG commercial landing receipt database (1984-2006).

Restricted Access Program

A special permit to fish for sea cucumbers commercially was required beginning with the 1992-1993 fishing season. Qualifications for the permit were based upon meeting a minimum 50-pound (22.7-kilogram) landing requirement during a four-year window period.

Historical timeline for the commercial sea cucumber fishery restricted access program

1992	*Section 8396*; Fish and Game Code. Required fishermen to obtain a sea cucumber permit, issued to fishermen based on a qualifying minimum 50 lb landing of sea cucumbers made between 01/01/1988 and 06/30/1991
1994	*Section 8396*, Fish and Game Code, amended. Allowed some trawl fishermen to obtain sea cucumber permits on appeal, without having to meet the minimum landing requirement. Specified that sea cucumber permits were non-transferable and established a $250 annual permit fee.
1997	*Section 8407*, Fish and Game Code. Repealed section 8396 of the Fish and Game Code; instituted separate trawl and dive sea cucumber permits; set up a permit transfer mechanism, and set a ceiling of trawl and dive permittees allowed in the fishery, based on the number of permits issued during the 1997-98 license year.

In 1997, legislation was enacted that imposed a new regulatory regime on the sea cucumber fishery. The major regulatory changes included creating separate permits for each gear type, and limiting the total number of permittees in the sea cucumber fishery. A permit transfer procedure and transfer fee of $200 was also initiated by the 1997 legislation. Sea cucumber dive permits must remain dive permits if transferred, while sea cucumber trawl permits if transferred may remain trawl permits or be converted to a dive permit.

The maximum number of permits allocated was based on the number of permits issued during the 1997-1998 permit year and the meeting of a minimum landing requirement. In 2000, there were 113 sea cucumber dive permittees and 36 trawl sea cucumber permittees. By 2006, a number of dive and trawl fishermen had left the fishery, and there were 92 sea cucumber dive permittees and 20 sea cucumber trawl permittees remaining.

Status of Biological Knowledge

Sea cucumbers are long, soft-bodied, marine invertebrates in the class Holothuroidea. They are related to other organisms in the phylum Echinodermata such as sea urchins and sea stars. Their skeleton has been reduced to small calcarious pieces (ossicles) in the body wall, which have distinct species-specific shapes.

The California sea cucumber reaches a maximum length of 24-inches (61-

California sea cucumber, *Parastichopus californicus*
Credit: Dave Ono

centimeters) and is red brown or yellow in color with red-tipped papillae. The warty sea cucumber is 12 to 16-inches in length (30.5 to 40.6-centimeters) and chestnut brown with black tipped papillae on the ventral surface. Comparatively few studies have been done with eastern Pacific sea cucumbers, and as recently as 1986, a new *Parastichopus* species, *P. leukothele*, was described that is distributed from Pt. Conception, California to British Columbia, Canada at depths of from 80 to 940 feet (24 to 287 meters). It resembles the California sea cucumber in size and shape but has white papillae or tubercles.

Warty sea cucumber, *Parastichopus parvimensis*
Credit: DFG

Sea cucumbers are broadcast spawners with fertilization taking place in the water column. Sea cucumber size is difficult to determine, since they can contract dramatically, making length measurements unreliable. Furthermore, they can take up large quantities of seawater, rendering body weights unreliable.

The California sea cucumber is distributed from Baja California to Alaska. The warty sea cucumber is distributed from Baja California to Monterey Bay, although it is uncommon north of Pt. Conception. The California sea cucumber is found from the low intertidal to 300 feet (91 meters), and the warty sea cucumber is found from the low intertidal to 90 feet (27 meters), generally in areas with little water movement.

Sea cucumbers are epibenthic detritivores that feed on organic detritus and small organisms within sediments and muds. Buccal tentacles trap food particles using an adhesive mucus. Sea cucumbers are non-selective with respect to grain size and ingest only the top few millimeters of sediment. One study of warty sea cucumbers around Santa Catalina Island found that those living on rock rubble were 27 percent smaller and seven times more numerous than those residing on sandy substrates. The detritus on rock rubble was found to have three times more organic material per gram compared to the detritus from the sand substrate, and sea cucumbers on the sand ingested eight times more sediment. In a recent study, California sea cucumbers were found to have the highest densities on shell debris, gravel, and boulders, and the lowest on mud and silt bottoms.

Sea cucumbers can reach moderately high densities and are thought to be important agents of bioturbation. During feeding and reworking of surface sediments, sea cucumbers can alter the structure of soft-bottom benthic communities. The California sea cucumber can crawl an average of 12 feet (4 meters) per day, exhibiting no directional bias, presumably due to the even distribution of detrital food. Tagging studies are difficult since external tags are frequently lost and internal tags can be shed through the body wall. Sea cucumbers are also known to have a predator escape response involving a rapid creeping or swimming behavior, which propels them away from danger. Water can also be taken up in the respiratory tree and then forcefully discharged to discourage attackers. Predators include sea stars, including the sunflower star, *Pycnopodia helianthoides*; various fishes such as kelp greenlings, *Hexagrammos decagrammus*; sea otters, *Enhydra* *lutris*; and crabs. *P. californicus* is host to a worm-like internal parasitic gastropod, *Enteroxenos parastichopoli*, and an external parasitic snail, *Vitriolina columbiana*. Both sea cucumber species can also serve as a commensal host to the polychaete scale worm, *Arctonoe pulchra*.

Sea cucumbers have a distinctive spawning posture, detaching from the substrate and forming an S-shape to release their gametes up and away from the benthic boundary layer (Figure 5.2). There are separate sexes and the sex ratio is approximately one to one. Individuals do not form spawning aggregations. Spawning is partially synchronous with a portion of the population spawning simultaneously. Triggers for spawning are largely unknown, however spawning is thought to coincide with phytoplankton blooms during sunny days in late spring and summer. Oocytes are light orange in color and surrounded by a jelly coat. After fertilization, the embryo hatches into the gastrula (64 hours) and starts to swim. A feeding auricularia larva develops 13 days after fertilization and begins ingesting phytoplankton. The auricularia develops into a doliolaria larva (37 days post-fertilization) losing up to 90 percent of its body volume and rearranging its ciliary bands. The final doliolaria larval stage metamorphoses (51 to 91 days post-fertilization) into a newly settled pentactula. Pentactula have five primary buccal tentacles, and attach

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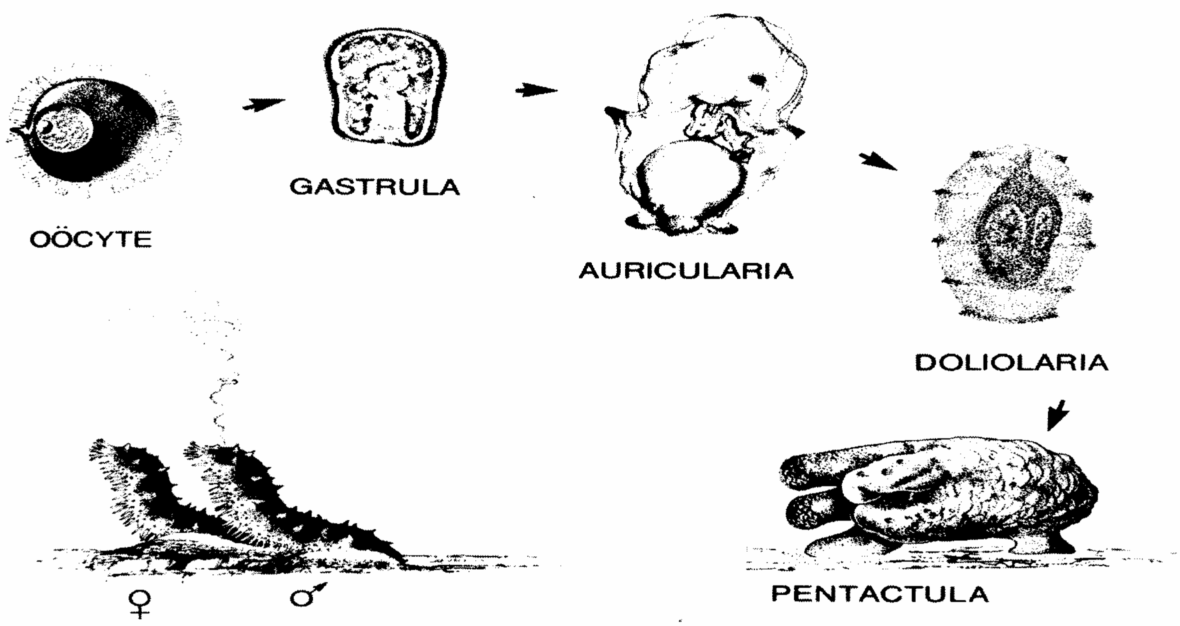

Fig. 2. Representation of spawning and development through settlement and metamorphosis of *P. californicus*. Development does not deviate significantly from that expected for an aspidochirote holothurian with planktotrophic larvae. Drawing is not to scale.

Figure 5.2. Life History of the California sea cucumber, *Parstichopus californicus*, (from Cameron and Frankboner. 1989. Journal of Experimental Marine Biology and Ecology, 127, 43-67)

to the substrate using a single pedicle. In the field, juveniles recruit to a variety of substrates, including rocky crevices, polychaete worm tubes, and filamentous red algae. Growth is slow in sea cucumbers. Juveniles become reproductively mature at 4 to 8 years.

Both species of sea cucumber undergo visceral atrophy each year. During atrophy the gonad, circulatory system, and respiratory tree are resorbed and reduced in size, and the gut degenerates. Feeding and locomotion stop prior to visceral atrophy, which occurs in the fall. Following the resorption of the visceral tissue the animal loses 25 percent of its body weight. The weight of the body wall cycles during the year, being the lowest early in the year and the highest in early fall prior to the start of visceral atrophy. Within two to four weeks regeneration begins, starting with the gut tube, then the respiratory tree and circulatory system, and finally the gonad regrows branched tubules. Juveniles also undergo yearly visceral atrophy; however, they do not have gonads at this stage. In the fall, animals may spontaneously eviscerate internal tissues if handled roughly, although this is not a common occurrence.

Status of the Populations

There is presently very little known about the population size of either California or warty sea cucumbers in California. The distribution of these species on rocky or sandy substrates is characterized as patchy, but warty sea cucumbers have demonstrated a seasonal aggregating behavior, possible as a precursor to spawning. Both sea cucumber species are also known to make seasonal vertical depth migrations. Sea cucumbers undergo sporadic recruitment, have a relatively high natural mortality, and are slow growing. Species with these life history traits tend to have a low maximum yield per recruit and are particularly vulnerable to overfishing.

The Channel Islands National Parks Service has been monitoring warty sea cucumbers at 16 sites in the northern Channel Islands and Santa Barbara Island since 1982 (Figure 5.3). These fishery independent data show that populations of warty sea cucumber are variable but have been declining at fished sites since 1990. Meanwhile, sea cucumber catches from the dive fishery have increased at some of these sites. Recent analysis comparing population trends at fished sites to those of two small reserves where fishing is prohibited indicate that populations at fished sites range from 50 to more than 80 percent lower than at protected sites.

Fishery independent sea cucumber density estimates have also been made using underwater video technology. Preliminary observations of California sea cucumbers in an established reserve in northern California (Point Cabrillo Marine Protected Area) at depths of 150 to 180 feet (46 to 55 meters) revealed densities averaging around 1,000 per acre (405 per hectare). By comparison, densities at a newly established reserve (Punta Gorda Ecological Reserve) were much lower, ranging from 120 to 350 per acre (49 to 142 per hectare). Only the large size classes were observed in these surveys, suggesting low levels of recruitment.

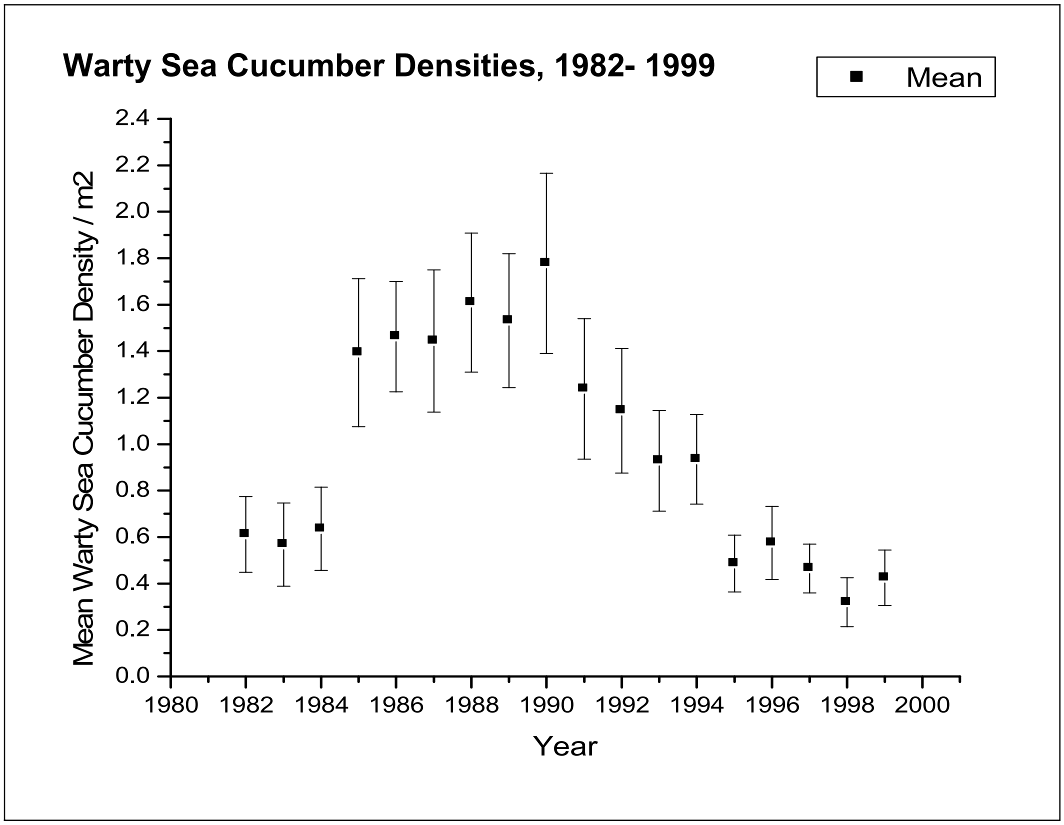

Figure 5.3 Density of the warty sea cucumber, *P. parvimensis*, quantified by the Channel Islands National Park at the northern Channel Islands (1982-1999).

Management Considerations

It is unknown if the current levels of fishing effort and harvest are sustainable, and whether the stocks of warty and California sea cucumbers are robust enough to support those fisheries over the long term. There are several activities that could help indicate the effectiveness of current management regulations:

- Maintain the logbook reporting requirements for the dive and trawl sea cucumber fisheries. In order to manage these two fisheries, it is important to know the quantities, location, and depths of each species taken. In 2003, individual codes were assigned to each sea cucumber species in the DFG landing receipt database.

- Additional fishery independent information could help inform management decisions for this fishery. Submersible, ROV, or diver video surveys of fished and unfished areas are potentially useful activities.

- Efforts to collect field data necessary to perform stock assessments and generate biomass estimates for both the warty and California sea cucumber would lay the foundation for improved management of these resources. The biological, catch, effort, and catch-per-unit-of-effort (CPUE) parameters derived from logbook data, along with field observations of sea cucumber distributions and densities, could be used to model the impact of different levels of fishing intensities. However, due to difficulties in interpreting CPUE data for dive fisheries, it would be preferable to conduct population modeling using fishery-independent data sources for abundance trends, such as described above.

- Finally, if the limited entry restrictions on the dive and trawl sea cucumber fisheries do not adequately limit the take of sea cucumbers at sustainable levels, additional management options, such as individual or area quotas, or seasonal closures, may be required. The restricted access regulations imposed on the dive and trawl sea cucumber fisheries in 1997 have effectively capped the number of sea cucumber permittees, and, have, over the proceeding nine years, contributed to a reduction in the number of licensed harvesters engaged in both fisheries. What has yet to be determined is whether the resultant levels of fishing effort and harvest are sustainable, and whether the stocks of warty and California sea cucumbers are robust enough to support those fisheries over the long term.

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Table 5.1 Commercial Landings (Pounds) of Sea Cucumbers, 1978-2006

Year	Pounds	Year	Pounds	Year	Pounds
1978	8,780	**1988**	159,106	**1998**	770,679
1979	69,438	**1989**	160,011	**1999**	600,875
1980	23,060	**1990**	147,284	**2000**	638,376
1981	128,362	**1991**	581,974	**2001**	712,660
1982	139,487	**1992**	549,191	**2002**	944,702
1983	163,495	**1993**	646,210	**2003**	758,567
1984	52,354	**1994**	646,926	**2004**	572,397
1985	59,076	**1995**	598,888	**2005**	580,020
1986	77,697	**1996**	839,382	**2006**	476,108
1987	107,678	**1997**	452,640		

Data sources: CDFG Catch Bulletins (1916-1983) and CDFG commercial landing receipts (1984-2006).

6. PISMO CLAM

Review of the Fishery

Commercial Pismo Clam Fishery

The Pismo clam, *Tivela stultorum*, gets its name from the Chumash Indian word "pismu," meaning "tar," because of the natural deposits of tar found in the Pismo Beach area. The Pismo clam is an important invertebrate species that once supported a significant commercial fishery, along with an extremely popular recreational fishery that still exists today. The commercial harvest of Pismo clams began in the early 1900s when horse-drawn plows were used to rake the beaches, and clams were hauled off in wagons for animal feed. The utilization of Pismo clam meat for human consumption grew to considerable importance by 1911, which led to the first regulations for managing the fishery (Table 6.1). Records of the commercial harvest of Pismo clams began in 1916, and continued through 1947 when the fishery was prohibited (Figure 6.1). During these 29 years, it is estimated that commercial diggers harvested 6.25 million pounds (2,834 metric tons) of Pismo clams (landings reported in round weight). Round weight is defined as the weight of the whole clam (including shell) before being processed. The average annual catch was nearly 100,000 pounds (45 metric tons) and the highest was 665,700 pounds (302 metric tons) in 1918. The sudden decrease in catch in 1942 was a result of beach closures by the U.S. Coast Guard that remained in effect during World War II. Overall, the commercial Pismo clam fishery was ranked third in economic importance to all mollusks, being exceeded only by oysters and abalone.

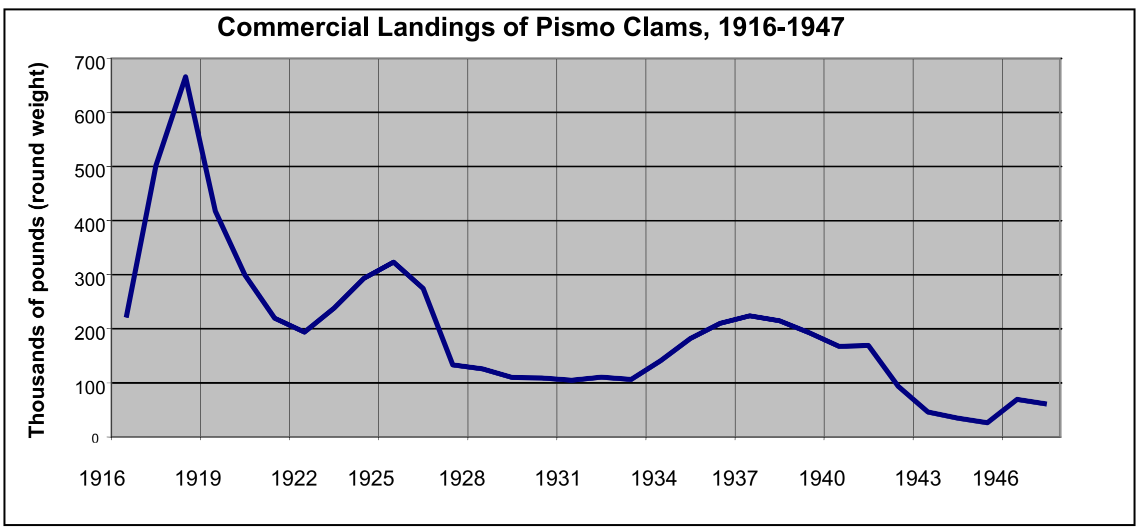

Figure 6.1. Annual commercial landings (pounds) of Pismo clam from 1916 to 1947. Data source: Bureau of Marine Fisheries (1949) Fish Bulletin with historical review (1916-1947).

The importation of Pismo clams from Baja California, Mexico occurred as early as 1919, and most likely continues to this day. In 1935, a total of 14,200 pounds (6.5 metric tons) of live Pismo clams were imported from Mexico to Long Beach, California, at which point they were shucked and canned. It is assumed that this venture was not economically successful, because no more clams were imported until 1941. Beginning that year, only the meat was imported to the U.S., the clams having been shucked at the beaches where they were dug. Shipments would arrive via boat, in 5-gallon (18-liter), refrigerated containers. At the U.S. canneries, the clams were cooked, minced, and packed into half-pound cans.

The importation of Pismo clam meat to canneries in California developed into an industry of considerable importance. From 1941 to 1947 the shipment of Pismo clam meat (reported in shucked weight) ranged from 10,800 pounds (4.9 metric tons) to 6.76 million pounds (3,069 metric tons) annually (Table 6.2). Shucked weight is defined as the weight of the clam meat after it has been processed. This development reached its peak in 1945 as a direct result of the tremendous demand put on all fishery products during World War II. The importation of Pismo clam meat stopped in 1949 due to logistical problems associated with shipping, and competition with other clam species in the U.S. domestic market. It is documented that Pismo clams were imported sporadically in small quantities up until 1962. After 1962 seafood imports from Mexico into the United States were not identified by species.

Mexican landing records for Baja California Norte show that from 1990 through 1999 Pismo clam landings ranged from a low of 822,000 pounds (373 metric tons) in 1994 to a high of 2.05 million pounds (930.7 metric tons) in 1992, with a 10-year average of 868,000 pounds (394 metric tons). In Baja California Sur, from 1978 to 1995, landings ranged from a low of 2.42 million pounds (1,098.6 metric tons) in 1984, to a high of 13.01 million pounds (5,906.5 metric tons) in 1981, with an 18-year average of 6.46 million pounds (2,933 metric tons). The total percentage of these landings imported into the United States cannot be determined.

Recreational Pismo Clam Fishery

Pismo clams remain an important sport fishery in California. They have a distinctive and excellent flavor; they are prepared as chowder, seafood cocktail, fried or eaten raw. Pismo clams have been linked to several human fatalities involving Paralytic Shellfish Poisoning (PSP). It is therefore advised that only the white meat be consumed and all dark meat and digestive organs be discarded.

The most common method of harvesting Pismo clams is with a six-tined potato fork. The digger works backward in a line parallel to the edge of the water probing with the fork, increasing the success rate with the broad side of the clam presented to the fork. Working parallel to the water is also a good safety practice since it allows the digger to watch for approaching breakers. Once a clam is struck it is lifted out and measured and placed in a sack, if legal. Regulations require that all undersize clams be reburied in the area from which they were dug. Another method is to shuffle one's bare feet along the bottom until a siphon or shell is felt. Pismo clams can be visually spotted during low tide by looking for the tufts of commensal hydroids exposed above the surface of the sand.

Diving for Pismo clams has become an increasingly popular sport among the recreational community. Divers search just beyond the breakers by probing the sand with a knife or looking for siphons, exposed shells, or tufts of hydroids. Diving for Pismo clams is particularly effective on beaches with a steeper sloping gradient. These types of beaches receive less exposure during low tide, and most of the clams are found in water too deep to target with a potato fork.

The historic epicenter of recreational clamming activity was once Pismo Beach itself. In 1949, an estimated 5,000 diggers per day harvested more than 2 million clams over a period of 2.5 months on a stretch of beach that had just been reopened to digging after being closed for 20 years. During that time, an additional estimated 1 million undersized clams were left stranded on the surface and wasted on that same stretch of beach.

Pismo Clam, *Tivela stultorum*
Credit: Kai Lampson

The recreational digger has probably been the largest contributing factor to losses incurred in the Pismo clam population. Current regulations are in place to prevent such a massive depletion. Recreational clamming is regulated by a 10 per day bag limit and a minimum size of 5-inches (127-millimeters) north of the San Luis Obispo/Monterey county line and 4.5-inches (114-millimeters) south of this county line. Sub-legal clams must be immediately reburied. In addition, clamming is closed during parts of the year and in specific geographic locations (Table 6.1). Healthy populations of Pismo clams can be found from Santa Barbara County to the U.S. Mexico Boarder. Digging for Pismo clams is not nearly as popular as it once was. There are no current estimates for the number of people who participate in the fishery, but Pismo clammers probably number in the several thousands.

Sea otters have been blamed for the loss of the recreational clam fishery at Pismo beach since the estimated sport catch declined form 343,000 clams in 1978 to zero by 1983. In actuality, the loss of the fishery at Pismo Beach cannot be entirely attributed to sea otter predation. The Pismo clam population was being fully utilized by the recreational fishery prior to the sea otter's arrival; the otters simply tipped the balance and caused the population to collapse. There is some evidence to suggest that a Pismo clam fishery might be able to coexist in an area utilized by otters. Relatively low adult Pismo clam densities have produced successful sets in the past and could do so if sea otter foraging pressure was low. Sea otter pressure does decline in an area when the large peripheral male group moves on to new areas. Such an occurrence most likely explains the resurgence of a recreational fishery at Pismo Beach between 1990 and 1993. During this period sea otters were foraging offshore and in other areas. In 1992, sea otters were observed again foraging in the Pismo Beach area, and in 1993 the last take of a legal clam was reported.

Status of Biological Knowledge

The Pismo clam has two symmetrical shells that are hinged together with interlocking teeth at one end by a dark raised ligament. The shell is thick, and the outside is smooth with fine concentric growth lines. It is covered with what appears to be a thin coat of varnish, the periostracum, which cracks and peels off when the shell is exposed to direct sunlight. The shells of individual clams are highly variable in both color and pattern. The characteristic color and pattern is solid pale buckskin, though they range from this to dark chocolate. Some individuals are marked with chocolate brown lines radiating from the margin. Surveys have shown that these "striped" Pismo clams comprise about 5 percent of the total population. A third color pattern consists of three light streaks radiating from the margin, though these streaks generally disappear completely with age. The tendency for stripes or streaks is a natural variation and the sex of the clam cannot be determined by pattern.

In the majority of Pismo clams, the sexes are separate with an equal proportion of males and females represented in populations. Pismo clams mature after their first winter in southern California and after their second winter in central and northern California. Sexually mature clams have been noted as small as 0.5-inches (12.7-millimeters) in shell length. Spawning usually begins in late July or early August and continues through November. Fertilization occurs externally when the male releases sperm and the female releases eggs into the surrounding water. The number of eggs per female is proportional to a clam's size. In laboratory-held clams, a 1.2-inch (30.5-millimeter) female contained 0.4 million eggs, and a 2.9-inch (73.7-millimeter) female had 4.7 million eggs. In comparison, a 5-inch (127-millimeter) female averages 15 million eggs. In nature, less than 1 percent of these eggs would become mature clams. Historic surveys have documented poor survival rates. For example, in one year only 33,000 clams resulted from an estimated 120 trillion eggs spawned. The mechanisms that cause these extremely high mortality rates and poor recruitment are not completely understood. Large surf, strong currents, shifting sand, red tide events, and sudden changes in temperature or salinity may all be contributing factors. Once a clam has settled out of the water column and onto the substrate, it is less susceptible to these forces, though mortality rates remain very high. Oil and other pollutants also play an important role in the mortality rate of the Pismo clam.

Little is known about the larval stages of the Pismo clam in nature. In laboratory culturing experiments, fertilized eggs hatched into larvae within approximately 48 hours. Laboratory larvae 60 to 70 hours old displayed the behavior of settling to the bottom and remaining benthic or near benthic throughout larval development. If larval Pismo clams in nature also exhibit a benthic phase, larval transport by near-shore currents may be limited, and recruitment would have to occur locally. At 22 to 55 days old clams have completely metamorphosed, developed a foot, and anchored themselves to sand grains with their thread-like byssus. The byssus helps the clam maintain itself in an environment of constantly moving sand and wave turbulence. As the clam increases with size the byssus disappears, and the clam's weight and burrowing power helps to maintain its relative position on the beach. Pismo clams characteristically orientate themselves vertically with the hinge and ex-current siphon towards the ocean, the mantle edge and in-current siphon towards the beach, and with the ligament at the center of the hinge oriented up. Pismo clams usually live in the intertidal zone on flat beaches of the open coast, but they have been found out to depths of 80 feet (24.4 meters), and are sometimes encountered in the entrance channels to sloughs, bays and estuaries. Their normal depth in the sand is 2 to 6 inches (51 to153 millimeters). Burrowing is accomplished by moving the foot rapidly to loosen the surrounding sand. Jets of ejected water then help to further loosen the sand along the sides of the shell.

The weight of the clam and the pull of the foot together drag the clam down through the sand.

The largest Pismo clam recorded in California came from Pismo Beach and was 7.37-inches (18.7-centimeters) across and estimated to be 26 years old. However, the size of a clam does not directly correlate with its age. A number of clams form Southern California have been aged as being over 35 years, though the majority of these clams were less than 6.5-inches (16.5-centimeters) across. The oldest Pismo clam on record was collected from Zuma Beach, California and was estimated to be 53 years old, measuring only 5.25-inches (13.3-centimeters) across. The age of Pismo clams can be determined by the concentric growth rings on the shell. The rings alternate from darker to lighter color, and are usually formed during the fall and winter months when the clam is exposed to prolong periods of disturbances, or during the spawning period.

The Pismo clam grows continuously throughout its life. As it grows the shell not only becomes thicker but increases in diameter. Growth varies considerably from month to month, with the greatest increase taking place in the spring, summer, and early fall months. The Pismo clam is about 0.009-inches (0.23-millimeters) at metamorphosis, and grows at an average rate of 0.084-inches (2.1-millimeters) for the first three years. Growth slows considerably as the clam ages, with the increase in shell length not more than 0.2-inches (5-millimeters) per year at age 10. Growth rates are dependent on water temperature and vary among beaches. A 4.5-inch (11.4-centimeter) clam could be from 5 to 9 years old. Along the central coast of California, clams are estimated to reach 4.5-inches (11.4-centimeters) between ages 7 and 8.

Fossil remains of Pismo clams have been found in Pleistocene deposits at least 25,000 years old in Santa Barbara and San Diego Counties. Thus the species has been present along our coast since the time of the last ice age. The Pismo clam belongs to the Veneridae family, which is characteristic of tropical seas. Though the Pismo clam is not tropical in distribution, it prefers warmer waters, being historically recorded from Half Moon Bay, California, to Socorro Island, Baja California Sur, Mexico. However, it has not been found at Half Moon Bay for decades, and its present range extends northward only to Monterey Bay. Pismo clams have been historically found at three of the Channel Islands: Santa Cruz, Santa Rosa, and San Miguel islands. Healthy populations are known to currently exist at Santa Cruz and Santa Rosa islands, while San Miguel Island has not been surveyed for Pismo clams.

Unsuccessful attempts have been made to introduce Pismo clams as far north as Washington State. Pismo clams do not fare well in extremely cold water, and are very susceptible to freezing temperatures during low tide due to their shallow orientation in the sand. Surveys have shown that Pismo clams that have been translocated north of their historic range usually die within the first year of being planted.

