STATUS OF THE FISHERIES REPORT AN UPDATE THROUGH 2008

Photo credit: Edgar Roberts.

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

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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, along with the Updates for 2003 and 2006, is available on the Department's website.

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

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

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Introduction

The Marine Life Management Act (MLMA) changed the way the California Department of Fish and 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 expected to use the best available science to guide management efforts.

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

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

The comprehensive 2001 document provides baseline information and references on all of California's economically and ecologically important marine species. In 2004, an *Annual Status of the Fisheries Report Through 2003* was completed by the Department and updated information was provided on 14 species or species groups. In 2008, the *Status of the Fisheries Report-An Update Through 2006* was completed providing updated information on 15 species. This report continues the series, with 23 sections, focusing on new species of interest (Kellet's whelk, hagfish), species with new information (eulachon, giant sea bass), and species with changes to management (thresher shark, sturgeons, groundfish). This continuing series of reports allows those who are interested in or participants in California's marine management, to have a common and updated source of information about important marine resources. All of the mentioned reports can be found on the Department's website at http://www.dfg.ca.gov/marine/status/index.asp.

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

- ***Commercial Fisheries Information System (CFIS)*** – Every time a commercial fisher lands his catch, a landing receipt is filled out documenting the market category, poundage, gear, price paid to the fisher, and other relevant information (FGC §8043). Market categories may be identified as individual (Pacific bonito, sablefish) or groups of species (unidentified skate, group deep nearshore rockfish). Landing receipts have been collected since 1916 to the present.
- ***Marine Recreational Fisheries Statistics Survey (MRFSS)*** – This national survey provided estimates of the fish caught recreationally in California through interviews with anglers and onboard observations. Species may be identified as individual (Pacific bonito, lingcod) or groups of species (skate and ray order, rockfish genus). This program began in 1980, with a brief hiatus from 1990 through 1992, and was terminated in California on December 31, 2003.

- ***California Recreational Fisheries Survey (CRFS)*** – This statewide survey was begun on January 1, 2004. The CRFS uses interviews with anglers and onboard observations to collect data on California's marine recreational fisheries, and estimates the catch and effort of angler fishing for marine finfish. Species may be identified as individual (Pacific bonito, lingcod) or groups of species (skate and ray order, sturgeon genus). Due to differences in sampling methodology MRFSS and CRFS are not directly comparable.
- ***Commercial Passenger Fishing Vessel (CPFV) logbooks*** – Every CPFV captain is required to submit a log for each fishing trip which documents the number of anglers aboard and the species and numbers and type of fish caught and released (FGC §7923; Title 14, CCR, §190). Species may be identified as individual (Pacific bonito, cabezon) or groups of species (unspecified rockfish, unspecified sturgeon). This program began in 1936, with a brief hiatus from 1941 through 1946, and continues today.

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

1 Coonstripe Shrimp, *Pandalus danae*

A coonstripe shrimp, *Pandalus danae,* caught near Crescent City, California. Photo credit: J. Bieraugel.

History of the Fishery

The California commercial fishery for the coonstripe shrimp, *Pandalus danae*, is a relatively new fishery. The first landing record for this species was in 1995; however, they were likely landed in small amounts prior to 1995 and recorded only in a general shrimp market category. Commercial coonstripe shrimp regulations adopted by the California Fish and Game Commission in 2002 (Title 14, CCR, §180.15) were devised cooperatively by the California Department of Fish and Game (Department) and fishers. Prior to 2002, the fishery was essentially unregulated. Current regulations cover general trap and vessel permit requirements, prohibit trawling, specify a closed season from November 1 through April 30, and provide a control date for a possible limited entry fishery. Logbooks are not required.

California has the largest directed coonstripe shrimp trap fishery on the west coast of North America. Most of the fishing activity takes place within a few miles of Crescent City Harbor. A formerly active trap fishery in southern Oregon has dwindled, culminating in landings of less than 10 pounds per season (4.5 kilograms per season) for the past three years. In the San Juan Islands of Washington state, there is small trap and trawl fishery for coonstripe shrimp. In southern British Columbia, there is short season trap fishery, a small directed trawl fishery and some coonstripe shrimp are caught incidentally in pink and sidestripe shrimp trawls. Total trap and trawl landings in both Washington and British Columbia are similar in size to California's trap fishery. In Alaska, coonstripe shrimp are not targeted, but are landed incidental to other fisheries.

The California commercial fishery for coonstripe shrimp had its first significant landings in 1996 and remained relatively stable from 1997 through 2002, averaging 78,200 pounds (36 metric tons) per year. After declining to a low of 22,200 pounds (10 metric tons) in 2007, the 2008 season yielded 85,200 pounds (39 metric tons), the second largest annual landings. Average landings for the fishery, since 1996, are almost 62,800 pounds (28 metric tons) (Figure 1-1).