The Pismo clam is a detritus filter feeder, although living single-cell organisms comprise a considerable portion of the diet. Water is taken in through the in-current siphon that has a very fine net of delicately branched papillae across the opening. The net forms a screen that excludes the entrance of large particles, but permits the intake of water and food, which then pass over the gills where food particles are trapped in strings of mucus. The mucus is brought directly into the stomach where food is carried towards the liver, and larger particles are expelled through the intestine. Despite this elaborate system, more than half of the contents of the stomach and intestine are sand.

The types of food utilized by Pismo clams include detritus from disintegrating plant and animal cells, phytoplankton, zooplankton, eggs and sperm, and bacteria. A 3-inch (7.6-centimeter) Pismo clam filters an average of 15.9 gallons (60 liters) of water during its feeding per day or 482 gallons (1,824 liters) a month. This amounts to approximately 5,790 gallons (21,915 liters) of water per year being strained by one 3-inch (7.6-centimeter) clam.

Pismo clams have many natural predators: humans, sharks, rays, gulls; moon snails, *Polinices spp.*; crabs; sea otters, *Enhydra lutris*; and some species of surf fishes (such as the California corbina, *Menticirrhus undulatus*). Humans have utilized Pismo clams for food for over 2,000 years, as evident from shells and fragments found in the kitchen middens of Native Americans. Bat rays, *Myliobatis californica*, have developed an efficient technique to pull clams from their beds by using their "wings" to establish a suction force similar in manner to the way a plumber's helper clears the drain of a kitchen sink. After the clams have been sucked from the sand, the ray can simply pick up, crush and swallow them. Gulls have learned to open live clams up to 3-inches (7.6-centimeters) in diameter by carrying them up to 50 feet (15 meters) into the air with their beaks and dropping them onto hard-packed sand. It only takes several attempts before the Pismo's shell shatters, or the abductor muscle tears, and the soft flesh is exposed. The moon snail drills a tiny hole in the clam's thick shell with a rasping tongue or radula. Once the hole is completed the snail inserts its radula to remove the soft flesh. Several crabs of the genus *Cancer* also feed upon Pismo clams. These crabs are able to crack clams up to 1-inch (25.4-millimeters) in diameter with their pincers.

Sea otters, efficient in harvesting Pismo clams, can quickly denude a local clam bed of everything except for small individuals. An adult sea otter needs to consume roughly 25 percent of its body weight each day in order to survive. An average male sea otter weighs 65-pounds (29.5-kilograms) and the females average 45-pounds (20.4-kilograms). This amounts to roughly 80 clams per otter per day if Pismo clams are their primary food source. A single otter has been observed to eat 24 clams in 2.5 hours. The extension of the sea otter's range to Monterey Bay in 1972, Morro Bay in 1973 and Pismo Beach in 1979 has precluded the recreational fishery for Pismo clams in those areas. In 1980, it was estimated that otters consumed over 700,000 Pismo clams in the Pismo Beach area.

Parasites of Pismo clams include a polychaete worm that bores into the shell, and the more common larval cestodes, which occur as small yellowish-white cysts. About one-third of all large Pismo clams are infected with cestodes. These cestodes have been identified as the larval stage of a tapeworm that infects stingrays and skates. Cestodes can impair the clam's sexual development but are in no way harmful to humans. Trematodes have also been reported in some clam populations. A commensal hydroid colony, *Clytia bakeri*, is often found attached to the edge of the shell nearest the surface, resembling a hairy tuft. Much less common are small, white, commensal pea crabs, *Fabia spp.*, (which are occasionally found in the mantle cavity of clams and feed on food particles collected in the gills).

Status of the Population

Over the past century, Pismo clam abundance has seriously declined in many parts of its historic range due to a number of fishery-dependent and fishery-independent factors. Historical observations have shown that Pismo clam populations are resilient and have the ability to rebound after just a few years of successful recruitment. The Department of Fish and Game first examined recruitment in 1919, and annual surveys have been conducted from 1923 to 2000 to obtain information on age, recruitment, year strength, and exploitation trends. Originally only Pismo Beach was surveyed, but after 1948, beaches in Morro Bay, Cayucos, Monterey County, and from Santa Barbara County to San Diego County were included. From 2000 to 2005 only Coronado Beach in San Diego County has undergone an annual survey by the Department of Fish and Game.

Surveys conducted form 2000 to 2005 at Coronado Beach indicated that the Pismo clam population was relatively stable and that some recruitment was taking place. Recent reports from clam diggers, as well as divers indicate that significant numbers of Pismo clams continue to be harvested from some of the beaches in southern California. In addition, Pismo clam populations at the Channel Islands appear to be stable, as shown by surveys conducted by the National Park Service.

Management Considerations

Past experience has shown that planting Pismo clams will most likely not expand the present range of the species, nor would it be expected to re-establish a population where the native stock is depleted. The spawn from planted clams would not help to repopulate a beach where the environmental conditions (shifting sand, erosion, pollution, etc.) are keeping the existing native population at a low level. Pismo clams were sporadically planted on beaches from Washington to the Mexican border from 1900 to 1989 with extremely low survivorship. None of the clams planted north of Monterey Bay survived more than three years after being relocated, with an average survivorship of less than one year. Even under optimal conditions, considering natural mortality, not more than 200 out of 1,000 one- or two-year old clams would be expected to reach legal size.

In southern California, the planting of large clams has paradoxically had a negative effect on local populations. News of a planting project eventually spreads, and the public turns out in mass to search for these clams. Not only are the planted clams immediately removed, but most of the native stock is also taken and the beach is left more barren than before the project. Past projects have shown that even if the clams are planted in Marine Protected Areas they are nevertheless not safe from poaching activities.

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Table 6.1. Regulations governing the take of Pismo clams, 1911 - present			
Year	**Minimum Size Limit**	**Bag Limit**	**Remarks**
1911	13 inches circumference (about 4⅞ inches diameter)	200	license required for sale of Pismo clams
1915	12 inches circumference (about 4½ inches diameter	50	
1917	4¾ inch diameter	50	Monterey Bay between Pigeon Point and Yankee Point open only between September 1 and April 30. All other areas open year round.
1921	4¾ inch diameter	36	
1927	5 inch diameter	15	Shipping of clams by common carrier prohibited and no clam out of the shell may be possessed unless being prepared.
1931	5 inch diameter	15	Sport fishing license required to take Pismo clams
1933	5 inch diameter	15	No digging for clams between ½ hour after sundown and ½ hour before sunrise. No clam digging implements in possession on beach during these hours.
1947	5 inch diameter	15	No Pismo clams taken in California can be sold
1948	5 inch diameter	10	
1949	5 inch diameter	10	All undersized clams must be returned form the hole which dug or to deep water.
1986	5 inch diameter north of the boundary between San Luis Obispo and Monterey counties 4 ½ inch diameter south of the boundary between San Luis Obispo and Monterey counties	10	May be taken in Santa Cruz and Monterey counties September 1 through April 30. In all other counties, except in state marine reserves or other marine protected areas which prohibit the take of clams, Pismo clams may be taken all year.
Data source is the Bureau of Marine Fisheries, California Division of Fish and Game (1950) Fish Bulletin (1911-1949) and California Code of Regulation, Title 14. Natural Resources (2005)			

Table 6.2. Commercial landings of Pismo clams (round weight in pounds) in California and imports of shucked meat (pounds) from Mexico, 1916-1947					
Year	**Landings From California**	**Imports From Mexico**	**Year**	**Landings From California**	**Imports From Mexico**
1916	220,600	------	**1932**	110,300	------
1917	502,100	------	**1933**	106,200	------
1918	665,700	------	**1934**	140,700	------
1919	417,500	------	**1935**	181,900	*14,224
1920	299,000	------	**1936**	209,800	------
1921	219,500	------	**1937**	224,000	------
1922	193,500	------	**1938**	214,600	------
1923	237,900	------	**1939**	192,700	------
1924	293,100	------	**1940**	167,500	------
1925	323,200	------	**1941**	168,800	10,837
1926	274,300	------	**1942**	93,600	90,979
1927	133,000	------	**1943**	45,900	565,764
1928	125,800	------	**1944**	34,500	1,464,974
1929	109,700	------	**1945**	26,100	6,676,775
1930	108,900	------	**1946**	69,200	1,426,062
1931	104,700	------	**1947**	60,600	159,968

------ No Pismo Clams were imported
* Live weight reported on fish receipts have been divided by 8 to supply the cleaned weight given here.
Data source is Bureau of Marine Fisheries (1949) Fish Bulletin with historical review (1916-1947).

7. CABEZON

Review of the Fishery

Fishing for cabezon, *Scorpaenichthys marmoratus*, started with the early Native Americans along the central California coast. In one study, cabezon represented five percent of the fish remains taken from exposed rocky coastal archaeological sites. Californians in the modern era did not target cabezon until the late 1930s. By the end of World War II, sportfishing interest in cabezon had increased markedly due to its edibility and relatively large size. Commercial interest in cabezon was generally low until the latter part of the 1900s, but has become a lucrative fishery since the 1990s. It remains so today with consistent market values of over $5.00 per pound. The importance of the cabezon fishery is reflected in the fact that it is now managed as its own separate harvest group with specific regulations for both sport and commercial fishing.

Private boat fishermen continually take most of the sport-caught cabezon in California. Over the 25-year period, 1981-2006, the average annual catch in number of fish landed for the private boat fishery was 34,300 fish, compared to 20,100 and 5,200 fish for beach/bank and man-made modes of fishing, respectively. The number of cabezon landed by private boaters peaked in 1984 at 55,400 fish statewide and the lowest annual catch for this group was 9,800 fish in 2006.

As game fish, significant numbers of cabezon in shallow, inshore waters makes them a popular target for free divers, in addition to those using scuba. A total of 3,000 cabezon were taken at nearly 150 Central California Council of Diving Clubs' free diving spearfish meets from 1958-2003, making it the eighth most frequently captured species out of 52 species landed. Meet locations ranged from San Luis Obispo County in central California to Mendocino County in northern California.

At present, Commercial Passenger Fishing Vessels (CPFVs) generally do not target cabezon, and only take a small amount of them compared to the total sport catch. Estimates from recreational sampling data show that in recent years the number of cabezon landed from CPFVs have contributed less than 10 percent of the total annual sport catch for this species. With the exception of CPFVs, there is little statewide historical data available for other modes of fishing regarding cabezon take prior to 1980. Starting in 1947, data collected from CPFV logbooks are available that show earlier landings of cabezon have at times been much greater than they have been since the 1980s (Figure 7.1). More restrictive management regulations since 1999 have contributed to this decline (see Management Considerations, below).

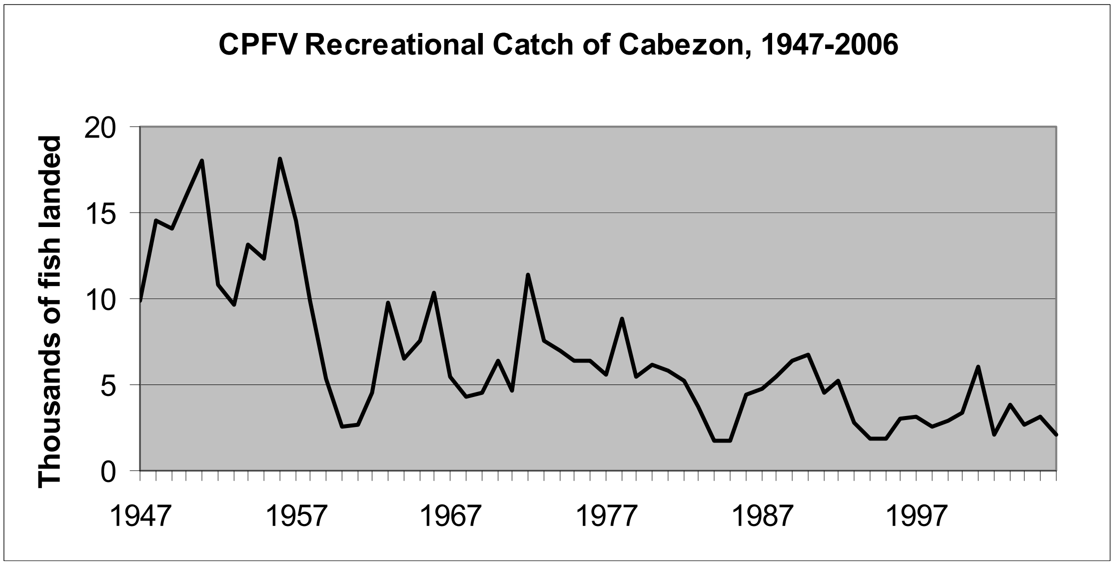

Figure 7.1. Recreational catches of cabezon from Commercial Passenger Fishing Vessels, 1947-2006. Data sources: CPFV logbook data. No data prior to 1947.

Historically, the vast majority of cabezon in California have been caught by recreational fishermen. However, from 1995 to 2002 commercial landings surpassed recreational take (Figures 7.2a and 7.2b). This sharp increase in commercial landings can be attributed to the advent of the nearshore live-fish fishery in the mid 1980s.

The nearshore live-fish fishery evolved from the demand for specialty foods in Asian restaurants and markets in southern California. Although starting out as an alternative fishery, it quickly expanded into a multimillion dollar industry by the early 1990s. Part of the reason for this boom was the willingness of consumers to pay a much higher price for live fish than dead fish of certain species, particularly plate-sized fish. That premium was passed on to fishermen in the form of higher ex-vessel prices (price per unit of weight paid to fishermen upon landing of catch) for live fish. Accordingly, average unit price per pound for cabezon has increased from $0.56 in 1991 to $5.03 in 2006 (Table 7.1), and unit prices have been recorded as high as $10 to $12 per pound most recently. Cabezon are one of the top four live-caught species groups in price per pound over the last five years, ranking only behind greenlings, rockfish and flatfish.

Following the recent adoption of more conservative harvest limits, commercial cabezon catch has stabilized at a lower level consistent with the set amount allocated by the state (see Management Considerations, below). In 2006, commercial landings of cabezon totaled 61,900 pounds (28 metric tons) and 87 percent (53,900 pounds) (24.5 metric tons) were brought to market in a live condition.

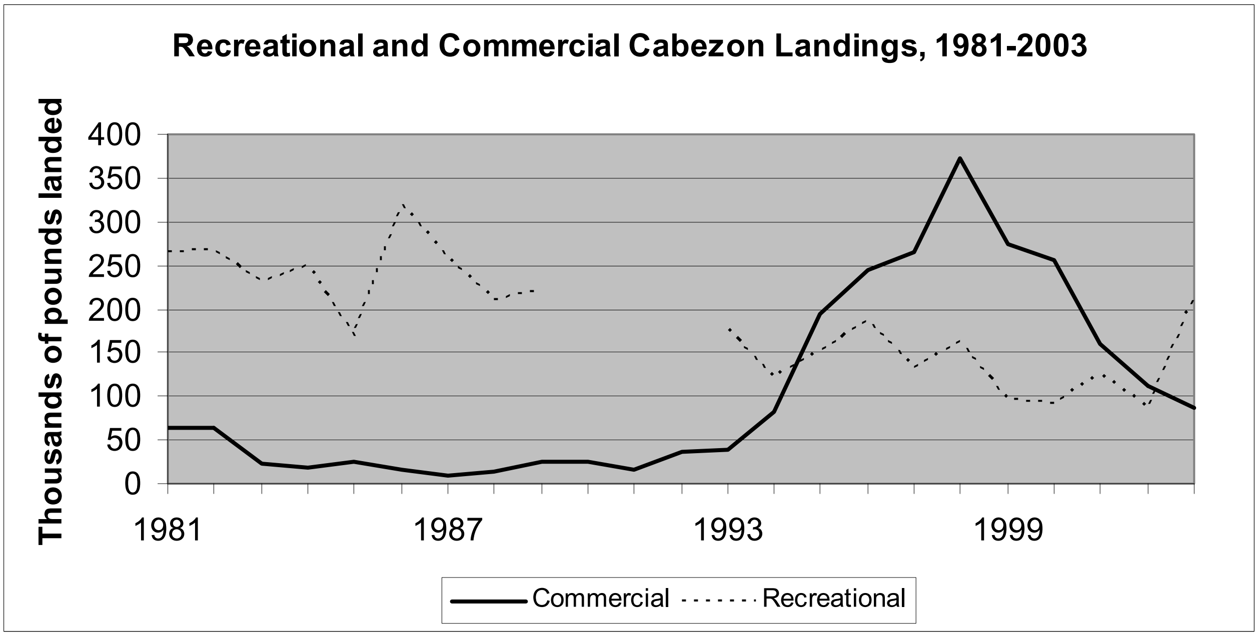

Figure 7.2a. Recreational and commercial landings in pounds for California-caught cabezon 1981-2003. Data sources: MRFSS recreational catch data and DFG commercial landing receipts.

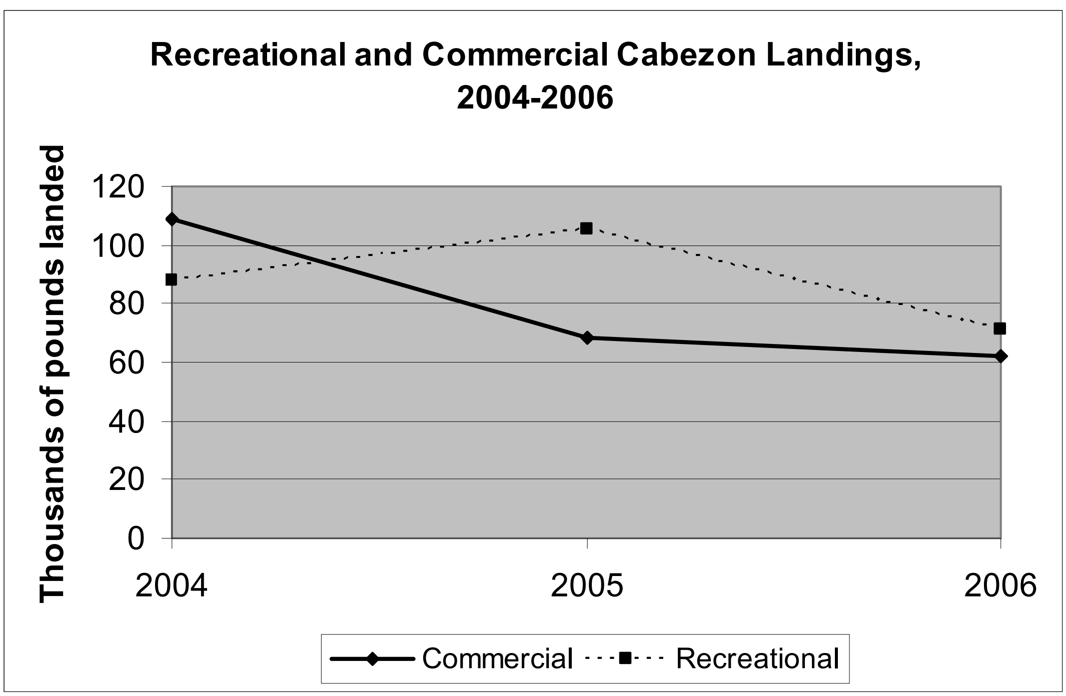

Figure 7.2b. Recreational and commercial landings in pounds for California-caught cabezon 2004-2006. Data source: CRFS recreational catch data and DFG commercial landing receipts.

Fishing revenue from the 2006 commercial harvest of cabezon was about $343,000 (ex-vessel 2006 dollars). The contribution to total business output for the State from this 2006 commercial harvest is estimated to be $661,000. Likewise, total employment and wages from cabezon is estimated to be the equivalent of 12 jobs and $304,000, respectively.

The primary gear types used to land cabezon have been hook-and-line and trap. Since 2003, these two have been the only legal gear types available for commercial take of this species. From 2003 through 2006, approximately 68 percent of cabezon were caught with hook-and-line and 32 percent with trap.

Status of Biological Knowledge

The cabezon is the largest member of the cottid family and the only species of this family large and accessible enough to produce a viable fishery. In Spanish, *cabezon* means big-headed or stubborn and, proportionally, the massive head is definitely the largest feature of this fish. The species name, *marmoratus,* refers to the marbled or mottled appearance of the body which can be reddish, greenish, or bronze. Generally, the belly is a pale turquoise or white, and there are no scales on the body. Anecdotal evidence from fish kept in aquaria suggests that cabezon have the ability to change color to match their surroundings. There is also some evidence that coloration may be used to determine sex at some life stages.

Cabezon range from Point Abreojos, Baja California to Sitka, Alaska and are common from Washington to southern California. Preferred cabezon habitat is hard bottom substrate, often in crevices or areas of high relief. Although the reported maximum depth for cabezon is 300 feet (91 meters), the majority of recreational and commercial catch occurs in waters less than 120 feet (37 meters). Adult fish frequent subtidal areas with rocky reefs, often in kelp beds, and also occur around breakwaters, jetties, oil platforms and other man-made structures.

In California, spawning occurs in late fall and early winter, peaking in January and February. Females deposit eggs in recesses on exposed rock where they adhere to each other forming a nest. Fertilization is thought to be external and evidence suggests cabezon spawn multiple times in a season. A large female that measures 30-inches (76-centimeters) and weighs 23-pounds (10-kilograms) can produce approximately 152,000 eggs. Nests can be 18-inches (46-centimeters) in length, 2- to 4-inches (5- to 10-centimeters) thick and vary in color from pale green to red. Males guard the nest until eggs are hatched. After hatching, the young of the year spend 3 to 4 months as pelagic larvae and juveniles. Pelagic juveniles are silvery in coloration and are commonly found underneath drifting kelp mats. Settlement occurs when juveniles reach a length of approximately 1.5-inches (4-centimeters) at which time they recruit into tide pools. Fish leave the intertidal zone before maturing but may revisit tide pools during high tides to forage as adults.

There have been several reports on the toxicity of cabezon roe. In the 1950s, the well-known ichthyologist Carl Hubbs published a personal account of eating cabezon roe. As part of an ongoing search for another caviar, Hubbs and his wife consumed the roe and flesh of a cabezon for dinner. Four hours later they "…awoke in misery…and were violently ill throughout the rest of the night." Laboratory evidence indicates that the roe is lethal to mice, rats, and guinea pigs. Anecdotal information on egg masses exposed at low tide suggests they are not preyed upon by natural predators such as raccoons, mink, or birds. Observations of captive cabezon have documented a female eating her own eggs with no resulting ill effects.

Length at maturity from one California study showed that 50 percent of females and males were mature at about 13-inches (33-centimeters; 2.3 years of age) and at about 12-inches (31-centimeters; 1.8 years of age), respectively. All fish larger than 18-inches (46-centimeters) and older than 7 years of age were found to be mature, regardless of sex. Females attain a larger size and grow slower than males. Cabezon can reach a maximum length of 39-inches (1-meter) and weigh as much as 25 pounds (11-kilograms), although average total length for sport-caught fish is 16-inches (41-centimeters) and 2.3 pounds (1-kilogram). Results of current research suggest that cabezon have a greater longevity than previously thought. Based on the maximum reported size of 39-inches (1-meter), it is probable that they could attain ages of 20 years or more**.**

Cabezon can be aptly described as "lie-in-wait" predators. Their mottled coloration enables them to blend in with their surroundings as they lie motionless waiting for their next meal. With large, robust pectoral fins set low on the body and a powerful tail, they quickly lunge after unwary prey, engulfing it in their large mouth. Their diet consists mainly of crustaceans, although large and small cabezon have different diets. Adult fish eat crabs, small lobsters, mollusks (abalone, squid, octopus), small fish (including rockfishes), and fish eggs. In preying on abalone, cabezon have a unique ability to pry smaller animals off of rocks, consume the meat and spit out the shell when done. Small juveniles consume amphipods, shrimp, crabs, and other small crustaceans. Juveniles are eaten by rockfishes and larger cabezon, as well as by lingcod, *Ophiodon elongatus*, and other sculpins. Large cabezon may be preyed upon by harbor seals, *Phoca vitulina richardsi*, or California sea lions, *Zalophus californianus*.

Status of the Population

The most recent California stock assessment on cabezon was completed in 2005. For this assessment cabezon were treated as different northern and southern California substocks based on differences in total removals, ecology, and current management needs. Point Conception was used as the delineation line between the two substocks. Reproductive output (mature female biomass) of the cabezon resource off northern California was estimated to be about 40 percent of the unfished stock, indicating a healthy population. Southern California's stock was estimated to be at about 28 percent of the unfished level. California's Nearshore Fishery Management Plan defines a groundfish species to be overfished if its reproductive output falls below 30 percent of its unfished stock. For this reason, the southern substock's status is of concern to managers, although the stock size is projected to increase due to good recruitment indicators.

Management Considerations

The cabezon became a federally designated groundfish in 1982 when the Pacific Fisheries Management Council (PFMC) adopted the Pacific Coast Groundfish Fishery Management Plan. Since then it has been managed under the joint jurisdiction of the state and the federal government. Prior to 1982, this species was managed by the California Department of Fish and Game (CDFG) through regulations adopted by the state legislature and the California Fish and Game Commission (FGC).

Since the late 1990s, considerable federal pressure developed to rebuild "overfished"[1] species and subsequent management actions designed to avoid these species shifted fishing effort into nearshore areas putting additional pressure on shallow species such as cabezon. At the same time, state and federal management took a more precautionary approach for unassessed, "data poor" species lowering harvest limits. In addition, the popularity of the commercial live-fish fishery increased dramatically in the 1990s resulting in even greater pressure on nearshore stocks.

California's Marine Life Management Act (MLMA) of 1998 was adopted in response to the need to take a more precautionary approach to management that prioritized resource sustainability, and to address the rapid development of the live-fish fishery. This important piece of legislation made the possession of a commercial nearshore permit mandatory and delegated finfish management authority to the FGC. Minimum commercial size limits for nearshore species including cabezon were enacted[2]. The MLMA also required that the FGC adopt a Fisheries Management Plan (NFMP) for nearshore finfish.

In 2000, under these new guidelines, the FGC adopted a precautionary approach for nearshore stocks with no assessment including cabezon which called for harvest limits to be set at 50 percent of historic landings.

Nineteen nearshore species including the cabezon are managed under provisions outlined in the NFMP, which was adopted by the FGC in 2002. The NFMP also mandated a precautionary management approach for stocks without quantifiable assessments so harvest limits continued to be set at 50 percent of historic landings until better information was available. In conjunction with the NFMP adoption, the FGC adopted a restricted access program which reduced the number

[1] "Overfished" is a formal federal or state designation used when the status of an assessed stock is determined to be at a critically low level; several important California groundfish species share this designation including bocaccio, canary, cowcod, widow and yelloweye rockfishes and previously, lingcod.

[2] In 2001 the commercial size limit for cabezon was increased from 14 to 15 inches.

of nearshore permittees regionally, limited approved gears to trap and hook-and-line, and provided for minimal bycatch in other fisheries.

Beginning in 2004, the harvest limit for cabezon has been based on assessment results and stock status. An overview of California Fish and Game Commission regulations for cabezon in 2006 were as follows:

- The total allowable catch (TAC) for cabezon in 2006, as well as in 2005, was 152,100 pounds (69 metric tons), of which the commercial fishery was allocated 59,300 pounds (27 metric tons) and the recreational fishery was allocated 92,800 pounds (42 metric tons).
- In past years, the commercial cabezon fishery closed early due to the projected catch exceeding its allocation. To avoid this, a mid-season reduction in commercial trip-limit amounts was adopted for September through October 2006. The change reduced the 2-month allotment from 900 pounds (0.4 metric tons) to 200 pounds (.09 metric tons) total take per permittee, and allowed the commercial cabezon fishery to remain open through the end of the year.
- Recreational bottomfishing seasons and/or depth restrictions were relaxed to some extent for all regions of California in 2006, allowing for increased fishing opportunity. There was no change in the 1-fish bag limit and 15-inch (38-centimeter) minimum size limit for cabezon for sport anglers.
- The total combined catch for sport and commercial fisheries in 2006 was estimated to be 87 percent of the TAC. In 2005 that combined total was estimated at 114 percent, exceeding the state TAC.

The most important data needs according to the stock assessment are: an accurate accounting of removals, especially from the recreational and live-fish fisheries, and a fishery-independent survey of cabezon population abundance. Both the recreational and commercial live-fish fishery take have traditionally been challenging to monitor. The sheer size and dispersed nature of recreational fishing in California makes it difficult to sample. The difficulty in monitoring the commercial live-fish fishery stems from the small and mobile nature of the landings, with fish often being transported directly to restaurants. Live-caught fish are also harder to handle if encountered by samplers and often fishermen are wary of having their premium catch examined, fearing reduced quality and trauma from being handled. To offset these difficulties, recent changes in the way the recreational fishery is monitored are designed to improve total sport take estimates, and greater enforcement of required commercial landings reporting will help reduce unreported catch. Ongoing fishery-independent research being undertaken in Morro Bay will provide managers with better information related to local and regional cabezon population demographics and abundance, especially if these efforts are expanded to other areas of California's coast. Study results have the potential to aid in future stock assessments by providing estimates of catch, fishing effort, catch-per-unit effort, mortality, population size, fish movement, and site fidelity, among other data.

Real-time monitoring of commercial landings could be used to reduce lag time between when catch is actually landed and when the data from the landing is available to managers electronically. Lag time is currently around 6 weeks, making it difficult to actively track the cabezon catch as it comes in, or know at any time during the season what portion of the TAC has been landed. Any reduction in this time lag would help keep catches closer to the TAC at the end of the year.

California has considered the adoption of a slot size limit for cabezon in the past, and it is a management tool that may be considered again should the stock status change.

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Table 7.1. Annual California commercial landings of cabezon in pounds, with ex-vessel value and average price per pound (lb) for years 1981-2006.							
Year	**Pounds**	**Ex-vessel Value**	**Avg. price/lb**	**Year**	**Pounds**	**Ex-vessel Value**	**Avg. price/lb**
1981	64,400	$10,221	$0.17	**1994**	82,900	$273,589	$3.05
1982	63,800	$10,038	$0.18	**1995**	193,800	$665,633	$3.07
1983	23,600	$3,889	$0.20	**1996**	245,200	$837,835	$3.18
1984	18,700	$2,534	$0.24	**1997**	264,900	$847,259	$2.99
1985	25,900	$5,685	$0.28	**1998**	372,800	$1,224,134	$2.94
1986	16,200	$3,716	$0.30	**1999**	274,700	$1,007,441	$3.41
1987	8,800	$2,658	$0.36	**2000**	255,900	$1,126,355	$3.95
1988	12,700	$5,423	$0.40	**2001**	159,400	$716,663	$4.12
1989	25,000	$7,600	$0.42	**2002**	110,900	$483,897	$4.07
1990	26,000	$9,209	$0.40	**2003**	87,500	$415,605	$4.21
1991	16,300	$13,436	$0.57	**2004**	109,100	$504,139	$4.19
1992	36,600	$50,847	$1.79	**2005**	68,200	$341,814	$4.65
1993	39,300	$123,273	$2.92	**2006**	62,300	$343,181	$5.08

8. CALIFORNIA SCORPIONFISH

California Scorpionfish, *Scorpaena guttata.* Photo credit: DFG

Review of the Fishery

California scorpionfish, *Scorpaena guttata*, known locally as sculpin, are an important part of the commercial and sport fishery in southern California, especially within the Los Angeles port complex. In the recreational fishery, they are taken primarily aboard commercial passenger fishing vessels (CPFV) and private/rental vessels, and occasionally from piers and jetties. From 1995-2000, California scorpionfish ranked fifth and sixth statewide in the top ten most commonly landed species from private/rental vessels and CPFV modes, respectively. Based on total number of California scorpionfish landed by mode from 2004-2006, 68.6 percent were CPFV, 22.9 percent were private/rental boat, 5.6 percent were man-made, and 2.8 percent were beach/bank (CRFS data, 2004-2006). Beaches and banks tend to be too shallow, thereby minimizing catch for this mode. California scorpionfish, because of their small size and relatively cryptic habits, comprise a very small percentage of recreational take by divers. A review of the Marine Recreational Fishery Statistical Survey (MRFSS) data show the average annual landing of California scorpionfish from the period of 1980 to 1989 was 285,900 fish and declined by 22 percent to 223,400 fish from the period of 1993 to 2003; landings peaked in 1989 at more than 700,000 fish (Figure 8.1). The California Recreational Fisheries Survey (CRFS) data show California scorpionfish landings have fluctuated between 50,000-90,000 fish per year since 2004 (Figure 8.2).