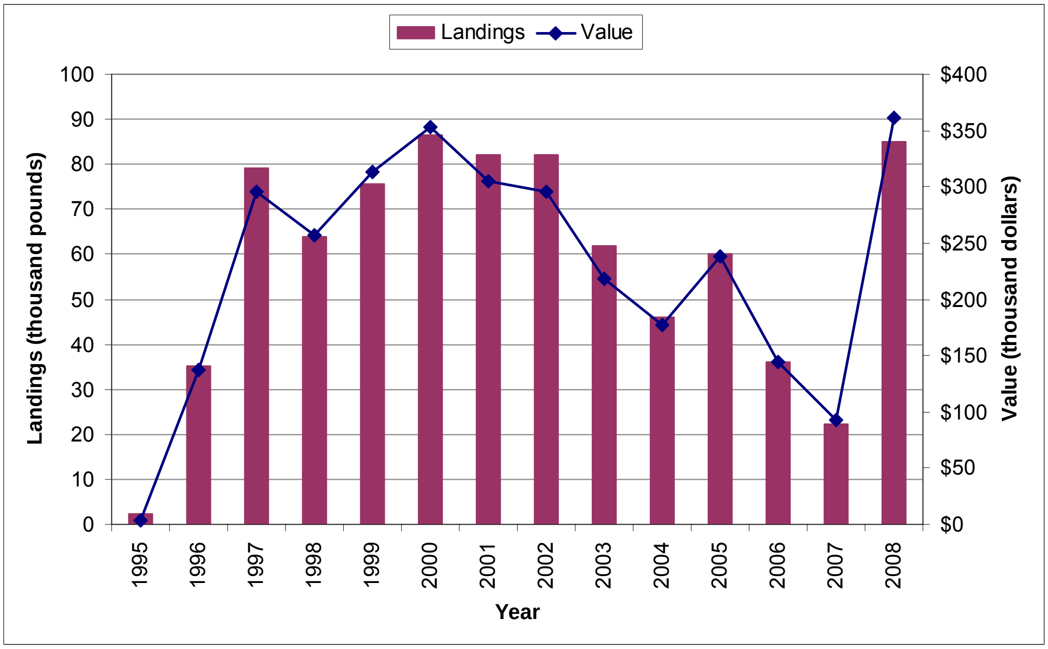

Figure 1-1. Coonstripe shrimp commercial landings and value, 1995-2008. Data source: CFIS data, all gear types combined.

Although catch-per-unit-effort is reportedly low, a high price per pound keeps diligent fishers interested. Fishers often soak gear for several days and can store several trips worth of Coonstripe shrimp alive before selling to the fish buyer. Count per pound ranges from 23 to 40 shrimp, but buyers prefer lower counts of larger shrimp. The live product is shipped to markets in the San Francisco and Los Angeles areas where consumers pay $5.99 to $6.99 per pound ($13.20 to $15.40 per kilogram), depending on quality. Since 1996, the average price paid to fishers has ranged from $3.52 to $4.25 per pound ($7.77 to $9.36 per kilogram). Paid the latter in 2008, total ex-vessel value was $361,800 (Figure 1-1). Average annual ex-vessel value from 1996 to 2008 was $245,400.

As an open access fishery, the size and composition of the fleet varies each year. Since 1995, there has been between 1 and 20 vessels making landings – mostly directed and some incidental. Only a few fishers consistently make substantial landings, others come and go. Seven vessels made landings in 2008, with four vessels catching the majority of the shrimp. All seven are also commercial Dungeness crab vessels. The coonstripe shrimp season, May 1 through October 31, complements the Dungeness crab season, December 1 through July 15. Since the enactment of the coonstripe shrimp vessel trap permit requirement in 2002, there are typically three times the number of permits sold as are used each year.

In the Crescent City area, fishers set traps on the muddy bottom near rocky reefs. The latest trap style is a tapered, circular design from Canada (Figure 1-2). Each trap weighs less than10 pounds (4.5 kilograms) and is constructed of mesh over a stainless steel frame. The traps are typically 39 inches (1 meter) diameter, 16 inches (41 centimeters) tall and have entry funnels 3 inches (8 centimeters) in diameter. Traps are fished in sets of 10 to 15 connected together on a long line string. Each end of the set is held down by a weight and marked with a buoy on the surface. Fresh fish, usually sardines, mackerel, herring or albacore, is used as bait. Some fishers position their traps at a rather specific depth, about 25 fathoms (46 meters), while others vary the depth and prospect as shallow as 12 fathoms (22 meters). The predominant fishers have about 500 traps, and may fish fewer. Gear is rarely lost, but does wear out.