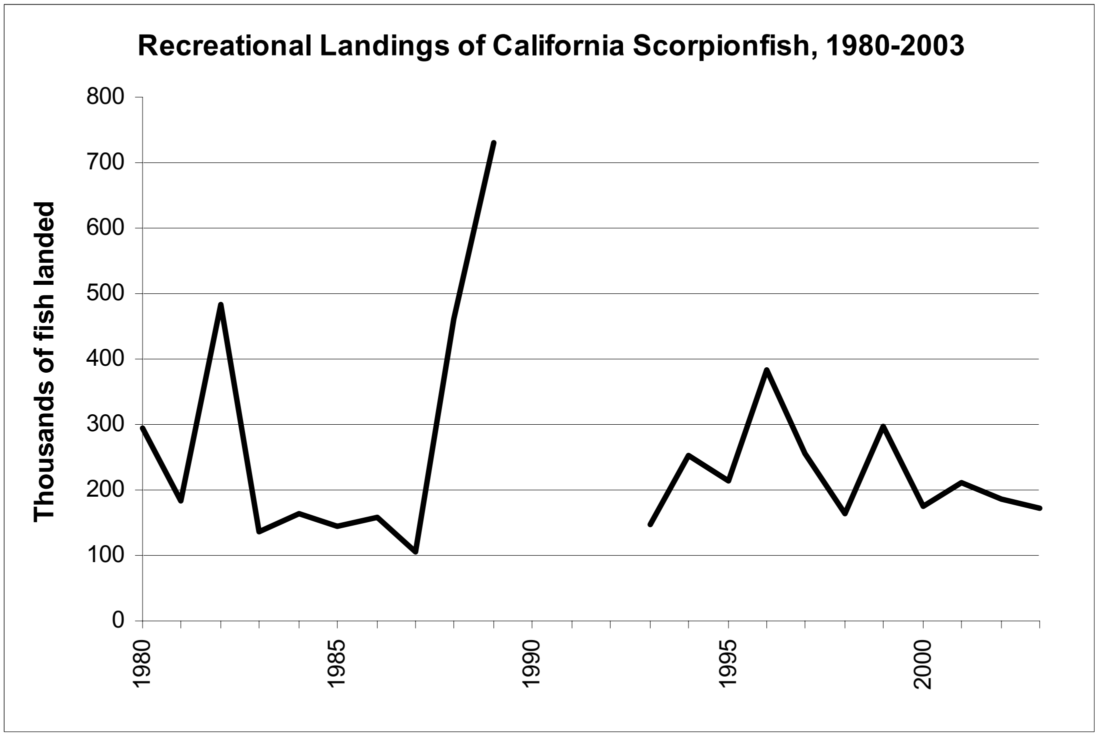

Figure 8.1. Recreational catch (in numbers of fish) of California scorpionfish from 1980-2003. Data Source: MRFSS data for all gear types; data not available for 1990-1992.

According to CPFV logbook data, partyboat landings of California scorpionfish decreased dramatically from a peak of 227,200 fish in 1999 to 72,700 fish in 2004 (Figure 8.3). The biggest decline was between the years 2001 and 2002; the latter year showed about half the amount of California scorpionfish landed in the previous year. This decrease in landings is most likely a result of reduced harvest limits and management measures implemented to protect "overfished" species which limited access to scorpionfish habitat, such as the adoption of depth restrictions and the implementation of closed fishing areas, and an overall effort shift to other fisheries and away from scorpionfish (see Management Considerations). From 2001-2006, CPFV logbook data show partyboat landings of California scorpionfish ranged between 72,700 and 162,600 fish. Partyboat landings have increased in the past three years (Figure 8.3) as harvest limits have increased, regulations have relaxed and more scorpionfish habitat has become available to fishing communities.

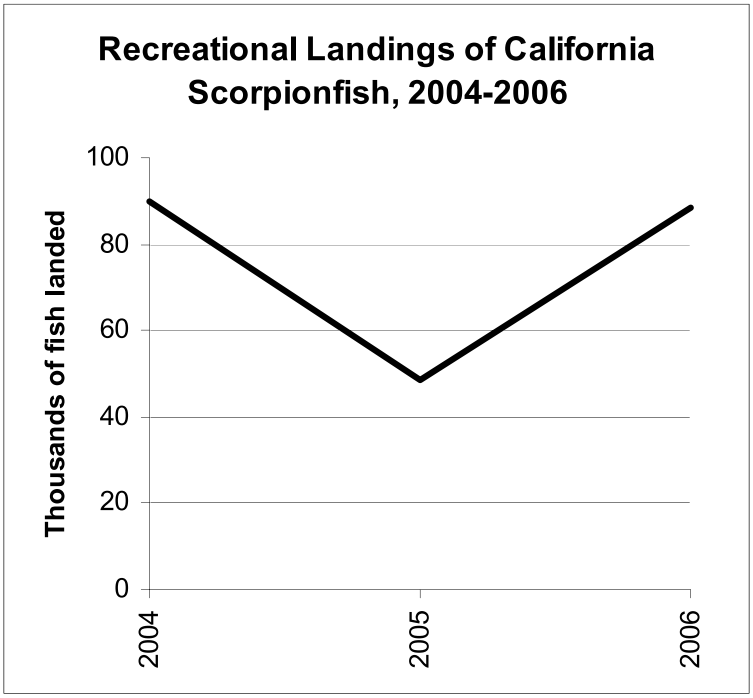

Figure 8.2. Recreational catch (in numbers of fish) of California scorpionfish, 2004-2006. Data Source: CRFS data for all gear types.

California scorpionfish are commonly targeted commercially by hook-and-line and trap, although they can be incidentally taken by trawl and gillnet. Hook-and-line gear tends be the dominant gear type for targeting California scorpionfish. According to landings data from the California Department of Fish and Game (CDFG), California scorpionfish exceeded 40,000 pounds (18 metric tons) for all years between 1992 and 2001, and peaked at 112,800 pounds (51 metric tons) in 1998. More recently, the landings have declined considerably to around 11,000 pounds (5 metric tons) from 2003-2005, and 5,900 pounds (2.7 metric tons) in 2006. Although many factors can affect total landings, two probable influences are regulatory changes such as the reduction in harvest limits in 2000 and implementation of the nearshore restricted access program in 2003 (see Management Considerations, below).

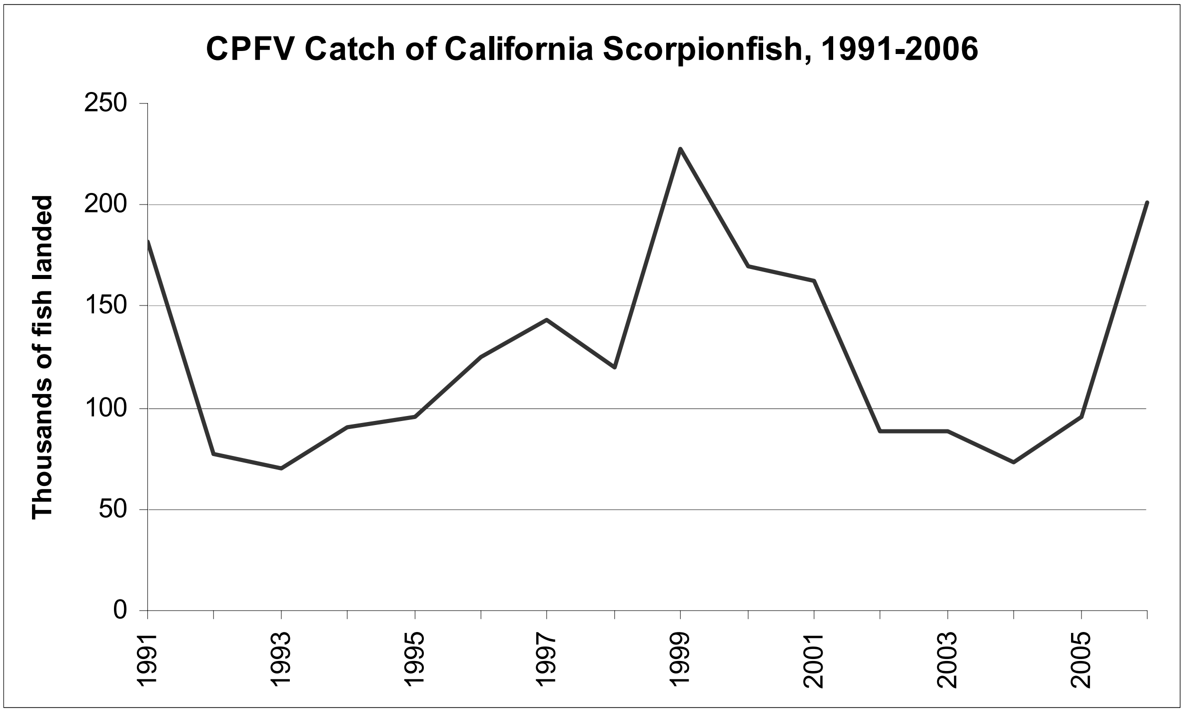

Figure 8.3. Commercial Passenger Fishing Vessel (CPFV) logbook catch data for California scorpionfish from 1991 to 2006. Data Source: CDFG commercial landing receipts, and CPFV log book data.

Another reason for fluctuation in commercial landings was due to the development of a new fishery. The live/premium fishery in the late 1980s resulted in an increase in commercial landings of California scorpionfish. The live component of the fishery has generated at least 50 percent of the total catch for scorpionfish for all years since 2000, except for 2004 in which live scorpionfish made up 28 percent of the total catch. In recent years the commercial market price for scorpionfish has been as high as $8.00 per pound for live fish. Total commercial landings have decreased in the last six years, regardless of live or dead condition (Figure 8.4 and Table 8.1) due to lower harvest limits and very low bycatch allowances (25 pounds (11 kilograms)) (see Management Considerations, below). Currently, the recreational sector lands a majority of the California scorpionfish total catch at 46,297 pounds in 2005 to 83,774 pounds in 2006, compared to the commercial sector at 11,405 pounds in 2005 and 5,856 pounds in 2006 (Table 8.1).

Fishing revenue from the 2006 commercial harvest of California scorpionfish is estimated at $17,000 (ex-vessel 2006 dollars). It is estimated that this same harvest contributed $33,000 to the total business output for the State. Likewise, total employment and wages from California scorpionfish is estimated to be the equivalent of 1 job and $15,000, respectively.

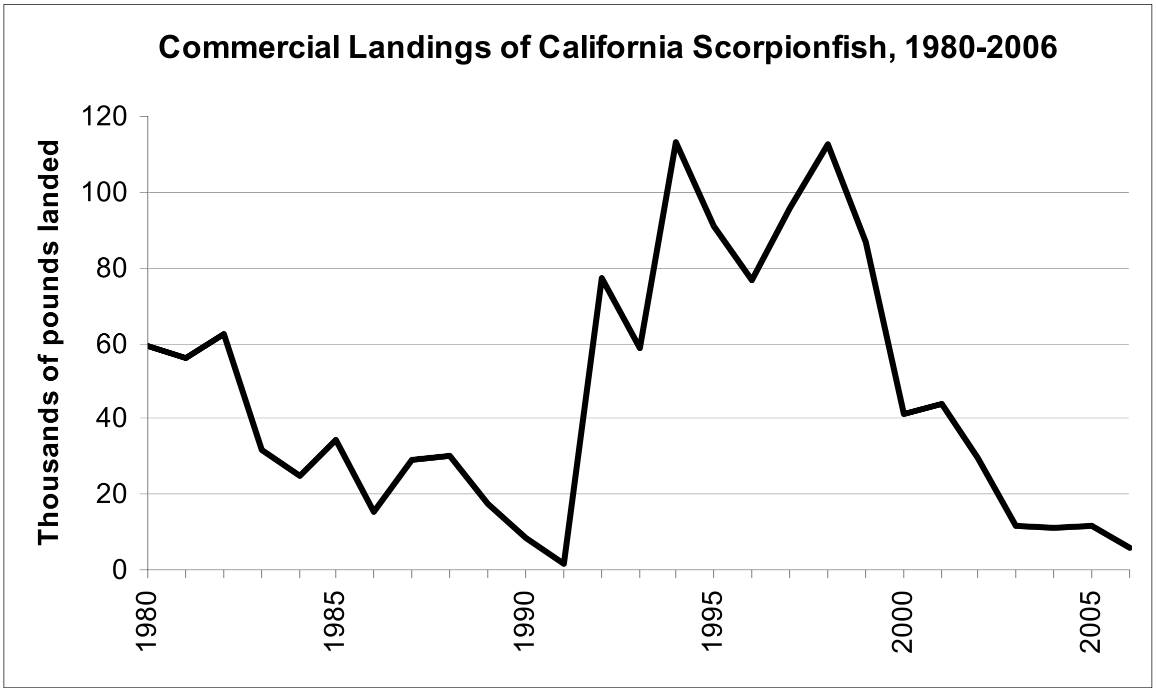

Figure 8.4. Commercial catch in pounds of California scorpionfish from 1980-2006.
Data Source: CDFG commercial landing receipts for all gear types.

Status of Biological Knowledge

The geographical range of the California scorpionfish extends from Monterey Bay (Central California) south to Uncle Sam Bank (Southern Baja California, Mexico); however this species is rare north of Santa Barbara. California scorpionfish prefer warmer waters, and a surge in catch rates north of Santa Barbara has been observed during El Niño years. California scorpionfish have been observed from the intertidal to 600 feet (183 meters), but the highest catch rates occur around 150 feet (46 meters). California scorpionfish are a benthic species, commonly found in sandy, muddy, and rocky habitats. Although frequently observed as a solitary species, aggregations are associated with prominent features such as rocks, boulders, sewer pipes, artificial reefs, and wrecks.

The California scorpionfish is a comparatively small species of the scorpaenid family, reaching a maximum size of 17-inches (43-centimeters). After 4 years of age, females grow faster and reach a larger size than males. The maximum age estimated for this species is 21 years, but rarely have male ages been estimated greater than 15 years. A few fish are mature at 6-inches (15-centimeters) at age one, over 50 percent are mature at 7-inches (18-centimeters) at age two, and all are reproductively mature at age four at 9-inches (23-centimeters).

Reproduction in the California scorpionfish is well documented. They are oviparous (egg layers) with external fertilization. The spawning season occurs from

April through September, and peaks in July. They exhibit extensive vertical spawning migrations in late spring and early summer, when adults move inshore from 120 to 360 foot (37 to 110 meter) depths. These large spawning aggregations form near the bottom, rise up, and approach the surface. After August, the aggregations disperse, with observed individuals having been recaptured 25 miles (40 kilometers) from the spawning area. Females release a mass of 0.05-inch (1.3-millimeter) diameter eggs embedded in a gelatinous "egg balloon". The egg balloon is a paired, hollow structure that is clear or light green in color. The balloon is about 0.1-inch (2.5-millimeters) thick and floats near the surface. After about 58 to 72 hours, the eggs hatch and 0.08-inch (2-millimeter) larval fish emerge. Juveniles remain hidden in mats of dense algae and among benthic encrusting organisms. Spawning occurs in the same areas every year, and studies have shown that many fish return annually to the same spawning grounds. The 2005 stock assessment showed evidence of several strong recruitments starting in 1984.

The California scorpionfish is highly cryptic, nocturnal, and feeds at night. They ambush their prey from stations of camouflage on the bottom. Juvenile California scorpionfish mainly consume gammaridean amphipods. The most important prey items in the adults include juvenile *Cancer* crabs, fishes such as anchovy and cusk-eels, octopi, isopods, and shrimp.

California scorpionfish are thick-bodied, with large dorsal spines and flexible fins. Their color is quite variable, ranging from bright orange-red through light brown, sometimes with purple streaks on the head, and black or dark brown spots covering the body. The sharp spines of the dorsal, anal, and pelvic fins are poisonous. At the base of each spine is a gland containing toxins which flow to the tip through a groove. The resulting pain from a spine-inflicted injury may be intense; however, very rarely is a spine injury fatal to humans.

Status of the Population

In May 2005, the first California scorpionfish stock assessment was completed along the California coast from Point Conception to the Mexico border. That portion of the stock was estimated to be healthy according to the management criteria set forth by the state. As a result, a new harvest limit was established based on this assessment that was higher than the previous one which had been in place since 2000, and was based on a precautionary approach to management. Both commercial and recreational regulations are in place to keep the fishery sustainable. The management outcomes based on the 2005 stock assessment are discussed in the next section.

Management Considerations

The California scorpionfish became a federally designated groundfish in 1982 when the Pacific Fisheries Management Council (PFMC) adopted the Pacific Coast

Groundfish Fishery Management Plan. Since then it has been managed under the joint jurisdiction of the state and the federal government. Prior to 1982, this species was managed by CDFG through regulations adopted by the state legislature and the California Fish and Game Commission (FGC).

Since the late 1990s, considerable federal pressure developed to rebuild "overfished"[1] species. Subsequent management actions designed to avoid these species shifted fishing effort into nearshore areas and put additional pressure on shallow water species such as California scorpionfish. At the same time, state and federal management took a more precautionary approach for unassessed, "data poor" species lowering harvest limits. In addition, the popularity of the commercial live-fish fishery increased dramatically in the 1990s resulting in even greater pressure on nearshore stocks.

California's Marine Life Management Act (MLMA) of 1998 was adopted in response to the need to take a more precautionary approach to management that prioritized resource sustainability, and to address the rapid development of the live-fish fishery. This important piece of legislation made the possession of a commercial nearshore permit mandatory and delegated finfish management authority to the FGC. Minimum commercial size limits for nearshore species including California scorpionfish were enacted. The MLMA also required that the FGC adopt a Fisheries Management Plan (NFMP) for nearshore finfish.

Under these new guidelines, in 2000 the FGC adopted a precautionary approach for nearshore stocks with no assessment including California scorpionfish rockfish which called for harvest limits to be set at 50 percent of historic landings.

Nineteen nearshore species, including the California scorpionfish, are managed under provisions outlined in the NFMP, which was adopted by the FGC in 2002. The NFMP also mandated a precautionary management approach for stocks without quantifiable assessments so harvest limits continued to be set at 50 percent of historic landings until better information was available. In conjunction with the NFMP adoption, the FGC adopted a restricted access program which reduced the number of nearshore permittees regionally, limited approved gears to trap and hook-and-line, and provided for minimal bycatch in other fisheries.

In 2003 and 2004, California scorpionfish was managed under a separate harvest limit split between the commercial and recreational sectors with the majority of the harvest limit allocated to the commercial sector. In 2003, the commercial sector landed only 25 percent of its available California scorpionfish allocation but the recreational sector exceeded its allocation. In 2004, the commercial sector landed 24 percent of its allocation and the recreational sector landed 69 percent. California scorpionfish was again placed into the "Minor Nearshore" category in 2005 and 2006, and was not managed with a separate harvest limit.

[1] "Overfished" is a formal federal or state designation used when the status of an assessed stock is determined to be at a critically low level; several important California groundfish species share this designation including bocaccio, canary, cowcod, widow and yelloweye rockfishes and previously, lingcod.

Harvest limits are set by the outcomes of stock assessments whenever possible; the most recent California scorpionfish assessment was completed in 2005 and the harvest limit was increased. Although the stock assessment indicated a healthy stock, there were some uncertainties in the data. For example, there was a large amount of variation in recruitment levels, and uncertainty in the value of natural mortality. In addition, site fidelity information gained from tagging studies would help inform managers of the appropriateness of regional management for this species. To fill in the information gaps concerning the stock structure, extensive tagging studies conducted in Mexican waters would be beneficial since a large proportion of the stock resides south of the Mexican border. Finally, an updated ageing study would improve future stock assessments.

The PFMC and the State of California continue to work as a coordinated effort to develop and adopt various management specifications to keep harvest within targets. Examples include area closures, depth restrictions, minimum size limits, and bag limits to regulate the recreational fishery. For the commercial fishery, license and permit regulations, finfish trap permits, gear restrictions, seasonal and area closures, depth restrictions, trip limits, and minimum size limits are used for management purposes.

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Table 8.1. Commercial landings (pounds) of California scorpionfish, 1980-2006

Year	Pounds	Year	Pounds	Year	Pounds
1980	59,168	**1989**	17,639	**1998**	112,822
1981	56,284	**1990**	8,407	**1999**	86,675
1982	62,264	**1991**	1,452	**2000**	41,252
1983	31,719	**1992**	77,323	**2001**	44,040
1984	24,984	**1993**	58,877	**2002**	29,761
1985	34,501	**1994**	113,123	**2003**	11,582
1986	15,544	**1995**	90,740	**2004**	11,034
1987	28,823	**1996**	76,444	**2005**	11,405
1988	29,869	**1997**	95,880	**2006**	5,856

Data Source: CDFG commercial landing receipts for all commercial gear types (1980-2006).

9. GOPHER ROCKFISH

Gopher rockfish, *Sebastes carnatus*. Photo credit: Todd Phillips

Review of the Fishery

The gopher rockfish is an important species in the nearshore rockfish group. However, it has been a minor component of the commercial and recreational rockfish fishery since at least the late 1960s. Gopher rockfish make up about 50 percent of the estimated take of the shallow nearshore rockfishes and 6 percent of all nearshore rockfish species combined.

Recreationally, gopher rockfish have not been considered a primary target of anglers, due to their small size. Nevertheless, they comprise a fair percentage of the recreational catch in California and have been landed in the following fishing modes: private/rental boats, commercial passenger fishing vessels (CPFVs), and shore-based (man-made structures, and beaches/banks). Based on all *Sebastes* species from 2004-2006, gopher rockfish comprise 9.3 percent of private/rental boat catch, 8.7 percent man-made catch, 4.7 percent CPFV catch, and 0.9 percent beach/bank catch (CRFS data, 2004-2006). Beaches and banks tend to be too shallow for gopher rockfish, thereby minimizing catch for this mode. Gophers comprise a very small percentage of recreational take by divers due to their small size and relatively cryptic nature. In 2001, according to CPFV logbook data, catches of gopher rockfish were 35,400 fish (Figure 9.1); prior to 2001, gopher rockfish were not reported separately in CPFV logbooks. From 2001-2006, CPFV logbook data show that landings of gopher rockfish ranged between 28,400 and 40,400 fish (Figure 9.1).

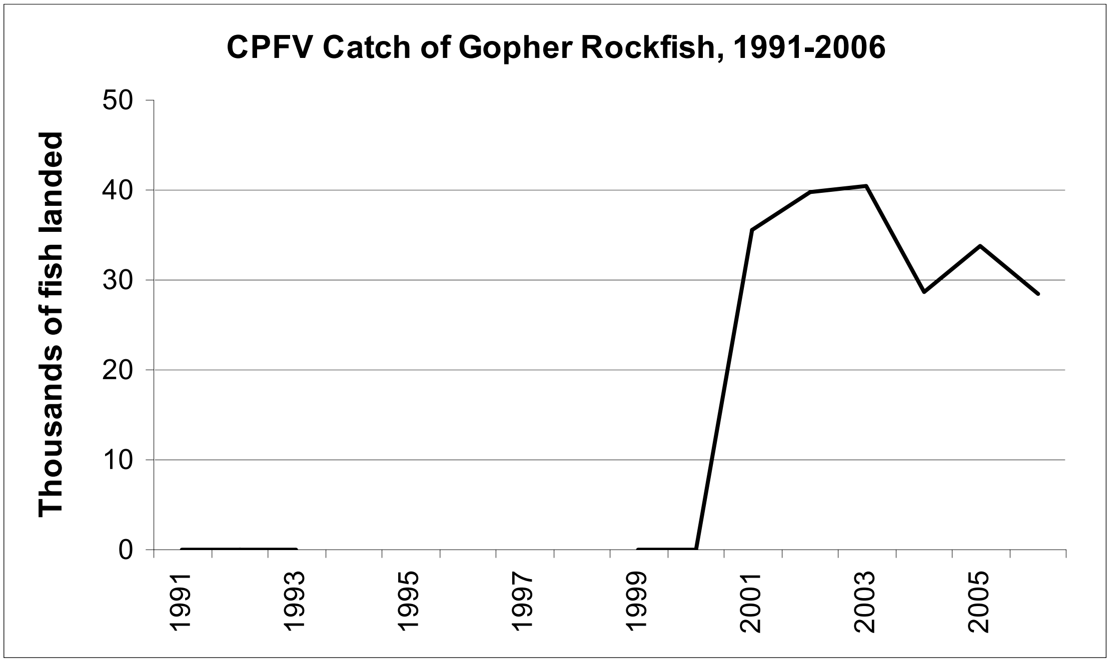

Figure 9.1. Commercial Passenger Fishing Vessel (CPFV) logbook catch of gopher rockfish from 1991 through 2006. Data Source: CDFG commercial landing receipts and CPFV logbook data. Data not available for 1994 through 1998.

A review of the Marine Recreational Fishery Statistical Survey (MRFSS) and the California Recreational Fisheries Survey (CRFS) data show landings of gopher rockfish peaked in 1986 with nearly 500,000 fish landed. Because of deliberate management action, the recreational harvest limit for gopher rockfish was reduced by 50 percent in 2000, and this is evident in the data (see Management Considerations, below). Gopher rockfish landings have declined by 35 percent since 1989 (Figures 9.2 and 9.3).

Historically, commercial landings of gophers have been recorded specifically as "gopher rockfish" and non-specifically as "gopher group", where the group market category contains multiple species. The latter category was introduced in the early 1980s. Prior to this time, gopher rockfish landings were minimal because of difficulty with monitoring the catch of all market categories, and improper monitoring specifically for gopher rockfish. The "gopher group" market category is mainly composed of gopher and black-and-yellow rockfishes, *Sebastes chrysomelas*, since distinguishing between these two species can be problematic. Presently, catch is required to be sorted to species, so use of the "gopher group" market category has been very limited since 2002.

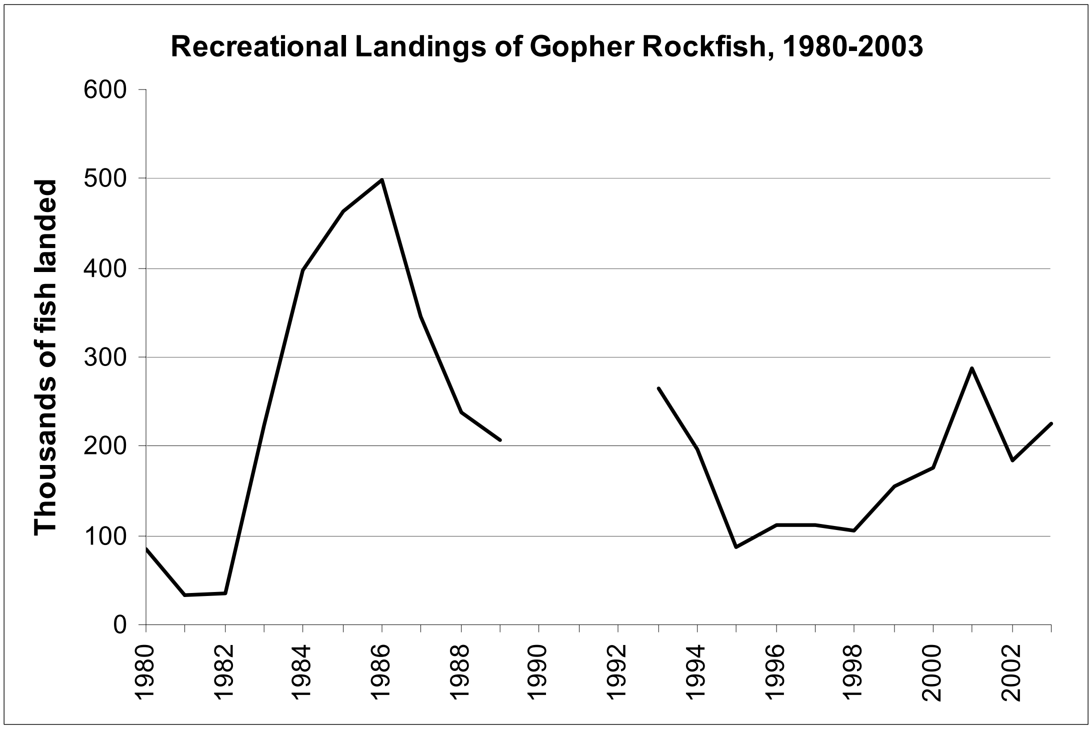

Figure 9.2. Recreational catch (in numbers of fish) of gopher rockfish from 1980 through 2003. Data Source: MRFSS data for all fishing modes and gear types; 1993 through 1995 data does not include CPFV mode. Data not available for 1990 through 1992.

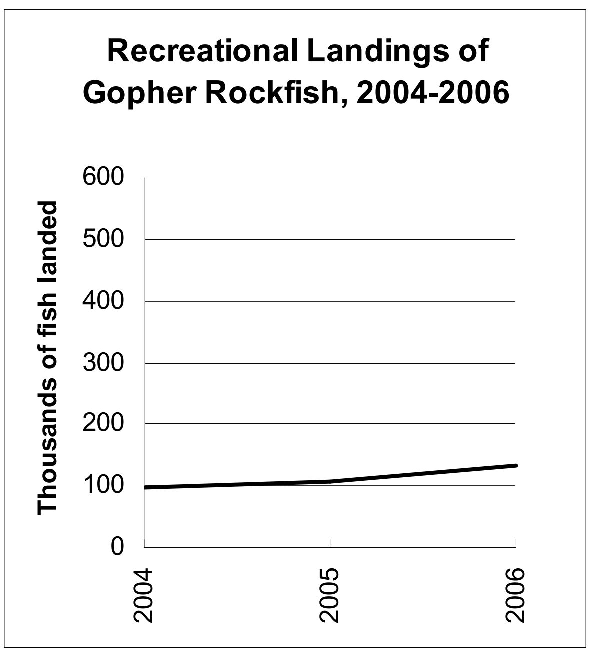

Figure 9.3. Recreational catch (in numbers of fish) of gopher rockfish.
Data Source: CRFS data for all fishing modes and gear types.

According to Department of Fish and Game's commercial landing receipt database, combined commercial landings of "gopher" and "gopher group" market categories exceeded 150,000 pounds (68 metric tons) in most years between 1988 and 1998, and peaked at 233,400 pounds (106 metric tons) in 1996, remaining high for the following two years. More recently, landings declined considerably to 37,800 pounds (17 metric tons) in 2004, 43,400 pounds (20 metric tons) in 2005, and 38,600 pounds (17 metric tons) in 2006. Low commercial landings in 2003-2006 are due in part to more restrictive management actions taken to keep catches under lower harvest targets (Figure 9.4; see Management Considerations)

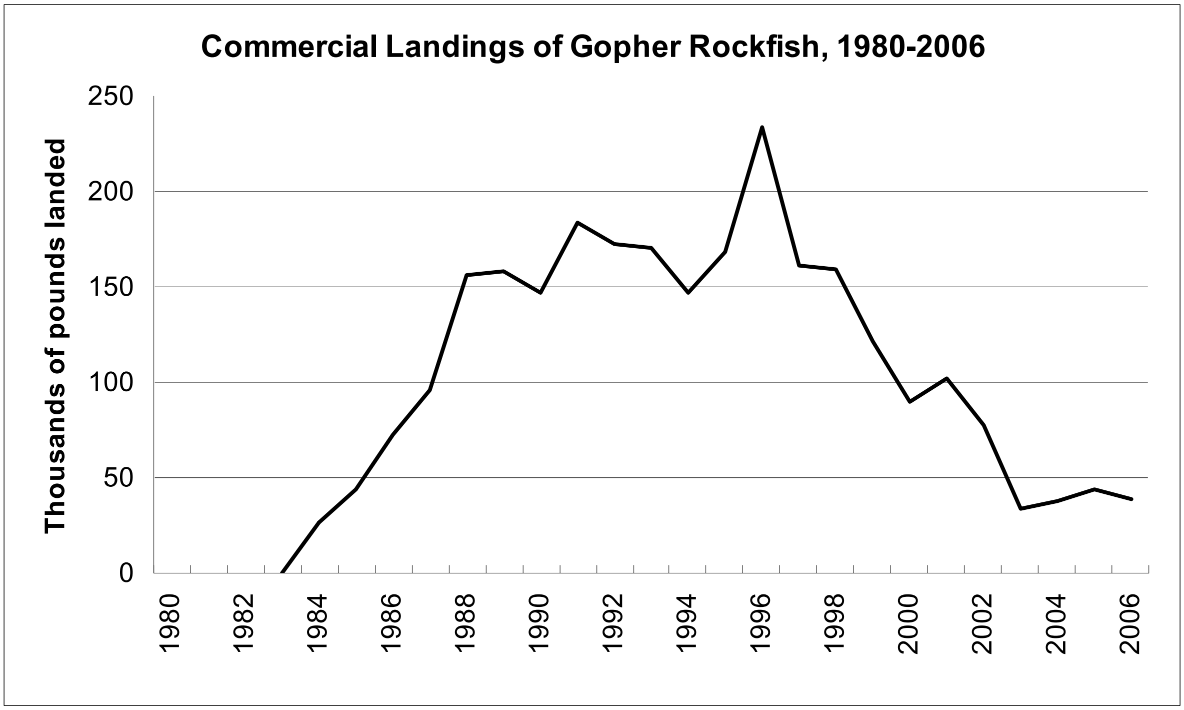

Figure 9.4. Commercial catch in pounds of combined gopher rockfish and gopher group market categories from 1980 through 2006. Data Source: CDFG commercial landing receipts for all gear types. Data not available prior to 1983.

Gopher rockfish are commonly targeted commercially with hook-and-line and trap gear, although they can be incidentally taken by trawl and gillnet. Development of the live/premium fishery in the late 1980s resulted in an increase in commercial landings of gopher rockfish. Live gopher rockfish are primarily caught by hook-and-line and are more valuable compared to dead fish. The average price per pound of live gopher rockfish in 1996 was $2.70/pound compared to $0.90/pound for dead fish. The demand for live fish has increased and currently the majority of gopher rockfish are landed in live condition. In 2005, 94 percent of gopher rockfish were landed live; this number dropped slightly to 77 percent in 2006 when the price reached an all-time high of $7.22/pound. The optimum size for live gopher rockfish is between one and two pounds because the market prefers attractive, plate-sized fish. Since this size is close to the size at maturity, there is a concern by managers to ensure gopher rockfish are allowed to reach spawning age before they are harvested in the live-fish fishery (see Management Considerations, below).

Fishing revenue from the 2006 commercial harvest of gopher rockfish was about $270,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $521,000. Likewise, total employment and wages from gopher rockfish is estimated to be the equivalent of 9 jobs and $240,000, respectively.

Commercial landings of gopher rockfish have changed regionally. Historically, the majority of catch has been landed in central California; however, the proportion of gopher rockfish landings by area has changed over time. Although landings in central California have decreased, landings north of Bodega Bay have remained constant with approximately 26 percent of all gopher rockfish landed in 2006. Landings have drastically decreased south of Point Conception over the last ten years, from 31,000 pounds (14 metric tons) in 1996 to 400 pounds (0.2 metric tons) in 2006. The decrease in gopher rockfish landings south of Point Conception is likely due to more restrictive management measures like lower commercial allocations and trip limits (see Management Considerations, below).

From 2004 to 2006, the number of total pounds landed by both recreational and commercial sectors fluctuated between 111,727 and 140,050 pounds annually. Currently, a majority of the total gopher rockfish landings is landed by the recreational sector. In 2004, a total of 121,577 pounds were landed by both sectors, with the recreational sector accounting for 69 percent. A similar trend was observed for 2005 and 2006; the recreational sector made up 61 percent and 72 percent of the total landings, respectively.

Status of Biological Knowledge

Life history characteristics, behavior, and morphology are strikingly similar between gopher and black-and-yellow rockfishes. The geographical range of gopher rockfish is similar to, but extends further south than black-and-yellow rockfish. The range is reported from Eureka (California) to Punta San Roque (southern Baja California), although they are rare north of Sonoma County (California) and south of Santa Monica Bay (California). Recent literature suggests their range extends further north to Cape Blanco (southern Oregon). Gopher rockfish have been observed from the intertidal to depths of 264 feet (81 meters), but adults are usually found at depths between 40 and 120 feet (12 and 37 meters), deeper than their black-and-yellow congeners. Black-and-yellow rockfish are more aggressive, and occupy the food-rich shallow zones, whereas gopher rockfish take competitive refuge in deeper zones.

Gopher rockfish prefer to occupy rocky habitats of nearshore kelp forests. They are found on the same reefs as kelp, *Sebastes atrovirens*; blue, *Sebastes* *mystinus*; and olive rockfishes, *Sebastes serranoides*. During high swell conditions, individuals take shelter in crevices associated with high relief areas. One study of a Baja Californian tide pool noted that 94 percent of all gophers surveyed were juveniles, suggesting that rocky intertidal habitats might be nursery areas for these subtidal species.

Gopher rockfish are a relatively small species of rockfish, reaching a maximum recorded length of 17-inches (43-centimeters). It is rare to observe gopher rockfish larger than 15-inches (38-centimeters) in central California; and 8-inches (20-centimeters) in southern California. Males grow at a slightly faster rate and reach maximum size at a younger age than females. Maximum age of gopher rockfish is 35 years, but few fish have been estimated older than 20 years. Estimates of size at maturity vary based on geographic range, with individuals maturing at a smaller size in southern California. Off central California, a few female gopher rockfish were mature at 8.3-inches (21-centimeters), while the largest immature female was 12.2- inches (31-centimeters) long. Males were estimated to mature at a smaller size than females.

Reproduction in the gopher rockfish is relatively well known. Like other *Sebastes*, gophers have internal fertilization that takes place after a series of courtship rituals. Females ranging between 176- and 307-grams (6.2- and 10.8-ounces) carry approximately 249 eggs per gram of body weight. Females release 0.2-inch (5-millimeter) larvae from January through May, peaking in March. After 30-90 days, larvae settle out of the plankton into kelp canopies. The settled larvae are large, about 1-inch (2.5-centimeters) in length, and remain close to the kelp fronds. Survival and subsequent recruitment of gophers are highly variable from year to year. The portion of the stock north of Point Conception showed evidence of weak recruitment in the 1970s, with peaks in the mid-1980s and mid-1990s, which suggests that recruitment has been somewhat enhanced during the shift to warmer ocean conditions.

Movement of adult gopher rockfish is limited. Their home range is usually rather small, especially if it includes high-quality, high-relief habitat. In southern California, home ranges increased with fish size and water depth, and were shown to be between 15 and 45 square feet (1.4 and 4.2 square meters). Gophers are also territorial. A study in southern California described three types of movement behavior in gophers: home-bodies, commuters, and floaters. The home-body types patrol and defend an area of the reef and occupy a shelter within it. The commuters are more transient, moving between shelter holes and feeding sites, but also displaying some territorial behavior. The floaters are non-territorial, inhabiting portions of other fish territories, and avoiding assault from dominant fish.

Gopher rockfish primarily feed at night on benthic crustaceans such as shrimp and small crabs, smaller fishes (juvenile rockfishes, sculpins, surfperch, and kelpfishes), gastropods and cephalopods. The adult diet is more varied, as juveniles prey mostly on zooplankors such as cyprids (barnacles).

Status of the Population

In May 2005, the first gopher rockfish stock assessment was completed along the California coast from Point Conception to the Oregon border. That portion of the stock was estimated to be healthy according to the management criteria set forth by the state. Both commercial and recreational regulations are in place to keep the fishery sustainable. The management outcomes based on the 2005 stock assessment are discussed in the next section.

Management Considerations

The gopher rockfish became a federally designated groundfish in 1982 when the Pacific Fisheries Management Council (PFMC) adopted the Pacific Coast Groundfish Fishery Management Plan. Since then it has been managed under the joint jurisdiction of the state and the federal government. Prior to 1982, this species was regulated by CDFG in conjunction with the state legislature and the California Fish and Game Commission (FGC).

Since the late 1990s, considerable federal pressure developed to rebuild "overfished"[1] species and subsequent management actions designed to avoid these species shifted fishing effort into nearshore areas putting additional pressure on shallow species such as gopher rockfish. At the same time, state and federal management took a more precautionary approach for unassessed, "data poor" species by lowering harvest limits. In addition, the popularity of the commercial live-fish fishery increased dramatically in the 1990s resulting in even greater pressure on nearshore stocks.

California's Marine Life Management Act (MLMA) of 1998 was adopted in response to the need to take a more precautionary approach to management that prioritized resource sustainability, and to address the rapid development of the live fish fishery. This important piece of legislation made the possession of a commercial nearshore permit mandatory and delegated finfish management authority to the FGC. Minimum commercial size limits for nearshore species including gopher rockfish were enacted. The MLMA also required that the FGC adopt a Fisheries Management Plan (NFMP) for nearshore finfish.

In 2000, under these new guidelines, the FGC adopted a precautionary approach for nearshore stocks including gopher rockfish. In the absence of a gopher rockfish assessment, harvest limits were set at 50 percent of historic landings.

Nineteen nearshore species including the gopher rockfish are managed under provisions outlined in the NFMP, which was adopted by the FGC in 2002.

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[1] "Overfished" is a formal federal or state designation used when the status of an assessed stock is determined to be at a critically low level; several important California groundfish species share this designation including bocaccio, canary, cowcod, widow and yelloweye rockfishes and previously, lingcod.

The NFMP also mandated a precautionary management approach for stocks without quantifiable assessments so harvest limits continued to be set at 50 percent of historic landings until better information was available. In conjunction with the NFMP adoption, the FGC adopted a restricted access program which reduced the number of nearshore permittees regionally, limited approved gears to trap and hook-and-line, and provided for minimal bycatch in other fisheries.

Harvest limits are set according to the outcomes of stock assessments whenever possible. The most recent assessment was completed for the gopher rockfish in 2005. Since the gopher rockfish cannot be managed separately from other nearshore rockfish species without significantly increasing bycatch, gopher rockfish was not removed from the nearshore rockfish group to be managed under a separate harvest limit. Instead, a point-of-concern was set at a level determined appropriate for the higher harvest limit that was adopted, based on the assessment and the contribution of gopher rockfish to the nearshore rockfish group. This allowed increased fishing opportunities in 2006 for anglers targeting shallow nearshore rockfish in waters off central California, effectively a harvest limit increase of over 50 percent from the status quo.

The PFMC and the State of California continue to work in a coordinated effort to develop and adopt various management specifications to keep harvests within targets. Specific regulatory measures for the commercial fishery have been used to manage rockfishes, including cumulative trip limits and season closures. Other regulatory actions include gear and depth restrictions and license and permit regulations such as finfish trap permits, nearshore fishery permits (2001), and restricted access permits (2003). For the sport fishery, season closures are used and maximum fishing depth was restricted starting in 2001. Daily bag limits for the rockfish, cabezon, *Scorpaenichthys marmoratus;* and lingcod, *Ophiodon elongates,* complex were decreased in 2000 to 10 fish with a two fish sub-limit for shallow nearshore species. The sub-limit was eliminated in 2004, mainly to protect gopher rockfish from increased discard mortality. More recent regulatory actions include the adoption of marine protected areas (MPAs) for the Channel Islands, and a network of MPAs along the central coast from Point Conception to San Mateo County, which will protect some portion of the stock.

Although the assessment indicated a healthy stock, there were some uncertainties in the data. For example, there was uncertainty in the measurement of relative abundance and in the value of natural mortality. Future gopher rockfish stock assessments would benefit from having additional length and age composition data collected throughout California and discard information from the commercial fishery.

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Further Reading

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Table 9.1. Gopher rockfish and gopher group commercial landings, 1916-2006

Year	Pounds	Year	Pounds	Year	Pounds
1916-1982	*no data*	**1990**	147,435	**1998**	158,674
1983	53	**1991**	183,231	**1999**	121,919
1984	26,103	**1992**	172,256	**2000**	89,949
1985	43,811	**1993**	170,079	**2001**	101,601
1986	72,714	**1994**	147,069	**2002**	77,280
1987	95,702	**1995**	167,911	**2003**	33,178
1988	156,017	**1996**	233,415	**2004**	37,803
1989	158,110	**1997**	161,204	**2005**	43,385
				2006	38,638

Data Source: CDFG commercial landing receipts for all commercial gear types; data not available for 1916-1982.

10. KELP GREENLING

Review of the Fishery

Anglers have enjoyed fishing for kelp greenling, *Hexagrammos decagrammus*, for sport and sustenance for over a hundred years. The first greenling fishery was established by prehistoric Native Americans. Coastal Native Americans from the rocky shores of central California harvested kelp greenling, as well as rockfishes, providing a major source of food for people living in these coastal communities. Excavation of central coast Native American midden sites indicates a fishery existed between 6200 B.C. and 1830 A.D. Over one half of all fossil fish remains from these sites contained kelp greenling; lingcod, *Ophiodon elongates*; cabezon, *Scorpaenichthys marmoratus*; and rockfish.

Today, kelp greenling is highly sought after by anglers and spear fishermen. Shore-based anglers take them from central to northern California, but they are more frequently targeted in the northern-most sections of the state. Between 1980 and 2006, shore angling accounted for 62 percent of all sport caught kelp greenling in California. The average angler catch for those years was 68,100 fish per year. Recreational landings of kelp greenling were much higher in the 1980s relative to the 1990s through 2003 (Figure 10.1a). The average angler catch per year from 1981-1989 and from 1993-2003 was 108,900 fish and 36,250 fish, respectively. Current data from 2004 through 2006 show a continuation of low catch levels (Figure 10.1b). Significant restrictions in regulations have occurred since the late 1990s which likely account for much of the observed decline (see Management Considerations, below). It is not known if any of the decline in annual recreational catch since the 1980s is a result of decreased abundance.

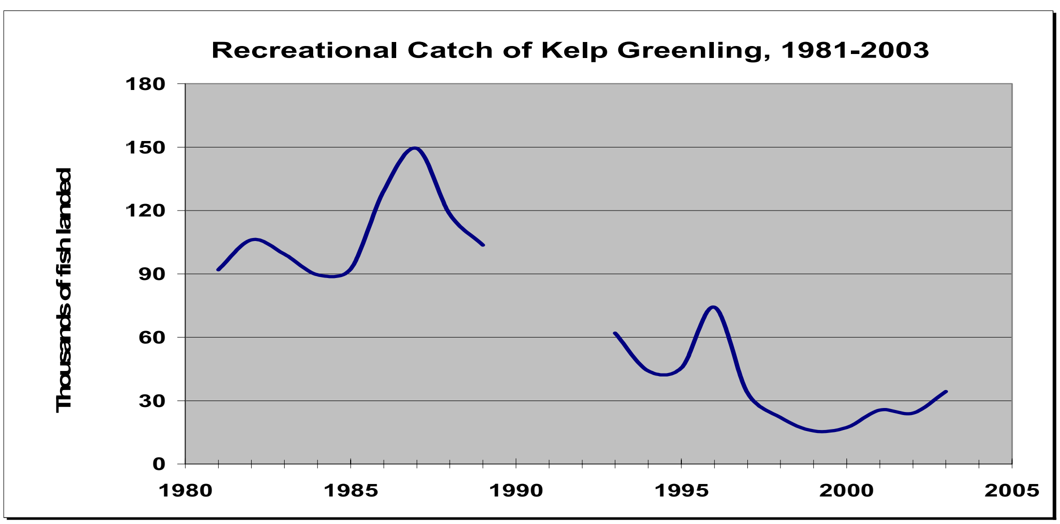

Figure 10.1a. Recreational catch (in numbers of fish) of kelp greenling from 1981 to 2003.Data source: MRFSS data for all gear types. No data available for 1990-1992.

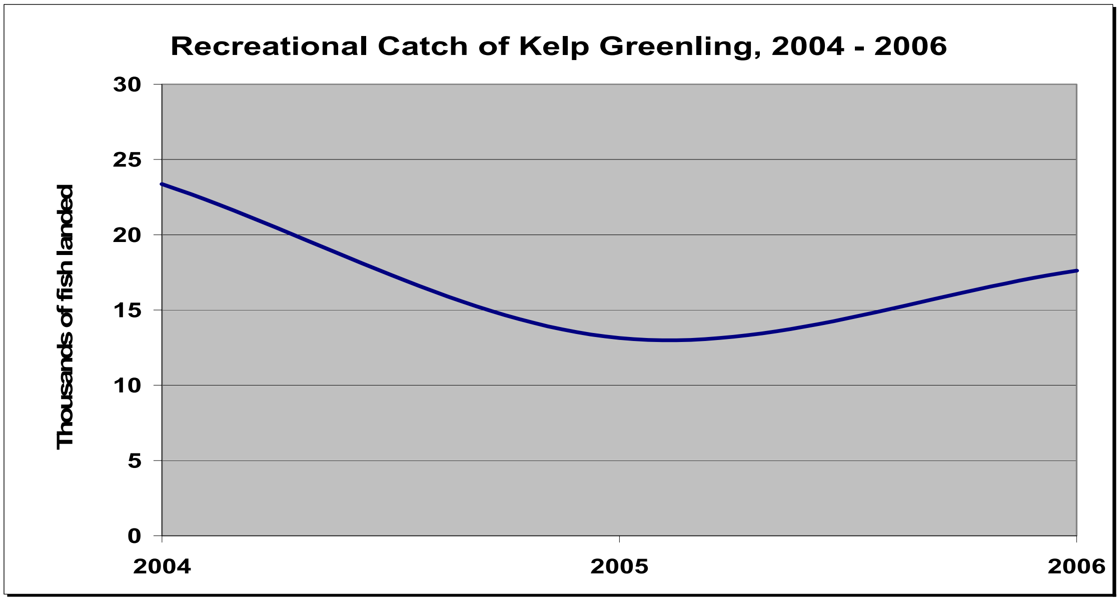

Figure 10.1b. Recreational catch (in numbers of fish) of kelp greenling from 2004 to 2006. Data source: CRFS data for all gear types.

Prior to 1999, there were no size limits and anglers could take 15 fish per day. In 1999, the bag limit for greenling was reduced to 10 fish per day followed by an establishment of a 12-inch (30.5-centimeter) size limit in 2000. A further reduction of the daily bag limit was instituted in 2003 when the limit was set at two fish and has remained so to the present.

Kelp greenling are commonly targeted commercially by hook-and-line and trap. Up until the 1990s, the commercial fishery for kelp greenling was largely based on incidental catch when fishing for lingcod and nearshore rockfishes. However, this pattern quickly changed in 1997 with the emergence of the nearshore "live-fish" fishery. Commercial landings of greenlings prior to 1997 peaked at 5,700 pounds (2.6 metric tons) per year. This number dramatically increased the following year to about 17,500 pounds (7.9 metric tons) and peaked at over 52,000 pounds (23.6 metric tons) in 2000 (Figure 10.2 and Table 10-1).

In the early years of the fishery, commercial landings played a minor role in overall landings of kelp greenling. From 1981 until 1998, sport fish landings accounted for the vast majority of kelp greenling landings. The large difference between commercial and recreational landings during this time period can largely be attributed to greenling being taken as incidental catch when fishing recreationally for other nearshore fish species. However, in 1999 and 2000, commercial landings exceeded recreational for the first time. This short-lived increase in landings resulted from commercial fishermen specifically targeting kelp greenling for the "live-fish" fishery. This trend was reversed starting in 2001 after implementation of new regulatory actions. Recreational landings continue to remain higher than commercial landings to date (Figure 10.2)

In 2001, the Department of Fish and Game set total allowable catch (TAC) limits and allocations to the recreational and commercial fisheries in order to better manage the fishery. This was the first time that kelp greenling was actively managed with ongoing monitoring. Initially in 2001, the commercial allocation was set at 19,400 pounds (8.8 metric tons) per year but was reduced to 13,400 pounds (6.1 metric tons) the following year. During this time, season, depth, and size limits were also imposed. This was followed by the implementation of a restricted access program in 2003 which limited the number of permits in the fishery. In order to comply with management decisions set forth in the Nearshore Fishery Management Plan (NFMP), (see Management Considerations, below) allocations were set at conservative low levels as a result of an unknown stock abundance. Currently, the annual kelp greenling commercial landings allocation is set at 3,400 pounds (1.5 metric tons).

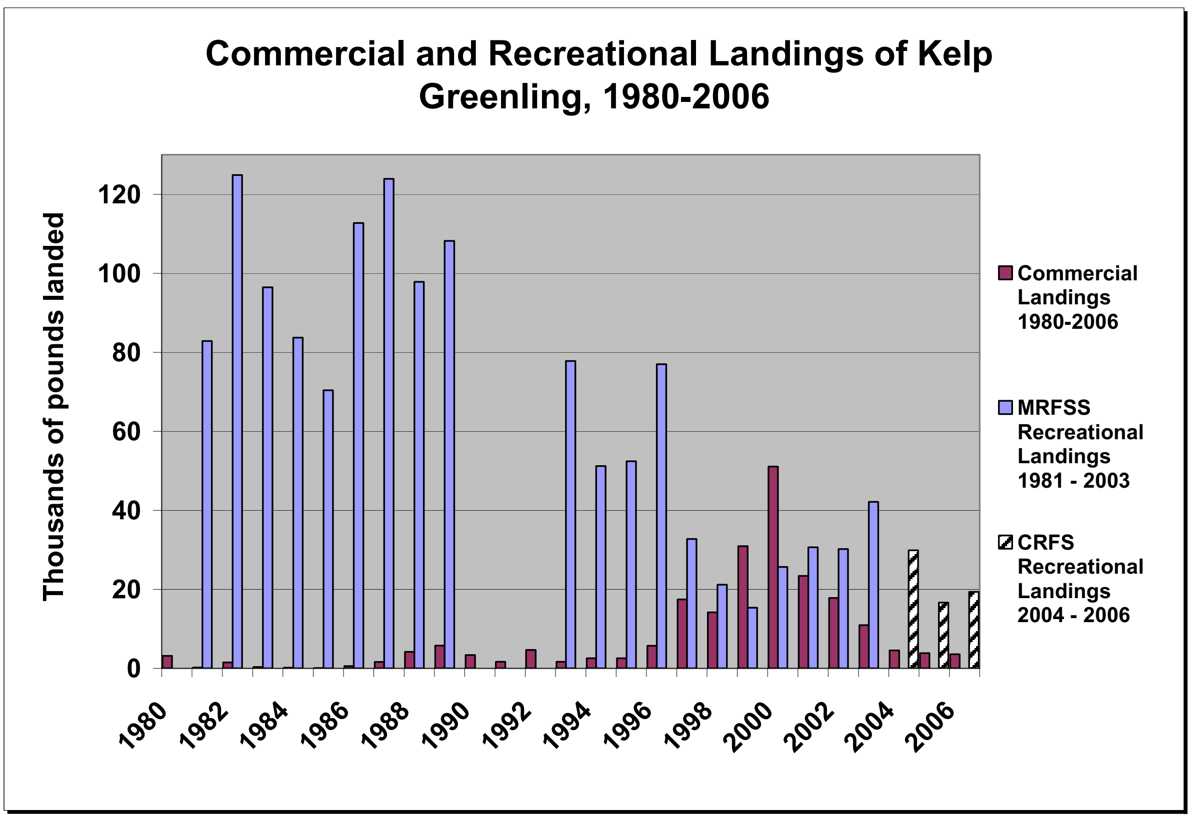

Figure 10-2. Annual kelp greenling landings (in pounds) for commercial landings from 1980 to 2006, MRFSS recreational landings 1981 to 2003, and CRFS recreational landing 2004 to 2006. No MRFSS data available for 1981and 1990 to 1992.

Fishing revenue from the 2006 commercial harvest of kelp greenling was about $24,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $45,000. Likewise, total employment and wages from kelp greenling is estimated to be the equivalent of 1 job and $21,000, respectively.

Status of Biological Knowledge

The kelp greenling is a member of the family Hexagrammidae, which includes rock greenling, *Hexagrammos lagocephalus*, and lingcod. They are abundant from the Aleutian Islands, Alaska, to central California but are occasionally seen as far south as La Jolla, in southern California. Kelp greenling inhabit kelp beds and rocky reefs but are also known to frequent sandy bottom areas; they are found subtidally to a depth of 150 feet (46 meters). Generally, they range in size up to 18-inches (45.7-centimeters) but have been reported to reach 24-inches (61-centimeters). Currently, studies are being conducted to determine the movement patterns of kelp greenling. It is unclear if they move between rocky reefs or prefer to stay on one reef. It has been documented that males show a high degree of site fidelity during breeding season, but it is not known whether this is a seasonal or long-term behavior.

Although males and females are similarly colored, it is easy to distinguish the sexes. Both sexes range in color from light grey to brown in body color, but males have blue irregular spots on their head and forebody, whereas females are speckled with red-brown to gold spots. For over 70 years, it was thought that the two sexes were different species until it was discovered that kelp greenling were sexually dimorphic.

The reproductive behavior of kelp greenling is similar to other hexagrammids and cabezon, *Scorpaenichthys marmoratus*. Females participate in multiple spawning events per season, and males exhibit egg-guarding behavior (nesting). Although it is not precisely known when the spawning season takes place for kelp greenling, it is believed to occur between September and December in California. During this time, males become increasingly territorial and often establish nesting sites among rocky outcroppings where increased water circulation occurs. By doing this, males increase the survivorship of young by providing protection from egg predation and by fanning to increase oxygen flow over their egg clutches. Spawning females, which mature by their fourth year, lay sticky egg masses that adhere onto kelp, rocky outcrops, and other substrate that males claim as nesting sites. Egg masses range from golf-ball to tennis-ball size and have an average of 4,000 eggs per cluster. Batch spawning females contribute a minimum of three egg clutches per spawning season, and multiple females may contribute egg clutches to a single nest.

Larvae incubate under male parental care for 4 to 5 weeks and emerge about 1/3-inch (8.5-millimeters) long. These larvae can spend up to a year in the plankton feeding on copepods before finally settling from the pelagic environment to the nearshore benthic community. There is no difference in growth rates for males and females for the first 3 years. At 3 years of age, both sexes are around 7-inches (17.8-centimeters); thereafter, males grow at a much slower rate than females. Males and females reach a maximum size of around 12-inches (30.5-centimeters) and 14-inches (35.6 cm), respectively, at around 12 years. Adult kelp greenlings consume a wide variety of food including crabs, amphipods, polychaetes, ascidians, and juvenile fishes. The primary predators of kelp greenling are fishermen, lingcod, and harbor seals, *Phoca vitulina*.

Status of the Population

There are currently no estimates of abundance for kelp greenling in California. Although a stock assessment was attempted in 2005, it was not accepted for management use because the biological data needed to establish trends in population growth were limited (see Management Considerations, below). It is likely that much of the observed decline in catch from recreational anglers is a response to a decrease in fishing pressure, stronger regulations limiting daily take and sizes, or depth and season restrictions. It is not known if any of the decline can be attributed to decreases in abundance or to other factors. The amount of annual recruitment of kelp greenling is unknown. This makes determining population replenishment very difficult and contributes to the overall lack of knowledge pertaining to kelp greenling population size and structure.

Management Considerations

The kelp greenling became a federally designated groundfish in 1982 when the Pacific Fisheries Management Council (PFMC) adopted the Pacific Coast Groundfish Fishery Management Plan. Since then, it has been managed under the joint jurisdiction of the state and the federal government. Prior to 1982, this species was managed by California Department of Fish and Game (CDFG) through regulations adopted by the state legislature and the California Fish and Game Commission (FGC).

Since the late 1990s, considerable federal pressure developed to rebuild "overfished"[1] species. Subsequent management actions designed to avoid these species shifted fishing effort into nearshore areas, putting additional pressure on shallow species such as kelp greenling. At the same time, state and federal

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California’s Marine Life Management Act (MLMA) of 1998 was adopted in response to the need to take a more precautionary approach to management that prioritized resource sustainability, and to address the rapid development of the live-fish fishery. This important piece of legislation made the possession of a commercial nearshore permit mandatory and delegated finfish management authority to the FGC. Minimum commercial size limits for nearshore species including kelp greenling were enacted. The MLMA also required that the FGC adopt a Fisheries Management Plan (NFMP) for nearshore finfish.

In 2000, under these new guidelines, the FGC adopted a precautionary approach for nearshore stocks including kelp greenling. In the absence of a kelp greenling assessment, harvest limits were set at 50 percent of historic landings.

Nineteen nearshore species including the kelp greenling are managed under provisions outlined in the NFMP, which was adopted by the FGC in 2002. The NFMP also mandated a precautionary management approach for stocks without quantifiable assessments so harvest limits continued to be set at 50 percent of historic landings until better information was available. In conjunction with the NFMP adoption, the FGC adopted a restricted access program which reduced the number of nearshore permittees regionally, limited approved gears to trap and hook-and-line, and provided for minimal bycatch in other fisheries.

Recreational and commercial catches are routinely monitored throughout the year to keep catches within annual TACs as much as possible. The commercial fishery has closed early for the past six years and commercial allocations were exceeded during five of those years. However, harvest allocations are being maintained at a very conservative level until better stock assessment data are available.

The significant gaps in sound scientific data represent one of the challenges in managing the kelp greenling fishery. As a result, kelp greenling will continue to be conservatively managed. Currently, the statewide total allowable catch for greenlings is 37,600 pounds (17 metric tons), of which the commercial fishery is allocated 3,400 pounds (1.5 metric tons) and the recreational fishery is allocated 34,200 pounds (15.5 metric tons).

A 2005 greenling stock assessment was not accepted for use in management due to limited scientific data. Specifically, there was uncertainty regarding greenling age, growth, and mortality rates. A basic knowledge of fish growth coupled with the relative numbers of juveniles and mature fish in the population are essential to help answer questions about how fishing affects the population’s long-term sustainability. It is helpful to know at what size and age a fish reaches sexual maturity and what percentage of the fish population is of reproductive size or age. Development of a fishery independent index of abundance, coupled with collecting more complete data on age and growth (including sex-specific length at age data), maturity, and movement patterns within California waters, will aid management. Current studies by CDFG are addressing movement patterns and growth, and will be used in future stock assessments and management.