Figure 1-2. A Crescent City commercial fisher empties a typical coonstripe shrimp trap onto a sorting table. Photo credit: J. Bieraugel.

Habitat damage and bycatch from this fishery is considered minimal. Since traps are set on muddy bottoms, they generally do not disturb coral, sponges and other fragile species often growing on rocks. Small shrimp and bycatch can escape the trap through the mesh, typically 0.5 inch square openings. Once onboard, the catch is carefully sorted and discards are thrown over, live if possible. Onboard fisheries observers have reported bycatch including hermit crabs; snails; juvenile Dungeness and rock crabs; decorator, umbrella and butterfly crabs; sunflower stars; hagfish; juvenile lingcod, cabezon and rockfish; sculpin; octopus; and other small shrimp.

Interest in recreational fishing also rose in the 1990s, presumably because the growing commercial fishery showed that the shrimp could be fished close to shore with lightweight traps. The recreational limit was increased from the general invertebrate species limit of 35 shrimp per day to 20 pounds (9 kilograms) per day in 1998 (Title 14, CCR, §29.88). There is no closed season or size limit for the recreational fishery. Effort and catch are believed to be minimal, although fishery surveys have not been conducted. This species is not targeted by commercial passenger fishing vessels.

Status of the Biological Knowledge

Coonstripe shrimp are crustaceans in the order Decopoda containing lobsters, crayfish, crabs and other shrimp. These caridean shrimp are members of the Pandalidae family, a family of cold water shrimp containing 24 genera and 162 species. Pandalid shrimp are medium to large size, have a laterally compressed body, a blade-like rostrum (spine-like extension of the anterior median carapace), well developed antennal scales and a muscular abdomen. The muscular abdomen, used for swimming propulsion, has little room for organs—making it desirable as food. Antennal scales act as rudders and brakes and make possible elaborate escape maneuvers. Pereopods, the longest limbs, are relatively small and more suited to perching than walking. Pincers (claws called chelae), usually on the first two pereopods, are small or lacking in pandalids. The coonstripe shrimp has unevenly sized chelipeds (pereopods with chelae), favoring one side for feeding and other for grooming. They are known to spend a considerable amount of time keeping body surfaces and chemoreceptors clean. Their limbs are equipped with tiny brush and comb-like groups of setae especially for this purpose. The rostrum terminates in three points and has 7 to 16 dorsal spines and 5 to 10 ventral teeth. Body color is generally a milky-translucent background with prominent red to brown stripes and dots, sometimes with white markings and blue dots. There are broken, diagonal stripes on the abdomen and strong banding on the legs and antennae. The name coonstripe is sometimes attributed to other pandalid shrimp species which also bear striped markings.

Coonstripe shrimp is also referred to as dock shrimp for its habit of sometimes living around pilings. Normally, juveniles live in shallower water while adults live in the sublittoral zone at depths up to 606 feet (185 meters). This epibenthic shrimp inhabits a variety of bottom substrates, from mud to gravel, usually in areas with strong currents and shelter to hide in by day. Wide ranging, they are found from Sitka, Alaska to at least Point Loma, California (San Diego County). The southern end of their range has been incorrectly stated as far north as San Francisco, but with confirmation that *Pandalus gurneyi* is a synonym of *P. danae*, it is likely that the coonstripe shrimp range extends into Baja California, Mexico. Sporadically caught in many fisheries and surveys, they have only been found in densities high enough to support a fishery in a few select locations. Prey items include polychete worms and small invertebrates such as copepods and amphipods. Predators are likely octopus, crabs and various groundfish. Biological information on coonstripe shrimp is somewhat limited.

Coonstripe shrimp were the first of the pandalid shrimp to be described as protandrous hermaphrodites, beginning as males and transforming into females during the course of their lives. Most of the shrimp hatch as males in the spring, usually April, and spend about 3 months nearby as larvae. Larvae are complete with two pairs of antennae, mandibles, eyes and thoracic appendages used for swimming. Once the juvenile form is attained, usually by June, they undergo rapid molting and growth. Four months later, usually October, they are sexually mature and begin breeding. In their second year of breeding most are still males. Subsequently, the shrimp begin transforming into females. In their third year, they breed as females and probably do not survive another year. A small percentage of coonstripe shrimp are primary females, hatching and living their entire lives as females, thus adding resiliency to the species. This anomaly is assumed to increase in response to environmental pressures, such as fishing selectively for large females, which may unbalance the sex ratio. However, laboratory experiments indicate that for coonstripe shrimp, genetics is a stronger influence on sex determination. Sex change triggers are still poorly understood.