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Table 10-1. Commercial landings (pounds) of kelp greenling, 1980-2006					
Year	**Pounds**	**Year**	**Pounds**	**Year**	**Pounds**
1980	3,147	**1990**	3,334	**2000**	51,070
1981	216	**1991**	1,645	**2001**	23,432
1982	1,477	**1992**	4,626	**2002**	17,817
1983	316	**1993**	1,651	**2003**	10,930
1984	158	**1994**	2,550	**2004**	4,533
1985	79	**1995**	2,577	**2005**	3,840
1986	609	**1996**	5,710	**2006**	3,581
1987	1,578	**1997**	17,445		
1988	4,180	**1998**	14,177		
1989	5,783	**1999**	30,925		

11. PACIFIC HERRING

Pacific Herring, *Clupea pallasi* Photo Credit: Ryan Watanabe

Review of the Fishery

Pacific herring, *Clupea pallasi,* landings peaked three times during the past century in response to market demands for fishmeal, canned fish, and sac-roe. During the intervening years, herring catches were low, when most of the herring catch was used as pet food, bait, or animal food at zoos. The herring reduction fishery peaked in 1918 at eight million pounds (3,632 metric tons), but this fishery ended in 1919 when reduction of whole fish into fishmeal was prohibited. From 1947 to 1954, herring were canned to supplement the declining supply of Pacific sardines, *Sardinops sagax*; landings during this period peaked in 1952 at 9.5 million pounds (4,313 metric tons). Canned herring, however, proved to be a poor substitute for sardines and limited demand led to the demise of this fishery by 1954.

In 1973, sac-roe fisheries developed along the West Coast of North America from Alaska to California to supply the demands of the Japanese market. This occurred after domestic Japanese herring stocks crashed due to overfishing and Japan and the Soviet Union agreed to ban the harvest of sac-roe herring in the Sea of Okhotsk. The Japanese government also liberalized import quotas, which opened the sac-roe market to United States and Canadian exporters. Since then, herring in California have been harvested primarily for their roe, with small amounts of whole herring marketed for human consumption, aquarium food, and bait. Herring ovaries (commonly referred to as “skeins” by those in the fishing industry) are brined and prepared as a traditional Japanese New Year’s delicacy called “kazunoko.” Brined skeins are leached in freshwater overnight and served with condiments or as sushi. Most herring taken in California are trucked from the port of landing to a processing plant for removal of skeins, brining and grading. Skeins are graded by size, color and shape, packed in plastic pails, exported for sale, and auctioned. Some herring are frozen and exported to China for processing where labor costs are low. Herring skeins from San Francisco Bay are typically smaller in size than those produced in British Columbia and Alaska, but are valued for their unique golden coloration.

The sac-roe fishery is limited to California's four largest herring spawning areas: San Francisco Bay, Tomales Bay, Humboldt Bay, and Crescent City Harbor. These areas are managed separately by the California Department of Fish and Game (DFG). San Francisco Bay has the largest spawning population of herring and produces 90 to nearly 100 percent of the state's annual herring catch. Annual catch quotas for San Francisco are based on the latest population estimates from spawning-ground surveys. Quotas are adjusted annually and are generally set between 10 to 15 percent of the amount of herring expected to return to spawn during that season at each spawning area. Quotas are set to maintain a sustainable fishery as well as providing sufficient Pacific herring to conserve living resources of the ocean that utilize herring as a food source. Currently Tomales Bay, Humboldt Bay, and Crescent City have fixed quotas of 350 tons (318 metric tons), 60 tons (54.5 metric tons), and 30 tons (27.2 metric tons), respectively. Quotas are set at levels thought to be sustainable for these areas and can be reduced if fishery managers note declines in returning biomass estimates.

The herring sac-roe fishery is managed through a limited entry system, which was implemented during the 1973-1974 season when 17 permits were issued. During the 1990s the number of herring permits peaked at over 450 with over 120 vessels participating. In contrast, during the 2006-07 season permit renewals fell to 250 and only 25 vessels elected to participate. This reduction of effort is only one of the many changes this fishery has undergone through history. During the 1979-1980 season the Fish and Game Commission decided not to issue any new round haul permits for the San Francisco Bay fishery with the intent of converting the sac-roe fishery to a gillnet only fishery. This was done to help alleviate gear conflicts and prevent quota overage due to the large net-sets. When it was clear that attrition alone would not retire all the round-haul permits, DFG then developed a five-year conversion plan which was completed during the 1997-1998 season. This marked the beginning of a gillnet only fishery. The most recent change in the sac-roe fishery occurred during the 2004-2005 season when the industry requested a mesh size reduction from 2⅛-inches (54-millimeters) to 2-inches (51-millimeters) in an attempt to access more of the available herring biomass. Fisherman sought this change due to a smaller size-at-age trend and lack of older age classes (larger fish) in the herring population. As would be expected, this regulation change is being closely monitored to determine any potential impact to the age structure of the population.

In California, sac-roe herring landings have peaked three times since the opening of the fishery with landings exceeding 20 million pounds (9,080 metric tons) during the 1982, 1989 and 1997 seasons (Figure 11.1). However, over the last decade landings have declined dramatically with total landings for the 2004-05 season the lowest on record at 362,000 pounds (164 metric tons). The value of the landings is based on the percentage of ripe skeins in the catch. Herring buyers calculate this by collecting several random 10-kilogram (22-pound) samples from each landing. Each fish sampled is sexed and ripe skeins are extracted and weighed. The total weight of the ripe skeins is then divided by 10 kilograms (22 pounds), resulting in the "roe count" or roe percentage.

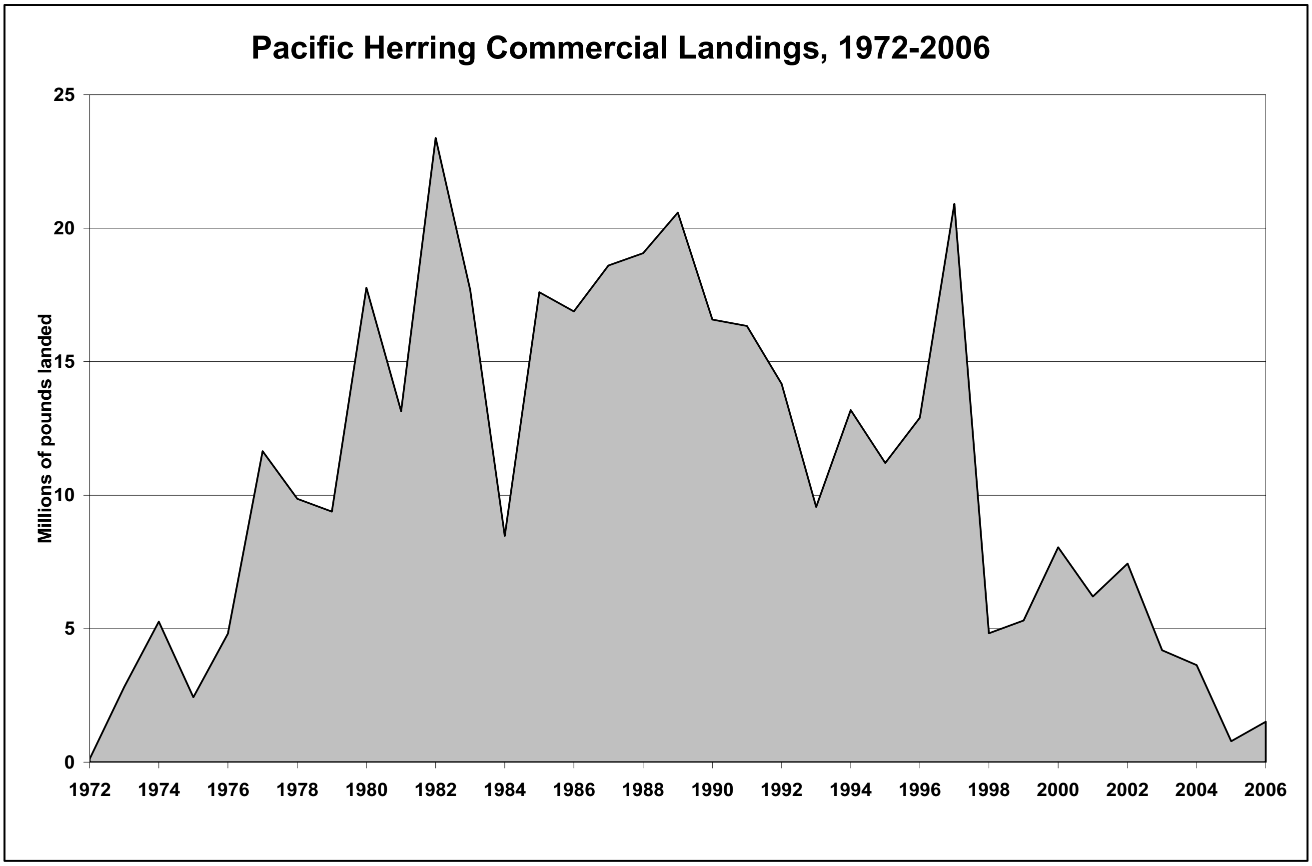

Figure 11.1. Commercial landings of Pacific herring in pounds from 1972 through 2006.
Data Source: CDFG commercial landing receipts.

A typical "roe count" for the San Francisco fishery in January is 13 to 14 percent. The ex-vessel price paid is based on 10 percent yield, and is adjusted for percentage points above or below. A yield of 10 percent or higher is considered the minimum acceptable by the sac-roe buyers. The base price for 10 percent roe count fish peaked at an estimated $2,000 per ton in 1979, when landing values reached as high as $4,000 per ton when adjusted for roe percentage. For the 2006-2007 season, the base price for California herring with 10 percent roe yield was an estimated $400 per ton of whole fish, and an ex-vessel price of $560 per ton when adjusted for roe percentage.

The California sac-roe fishery has experienced a steady price decline in recent years, mostly due to the changing markets and individual tastes. During the 1995-96 season, the ex-vessel seasonal value of the sac-roe catch in the San

Francisco fishery reached its peak at over 19.5 million dollars. Fishing revenue from the 2006 commercial harvest of Pacific herring was about $426,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $822,000. Likewise, total employment and wages from Pacific herring is estimated to be the equivalent of 15 jobs and $378,000, respectively.

As the primary buyer of sac-roe, the decline in value can be traced back to Japan. Changing demographics have moved kazunoko from a traditional holiday gift to an everyday product. Increased competition from Russia, Canada, Alaska and Europe has also contributed to lowering ex-vessel prices for California sac-roe herring.

Another aspect of California's herring industry is the roe-on-kelp fishery. Beginning in 1965, scuba divers harvested species of algae with herring eggs attached from Tomales and San Francisco Bays. In the 1984-1985 season, a sac-roe permittee received a permit on an experimental basis, to harvest roe-on-kelp using unenclosed floating rafts from which fronds of giant kelp, *Macrocystis pyrifera,* were suspended. This product known as "komochi kombu" or "kazunoko kombu" is also a Japanese delicacy and prepared similarly to kazunoko. There are 11 roe-on-kelp permits available for the fishery in San Francisco Bay; which are available to permittees willing to trade their sac-roe permits for roe-on-kelp permits.

The giant kelp used in this fishery is harvested from Monterey Bay, along the Ventura County coast, and the Channel Islands. The kelp is trucked to San Francisco Bay, suspended from floating rafts or longlines beneath piers. Rafts are positioned and anchored in locations where herring spawning is expected to occur. When spawning begins, suspended kelp is left in the water until several egg layers have been deposited or spawning ends. Preliminary roe-on-kelp product grading is conducted by the permittee prior to harvest to determine if coverage warrants harvesting. Once the product is harvested, grading begins. Price is determined by several quality factors; uniformity of egg coverage, thickness or number of egg layers, kelp condition, presence of eyed embryos, and the presence of silt. Roe-on-kelp has a per pound value much higher than herring roe, with current ex-vessel prices ranging from $7 to $18 per pound. As of 2007, there were 4 roe-on-kelp permits participating in the in San Francisco Bay fishery.

Throughout the history of this fishery, regulations have changed and expanded yearly. Management concepts new to commercial fishing in California were introduced as the herring fishery developed. These include limited entry permits, permits issued by lottery, individual vessel quotas, quota allocation by gear, the platoon system used to divide gillnet vessels into groups, the transferability of sac-roe fishery permits, and the conversion of round haul permits to gillnet permits. Controversy has surrounded management decisions, but they have proven to be effective solutions to socioeconomic conflicts. In the future, the Pacific herring fishery will continue to undergo significant changes, and as fishing opportunities, markets and ocean conditions change, it must continue to adapt in order to remain viable and sustainable.

Status of Biological Knowledge

Pacific herring are found throughout the coastal zone (waters of the Continental Shelf) from northern Baja California on the North American coast, around the rim of the North Pacific Basin and Korea on the Asian coast. In California, herring are found offshore during the spring and summer months foraging in the open ocean. Beginning as early as October and continuing as late as April, schools of adult herring migrate inshore to bays and estuaries to spawn. Schools first appear in the deep water channels of bays to ripen (gonadal maturation) for up to two weeks, then gradually move into shallow areas to spawn. School size varies, but can be as large as tens of thousands of tons and miles in length. Known spawning areas in California include San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor. The largest spawning aggregations in California occur in San Francisco and Tomales bays.

Most of these spawning areas are characterized as having reduced salinity, calm and protected waters, and spawning-substrate such as marine vegetation or rocky intertidal areas. Salinity is an important factor in the success of fertilization and embryonic development, and reduced salinity may act as a cue for spawning. Spawning occurs in the intertidal and shallow subtidal zones, when males release milt into the water column. A pheromone in the milt causes the females to extrude adhesive eggs on a variety of surfaces including: vegetation, rocks, and man-made structures such as pier pilings, boat bottoms, rock rip-rap, and breakwaters.

Fecundity is 226 eggs per gram of body weight, and a large female herring may lay 40,000 to 50,000 eggs. Female herring come in contact with the substrate while spawning, extruding a strip of adhesive eggs that is two to three eggs wide. Repeated passes by thousands upon thousands of females can build the eggs up to a thickness of four to five layers. Spawn depth distribution is generally shallower than 30 feet (9 meters) deep, but has been found to a depth of 60 feet (18.3 meters) in San Francisco Bay. A large spawning run may last a week and can result in 20 miles (32 kilometers) or more of the shoreline being covered by a 30-foot-wide (9-meter-wide) band of herring eggs. Immediately, after spawning, the adult herring leave the bay. Embryos (fertilized eggs) typically hatch in about 10 days, determined mainly by water temperature.

Herring Eggs on Eelgrass, *Zostera marina* Photo Credit: Ryan Bartling

During the incubation period, embryos are vulnerable to predation by marine birds, fish, and invertebrates. They may also die from desiccation or freezing if exposed during low tidal cycles. Normally, between 50 and 99 percent of herring embryos die before hatching. Human induced causes of mortality at this stage include smothering caused by suspended sediments from dredging, and toxic anti-fouling agents such as creosote on pier pilings. Herring embryos hatch into larvae, which metamorphose into juvenile herring. The distribution of larval herring in bays and estuaries is not well documented, but juvenile herring from San Francisco Bay have been found as far the Delta Pumping Plant in Tracy, approximately 80 miles (129 kilometers) inland from the spawning grounds. Juveniles may remain in the bay until summer or early fall, when they migrate to the open ocean.

Their distribution while in the ocean is not well understood, though Canadian research conducted on herring in Georgia Straight, British Columbia (BC) suggests that 1- and 2-year old herring occupy inshore waters and older herring occupy shelf waters. In BC waters, during summer months, juvenile herring were found in shallow nearshore waters of less than 164 feet (50 meters), all of which were comprised of similar-sized individuals. Based on the same BC data, Pacific herring may have little direct competition for food between age classes, and the first opportunity for direct interaction may be when herring sexually mature and join the spawning stock. Some herring reach sexual maturity at age two when they are about 7-inches (18-centimeters) in length; all are sexually mature at age three. California herring may live to be 9 or 10 years old and reach a maximum length of about 11-inches (28-centimeters). However, it is extremely rare to find fish that are older than 7 years of age.

While in the ocean, adult herring feed on macroplankton such as copepods and euphausiids. Larval and juvenile herring are believed to feed on molluscan larvae and other zooplankton while in bays and estuaries. Herring are a forage species for a diverse group of marine fishes, birds, and mammals. Spawning events in particular provide an opportunity for feeding. As herring move into shallow water to spawn, a feeding frenzy may commence which can last for several days. Gulls, cormorants, pelicans and other marine birds; California and Stellar sea lions *Zalophus californianus* and *Eumetopias jubatus*; harbor seals, *Phoca vitulina richards*i, invertebrates and a variety of fishes (including sturgeon in San Francisco Bay) feast on adult herring and embryos.

Status of the Population

The size of herring spawning populations in Tomales and San Francisco Bays are estimated annually from spawning-ground surveys. Beginning with the 1982-1983 season, hydroacoustic surveys were also used in San Francisco Bay. As of the 2003-2004 season, the department reverted to using only spawning-ground surveys. This followed a peer review which indicated hydroacoustic surveys often overestimated the spawning biomass and are a poor predictor of returning herring stocks. The review panel recommended that the spawn survey be used as the primary index of abundance and as the biomass estimate for setting the fishery quota until an integrated catch-at-age model can be developed and verified for San Francisco Bay. Due to staffing changes, no spawning biomass assessment or commercial catch assessments were conducted in Tomales Bay during the 2006-2007 season. However, spawning ground surveys and fishery monitoring is planned for the 2007-2008 season. Starting with the 2007-2008 season the Department will conduct Pacific herring spawn assessment surveys on a 3-year cycle in Humboldt Bay with the next spawn assessment survey to be conducted during the 2009-2010 season. A spawn assessment survey may be conducted sooner if the Department receives data that raises concern about the health of the Humboldt Bay Pacific herring spawning population. For Crescent City Harbor, individual spawning runs have been estimated, but no seasonal population estimates have been made for this area. Effort has been historically low and only occurs when significantly large schools make fishing profitable.

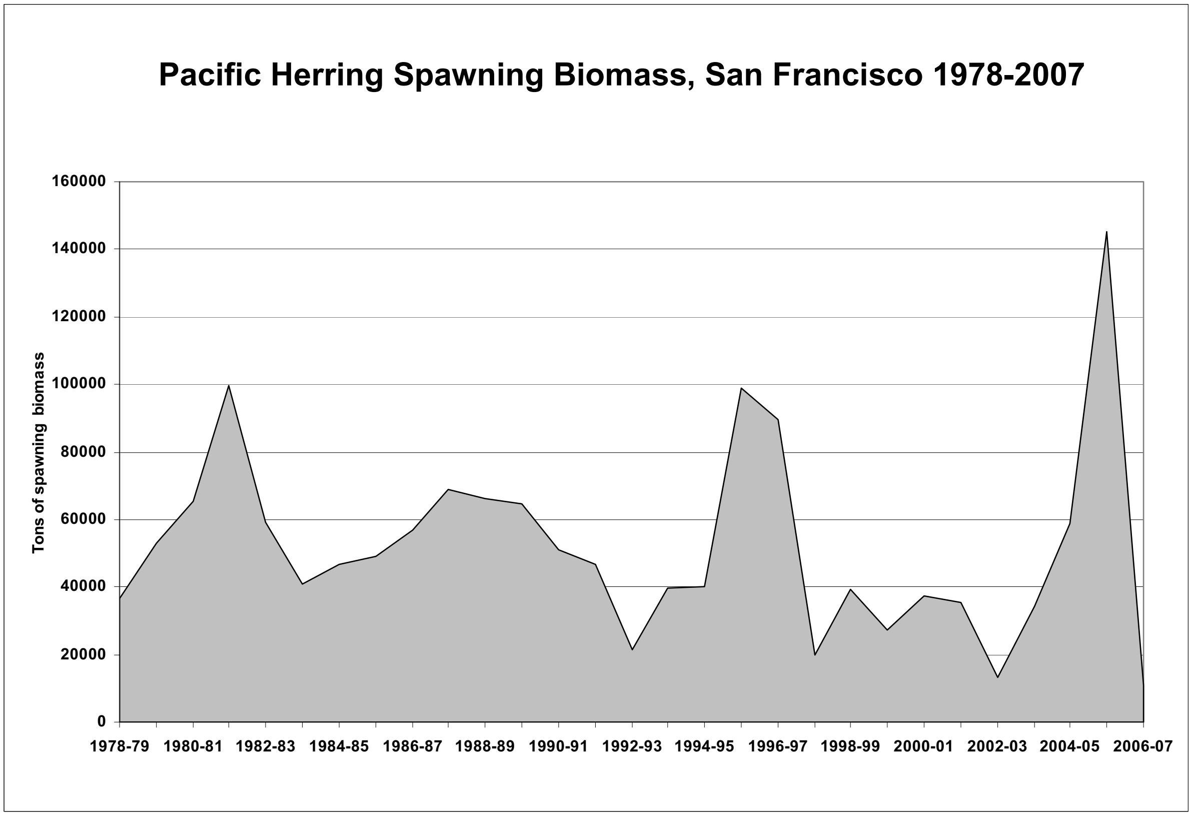

Figure 11.2. The spawning biomass of Pacific herring (in tons) in San Francisco Bay from 1978 through 2007. Data Source: CDFG Spawning Ground Surveys

All herring spawning areas in California have experienced a wide fluctuation in spawning biomass throughout the history of the fishery (Figure 11.2). In San Francisco Bay, herring biomass has ranged from a high of 145,000 tons (131,660 metric tons) to a low of under 11,000 tons (9,988 metric tons), with peaks occurring in 1982 (99,600 tons (90,436 metric tons)), 1988 (68,900 tons (62,561 metric tons)), and 1996 (99,050 tons (89,937 metric tons)). The lowest biomass estimates have occurred during or just after El Niño events: 40,800 tons (37,046 metric tons) in 1984; 21,000 tons (19,068 metric tons) in 1993; and 20,000 tons (18,160 metric tons) in 1998. For the 2006-07 season, the spawning biomass estimate was 10,900 tons (9,897 metric tons), a 92 percent decrease over the previous season's record high estimate of 145,000 tons (131,660 metric tons). This estimate is the lowest recorded in the history of the roe herring fishery and follows the pattern of low biomass estimates during El Niño events. The Tomales Bay spawning biomass estimates have ranged from a high of 22,200 tons (20,158 metric tons) in 1978 to a low of 345 tons (313 metric tons) in 1990 with an average of 4,900 tons (4,449 metric tons) per season since 1972. During the California drought, which lasted from 1987 to 1992, the herring spawning population severely declined in Tomales Bay. Due to the low returning biomass, the Department closed the Tomales Bay commercial herring fishery from 1990 through 1992 to speed recovery. Since reopening, the returning biomass in Tomales Bay has continued to fluctuate from year to year. The last spawn estimate in 2005-2006 recorded 2,000 tons (1,816 metric tons) of herring, down from the previous five seasons. Due to the low exploitation rate, current levels of harvest do not seem to be a factor in the biomass decline for Tomales Bay. Since 1974, there have been 11 spawning biomass surveys conducted in Humboldt Bay with the average biomass estimate for those surveys of 386 tons (350.5 metric tons). The upper range for that period is a 950 ton (863 metric ton) estimate from the 2001-2002 season with the lowest estimate recorded at 7 tons (6.4 metric tons) during the 2006-2007 season. Historically, this population supported a small, but successful fishery with a 60-ton (54.5-metric ton) quota for many years. However, with the observed decline in the spawning population, fishing effort has also declined. No fishing effort has occurred since the 2004-2005 season.

Management Considerations

Herring abundance fluctuates greatly due to large variations in spawning recruitment. This is influenced by complex environmental factors that operate on various time scales such as short term storms, middle term El Niño-Southern Oscillation (ENSO) events and long term Pacific Decadal Oscillation events. Recently, it has become clear that abundance may be tied to multiple events and not simply an El Niño period. Examples include changing ocean conditions (i.e. low primary productivity, increased temperature and decreased upwelling), potential displacement by sardine populations, and increased predation. Each of these factors needs to be studied further to better understand their impacts on the population. It would also be desirable to conduct genetic studies of California Pacific herring populations. Within each California bay where herring fishing occurs, management presumes that the spawning population is a separate stock, although this assumption is unproven genetically. Results of tag and recovery studies from Canada indicate that 25 percent of herring may stray between adjacent spawning areas in British Columbia. If California herring populations are more homogeneous than previously thought, the current management strategy for setting seasonal quotas from bay to bay may benefit from reevaluation.

Due to the reduction of fishing effort and below average landings in recent years, the impact of the commercial fishery on the overall abundance of herring stocks in California is thought to be minimal. However, recent data does suggest that there is a trend for decreasing in length-at-age in recent years. This could be due to long or short term environmental factors which result in poor ocean conditions, low food availability, poor health, increased competition, or other factors. Length-at-age for herring may be an indicator of the populations response to current ocean conditions.

The greater concern is the truncation of age classes. It is unknown why this pattern continues to persist with commercial harvest remaining so low. Rebuilding of the age class structure, especially in the older age classes (4-6 year-olds), has not occurred and it appears that oceanic mortality may be responsible. Research is needed to understand how environmental factors affect herring survival, particularly during different stages of their life history, so that we may better predict year-class strength.

The Department is striving to incorporate an ecosystem approach to management of its marine resources. The harvest level used for Pacific herring to some extent takes into consideration this species' role in the marine food web and its connection to environmental factors, but these relationships are not well understood. Most aspects of herring biology and ecology would benefit from further scientific research to improve existing herring management and further incorporate an ecosystem approach.

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12. PACIFIC SALMON

California's salmon resources are many things to the people of California. They are a source of highly nutritious food for the general population and an important source of income for the commercial salmon industry. Recreational anglers value them for their excellent sporting qualities and Native Americans celebrate them in annual events welcoming the returning adults. Salmon play a key role and occupy a unique niche within the State's highly diverse marine and inland ecosystems. They are a high level predator, but also contribute to the sustenance of other high level predators. In addition, their spawned-out carcasses enhance the nutrient base of their ancestral spawning streams. Like other anadromous species (migrate from the ocean to freshwater streams to spawn), 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 many naturally spawning populations of salmon becoming so diminished that, in some cases, they face biological extinction or have been completely extirpated from their native range. A brief overview of the importance and role of salmon in the management of California's living marine fishery resources follows.

Review of the Salmon Fishery

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

Salmon fisheries existed in California long before European settlers made their first appearance in the state circa 1775. Native Americans may have harvested over 8.5 million pounds (3,859 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 2,000 pounds (0.9 metric tons) a year, but it was also used as barter with other tribes. Salmon was consumed fresh or dried and smoked for later use throughout the year. The fish were of such significance to these early fishers that ceremonies and rituals honoring their existence and importance were created. Traditional fishing methods included 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, these gill net salmon fisheries were well established in the San Francisco area (primarily Suisun and San Pablo bays) and the lower Sacramento and San Joaquin rivers. The fishery gradually spread to include river basins north of San Francisco, although the Sacramento-San Joaquin fishery remained the largest. Growth of this fishery was stimulated by the canning industry. In 1864, the first salmon cannery on the Pacific coast started operations on the Sacramento River. By 1880, there were 20 canneries operating in the Sacramento-San Joaquin river system and intensified fishing efforts provided them with an ample supply of salmon. The fishery reached its peak in 1882 when about 12 million pounds (5,448 metric tons) were landed and processed.

Shortly thereafter, the fishery collapsed due to a sudden decline in salmon stocks caused primarily by the pollution and degradation of rivers by mining, agriculture, and timber operations, combined with increased fishery landings. By 1919, the last cannery had shut down and one by one, the rivers became 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 inland commercial fishing area open to the general citizens of California (Sacramento-San Joaquin rivers) was permanently closed.

The ocean troll commercial salmon fishery began in Monterey Bay during the 1880s. These early fishers 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 grew to approximately 200 boats and by 1916, had expanded north to Fort Bragg, Eureka, and Crescent City.

During the 1920s and 1930s, a typical salmon troller fished four to nine lines that each carried five or more hooks with up to 30-pounds (13.6-kilograms) of lead attached to keep the line at the proper depth. In 1935, an estimated 570 trollers were active in the fishery. Pulling weights, lines, and salmon onto a moving boat by hand was a backbreaking job, so power gurdies were soon developed to pull the lines and, by the mid-1940s, were used by most of the professional salmon trollers.

Commercial salmon vessel trolling north of Golden Gate Bridge.

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 fleet had nearly doubled to 1,100 vessels and was continuing to grow. The fleet peaked at almost 5,000 vessels in the 1970s and included many summer fishermen who had other jobs during the remainder of the year. Some of these summer participants were serious about commercial fishing and had adequate ocean-going boats, but most used small sport-type boats that could be conveniently towed on a trailer. In 1983, a limited entry program was established for the fishery.

Since its inception, the number of active participants has steadily declined. In 2006, less than 500 vessels were active in the fishery.

Salmon trollers today still use the basic fishing techniques developed during the 1940s, including powered gurdies and trolling four to six main lines. 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 baitfish schools and in pinpointing the depth at which to position lures. Precise vessel positioning is made possible through the use of global positioning systems. It is easy today to replicate a troll path or "tack" within a few feet of a previous or suggested path. Collectively, these instruments have significantly improved the efficiency of the modern troller compared to 60 years ago.

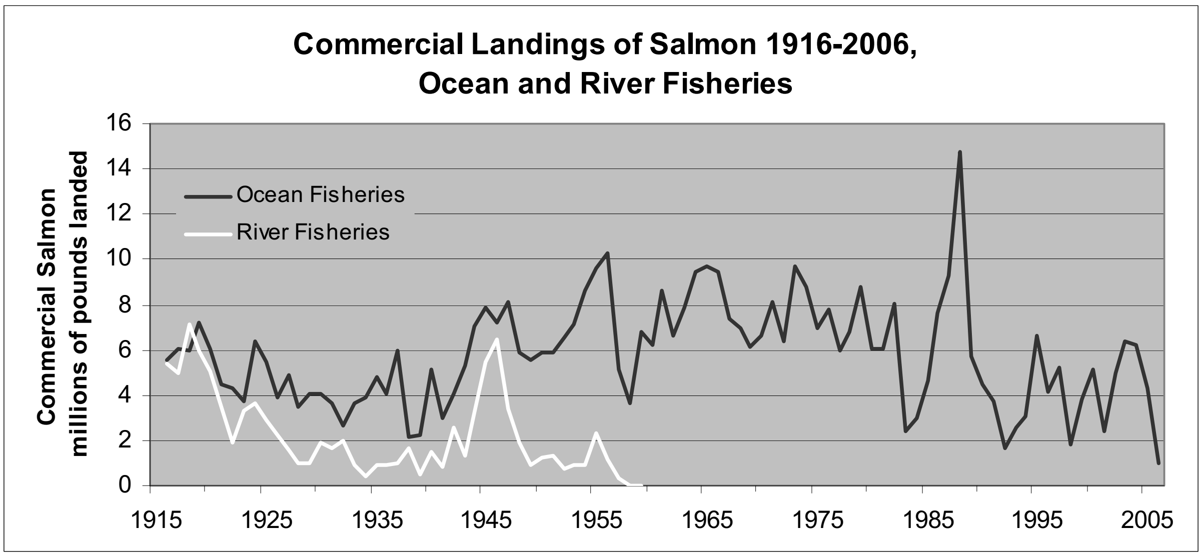

Figure 12.1. Annual commercial landings (pounds) of salmon taken in the river and ocean fisheries from 1916 to 2006. Catch data includes Chinook and coho salmon taken in the ocean and California coastal rivers, including the Sacramento and Klamath. The Klamath River commercial fishery closed in 1934 and the Sacramento commercial fishery closed in 1957. The take of coho salmon in river fisheries was prohibited after 1922. Data Source: CDFG Catch Bulletins and commercial landing receipts.