Coonstripe shrimp are unusual shrimp in that ovigerous (egg bearing) females can be found throughout the year (Figure 1-3). In studies from southern British Columbia, egg bearing females were mainly encountered from November to April. Recent anecdotal information from the California fishery indicates egg bearing females are encountered throughout the fishing season, especially near the beginning. Dockside sampling conducted by the Department in 1997, prior to the seasonal closure regulation, found the number of ovigerous females caught in the Crescent City fishery declined from 100 percent at the end of March to less than five percent at the end of June. During May 1997, corresponding to the first month of the current season, at least 50 percent of females caught were ovigerous. Larval recruitment in the closely related pink shrimp, *Pandalus jordani*, has been linked to ocean conditions and the strength and timing of the spring transition. Each year, along the Pacific Coast of North American between San Francisco, California (38° North Latitude) and the Queen Charlotte Islands, British Columbia, Canada (52° North Latitude), the coastal winds switch from the southerly winds of winter to the northerly winds of summer producing the spring transition. Some years, the impact of taking egg bearing females in late spring can have a large effect on recruitment because those may be the very eggs with the best chance of survival. Further investigation is necessary to understand how this concept relates to coonstripe shrimp recruitment.

Figure 1-3. A female coonstripe shrimp bearing eggs (green) along the underside of her abdomen. Photo credit: Scott Groth, ODFW.

The habit of continual breeding also complicates determining size at age for coonstripe shrimp. Research, again from British Columbia, found that males maturing in October of their first year averaged about 2.5 inches (6-7 cm) total length (TL), averaged 3.4 inches TL (8.5 centimeters) the following October and after becoming female by the third October, averaged 3.9 inches TL (10 centimeters). Large specimens can reach 5.5 inches TL (14 centimeters).

Coonstripe shrimp find their mates using a strategy called pure searching. Males do not guard the female or a territory. This avoidance of conflict allows them to be smaller without the necessary fighting chelipeds. The two sexes have chance encounters and may not even acknowledge each other until after the female molts and is therefore ready to mate. This strategy is found in populations of mobile species occurring in sufficient density that meetings are frequent. Mating is brief and females have the option to physically reject copulation and the depositing of the spermatophores. Soon after successful mating, the female extrudes, fertilizes and attaches the eggs to her swimming appendages where they are carried until hatching. Incubation of the eggs by the female produces lower fecundity but also lowers mortality before hatching. Cold water shrimp carry only a few hundred to a few thousand eggs each year and coonstripe shrimp averages 1140 eggs per year. This is a relatively small amount compared to warm water shrimp who release tens of thousands of eggs annually. Like most cold water shrimp, the life history of coonstripe shrimp makes them unsuitable for aquaculture and susceptible to overfishing, especially in combination with habitat damage or climate change. There is currently no aquaculture of this species.

Status of the Population

Based on the short history of the fishery, the effort, landings and value appear relatively stable. However, to date there have been no estimates of abundance or other population parameters, such as recruitment and mortality rates, with which to assess the stock for sustainability. The relatively limited distribution of the fishable stock of coonstripe shrimp would seem to increase its vulnerability to overfishing.

Management Considerations

Although there are currently few active participants, coonstripe shrimp is an open access commercial fishery with no trap limits, and each year about three times as many permits are sold as vessels make landings. There is little to no interest within the industry in pursuing a permit or trap restriction program at this time. However, a control date of November 1, 2001 has been set in case a restricted access program is considered in the future (Title 14, CCR, §180.15); trap limits should be considered simultaneously. Gear cost and low catch-per-unit-effort will likely keep both the commercial and recreational fisheries from expanding rapidly, but effort should be monitored.

The current seasonal closure of the fishery is based on biological information from Canadian stocks, a short dockside sampling program in Crescent City and recommendations from local fishers. Although the season is designed to avoid the most common period of egg bearing females—sampling catch composition over a longer time period would check the effectiveness of this strategy. There is no closed season for the recreational fishery; egg bearing females can be legally harvested year round. Conservative management of this fishery is necessary because of the lack of data on this species. Further investigation of life cycle timing, the relationship of larval recruitment to ocean conditions and what portion of the stock is taken each year would help determine the impact of harvesting ovigerous females.

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Coonstripe shrimp commercial landings and value, 1995-2008.

Year	Pounds	Value
1995	2,486	$3,729
1996	35,136	$137,734
1997	79,173	$295,017
1998	63,809	$256,431
1999	75,540	$312,906
2000	86,369	$353,627
2001	82,149	$305,265
2002	82,239	$295,505
2003	62,003	$218,533
2004	45,989	$177,448
2005	60,184	$238,551
2006	35,937	$144,664
2007	22,142	$92,706
2008	85,176	$361,801

Data Source: CFIS data, all gear types combined.

2 Kellet's Whelk, *Kelletia kelletii*

Kellet's whelk, *Kelletia kelletii*. Photo credit: Gerald and Buff Corsi © California Academy of Sciences.

History of the Fishery

The Kellet's whelk, *Kelletia kelletii*, is a large subtidal gastropod that is subject to a steadily increasing commercial fishery. Historically, Kellet's whelks have been found in archeological and paleontological sites in southern California. The earliest recorded commercial landing data specific to Kellet's whelk dates back to 1979, but prior to this it may have been recorded as miscellaneous mollusks or sea snails. Landings data indicate an increase in take starting in 1993 at 4590 pounds (2 metric tons), with highest landings in 2006 of 191,177 pounds (87 metric tons), over a forty-fold increase in thirteen years (Figure 2-1). An 81 percent increase in landings occurred between 2005 and 2006.

Kellet's whelk landings have been reported at 24 ports from 1979 to 2008, with 80 percent of landings occurring at four ports. The majority of landings (439,828 pounds, 200 metric tons) occurred at Santa Barbara, with approximately 40 percent of the total landings reported. The other three top ports were Terminal Island, San Diego, and San Pedro, with cumulative landings of 178,264 pounds (81 metric tons), 152,647 pounds (69 metric tons) and 136,971 pounds (62 metric tons), respectively.

Ex-vessel value from the 2008 commercial harvest of Kellet's whelks was approximately $132,700, with price per pound averaging $0.82 ($1.81 per kilogram). Since 1979, the fishery's ex-vessel value has ranged from $94 (1988) to approximately $136,000 (2007) and the ex-vessel price has ranged from $0.24 per pound ($0.53 per kilogram) in 1981 to $0.88 per pound ($1.94 per kilogram) in 1992.

Since 1979, 89 percent of all harvested Kellet's whelks have been taken incidentally in lobster and crab traps when they enter to prey on bait and injured crustaceans. The other method of take is diving. Ninety-nine percent of Kellet's whelks are used for human consumption and are mainly sold in live fish markets.

The Kellet’s whelk is usually taken incidentally in the lobster or rock crab fisheries. Both of these fisheries have restricted permits specific to their fishery. Rock crab fishers must also have a general trap permit, while the spiny lobster permittee is exempt from the general trap permit requirement. Commercial divers are required to have a commercial fishing license, and may only take whelks further than 1000 feet (305 meters) beyond the low tide mark, as the take of any snails is prohibited in the tidal invertebrate zone (Title 14, CCR, §123).

Recreational take of Kellet’s whelk by hand is allowed (Title 14, CCR, §29.05) outside of the 1000 foot (305 meter) tidal invertebrate zone. Except where prohibited in state marine reserves, state marine parks and state marine conservation areas the bag limit is 35 animals with no closed season.

Research demands dictate the number of Kellet’s whelks that are collected each year under Scientific Collecting Permits (SCP). This number varies widely depending on current research trends and SCP reporting.