Estimates of commercial salmon catches are available in one form or another for years as early as 1874. In 1952, the California Department of Fish and Game (Department) began a systematic sampling of commercial ocean salmon landings. During the 1960s and 1970s, the industry enjoyed relatively high and consistent harvests, mainly of Chinook, averaging almost 8 million pounds (3,632 metric tons) dressed (gutted and gills removed) weight. The following two and a half decades produced much more variable catches. The largest commercial landings observed in California occurred in 1988 when more than 14.4 million pounds (6,538 metric tons) of Chinook (1.3 million fish) and 319,500 pounds (145 metric tons) of coho (51,000 fish) were landed. The lowest landings occurred in 2006 when just over 1 million pounds (454 metric tons) of Chinook (68,800 fish) were taken in the commercial ocean fishery. Although oceanic and in-river conditions play a major role in salmon catches, variation among years can also be attributed to changes in fishery regulations and reduced fishing effort. Since the mid-1980s, progressively more restrictive regulations have been placed on the ocean fishery to protect salmon stocks of special concern. (Figures 12.1 and 12.2 and Table 12.1)

Fishing revenue from the 2006 commercial harvest of Pacific salmon was about $5.3 million (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $10.1 million. Likewise, total employment and wages from Pacific salmon is estimated to be the equivalent of 80 jobs and $4.7 million, respectively.

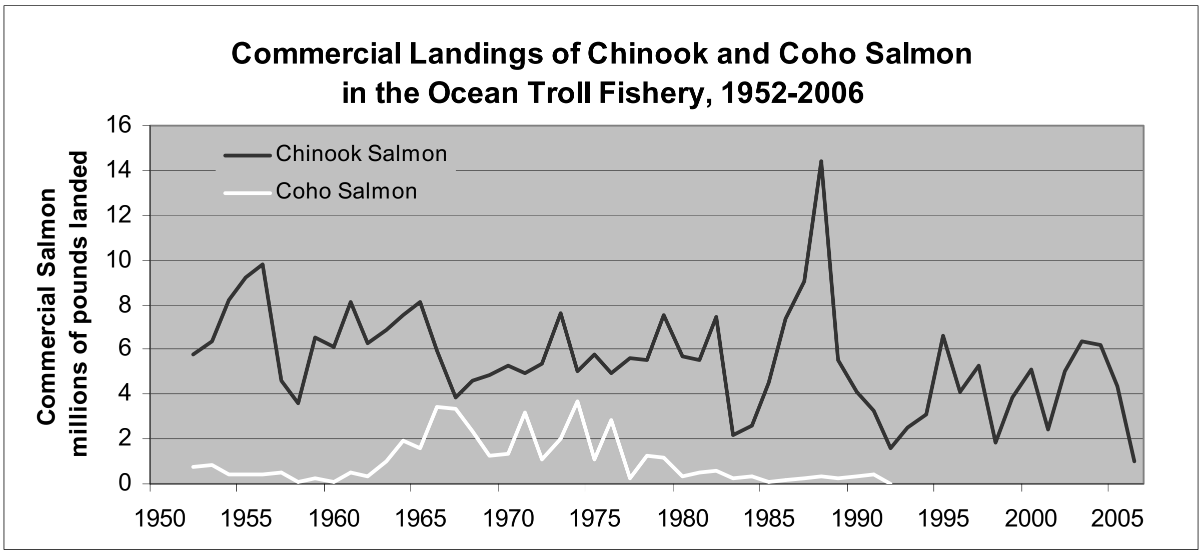

Figure 12.2. Annual commercial landings (pounds) of Chinook and coho salmon in the California ocean troll fishery from 1952 to 2006. The take of coho salmon was prohibited after 1992. Data Source: CDFG Ocean Salmon Project and commercial landing receipts.

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 private skiffs and CPFVs. From its initial monitoring through the 1980s, 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 been increasing and accounted for 32 percent on average of the total annual landings. In 2006, the sport salmon catch exceeded the commercial catch for the first time since monitoring began, contributing 57% of total Chinook landings. In addition, the sport catch has also been more evenly distributed between CPFVs and private skiff anglers in recent years. The highest sport landings occurred in 1995 when anglers landed a record 397,200 Chinook; the lowest landings in recent years occurred after strong El Niño events in 1983 (63,800 Chinook), 1978 (72,700 Chinook) and 1992 (73,600 Chinook). (Figure 12.3 and Table 12.2)

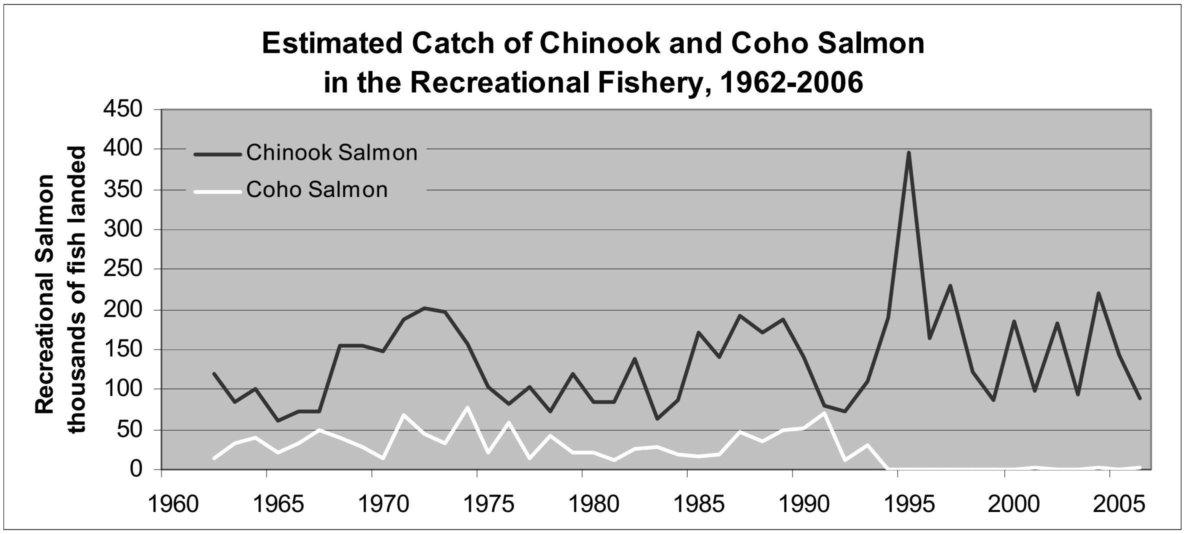

Figure 12.3. Estimated annual catch of Chinook and coho salmon in the California ocean recreational fishery from 1962 to 2006. The take of coho salmon was prohibited after 1995. Data Source: CDFG Ocean Salmon Project.

During the early 1990s, a fishing technique known as mooching began to gain popularity among salmon sport 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 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 when caught by mooching.

Onboard observations conducted by the Department’s Ocean Salmon Project (OSP) on CPFVs during 1993-1995 found that 60 percent of the sublegal salmon (<20-inches (51-centimeters) total length) caught via mooching were hooked in the gut or gills. Since studies have shown that 80 to 90 percent of sublegal salmon hooked in the gut or gills die, there was concern that this fishing technique could seriously impact stocks of special concern. Studies conducted by the OSP during 1995-1997 found that the use of circle hooks significantly reduced the hooking mortality on sublegal salmon.

Beginning in September 1997, all sport anglers mooching with bait were required to use circle hooks to reduce the hooking mortality on all released salmon, including coho. The popularity of mooching peaked in 1995 when almost 80 percent of anglers in the San Francisco and Monterey Bay areas mooched for salmon. In recent years, the proportion of anglers mooching has gradually declined due to a change in the distribution and schooling patterns of salmon off California. Not only have the salmon been more offshore, but the schools have also been more dispersed. In 2006, only 13 percent of anglers mooched for salmon, primarily in the Monterey Bay area.

The State's jurisdiction over tribal commercial fishing in the Klamath Basin 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 court ruled that the right of a tribal member to fish on a reservation was created by presidential executive order, which was derived from statute and thus not subject to state regulation.

In 1977, the Bureau of Indian Affairs (BIA) took over the management of tribal reservation fisheries in the Klamath Basin and the lower 20 miles of the Klamath River was opened to tribal gill net fishing for subsistence and commercial harvest; however in 1978, the BIA closed the fishery. The so-called Conservation Moratorium remained in effect until 1987 when the BIA reopened commercial fishing by Native Americans on the lower Klamath River. In 1993, the Department of the Interior determined that the Yurok and Hoopa Valley Indian tribes possessed a federally reserved right to take 50 percent of the harvestable surplus of Klamath Basin fall Chinook 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 water temperatures less than 56° F (13.3˚ C), clear water, suitable gravel riffles, and a stream velocity sufficient to permit excavation of redds (nests) and provide high subgravel flow to the deposited, fertilized eggs. The female digs the nest, lays the eggs, and covers them after the male fertilizes them. After a period of time, depending primarily on water temperature (usually 50-60 days in California), the eggs hatch into yolk sac larvae (alevins), which remain buried in the gravel until the yolk sac is absorbed. The young salmon (fry) wriggle up out of the gravel and begin feeding on microscopic organisms.

When the salmon are about 2-inches (52-millimeters) 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 stream-residency by these juveniles varies according to species and race. Following a period of rapid growth, the salmon begin changing physiologically in preparation for life in the ocean. A young salmon that has undergone the anatomical and physiological changes that allow it to live in the ocean is called a smolt. Following an instinctive internal cue, the smolts begin migrating in schools downstream towards the ocean.

Many of the fish pause in estuaries, remaining there until the smoltification process is completed. The salmon then enter the sea where they begin a period of rapid growth. After spending 1 to 6 years in the ocean, depending on species, they become sexually mature and begin their arduous journey upriver to their natal stream.

Chinook salmon

Chinook are the largest of the salmon species. The State record for a sport-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.

In California, there are two primary basins that support the majority of the State's Chinook: the Central Valley (Sacramento-San Joaquin rivers and their tributaries) and the Klamath Basin (Klamath-Trinity rivers and tributaries). Chinook are also found in many coastal streams north of San Francisco Bay.

Historically, 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 temperatures.

The female Chinook selects a nesting site that has good subgravel water flows to ensure adequate oxygenation. Since Chinook eggs are larger and have a smaller surface-to-volume ratio, they are also more sensitive to reduced oxygen levels than eggs of other Pacific salmon. Female Chinook will defend their redds once spawning has begun and will stay on the 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.

Chinook spend 2 to 6 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.

Ocean fisheries can have a significant impact on the average age of spawning Chinook because ocean-fishing gear often selects for larger, older fish. In addition, minimum size limits allow for the harvest of Chinook in the sport fishery starting at age two (≥20-inch (51-centimeter) minimum) and in the commercial fishery at age three (≥26-inch (66-centimeter) minimum). As ocean harvest rates increase, the average age of adult spawners declines. Fish destined to mature at age five must survive two more years of ocean fisheries than fish destined to mature at age three. It has not been documented that the selectivity of the ocean fisheries for older maturing fish has adversely affected the genetics of the populations, but it has probably reduced the utilization of spawning habitats that are best suited for larger, older fish. Larger fish, for example, are probably better able to utilize the larger gravel found in the main stems of most river systems. High rates of ocean harvest in recent decades have led to the virtual disappearance of five-year-olds in Chinook salmon runs throughout the State.

All Pacific salmon exhibit a strong tendency to return at a specific time each year to spawn in their natal streams. This has resulted in the development of distinct stocks, or populations, within each species that are, to varying degrees, both reproductively and behaviorally isolated. Stocks are often grouped into “runs” based on the time of the year during which their upstream spawning migration occurs. 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 runs are found in the Central Valley basin, with fall run being the most numerous. Although relatively large numbers of winter and spring Chinook occurred historically in the upper Sacramento drainage, they were significantly reduced by the construction of Shasta Dam in 1945. Spring Chinook also existed in the San Joaquin River basin but the completion of Friant Dam in 1942 contributed to the run’s subsequent extirpation. Late-fall Chinook are found primarily in the upper Sacramento River.

In the Klamath Basin, only fall and spring Chinook are found; the abundance of both runs reduced by barrier dams built in upper river areas during the late 1800s. On the coast, fall runs exist in the Eel, Mad, and Smith rivers. Spring Chinook also appear occasionally in the Eel and Smith rivers. Smaller coastal rivers have only fall Chinook.

Fall run. Fall Chinook salmon are the most numerous salmon in California today. They arrive in spawning areas between September and December, depending upon the river system, but peak arrival time is usually during October and November. 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, as well as in tributaries, from early October through December. In general, there is a large outmigration of fry and fingerlings from the spawning areas between January and March. An additional outmigration from the spawning areas, consisting primarily of smolts, occurs from April through June. The juveniles enter the ocean as smolts between April and July.

Late-fall run. 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 bulk of the juveniles leave the upper river between October and February. Late fall smolts enter the ocean between November and April.

Winter run. Winter Chinook salmon are unique to the Sacramento River system. Adults arrive in the upper Sacramento River spawning area from mid-December through early 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 though the following March, but the bulk of the juveniles move seaward in September. Winter run smolts enter the ocean between December and May. The adults mature and spawn 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 and spawn between late August and early October. Emergence of fry varies among drainages with fry emerging in some tributaries as early as November, while fry in other areas wait until late March to appear. Juveniles either exit their natal tributaries soon after emergence or remain throughout the summer, exiting the following fall as yearlings, usually with the onset of storms starting in October. Yearling emigration from the tributaries may continue through the following March, with peak movement usually occurring in November and December. Juvenile emigration alternates between active movement, resting and feeding. Juvenile salmon may rear for up to several months within the Delta before ocean entry. Spring Chinook runs tend to be dominated by three-year-old fish followed by four-year-olds and jacks.

Ocean distribution. The development and widespread use of the coded wire tags (CWT) 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 Central Valley fall Chinook are distributed primarily off of California and Oregon, they are also frequently recovered off Washington and British Colombia. A few fish have even ventured as far north as Alaska. Klamath River fall Chinook 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.

Coho salmon

Coho salmon are smaller than Chinook salmon; the average size of a mature coho is 7- to 12-pounds (3.2- to 5.4-kilograms). The California record for a sport-caught coho salmon is 22-pounds (10-kilograms), taken on Paper Mill Creek (Marin County) in 1959. The world record is a 33-pound (15-kilogram) coho caught by a sport angler in British Columbia in 1989.

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

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

Genetic analysis of California coho populations has indicated a wide degree of mixing of the stocks in the past, probably reflecting historical stocking and transplantation practices involving hatchery fish. Recovery of CWTs from California hatchery coho stocks have shown that they were historically 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, a multitude of factors have contributed to the decline of salmon stocks. These include unscreened irrigation diversions in the Sacramento Valley, the Delta and in the San Joaquin Valley; poor or lost gravel deposition in salmon spawning and rearing areas; pollution; aberrant river flow fluctuations caused by alternating water-release schedules from dams to meet downstream water-quality standards and water diversion contracts; elevated water temperatures stemming from power generation operations and reduction in cold water storage as reservoirs are emptied to meet agricultural contracts; and impediments to migration such as dams or diversions. The massive export of water from the southern Sacramento-San Joaquin Delta has probably been the greatest cause of decline in Central Valley salmon.

Red Bluff Diversion Dam on the upper Sacramento River continues to be a significant impediment to adult upstream migration, a major point of diversion and loss of downstream migrating juveniles, and a haven for predatory Sacramento pikeminnow, *Ptychocheilus grandis,* and non-native striped bass*, Morone saxatilis*. Lifting of the gates at this facility has been implemented in the fall through spring to protect all races of Chinook; however, the Bureau of Reclamation has determined that current dam operations do not adequately allow passage of ESA listed species. To help address this issue, the Bureau of Reclamation and the Tehama-Colusa Canal Authority developed an Environmental Impact Statement in 2002 to generate options that maximized fish passage while minimizing impacts to the agricultural irrigation supply. Following an extended public review and comment period, an option was selected that raised the gates for 10 months (closed July and August) and added a new pumping station to provide agricultural water.

<u>Central Valley Fall Chinook</u>. Fall Chinook are the most abundant of the four races of Central Valley salmon (Figure 12.5), spawning predominately in the Sacramento River basin. The run is heavily supplemented by production at five hatcheries. The spawning populations of fall Chinook in the Sacramento River and San Joaquin drainages averaged about 362,000 from 1952 to 1959; 270,000 from 1960 to 1969; 210,400 from 1970 to 1979; 255,000 from 1980 to 1989; 259,700 from 1990 to 1999; and 519,100 from 2000 to 2006. The average run size during the last decade was nearly double that observed the previous three decades; however this was due primarily to enormous runs (greater than 575,000) during 2001-2003. Although the escapement in 2006 was near the 30-year average (268,200 spawners), it also included the lowest number of jacks on record.

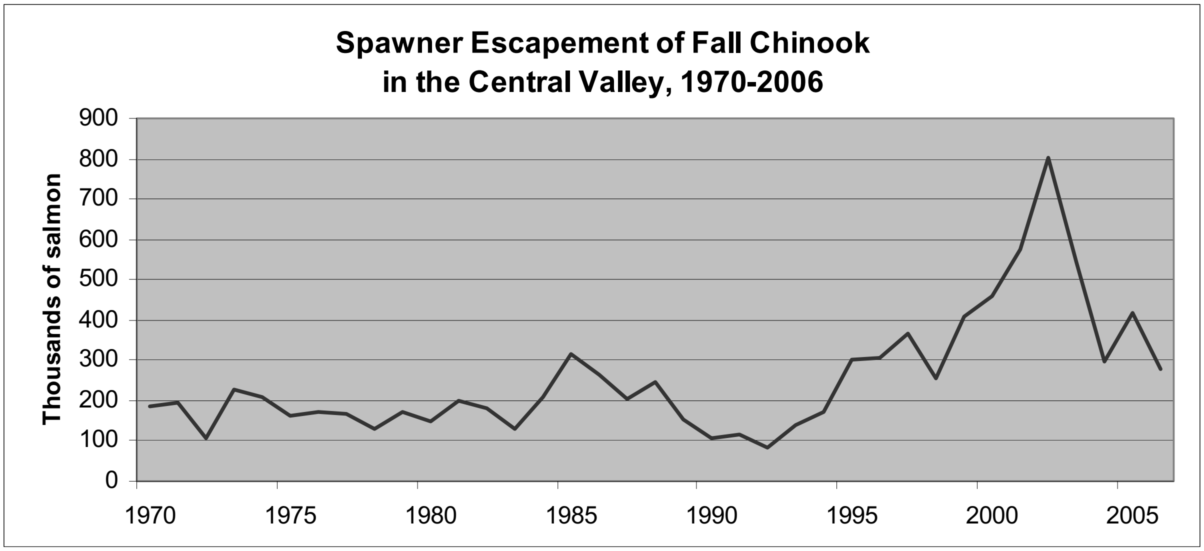

Figure 12.5. Escapement of Fall Chinook to the Central Valley from 1970 through 2006. Data Source: CDFG.

Central Valley Late-fall Chinook. Late-fall Chinook spawn primarily in the main stem Sacramento. The run, which was not identified until the construction of a dam and fish ladder at Red Bluff enabled monthly counts of spawners, averaged between 10,000 to 15,000 spawners with some years seeing as many as 40,000 spawners (Figure 12.6). The late-fall run is highly variable, but has been on an increasing trend since the severe decline in the mid-1990s. More recent estimates of run size have been made difficult by changes in the operation of the Red Bluff Diversion Dam.

Sacramento River Winter Chinook. Winter Chinook was the first anadromous fish to receive protection under the Federal Endangered Species Act (ESA) in 1989, immediately following its listing under the California Endangered Species Act (CESA) the same year. Winter Chinook no longer exist in any of its original spawning habitat above Shasta Dam and the run persists only because of the new habitat created by cold water releases from the dam into the mainstem Sacramento River. The spawning populations below Shasta declined from an average of 28,000 fish observed in the 1970s to only a few hundred in the early 1990s. More recently, spawning populations have been on the increase and averaged 7,400 from 2001 to 2006 (Figure 12.6). Because of the winter Chinook's unique life history, ocean fisheries are structured to target more abundant fall Chinook during spring and summer months, reducing the impact on this listed stock.

Central Valley Spring Chinook. Spring Chinook, which were historically the second most abundant run, now spawn in relatively small numbers in streams in the northern Sacramento River basin. Spawning populations are extremely variable but have been on an upward trend since the late 1990s, particularly the Deer and Butte Creek stocks (Figure 12.6). Spring Chinook are listed as threatened under the ESA

(1999) and CESA (1999).

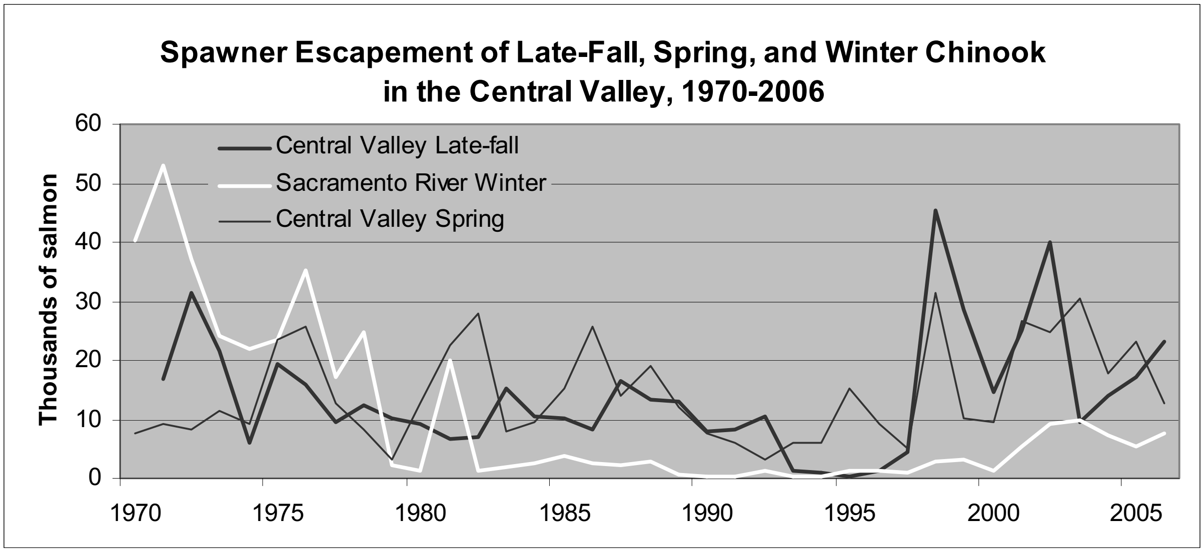

Figure 12.6. Escapement of Central Valley late-fall Chinook, Sacramento River winter Chinook and Central Valley spring Chinook from 1970 through 2006. Data Source: CDFG.

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

Coastal Chinook and Coho Populations. Coastal California streams support small populations of coho and Chinook salmon. Habitat blockages, logging, agriculture, urbanization and water withdrawals have resulted in widespread declines of both species. All coastal coho populations in California are listed as threatened under the ESA (1996 and 1997) and coho south of San Francisco are listed as endangered under CESA (1995). California Coastal Chinook, which include northern California coastal streams between and including Redwood Creek and the Russian River, are listed as threatened under the ESA (1999). Spawning population estimates are limited for coastal Chinook to nonsystematic surveys of a few tributaries of the Mad and Eel rivers.

Klamath Basin. The Klamath Basin has two hatcheries and supports fall and spring run Chinook within its two primary rivers, the Klamath and Trinity. The adult spawning populations of fall Chinook in the Klamath Basin ranged from a low of 18,100 (hatchery and natural) in 1991 to almost 199,700 in 1995. The population seems to be cyclical with several years of high spawners followed by several years of low numbers of returning fish (Figure 12.7).

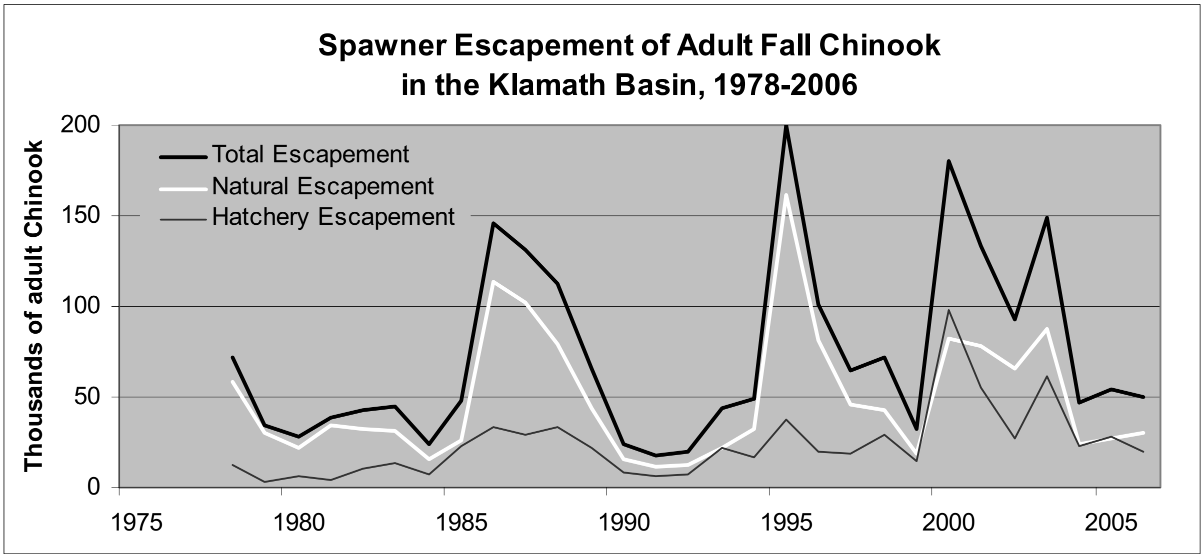

Figure 12.7. Escapement of adult fall run Chinook in the Klamath Basin from 1978 through 2006. Data Source: CDFG.

In 2002, an unprecedented fish-kill in the Klamath Basin of approximately 35,000 salmon, among other fishes, died prior to spawning primarily due to disease outbreaks as a result of reduced water flow 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. The Shasta River, an important spawning stream in the upper Klamath, has historically supported over 63,000 adults, but only 700 adult Chinook spawned there in 2006. Spring Chinook in the Trinity and Salmon rivers in the Klamath Basin have also been at very low levels in recent years and are largely supported by hatchery production.

Salmon Management

In 1947, the Pacific Marine Fisheries Commission (PMFC) 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 PMFC was a 26-inch (66-centimeter) total length minimum size limit and a March 15 to October 31 maximum season length for Chinook. For many years the states uniformly adopted the 26-inch (66-centimeter) standard 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 (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 Act created regional fishery management councils to develop fishery management plans and recommend fishing regulations to the states, Native American tribes, and the National Marine Fisheries Service (NMFS). Thus the Pacific Fishery Management Council (PFMC) was created with management authority over the federal fisheries off the coasts of Washington, Oregon and California. Representation on the PFMC currently includes the chief fishery officials of California, Idaho, Oregon, and Washington, the NMFS, a Native American representative, and eight knowledgeable private citizens. The PFMC receives advice from a Salmon Technical Team (STT) and a Salmon Advisory Sub-panel composed of various industry, tribal, and environmental representatives.

The PFMC's Salmon Fishery Management Plan (FMP) was developed in 1977 and was the first FMP developed by the organization. The PFMC annually develops management measures that establish fishing areas, seasons, quotas, legal gear, possession and landing restrictions, and minimum lengths for salmon taken in federal waters off Washington, Oregon, and California. The management measures are intended to prevent overfishing while achieving optimum yield and to allocate the ocean harvest equitably among ocean commercial and recreational fisheries. The measures must meet the goals of the FMP that address spawning escapement needs and allow for freshwater fisheries. The needs of salmon species listed under the federal Endangered Species Act (ESA) must also be met as part of the process. The measures recommended to the NMFS by the PFMC must be approved and implemented by the Secretary of Commerce.

In 1979, a moratorium was placed on the issuance of permits to new participants in the ocean commercial salmon fishery. This was done primarily to reduce the overall fishery impacts on the resource and ensure sustained income for participating trollers. During the 1980s, California ocean salmon fisheries were increasingly regulated under quotas and area closures; and in 1983, a limited-entry program was implemented that capped the fishery at just over 4,600 commercial salmon vessels.

Klamath River fall Chinook (KRFC) was one of the first salmon stocks to be managed under the PFMC's Salmon FMP in 1983. The FMP's conservation objective requires that a minimum of 35,000 KRFC adults return to spawn in natural areas each year. In addition, there can be no more than a 67 percent natural spawner reduction rate in the ocean fisheries. The ocean fisheries must also be managed to provide for the federally reserved fishing rights of the Yurok and Hoopa Valley Indian tribes (i.e., 50 percent of the allowable KRFC harvest). Both in the early 1990s and between 2004 to 2006, Klamath fall Chinook failed to meet their adult spawner escapement objective. During the 2006 management cycle, it was predicted that the KRFC would not meet their spawner escapement goal, even with the complete closure of all ocean fisheries. An emergency rule was issued by NMFS that allowed PFMC to structure the ocean fisheries so that no less than 21,000 KRFC adults return to spawn in natural areas the following fall.

The FMP also established a conservation objective for Sacramento River fall Chinook. It requires that ocean fisheries are managed to allow a range of 122,000 to 180,000 natural and hatchery adults return each year to spawn. This goal has been met every year since 1992.

With the listing of Sacramento River winter Chinook as endangered under ESA and CESA in 1989, a new dimension was added to salmon management. The ESA requires that NMFS assess the impacts of ocean fisheries on listed salmon populations and develop standards that avoid the likelihood of jeopardizing their continued existence. The initial ESA jeopardy standard for winter Chinook required a 31 percent increase in the adult spawner replacement rate relative to the observed mean rate for 1989 to 1993. To meet the goals of this standard, additional restrictions were placed on California's commercial and recreational fisheries, including increased minimum size limits designed to protect the smaller-at-age winter Chinook.

In April 2000, NMFS placed a cap on the ocean harvest rate (≤16 percent) of age-4 Klamath fall Chinook to protect California coastal Chinook stocks. Since information on California coastal Chinook was very limited, Klamath fall Chinook were considered the best surrogate for estimating fishery impacts on these stocks. In 2002, the NMFS modified the winter Chinook jeopardy standard to include season opening and closing date restrictions, in addition to minimum size limits, to provide additional protection to this endangered stock.

There are currently 16 Evolutionarily Significant Units (ESUs) of salmon under the ESA. As the listings have occurred, NMFS has initiated formal consultation standards and issued "Biological Opinions" that consider the impacts resulting from implementation of the FMP or from annual management measures to listed salmon stocks. NMFS has also reinitiated consultation on certain ESUs when new information becomes available on the status of the stocks or on the impacts of the FMP on these stocks. Amendment 12 of the 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 NMFS jeopardy standards or recovery plans to meet immediate conservation needs and long-term recovery of the species." Amendment 14 of the FMP specified those listed ESUs and clarified which stocks in the FMP management unit were representative of the ESUs.

The NMFS has concluded that the harvest of the relatively abundant Central Valley fall Chinook stocks could continue at reduced levels in California's ocean fisheries without jeopardizing the recovery of listed Chinook and coho populations. The California Fish and Game Commission, PFMC and NMFS have implemented various protective regulations to reduce fishery impacts on California populations of

Central Valley winter and spring Chinook, and coastal Chinook and coho, all of which are listed. In 1992, the PFMC began to severely curtail the ocean harvest of coho salmon in California due to the depressed condition of most coastal stocks. In anticipation of the federal listing of California coho salmon stocks, the NMFS extended the protective measures to a complete prohibition of coho retention off California.