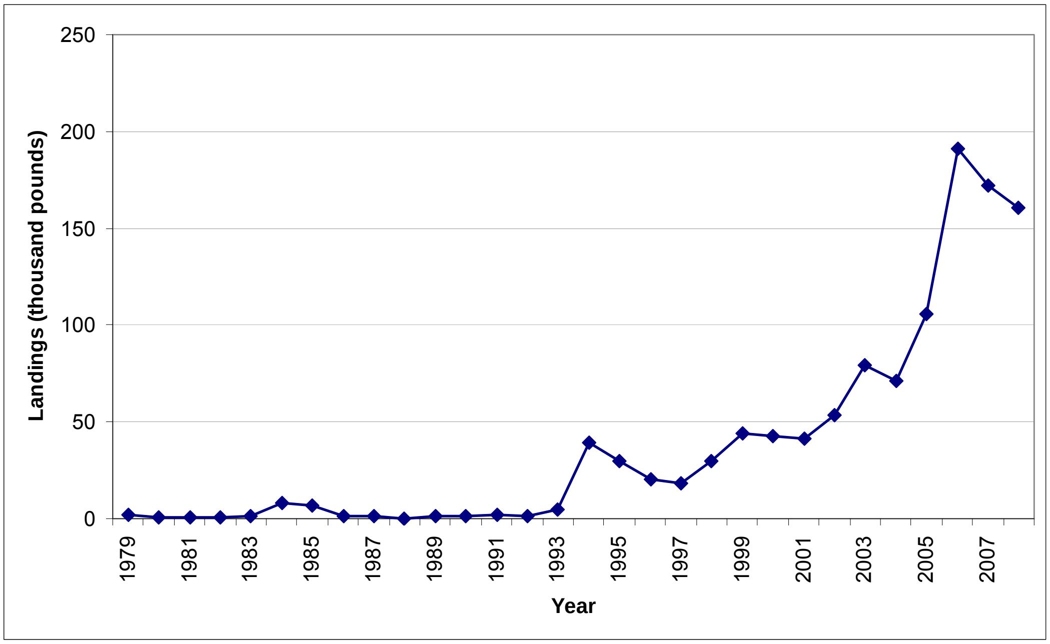

Figure 2-1. Kellet's whelk commercial landings, 1979-2008. Data source: CFIS data, all gear types combined. Data not available prior to 1979.

Status of the Biological Knowledge

Kellet’s whelks are the largest buccinid gastropods found in southern California. The robust, spindle shaped, spiraled shell can reach 6.9 inches (17.5 centimeters) in length. Shells are white to tan and are often covered with encrusting organisms such as bryozoans, sponges and algae.

The Kellet’s whelk is commonly found in kelp forests and on rocky reef habitat from central Baja California to Point Conception, California. It has also been found in sandy habitat adjacent to reef structure and buried under sand or shell debris. Rarely found in the intertidal, the Kellet's whelk depth ranges from low intertidal to 230 feet (70 meters). In 1981, observations of adult Kellet's whelks were reported in Monterey County, 250 miles (400 kilometers) north of its previously known northern boundary range.

Kellet's whelks display sexual dimorphism with females being the larger individual in a mating pair. Females are generally sexually mature between 2.6 and 2.8 inches (6.5 and 7.0 centimeters), with males maturing at slightly smaller sizes. Fertilization is internal, and spawning occurs annually in March, April and May, with aggregations of 15 to 20 mating pairs commonly seen during spawning. Reports exist of 200 to 300 individuals observed within one 215 square foot (20 square meter) area.

Oval shaped egg capsules are deposited in clusters on hard substrate, including reef, discarded mollusk shells or other Kellet's whelks, with egg laying speculated to be favored on substrate already containing Kellet's whelk egg capsules. Egg deposition may occur over several days at several locations, or all within one day. Egg capsules generally contain between 400 and 1200 eggs with the height of the capsule, and number of eggs directly correlated to the size of the spawning female. Egg capsule height generally ranges between 0.2 and 0.4 inches (6 and 9 millimeters) and may occasionally contain up to 2200 eggs. Embryos begin development within the capsule and emerge into the water column as free swimming veliger larvae. Veliger size is inversely related to egg capsule size, with smaller capsules containing larger veligers. The length of time in the planktonic larval stage is unknown.

Kellet's whelks are slow growing, and growth rates are uncertain. Studies have suggested growth of 0.3 to 0.4 inches (7 to 10 millimeters) per year until sexual maturity. Once reaching sexual maturity, growth slows considerably and it has been suggested that it takes at least 20 years to reach 3.5 inches (9.0 centimeters). In a year-long tagging study in southern California the majority of the 188 animals recaptured showed no growth.

Kellet's whelks are opportunistic carnivores that feed on dead or dying organisms, often forming feeding aggregations. However, they will also actively pursue prey including several species of turban snails. Ingestion occurs through the scraping of the radula, a tonguelike structure bearing rows of teeth, and the muscular suction action of the prehensile proboscis, a tubular extension used for feeding which can be extended up to three times the length of the shell. They are voracious eaters and often feed on bait and injured crustaceans in commercial crab and lobster traps.

Predators include the moon snail, sea stars, octopus and also sea otters in central California. Juvenile Kellet's whelks are also eaten by a variety of fish. Kellet's whelks are often found feeding alongside its predator, the giant seastar.

Status of the Population

There is a paucity of knowledge on the overall status of the Kellet's whelk population. In 1980, the first live Kellet's whelks were observed at the Hopkins Marine Life Refuge in Monterey, California, expanding it's previously known range by over 250 miles (400 kilometers) from Point Conception, California. Biogeographical research indicates that a population had existed there for several years before individuals were detected as adults. No paleontological records exist for this population in central California. Studies suggest that the Kellet's whelk range expanded to Monterey Bay in the 1970s or early 1980s, possibly due to an El Niño event, and is dependent on recruits from southern California. Lack of reproductive success in this newly established population is evidenced by the lack of recruits, few juveniles and many large adults.