SALMON: DISCUSSION

Challenges to Inland Salmon Management

Maintaining salmon runs in California depends on the restoration and preservation of the State's rivers and streams as living systems. A poor law or regulation affecting fishing can be changed long before the damage it causes becomes permanent, but a stream that is blocked near its mouth by an impassable dam will produce no more salmon. A stream kept dry through the spawning season by diversion is no better, but may prove salvageable if water can eventually be provided. Diverting all the water from a stream during the downstream migration period of juveniles will prevent any of them from reaching the ocean, even if adequate fish screens are in place to keep them from entering the irrigation canals. Reducing stream flows or removing vegetation that provides shade may result in a stream becoming too warm for salmon. Siltation from logging or road construction can smother salmon eggs and suppress production of aquatic invertebrates upon which the young fish depend for food. The decline in California's salmon populations vary somewhat from river to river, but there are two major causes: (1) destruction or loss of habitat, and (2) water diversion.

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 Improvement Act of 1992 required a program designed to double natural production of anadromous fish in Central Valley streams. In 1995, the federal government and California initiated the CALFED Bay-Delta program to address environmental and water management problems associated with the Bay-Delta system. The primary mission is to develop a long-term comprehensive plan that will restore ecological health and improve water management for the beneficial uses of the Bay-Delta system. In 2002, the Legislature created the California Bay-Delta Authority to oversee implementation of the Bay-Delta Program, and 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. To date, the CALFED has invested more than $850 million dedicated to improving water quality and restoring habitats, among other local improvement projects. Projects include providing fish passage ways including 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.

Many similar improvements have also been made in the Klamath Basin. The 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 in-stream, riparian, and upland protection and restoration, fish rearing, water conservation and water quality improvement, assessment and research, and community education. The “Klamath Act” also created the Klamath Fishery Management Council (KFMC) and several advisory groups, including the Klamath River Technical Advisory Team (KRTAT) and the Klamath River Basin Task Force (KRBTF). The KFMC provides guidance to the PFMC regarding allocation among user groups to help achieve efficient and effective use of the Basin’s resources. In September of 2006, the Klamath Act expired and was not reauthorized by Congress; thus the KFMC, KRTAT, and KRBTF no longer officially exist.

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

Hatchery fish have been important to maintaining ocean and in-river fisheries, but have incorrectly been perceived as a viable alternative to maintenance of natural spawning populations. Unfortunately, a successful hatchery program can mask the decline in the natural run due to straying of the returning adults, and this appears to be the case for Chinook in many areas of the Central Valley and the Klamath River basin. Hatchery adults spawning in the wild can compete with naturally produced fish for adult spawning and juvenile fish rearing areas. Interaction of hatchery and naturally produced salmon is most acute in the close vicinity of the rearing facilities. Battle Creek below Coleman Hatchery and Bogus Creek adjacent to Iron Gate Hatchery typically are overloaded with spawning fish each fall due to straying of hatchery adults. To help mitigate these issues, the Central Valley hatcheries have modified operating procedures to accept all returning fish to reduce competition and help protect the genetic integrity of naturally spawning stocks. In addition, the Central Valley has initiated a Constant Fractional Marking (CFM) program to aid in determining the success of restoring naturally spawning populations. The CFM program will 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.

Trucking operations in the Central Valley have greatly increased hatchery fish survival by reducing in-stream losses of fish to diversions and predators. However, these operations have also reportedly increased the rate of straying of returning adults, possibly to the detriment of the naturally produced fish. As a result of reviewing off-site release data, it was determined that the risks posed to natural populations seemed to outweigh the benefits from increased survival of off-site releases. The CDFG and NMFS have advised all California hatcheries to release fish at or near the hatchery whenever feasible.

Many salmon sport 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 important 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. Of the coastal streams, the Klamath Basin receives by far the most effort, followed by the Smith and Eel. Much of the fishing in coastal river systems occurs in estuaries. The Klamath and Smith river mouths draw large numbers of anglers from great distances and concentrate them in a small area. The term "madhouse" is appropriate during the peak of a good run. The catch in both of these rivers consists primarily of Chinook salmon.

Challenges to Ocean Management

Ocean salmon fisheries harvest a mixture of stocks that can differ greatly in their respective abundance and productivity. It has long been recognized that the management of mixed stock salmon fisheries is difficult and complex; fisheries supported by hatcheries can deplete less productive, naturally produced stocks unless programs are in place to monitor and evaluate their status and make necessary adjustments in harvest. Ideally, some differences in the spatial and temporal distribution of “strong” and “weak” stocks exist that allow managers to develop measures that selectively protect stocks of concern. When faced with the difficulties of estimating ocean distribution and presence of salmon from weak stocks, fishery managers prefer a precautionary approach to reduce ocean harvest rates to levels sufficiently low that ocean impacts are unlikely to extinguish these weak ESA populations of salmon.

Ocean abundance estimates are not available for most of California's listed salmon and harvest rates on these stocks are subject to speculation. Determining levels of harvest that are appropriate for recovery is challenging. Without 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 precipitation. An incremental approach to harvest reductions seems to have produced encouraging results with respect to winter Chinook. At the time of listing, spawning populations were estimated at less than 200 fish. In 2006, more than 17,000 winter Chinook returned to spawn in the Sacramento River.

In 2005, a pilot-study was initiated by the Department and CALFED to determine the age structure of all Central Valley Chinook, including the listed winter and spring Chinook. Age-specific data will aid in determining population size, hatchery/natural proportions, and ocean abundance by age, similar to the Klamath Basin program currently in place.

During the last several years, there have been several test fisheries conducted in California to evaluate the use of Genetic Stock Identification (GSI) in ocean fisheries management. There are many distinct salmon stocks off California and although population sizes vary year to year, some of these stocks are relatively productive and could support a substantial fishery while others cannot withstand much fishing pressure at all. These stocks co-mingle along the coast and, at the time of harvest, it is usually impossible to determine which salmon come from abundant stocks and which come from weaker stocks in need of protection. Regulations are crafted each year to protect the weak stocks, using the best available information from CWTs and modeling outputs based on past fishing seasons. This sometimes results in severely constraining fishermen's access to more abundant salmon stocks. The GSI technology for identifying Chinook stocks is now developed to the point where it may be potentially useful for fishery management. Genetics labs from Alaska to California have collaborated on a coastwide data base that includes over 120 Chinook stocks on the Pacific coast. However, when stocks of special concern are at extremely low abundance and comprise a very small fraction of ocean catches, even GSI methods are unlikely to produce accurate estimates of ocean impacts on 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. The long-term goal is to increase the information available to managers on the temporal and spatial distribution of west coast salmon stocks.

Although the KRFC escapement in 2006 surpassed the lowered floor of 21,000 adult natural spawners established by NMFS emergency action, it was the third consecutive year that the KRFC missed the FMP conservation objective spawner floor of 35,000 natural adults. As a result, the stock was declared overfished which automatically triggered an overfishing review and rebuilding plan by the PFMC's STT. This report is to be completed by March 2008. In addition, after multiple public hearings and a thorough environmental assessment, the PFMC recommended and NMFS approved a FMP amendment that allows for the limited harvest of KRFC in ocean salmon fisheries whenever shortfalls are projected. This amendment increases the flexibility in the rule-making process whenever KRFC conservation goals are not expected to be met and would provide for a de minimus, or limited, fishery. Amendment 15 of the FMP is intended to allow PFMC to continue fishing without the need for NMFS to approve an emergency rule.

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

Specific Management Recommendations

The major threat to California's salmon resource continues to be degradation and elimination of freshwater and estuarine habitats. Restoration of inland spawning and rearing habitats and renegotiation of inland water management policies, particularly in the Klamath Basin, must be pursued if salmon production levels from naturally spawning areas are ever to return to their former levels. Prudent regulation of the fisheries will be required to equitably distribute the available fish between the various ocean and in-river users and to meet spawning escapement needs. To these ends, the California Department of Fish and Game should:

1) Continue its efforts to improve, restore, and enhance freshwater and estuarine habitats for salmon. Specific focus should be on:
   a. Maintenance and improvement of suitable stream flows and temperatures
   b. Screening of water diversions
   c. Participation in discussions regarding water diversion contracts
   d. Abatement of pollution sources, chemical and thermal
   e. Reductions in siltation and gravel compaction levels
   f. Control of naturally occurring diseases such as Ich and columnaris, and preventing Infectious Hematopoetic Necrosis (IHN) and bacterial kidney disease (BKD) in the hatcheries.
2) Continue development and implementation of plans addressing habitat and fishery management to reverse the status of depleted salmon stocks, in particular Klamath Basin and Central Valley spring Chinook, Sacramento winter Chinook and California Coastal Chinook and coho stocks.

3) Support studies to determine the run size at age, particularly for stocks in the Central Valley.
4) Continue funding of Central Valley monitoring programs and CWT constant fractional marking.
5) Develop cohort reconstruction and ocean harvest models for key California salmon stocks.
6) Operate hatcheries and rearing facilities and conduct fish stocking practices responsibly to minimize effects on natural production.

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Table 12.1. Commercial Salmon Harvest in Pounds (Page 1 of 3)						
Year	Chinook	Coho	Ocean Total [a]	Sacramento	Klamath [b]	Total
1916	----	----	5,592,216	3,450,786	1,896,592	10,939,594
1917	----	----	6,085,997	3,975,487	999,097	11,060,581
1918	----	----	5,933,346	5,938,029	1,221,813	13,093,188
1919	----	----	7,208,382	4,529,222	1,408,123	13,145,727
1920	----	----	6,066,190	3,860,312	1,207,317	11,133,819
1921	----	----	4,483,105	2,511,127	996,700	7,990,932
1922	----	----	4,338,317	1,765,066	131,741	6,235,124
1923	----	----	3,736,924	2,243,945	1,109,391	7,090,260
1924	----	----	6,374,573	2,640,110	1,000,586	10,015,269
1925	----	----	5,481,536	2,778,846	126,371	8,386,753
1926	----	----	3,863,677	1,261,776	958,626	6,084,079
1927	----	----	4,921,600	920,786	669,543	6,511,929
1928	----	----	3,444,306	553,777	480,483	4,478,566
1929	----	----	4,033,660	581,497	429,714	5,044,871
1930	----	----	4,085,650	1,213,698	703,546	6,002,894
1931	----	----	3,666,841	941,605	686,065	5,294,511
1932	----	----	2,649,204	1,264,987	703,990	4,618,181
1933[c]	----	----	3,657,661	454,253	446,520	4,558,434
1934	----	----	3,921,530	397,572	-	4,319,102
1935	----	----	4,773,112	888,868	-	5,661,980
1936	----	----	4,093,475	949,179	-	5,042,654
1937	----	----	5,934,996	974,871	-	6,909,867
1938	----	----	2,170,921	1,668,376	-	3,839,297
1939	----	----	2,238,755	496,933	-	2,735,688
1940	----	----	5,160,393	1,515,588	-	6,675,981
1941	----	----	2,946,030	844,963	-	3,790,993
1942	----	----	4,063,306	2,552,944	-	6,616,250
1943	----	----	5,285,527	1,295,424	-	6,580,951
1944	----	----	7,021,848	3,265,143	-	10,286,991
1945	----	----	7,912,754	5,467,960	-	13,380,714
1946	----	----	7,196,527	6,463,245	-	13,659,772
1947	----	----	8,104,297	3,380,484	-	11,484,781
1948	----	----	5,860,915	1,939,801	-	7,800,716
1949	----	----	5,531,021	899,090	-	6,430,111
1950	----	----	5,867,346	1,202,890	-	7,070,236
1951	----	----	5,849,530	1,343,171	-	7,192,701
1952	5,785,214	751,677	6,536,891	738,081	-	7,274,972
1953	6,335,634	800,589	7,136,223	896,696	-	8,032,919
1954	8,167,724	431,855	8,599,579	900,961	-	9,500,540
1955	9,245,882	411,114	9,656,996	2,320,746	-	11,977,742
1956	9,814,366	460,536	10,274,902	1,139,585	-	11,414,487
1957	4,640,709	536,200	5,176,909	321,824	-	5,498,733

1958	3,576,385	80,456	3,656,841	----	-	3,656,841
1959[d]	6,543,223	225,476	6,768,699	463	-	6,769,162

Table 12.1. Commercial Salmon Harvest in Pounds (Page 2 of 3)

Year	Chinook	Coho	Ocean Total [a]	Sacramento	Klamath [b]	Total
1960	6,096,384	125,061	6,221,445	-	-	6,221,445
1961	8,100,964	536,943	8,637,907	-	-	8,637,907
1962	6,301,520	371,341	6,672,861	-	-	6,672,861
1963	6,829,048	1,019,642	7,848,690	-	-	7,848,690
1964	7,562,445	1,918,770	9,481,215	-	-	9,481,215
1965	8,102,205	1,571,469	9,673,674	-	-	9,673,674
1966	5,979,027	3,467,427	9,446,454	-	-	9,446,454
1967	3,866,374	3,375,944	7,242,318	-	-	7,242,318
1968	4,612,488	2,337,629	6,950,117	-	-	6,950,117
1969	4,895,322	1,234,529	6,129,851	-	-	6,129,851
1970	5,269,494	1,341,820	6,611,314	-	-	6,611,314
1971	4,925,826	3,183,830	8,109,656	-	-	8,109,656
1972	5,372,779	1,050,355	6,423,134	-	-	6,423,134
1973	7,586,832	1,993,863	9,580,695	-	-	9,580,695
1974	5,048,456	3,700,084	8,748,540	-	-	8,748,540
1975	5,781,321	1,128,304	6,909,625	-	-	6,909,625
1976	4,943,891	2,843,849	7,787,740	-	-	7,787,740
1977	5,637,016	283,222	5,920,238	-	-	5,920,238
1978	5,492,397	1,295,200	6,787,597	-	-	6,787,597
1979	7,547,752	1,197,983	8,745,735	-	-	8,745,735
1980	5,715,203	301,566	6,016,769	-	-	6,016,769
1981	5,534,833	477,237	6,012,070	-	-	6,012,070
1982	7,448,589	551,939	8,000,528	-	-	8,000,528
1983	2,144,365	266,412	2,410,777	-	-	2,410,777
1984	2,621,248	348,417	2,969,665	-	-	2,969,665
1985	4,519,113	80,396	4,599,509	-	-	4,599,509
1986	7,396,810	201,500	7,598,310	-	-	7,598,310
1987	9,047,188	245,608	9,292,796	-	-	9,292,796
1988	14,430,838	319,489	14,750,327	-	-	14,750,327
1989	5,489,784	230,581	5,720,365	-	-	5,720,365
1990	4,122,400	313,731	4,436,131	-	-	4,436,131
1991	3,237,900	459,200	3,697,100	-	-	3,697,100
1992[e]	1,632,100	10,901	1,643,001	-	-	1,643,001
1993	2,537,000	-	2,537,000	-	-	2,537,000
1994	3,103,128	-	3,103,128	-	-	3,103,128
1995	6,633,000	-	6,633,000	-	-	6,633,000
1996	4,113,000	-	4,113,000	-	-	4,113,000
1997	5,248,250	-	5,248,250	-	-	5,248,250
1998	1,847,350	-	1,847,350	-	-	1,847,350
1999	3,852,601	-	3,852,601	-	-	3,852,601
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

Table 12.1. Commercial Salmon Harvest in Pounds (Page 3 of 3)

Year	Chinook	Coho	Ocean Total [a]	Sacramento	Klamath [b]	Total
2005	4,347,388	-	4,347,388	-	-	4,347,388
2006 [f]	1,029,708	-	1,029,708	-	-	1,029,708

a. Prior to 1952, harvest was not available by species.
b. Also includes other coastal ports.
c. Klamath and other coastal ports closed after 1933.
d. Sacramento ports closed after 1959.
e. Coho were no longer permitted for take after 1992.
f. Preliminary data.
Data Source: DFG Catch Bulletins, DFG Ocean Salmon Project, and commercial landing receipts.

Table 12.2. Recreational Harvest in Numbers of Fish (Page 1 of 2)					
	Chinook		Coho		
Year	CPFV	Skiff	CPFV	Skiff	Total
1962	85,700	33,900	1,900	11,100	132,600
1963	66,200	17,600	6,300	26,300	116,400
1964	77,300	24,600	14,700	24,800	141,400
1965	46,000	14,200	5,700	14,800	80,700
1966	62,700	10,900	7,500	24,900	106,000
1967	60,900	11,700	24,000	26,300	122,900
1968	113,600	40,600	14,000	26,400	194,600
1969	100,000	55,800	11,400	16,800	184,000
1970	93,000	54,800	5,300	9,300	162,400
1971	108,400	79,900	22,400	45,000	255,700
1972	139,800	60,700	11,800	32,700	245,000
1973	119,500	78,500	5,200	26,500	229,700
1974	91,700	65,800	16,200	60,400	234,100
1975	68,300	35,400	5,500	15,800	125,000
1976	50,600	30,400	15,300	42,600	138,900
1977	54,700	49,600	2,400	11,800	118,500
1978	42,000	34,100	3,600	41,000	120,700
1979	71,800	40,600	2,000	14,500	128,900
1980	62,900	22,500	1,700	20,400	107,500
1981	59,600	24,200	1,100	9,500	94,400
1982	91,500	47,200	3,900	22,800	165,400
1983	46,500	17,300	500	26,700	91,000
1984	68,200	19,600	800	18,200	106,800
1985	107,300	63,800	1,400	14,400	186,900
1986	86,500	55,100	2,200	16,500	160,300
1987	121,800	70,700	4,300	43,000	239,800
1988	109,100	62,300	3,500	31,200	206,100
1989	105,000	81,700	6,200	43,400	236,300
1990	78,300	61,600	10,200	41,500	191,600
1991	39,900	40,600	13,500	55,800	149,800
1992	42,400	31,100	1,000	10,500	85,000
1993	66,000	44,000	4,200	25,600	139,800
1994[a]	99,100	84,100	25	500	183,725
1995[a]	182,000	215,200	25	900	398,125
1996	72,908	91,245	closed	635	164,788
1997	122,300	106,600	closed	500	229,400
1998	59,700	62,300	closed	100	122,100
1999	40,500	47,400	closed	600	88,500
2000	91,900	94,000	closed	400	186,300
2001	43,200	55,600	closed	1,243	100,043
2002	85,107	96,937	closed	785	182,829
2003	48,300	46,387	closed	550	95,237

2004	124,656	96,458	closed	1,406	222,520

Table 12.2. Recreational Harvest in Numbers of Fish (Page 2 of 2)					
	Chinook		Coho		
Year	CPFV	Skiff	CPFV	Skiff	Total
2005	61,347	81,910	closed	662	143,919
2006[b]	34,688	54,791	closed	1,417	90,896

a. Recreational fishing for coho was allowed before May 1 during 1994 and 1995. Coho were no longer permitted for take after 1995.
b. Preliminary data.
Data Source: DFG Ocean Salmon Project.

13. WHITE SEABASS

Review of the Fishery

White seabass, *Atractoscion nobilis,* have been taken by California anglers for at least a century. Coastal Indian middens have yielded many white seabass otoliths (ear bones) suggesting this species was highly regarded for food and possibly used for ceremonial purposes.

There was a commercial fishery in the San Francisco area from the late 1800s to the mid-1920s. Before 1982, California commercial fishermen landed thousands of pounds of white seabass taken in Mexico. Often these landings comprised more than 80 percent of the annual catch. Since then, the Mexican government has denied access permits to United States fishermen, and the fishery is concentrated in southern California (Figure 13.1). Although the frequency of white seabass caught north of Point Conception has increased, these landings still represent less than 20 percent of the total California catch. An exception occurred in 2001, when 36 percent of commercial white seabass landings occurred north of Point Conception.

Commercial landings of white seabass have fluctuated widely over the past 90 years of record keeping. Since 1959, when 3.5 million pounds (1,588 metric tons) were landed, the trend has been one of general decline. However, landings since 1999 have exceeded 200,000 pounds (91 metric tons) annually (Figure 13.1), which is a modest increase over the period of 1983-1998.

The minimum legal size for a recreationally caught white seabass is 28-inches (71-centimeters) total length, which corresponds to a weight of about 7-pounds (3-kilograms). The average commercially caught white seabass is nearly 40-inches (102-centimeters) and weighs 20-pounds (9-kilograms).

White seabass has always commanded relatively high prices because of consumer demand. In 2006, commercial fishermen typically received $3.00 per pound for whole fish. At the retail level the fish are sold fresh, primarily as fillets and steaks. Fishing revenue from the 2006 commercial harvest of white seabass was about $796,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State from this 2006 commercial harvest is estimated to be $822,000. Likewise, total employment and wages from white seabass is estimated to be the equivalent of 27 jobs and $706,000 respectively.

During the early years of the fishery, commercial catches were made using gillnets, hook-and-line, and round haul nets such as lamparas and purse seines. Purse seining was curtailed in the late 1920s because decreasing catches made it uneconomical. Since the take of white seabass by round haul nets was prohibited in the early 1940s, gillnets have been the major commercial fishing gear. Set gillnet fishing for white seabass within state waters was prohibited beginning in 1994. Today, drift gillnetting is the primary fishing method used. Some commercial hook-and-line fishing takes place during the early spring in southern California when large white seabass are available.

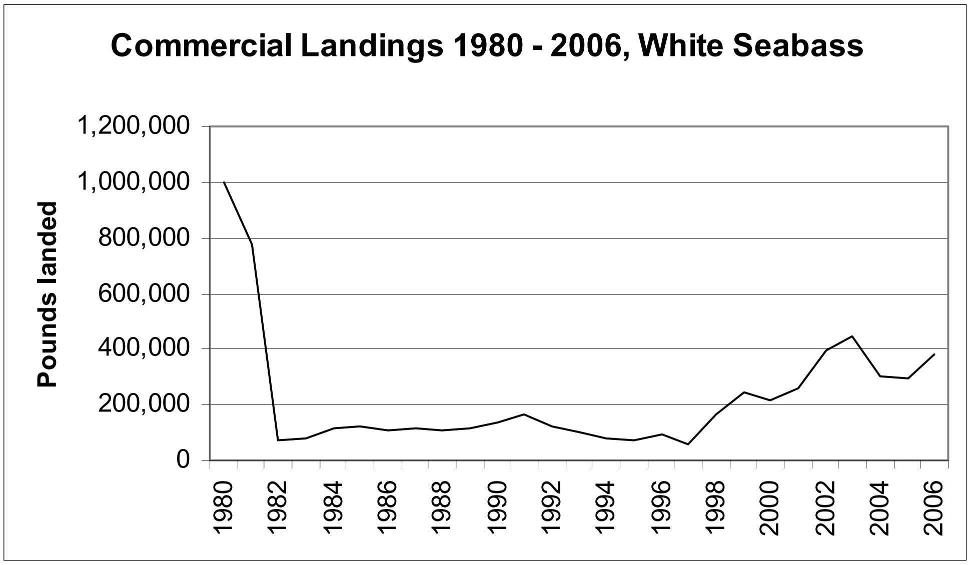

Figure 13.1. California commercial landings (pounds) of white seabass from 1980 through 2006. Prior to 1982 white seabass harvested in Mexico made up the majority of California's landings. Data source: CDFG commercial landing receipts.

Recreational fishing for white seabass began around the turn of the twentieth century. Because of their size and elusive nature, white seabass are popular with anglers. Historical records show anglers on commercial passenger fishing vessels (CPFVs), fishing in California waters, landed an average of 33,400 white seabass annually from 1947 through 1959. The average annual catch steadily declined to 10,400 fish in the 1960s, was 3,400 fish in the 1970s, and 1,200 fish in the 1980s, and then increased to 3,000 fish in the 1990s. From 2000 through 2006 an annual average of 8,200 fish were caught, most likely a result of stronger recruitment of young white seabass in 1997 and 1998 (Figure 13.2). White seabass are also caught by anglers aboard private boats, but accurate estimates of total catch by private boat anglers are difficult to obtain.

While the 28-inch (71-centimeter) minimum size also applies to recreational anglers, most of the white seabass caught prior to the 1990s (kept and released) were between 20- and 24-inches (51- and 61-centimeters). In a survey of private boaters at launch ramp facilities from 1978 through 1982, biologists found only 6 to16 percent of the white seabass kept were of legal size. In a similar survey aboard CPFVs from 1985 through 1987, biologists reported 16 to 25 percent of the seabass caught were legal. However, this has changed dramatically with the apparent increase in the abundance of legal-sized white seabass. During the period from 1995 through 1999, data collected from private boat anglers revealed 77 percent of the white seabass were legal size, while data from CPFV anglers showed 80 percent of the white seabass were legal size. In more recent years, 2000 through

2006, 80 percent of the observed catch from private boat anglers were legal size and 95 percent of the observed catch from CPFV anglers were legal size.

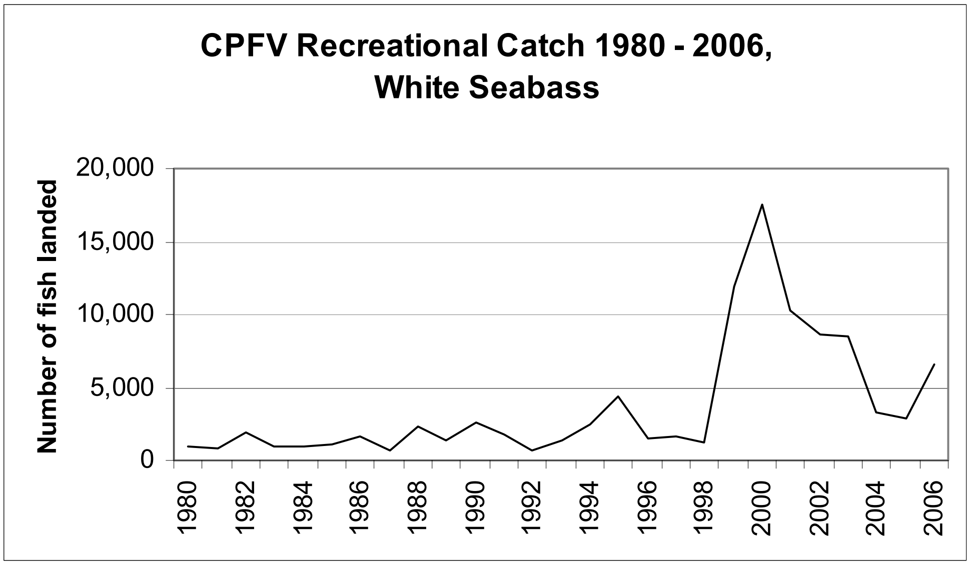

Figure 13.2. The California CPFV recreational catch (numbers of fish) of white seabass from 1980 through 2006. Data source: Commercial Passenger Fishing Vessel (CPFV) log data.

White seabass are captured more often with live bait than with dead bait or lures, but all are effective when the fish are actively feeding. White seabass can sometimes be brought to the surface by heavy chumming with live bait. Anglers fishing around Santa Catalina Island have reported consistently good catches using live market squid, *Loligo opalescens*, and Pacific sardine, *Sardinops sagax,* as bait. Spearfishing for large white seabass by free divers (i.e. without scuba) may be successful in kelp beds.

The California Fish and Game Commission (Commission) established a fishing season of September 1 through August 31 of the following year for both the commercial and recreational fisheries. The Commission also adopted an optimum yield (OY), based on a maximum sustainable yield proxy of the unfished biomass, and is currently set at 1.2 million pounds (544 metric tons). In the 2006/07 season, the total recreational and commercial harvest was 519,600 pounds (235 metric tons), less than half of the allowable catch.

Total catch of white seabass increased from the late 1990s to 2001, peaking in 2001/02 at 1.07 million pounds (485 metric tons) (Table 13.1), just below the 1.2 million pound (544 metric ton) OY. The 2006/07 season marked the third consecutive season of an increase in total catch; the recreational catch increased 58 percent and the commercial catch increased 7 percent compared to the previous season. Estimates of recreational take for the last three and a half fishing seasons are from an improved recreational fishing survey (implemented January 2004) and thus the total estimates from the 2003/04 to 2006/07 seasons may not be directly comparable to estimates from previous seasons due to changes in methodologies in calculating the estimates.

Table 13.1. Total catch (pounds) of white seabass, 1997/98 - 2006/07			
Season	Recreational	Commercial	Total
1997/98	155,909	134,306	290,215
1998/99	410,607	263,439	674,046
1999/00	588,760	218,842	807,602
2000/01	245,835	215,692	461,527
2001/02	663,651	402,537	1,066,188
2002/03	556,684	483,410	1,040,094
2003/04	98,656	304,939	403,595
2004/05	116,734	288,547	405,281
2005/06	65,168	389,873	455,141
2006/07	103,131	416,420	519,551

Source: CDFG commercial landing receipts. The 2004 - 2007 recreational data are from CRFSS, and the previous years of recreational data are from MRFSS.

White seabass regulations have been in effect since 1931, and have included a minimum size limit, closed seasons, bag limits, and fishing gear restrictions. These regulations are still in effect today, with slight variations.

The Commission adopted the White Seabass Fishery Management Plan (WSFMP) in June 2002. To view the plan, please go to this Department of Fish and Game (DFG) web site link: http://www.dfg.ca.gov/marine/wsfmp/index.asp. The WSFMP includes a provision for annual monitoring and assessment of the white seabass commercial and recreational fisheries. The White Seabass Scientific and Constituent Advisory Panel (WSSCAP) was established to assist DFG and the Commission with the review of the fishery assessments, management proposals, and plan amendments. The annual review includes fishery-dependent data (e.g., commercial and recreational landings and length frequencies), and fishery-independent data (e.g., recruitment information), as well as documented changes within the social and economic structure of the recreational and commercial industries that utilize the white seabass resource within California. The review also includes information, when available, on the harvest of white seabass from Mexican waters and other relevant data. Based on the results of the annual review, in cooperation with the WSSCAP, DFG will provide management recommendations, if needed, to the Commission.

Status of Biological Knowledge

The white seabass is the largest member of the croaker family (Sciaenidae) in California. Fish weighing nearly 90-pounds (41-kilograms) with lengths of 5 feet (1.5 meters) have been recorded, but individuals larger than 60- pounds (27-kilograms) are seldom seen. White seabass range from Magdelena Bay, Baja California, Mexico to the San Francisco area. They are also found in the northern Gulf of California. During the strong El Niño of 1957-1959, white seabass were reported as far north as Juneau, Alaska and British Columbia, Canada.

The center of the white seabass population appears to be off central Baja California. Genetic research on white seabass populations shows that some mixing of fish from California and Mexico occurs. However, there may be local subpopulations of fish that do not mix regularly. While the question of population continuity remains unresolved, there is evidence that each summer the fish move northward with warming ocean temperatures (as demonstrated by catches). Biologists believe the movement is probably spawning-related.

Spawning occurs from April to August, with a peak in the late spring to early summer. Fecundity (egg productivity) for this species has not been determined, but a maturity study in the late 1920s reported females begin maturing when 4-years old (nearly 24-inches (61-centimeters) in length), and some males matured at 3-years (nearly 20-inches (51-centimeters) in length). All white seabass have probably spawned at least once by age 6 (nearly 32-inches (81-centimeters) in length).

The eggs, which are the largest of any croaker on the west coast (approximately 0.05-inch (1.3-milimeters) in diameter), are planktonic. The larvae, which are darkly colored, have been collected from Santa Rosa Island, California to Magdelena Bay, Baja California, Mexico. Most are found in the inshore areas of Sebastian Viscaino and San Juanico Bays, Baja California, Mexico, indicating major spawning occurs off central Baja California.

Young-of-the-year white seabass, ranging in length from 0.25- to 2.25-inches (6- to 57-millimeters), inhabit the open coast in waters 12 to 30 feet (4 to 9 meters) deep. They associate with drifting macroalgae in areas of sandy ocean bottom. Sometime between the ages of 1 and 3 years old, some juveniles may move into protected bays where they utilize eelgrass communities for cover and forage. Older juveniles are caught off piers and jetties and around beds of giant kelp. Adult white seabass occupy a wide range of habitats including kelp beds, reefs, offshore banks, and the open ocean. Adult white seabass eat Pacific mackerel, *Scomber japonicus*; Pacific sardines; market squid; pelagic red crabs, *Pleuroncodes planipes*; and Pacific herring, *Clupea pallasii.*

Laboratory spawning of white seabass was first induced in 1982. Beginning in 1983, the CDFG initiated the Ocean Resources Enhancement and Hatchery Program (OREHP) to test the feasibility of raising white seabass for population enhancement. That goal was achieved in the first 10 years of the program and program goals have been expanded to test the feasibility of enhancing marine fish populations through the stocking of cultured fish. By 2006, more than 1,143,000 juvenile white seabass had been released off southern California after spending time in one of 13 growout facilities located throughout the mainland coast and at Santa Catalina Island. Additionally, valuable life history information has been gathered during this program through ecological surveys, tagging, and genetic studies. However, more work is necessary to determine if artificial propagation is successful in enhancing the white seabass population.

Status of the Population

The range of the white seabass population has contracted since the early part of the twentieth century, and few are found regularly north of Point Conception. Limited data are available concerning the status of white seabass in Mexico.

Population estimates have not been made. Fishery biologists have been concerned about the decline in landings since the late 1920s when almost 3 million pounds (1,350 metric tons) were reported landed. Today, this concern still exists within the scientific community, commercial fishing industry, and with the angling public. However, in the last five years ending with 2006, total annual commercial catch averaged approximately twice that of the previous five years.

Human-induced changes, such as pollution, overfishing, and habitat destruction, have probably contributed to this long-term population decline. However, natural environmental changes can also influence the population. The warm ocean water period beginning with the 1982-1983 El Niño helped to increase the survival of young fish. Young fish surveys conducted in southern California, as part of OREHP, showed a dramatic increase in the number of white seabass taken in research gillnet sets during the past decade. During research work in 1997, over 600 juvenile white seabass were captured; in 1998 approximately 700 juvenile fish were taken; in 1999 slightly over 1,300 juveniles were captured, and in 2004, the latest year for which there are complete data, 1,200 juvenile fish were captured. Anecdotal evidence from commercial fishermen and recreational anglers confirms this increase in juvenile white seabass. It is unknown whether this increase in juveniles will subsequently enhance the adult spawning population.

To assist the Commission in determining if management measures need to be modified or added, the WSFMP framework includes points of concern criteria to help determine when management measures are needed to address resource issues. The points of concern are:

1. catch is expected to exceed the current harvest guideline or quota;
2. any adverse or significant change in the biological characteristics of white seabass (age composition, size composition, age at maturity or recruitment) is discovered;
3. an overfishing condition exists or is imminent;

4. any adverse or significant change in the availability of a managed species' forage for dependent species or in the status of a dependent species is discovered;
5. new information on the status of white seabass;
6. an error in data or stock assessment is detected that significantly changes estimates of impacts due to current management.

The 2007 report to the Commission indicated none of the points of concern criteria were met, and thus no management changes for the white seabass fisheries are recommended at this time.

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Updated June 2006
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Further Reading

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14. LEOPARD SHARK

Review of the Fishery

The leopard shark, *Triakis semifasciata*, is targeted by recreational anglers, small-scale commercial fisheries, and marine aquaria collectors in ocean waters adjacent to California. Recreational anglers land the majority of the leopard shark catch, primarily using baited hooks. However, some are taken by divers using spears, and even bow and arrow.

Catch (number of fish) estimates for sport-caught leopard shark from 2004 to present were generated from the California Recreational Fishery Survey (CRFS). Prior to CRFS, catch and effort estimates for California were based on data from the Marine Recreational Fishery Statistics Survey (MRFSS). MRFSS data is available from 1980 through 2003, except for the years 1990 through 1992 when sampling was suspended due to lack of funding.

Although the catch estimates from the two surveys are not directly comparable, they do indicate that catches of sport-caught leopard shark have been relatively stable following the implementation of a three fish bag limit and 36-inch (0.9-meters) total length (TL) minimum size limit in 1992. Prior to 1992, the MRFSS data indicate the average annual catch was 450,000 pounds (204 metric tons) compared to 148,000 pounds (67 metric tons) after the 1992 regulations were implemented. From 2004 to 2006, the CRFS catch estimates indicate an average of 130,000 pounds (59 metric tons) was taken annually (Figure 14.1).

According to historical survey data, private boaters land the majority (55 percent) of leopard shark in the recreational fishery, followed by shore-based anglers (Man Made and Beach/Bank) (44 percent), and Commercial Passenger Fishing Vessels (CPFV) (1 percent). A tag and recapture study conducted on the central California coast during the 1980s also showed similar catch proportions by the different fishing modes. Survey statistics also indicate anglers fishing from San Francisco to Eureka catch the majority of leopard sharks in bays; whereas anglers fishing south of San Francisco catch leopard sharks primarily in nearshore coastal waters. Recent catch estimates indicate roughly half of the annual sport catch comes from within San Francisco Bay.

Beginning in 2005, recreational groundfish closures and depth restrictions were applied to all federally managed groundfish species in order to allow overfished stocks to rebuild. However, exceptions were incorporated into the regulations allowing the take of leopard shark during the groundfish closures within specified enclosed bays, including San Francisco Bay.

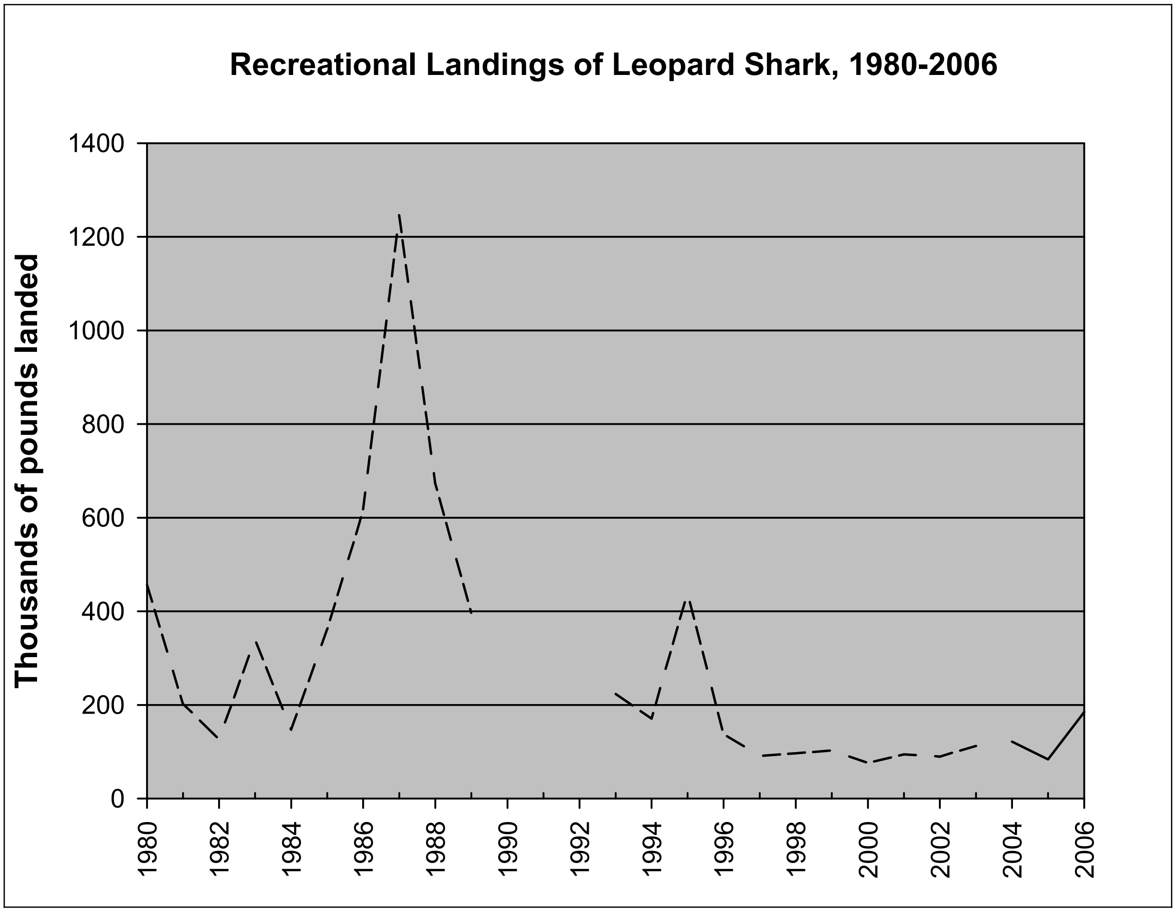

Figure 14.1. Catch estimates (thousands of pounds) for leopard shark from 1980-2006. Estimates derived from the MRFSS are a dashed line, and estimates derived from the CRFS are a solid line.

Documentation of commercial leopard shark landings began in 1977, and since that time California landings have ranged from a high of 103,000 pounds (47 metric tons) in 1983 to a low of 14,000 pounds (6 metric tons) in 1996 (Figure 14.2). These catch statistics indicate that commercial take is minor compared to the recreational fishery. However, it is important to note that leopard shark landings are subject to reporting bias since an unknown number are lumped with other shark species in the “shark unspecified” market category on commercial landing receipts.

Over the past 15 years, annual landings have averaged 26,000 pounds (12 metric tons). Most of the reported commercial leopard shark catch occurs incidentally in gillnet and trawl fisheries. However, a small hook-and-line fishery targets this species in San Francisco Bay. In 1994, the implementation of a minimum commercial size limit of 36-inches (0.9-meters) TL and the exclusion of gillnet gear in State waters south of Point Arguello resulted in a dramatic drop in landings. Landings have remained relatively stable since then (Figure 14.2). In 2002, the use of gillnet gear was also prohibited along the central California coast in 360 feet (110 meters) or less from Point Reyes to Point Arguello, which appears to have further stabilized gillnet landings. Gillnets have been prohibited north of Point Reyes since 1987.

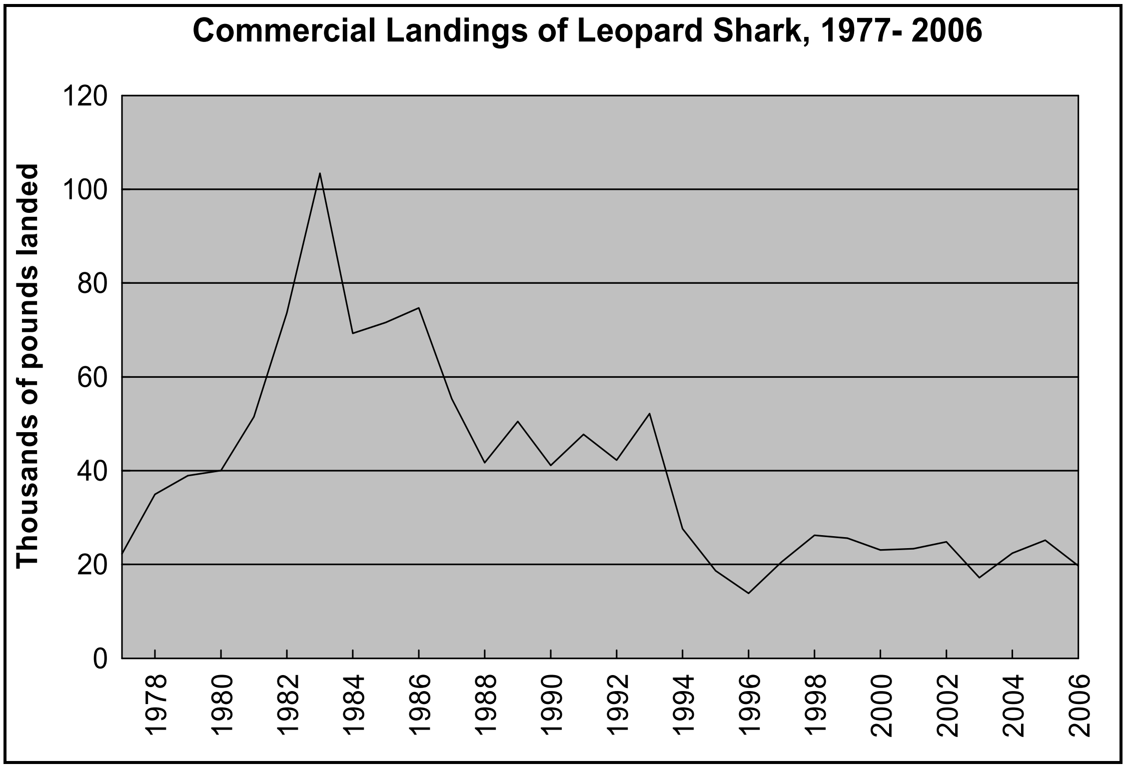

Figure 14.2. Commercial landings of leopard shark from 1977–2006. Data source: CDFG commercial landing receipt data.

Fishing revenue from the 2006 commercial harvest of leopard shark was about $20,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $39,000. Likewise, total employment and wages from leopard shark is estimated to be the equivalent of 1 job and $18,000 respectively.

Leopard shark pups have also been targeted by marine aquaria collectors due to their desirability as aquarium fish. Collecting pups for marine aquaria display became illegal in 1994 when the 36-inch (0.9-meters) TL commercial size limit went into effect. However, a black market for pups continues today.

In 2006, a three-year investigation involving the CDFG, NOAA Fisheries Service, and U.S. Fish and Wildlife Service, as well as investigators in the United Kingdom, Netherlands, and others resulted in the arrest and prosecution of several individuals charged with violating the Lacey Act. The Lacey Act is the Federal law which prohibits the possession, take, purchase, or sale of any wildlife taken in violation of any state or federal regulation. Investigators estimated that from 1992 to 2004, 20,000 to 25,000 leopard shark pups were poached from San Francisco Bay, and 30,000 to 33,000 pups were poached from coastal waters off Los Angeles, Ventura, and Santa Barbara counties from 1992 to 2003. These estimates are significant when compared to recreational and commercial leopard shark landings. However, the recent convictions appear to have curtailed most of the illegal take of leopard shark pups at this time.

Status of Biological Knowledge

Leopard sharks are endemic to the Eastern North Pacific Ocean, ranging from Willipa Bay, Washington, to Mazatlan, Mexico, including the Gulf of California. This species is common in California waters, primarily in shallow water areas less then 60 feet (18 meters), although it has been found as deep as 273 feet (83 meters). These sharks are seasonally abundant in central and northern California bays and estuaries, but leave for the open coast in the winter months. South of central California, leopard sharks occur year-round along the open coast, particularly among kelp forests, rocky reefs, and sandy beach areas.

Nomadic, active swimmers, leopard sharks often form schools that are segregated by size and sex. Large groups may suddenly appear in an area and then quickly move on. They are also known to form aggregations with other elasmobranch species, such as bat rays, *Myliobatus californiaca*; smoothhound sharks, *Mustelis spp*.; and sevengill sharks, *Notorynchus cepedianus*. Studies in central and northern California bays and estuaries have shown that leopard shark movements are tidally influenced. They move into shallow mudflat areas to forage during high tides, and retreat to deeper water as the tide goes out. Studies also indicate that the seasonal abundance and movements of leopard sharks in bays and estuaries are likely influenced by prey availability as well as changes in salinity, temperature, and dissolved oxygen. Results from tag-recapture studies have demonstrated that the leopard sharks in San Francisco Bay are largely residential, although about 10 percent of the recaptured sharks made seasonal migrations out of the bay to the open ocean in fall and winter months.

Despite many tagging studies, little is known about the large-scale movements and population structure of leopard sharks. Tag-recapture studies have shown that this species can cover large distances. Leopard sharks tagged in Elkhorn Slough have been recaptured in San Francisco Bay, and vice versa. One shark tagged in San Francisco Bay was recaptured in Santa Monica Bay 10 years later. A leopard shark caught and tagged at Santa Catalina Island was recaptured in Carlsbad, indicating these sharks may be making offshore-onshore movements in southern California. However, recent genetic research on the structure of leopard shark populations indicates limited exchange occurs between regional stocks in California.

Leopard sharks are viviparous (live-bearing), with females giving birth to 7 to 36 young during the annual reproductive cycle. Gestation is estimated at 10 to

12 months, with pupping occurring March through July, peaking in April and May. Size at birth ranges from 7- to 8-inches (18- to 20-centimeters). Males mature at 27- to 47- inches (0.7- to 1.2-meters) (7 to 13 years) and females mature at 43- to 51-inches (0.7- to 1.3-meters) (10 to 15 years). Males live to at least 24 years of age, while females live to at least 20 years. The average annual growth rate for males is 0.75-inches (1.9-centimeters), and they reach a maximum length of 59-inches (1.5-meters). Females grow about 1-inch (2.5-centimeters) annually and reach a maximum length of at least 71-inches (1.8-meters). However, there is one record of a female measuring 83-inches (2.1-meters).

Little is known about the mating behavior of leopard sharks. In fact, there has been only one documented observation of mating activity in the wild, which took place off La Jolla, California, in August of 2003. Mating behavior was observed in a small aggregation of nine sharks, about 65 feet (19 meters) from shore in 3 to10 feet (0.3 to 3 meters) of water. This observation supports the assumption that leopard shark mating takes place after spring parturition (giving birth), in the summer months.

Leopard sharks are opportunistic feeders, feeding on a wide variety of primarily benthic prey. Their diet is known to vary by location, season and shark size. Large adults are mostly piscivorous (fish eaters); eating anchovies, herring, sculpins, croakers, surfperch, rockfish, flatfish, and small elasmobranches; while smaller adults and juveniles consume greater proportions of crustaceans, clam siphons; innkeeper worms, *Urechis caupo*, and fish eggs. Leopard sharks are preyed upon by other shark species such as sevengill sharks and white sharks, *Carcharodon carcharias*.

Leopard Shark, *Triakis semifasciata.* Photo credit: CDFG

Status of the Population

Leopard sharks are one of three shark species under the management authority of NOAA Fisheries through the Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP). At this time, leopard shark stocks have not been assessed, and fall into the “Other Fish” management complex, which includes all Groundfish FMP species that are not rockfish or flatfish and have not had a stock assessment. A combined annual harvest guideline was established in 1983 for the “Other Fish” complex, which includes sharks, rays, ratfish, morids, grenadiers, and other groundfish species. Currently, the harvest guideline (optimum yield) for the “Other Fish” complex is set at 8,000 tons (7,264 metric tons) for West Coast fisheries.

Although the size of the California leopard shark population has not been estimated, recreational and commercial fishery catch statistics indicate that current management practices have been effective in protecting the resource. The curtailment of gillnet operations in nearshore waters, and the implementation of a recreational size and bag limit for leopard shark in the 1990s reduced and stabilized fishing mortality for this species.

Management Considerations

Current management measures appear to be effective in preventing over-harvest, and should remain in place. Nevertheless, increased outreach is needed to improve compliance with commercial landing receipt requirements for the marine aquaria trade and to eliminate illegal poaching of pups and the killing of gravid females to obtain live pups. Leopard sharks have a restricted geographic range, and genetic research suggests there is a limited exchange among regional populations. This species may therefore be vulnerable to overexploitation and habitat disturbance in areas with high human populations. Additionally, this species is slow growing, with a late maturity age, and long gestation period, suggesting it is vulnerable to overfishing. Future management should also take into account the potential impacts of poaching and other undocumented take, as well as the overall vulnerability of this species in shallow, nearshore habitats, especially areas thought to be important nursery grounds.

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Revised May 2007
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15. SHORTFIN MAKO SHARK

Shortfin Mako Shark, *Isurus oxyrhinchus*
Credit: DFG

Overview of the Fishery

The "peregrine falcon" of sharks, the shortfin mako, *Isurus oxyrinchus*, may be the fastest swimming of all sharks. Sometimes referred to as "bonito shark", it is a spectacular fighter when hooked and much sought-after by sportsmen worldwide. Immortalized by the writings of Earnest Hemingway and Zane Grey, mako shark have posed an angling challenge to dedicated big game fishermen since the early 1900s. A close relative, the longfin mako shark (*Isurus paucus*), does not occur off California.

In California, the commercial exploitation of the mako shark did not begin until the 1970s. Rapidly expanding consumer demand for shark meat as a nutritious and tasty alternative to red meat and other seafoods fueled the expansion of a shark fishery. During the late 1970s a drift gillnet fishery targeting swordfish, *Xiphias gladius*, and common thresher shark, *Alopias vulpinus*, developed off southern California. Mako shark were a bycatch of that fishery. An experimental directed fishery for mako shark using drift longline gear was authorized by the Fish and Game Commission (Commission) in 1988. This gear proved very efficient at catching mako shark. The Commission chose not to renew this controversial experimental fishery in 1992.

A shortfin mako shark taken on hook-and-line fishing gear.
Credit: CDFG

Today, mako sharks are commercially harvested by drift gillnet, hook-and-line and harpoon fishing gears. Most of the mako shark harvest is taken incidentally by the drift gillnet fishery targeting thresher sharks and swordfish. Annual landings have fluctuated from a high of 612,000 pounds (278 metric tons) in 1987 to 69,000 pounds (31 metric tons) in 2006 (Figure 15.1). A general decline in landings has occurred since the late 1990s.

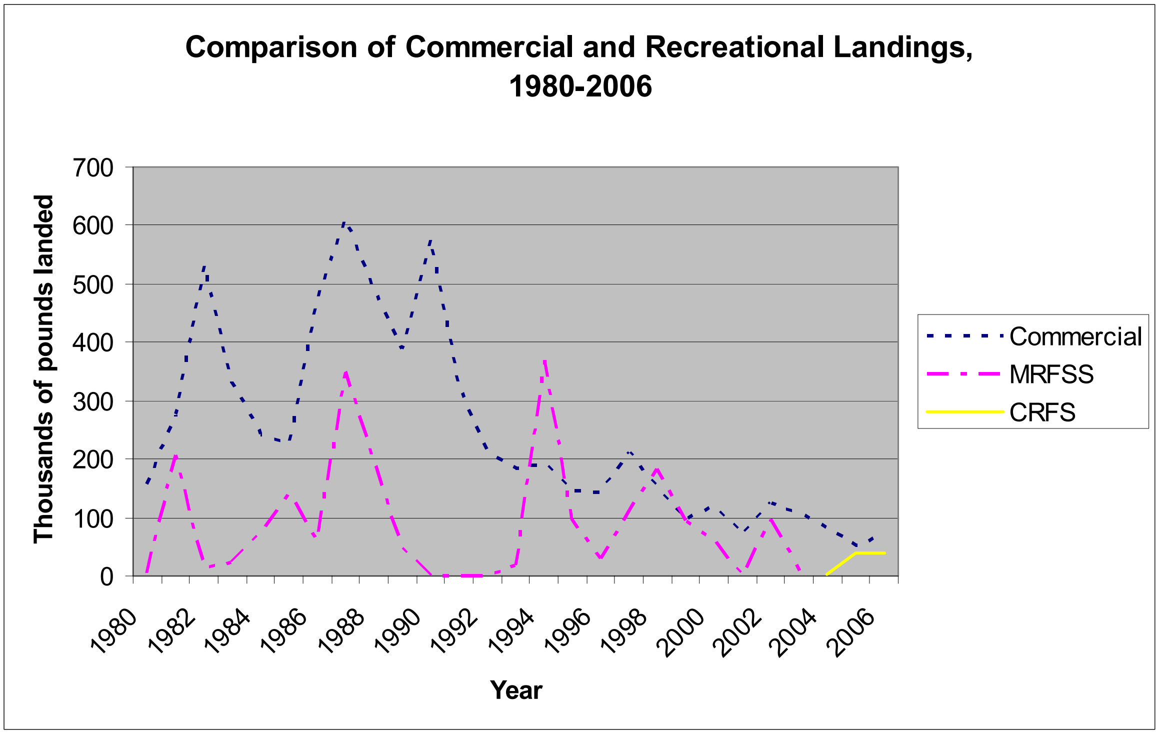

Figure 15.1. Landed weights of shortfin mako shark for commercial and recreational harvest from 1980-2006. Data source: CDFG commercial landing receipt data, recreational estimates derived from the MRFSS 1980-2003, and from the CRFS 2004-2006.

Fishing revenue from the 2006 commercial harvest of shortfin mako shark was about $79,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $151,000. Likewise, total employment and wages from shortfin mako shark is estimated to be the equivalent of 3 jobs and $70,000, respectively.

California recreational fishermen began targeting mako shark in the 1980s. Statistically estimated catch weights of sport caught mako shark shows a trend very close to that of commercial landings (Figure 15.1). Peak periods occurred in 1987 with 348,000 pounds (158 metric tons) landed and in 1994 with 370,000 pounds (168 metric tons) landed. Statewide sport catch estimates from the Marine Recreational Fisheries Statistics Survey (MRFSS) show annual catch numbers reached a high in 1987, with almost 22,000 mako taken (Figure 15.2). Another peak was observed in the mid-1990s. Since then the catch numbers have fluctuated a great deal. Estimates from the California Recreational Fisheries Survey (CRFS) were 6,000 sharks taken in 2006, down from the 15,000 taken in 2005. Annual catch numbers from commercial passenger fishing vessel (CPFV) logs describe a similar, though smaller trend (Figure 15.2). Presently, CPFVs schedule shark trips at most southern California ports. Shark fishing tournaments that target mako shark are prestigious events that draw as much attention as marlin fishing tournaments. There is currently no minimum size limit for mako shark.

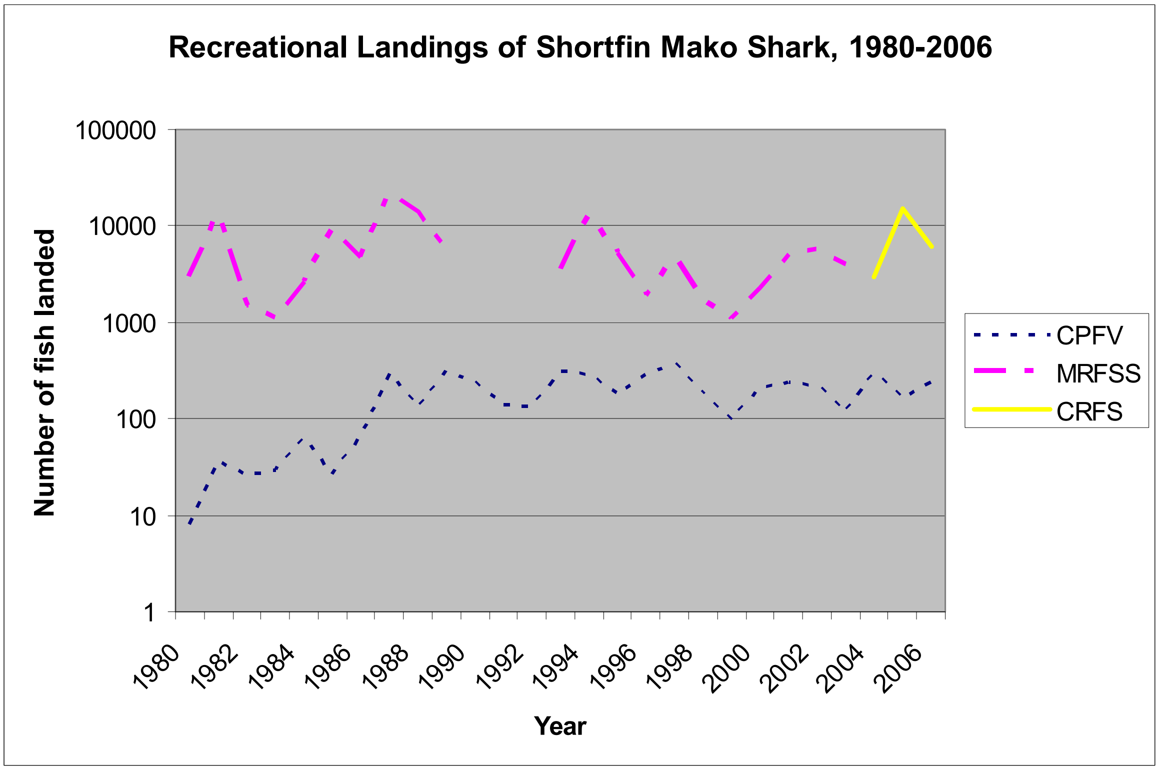

Figure 15.2. Recreational catch (numbers of fish) for shortfin mako shark from 1980-2006. CPFV log totals are a dotted line, estimates derived from the MRFSS are a dashed line, and estimates derived from the CRFS are a solid line.

Status of the Biological Knowledge

The mako shark is a member of the Lamnidae family: a small group of large, fast-swimming sharks that includes the white shark, *Carcharodon carcharias*. These sharks have common adaptations for high-speed swimming: a conical snout, very large gills for efficient gas exchange, streamlined body and lunate tail shape. Mako shark possess an advanced endothermic circulatory system that keeps their swimming muscles warmer than the surrounding water. Reliably measured at swimming speeds over 35 mph, the mako shark is probably the fastest shark.

These adaptations for speed allow the mako shark to feed on other fast moving species such as tunas, swordfish, porpoise and other sharks. Fishery research off California suggests mako shark feed primarily during the day. They are opportunistic feeders and will eat whatever is abundant in their surroundings.

Mako shark are found around the world in warm and temperate seas, in the Pacific Ocean from the Columbia River mouth to Chile. Juvenile mako shark are common from the U.S.-Mexico border northward to Washington. Research suggests a nursery area exists off southern California, particularly south of Los Angeles to the U.S. border. Juvenile fish off southern California appear to be resident for two years after birth. Afterwards, they may move offshore or further south. Juveniles tagged off southern California have been recaptured as far north as Point Arena near Fort Bragg, and as far south as Acapulco, Mexico and westward to Hawaii.

They can grow to a length of almost 13-feet (4-meters) and a weight of 1,250-pounds (567-kilograms). Males mature at about 6.5-feet (2-meters) (7 to 9 years), while females mature at about 8.5-feet (2.6-meters) (19 to 21 years). Development of young embryos is ovoviviparous, producing eggs that are hatched within the body. Developed pups are known to prey upon less-well developed siblings in the mother's uterus. Litters are large, usually 8 to 10 pups; the pups are probably born at 27- to 28-inches (69- to 71-centimeters) in length. Growth is very rapid initially, increasing by about 15-inches (38-centimeters) the first year. Males and females grow at similar rates until about age 7 years, after which the relative growth of males declines compared to females. They are estimated to live to a maximum 29 years of age.

Fish and Game biologist holding a shortfin mako shark pup during a tagging research study.
Credit: DFG

Status of the Population

The population of shortfin mako shark off California is not being over- fished. Present fishery harvest levels are well below harvest guidelines imposed by NOAA Fisheries. There is some concern that fishing pressure may negatively affect sharks that have aggregated in pupping areas off southern California and northern Mexico. However, further investigation is needed to clarify this issue.

Management Considerations

A Highly Migratory Species Fishery Management Plan (HMS FMP) developed by the Pacific Fishery Management Council was adopted by the U.S. NOAA Fisheries in March of 2004. The plan provides a management framework for 13 species of tunas and sharks, including the shortfin mako, harvested within the 200-mile U.S. Exclusive Economic Zone (EEZ) and adjacent high seas waters off the contiguous West Coast states.

Adoption of the HMS FMP provides for implementation of new management and conservation tools, consolidation of existing state and federal regulations, and international agreements for HMS. The new conservation and management tools include harvest control rules for shortfin mako shark. Since basic population dynamic parameters for mako shark are unknown, it is being managed with a precautionary harvest guideline of 330,700 pounds (150 metric tons).

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Further Reading

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