During a four year study (1997 to 2000) of Kellet's whelks at eleven sites throughout their range, the newer northern populations had significantly lower densities than those of historic southern populations in 1997 [0.65 ± 0.22 per square foot versus 8.39 ± 0.97 per square foot (0.06 ± 0.02 per square meter historically versus 0.78 ± 0.09 per square meter)]. Size frequency distributions also differed significantly, with newly inhabited regions dominated by older, larger individuals and historically inhabited regions characterized by normal size distributions and higher frequencies of juveniles (less than 1 percent in the north versus 39 percent in the south).

Other southern California studies have been completed on a localized scale. One study near Little Cojo Bay, Santa Barbara County (1980-1981), concluded that the population was stable and could potentially support a small commercial fishery. A 1995 population study at a subtidal reef off La Jolla, California, suggested the population was stable and dominated by sexually mature adults, showing low mortality, with low, but steady recruitment.

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) coastal biodiversity survey data collected between 1999 and 2007 indicate that Kellet's whelk densities in historically inhabited regions average 0.43 whelks per square foot (0.04 whelks per square meter) and densities from the newly inhabited regions average 0.11 whelks per square foot (0.01 whelks per square meter). The site with the highest average density in the northern region is at Jalama (Santa Barbara County) with 0.64 whelks per square foot (0.06 whelks per square meter), just north of the historic range. The southern site with the highest density is at Naples (Los Angeles County) with 3.22 whelks per square foot (0.30 whelks per square meter), followed by Coho (Santa Barbara County) with 2.58 whelks per square foot (0.24 whelks per square meter). Coho is just south of Point Conception and the distance separating Coho and Jalama is less than 10 miles (16 kilometers).

Management Considerations

Subject to a rapidly expanding fishery, the harvest of Kellet's whelks is not regulated by a minimum size limit, season, or any type of harvest quotas. Due to life history characteristics such as slow growth rates and aggregate feeding behavior, and the lack of knowledge on the impact of increased fishing rates, interim regulations should be implemented under a precautionary principle until a stock assessment can be completed.

Establishing a minimum size limit of 3.0 inches (7.6 centimeters) in shell length to allow for successful reproduction prior to harvest, and a closed season from March through May to protect spawning aggregations would be beneficial to the fishery.

Future considerations may include the southern range expansion of the sea otter, as foraging otters have impacted Kellet's whelk populations occurring within their current range. There are commercial fishers interested in targeting Kellet's whelk with specially designed traps. To fish such traps an experimental gear permit would be required. The issuance of an experimental gear permit requires a logbook for all fishing activities, and an evaluation by the California Department of Fish and Game and the California Fish and Game Commission of the sustainability of such a fishery based on the data generated.

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Kellet's whelk commercial landings, 1979-2008.			
Year	**Pounds**	**Year**	**Pounds**
1979	1,958	**1994**	39,513
1980	645	**1995**	29,959
1981	860	**1996**	20,391
1982	550	**1997**	18,453
1983	1,265	**1998**	29,698
1984	8,032	**1999**	43,779
1985	7,098	**2000**	42,716
1986	1,680	**2001**	41,039
1987	1,216	**2002**	53,563
1988	142	**2003**	79,248
1989	1,033	**2004**	71,304
1990	1,621	**2005**	105,764
1991	1,983	**2006**	191,177
1992	1,584	**2007**	172,201
1993	4,590	**2008**	160,696

Data Source: CFIS data, all gear types combined. Data not available prior to 1979.

3 Pacific Hagfish, *Eptatretus stoutii*

Pacific hagfish, *Eptatretus stoutii*. Photo credit: Andrew Clark.

History of the Fishery

Pacific hagfish, *Eptatretus stoutii*, are the target of a robust, statewide re-emerging fishery. Prior to 1982, hagfish were not landed or targeted by California fishers. Most fishers targeting deep water species viewed hagfish as a nuisance, eating bait or destroying catch. Hagfish were noted for ruining hooked or netted sharks as well as hooked shelf and slope rockfish. Hagfish would burrow into the fish, eat the internal organs and, if time allowed, the rest of the fish. Pacific hagfish would also interfere with various trap fisheries, such as Dungeness crab, by eating the bait. In Korean waters, two related species, inshore hagfish, *E. burgeri*, and brown hagfish, *Paramyxine atami*, were being pursued for food and an eel skin leather trade.

In 1983, eel skin leather products were gaining popularity and fishing effort for hagfish increased in Korea. By 1985, 400 vessels were landing up to 3000 short tons (2722 metric tons) annually. From 1986 to 1987 there were approximately 600 vessels and up to 35 processors in the Korean port of Pusan. Due to fishery depletion, Korean hagfish processors began to look for outside sources of hagfish.

By late 1987, Korean processors began to solicit California fishers, mostly from the San Francisco and Monterey port areas, to target hagfish. After one year of fishing, 8 vessels had landed 345 short tons (313 metric tons) (Figure 3-1). The hagfish were frozen and shipped to Korea for processing. All hagfish meat was discarded due to Korean importation laws and due to the use of the anesthetic MS222. California fishers would apply MS222 to the hagfish catch to reduce activity and to prevent hagfish from biting each other. MS222 is highly toxic and made the flesh unfit for human consumption.

Shortly thereafter, interest in hagfish increased and California fishing activity surged. In 1989, statewide landings reached 1321 short tons (1200 metric tons) from 80 participating vessels. The ports with the greatest activity were Ventura, Santa Barbara, Oxnard and San Francisco. Landings reached the highest on record in 1990 with 2490 tons (2260 metric tons) from 56 participating vessels. Ironically, during this time, Korean interest in hagfish from California declined along with the price. During the 1990 fishing season, skins of hagfish from California became less desirable due to holes from bites from other hagfish and unexplained pinholes commonly occurring in the dorsal part of the skin. During the curing process, these holes and bite marks would stretch and make the skin piece unusable. Hagfish demand decreased in 1991, and total landings fell to 151 short tons (137 metric tons). From 1992 to 2004, annual landings ranged from 0 to 202 short tons (0 to 183 metric tons) and averaged 34 short tons (31 metric tons).

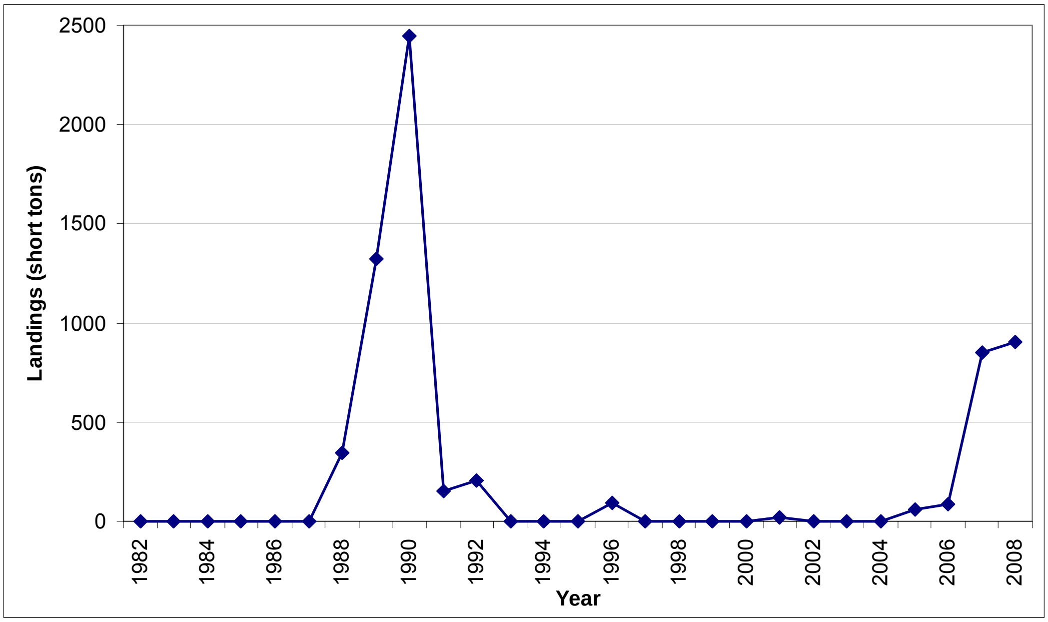

Figure 3-1. Pacific hagfish commercial landings, 1982-2008. Data source: CFIS data, all gear types combined.

Fishing effort and landings increased again in 2005 with a renewed interest in Pacific hagfish from California. This time the species was sought primarily for human consumption in Asia, mostly in Korea. Most hagfish were caught and sold live to local fish receivers, and this practice continues today. Typically, hagfish are placed in holding tanks owned by fish receivers for a few days for several reasons: 1) to allow emptying of the hagfish' digestive tract; and 2) to allow receivers to build their inventory before sale. A hagfish buyer then purchases the fish from the receiver and exports them live to Korea. Once in Korea, the hagfish are processed for human consumption. In addition, any large hagfish in good condition are still processed for their skins.

California landings in 2005 and 2006 were minimal, but sharply increased in 2007 to 852 short tons (773 metric tons) (Figure 3-1). Ex-vessel ranged from $0.25 to $2.00 per pound ($40.55 to $4.41 per kilogram), averaging $0.78 per pound ($1.72 per kilogram). In 2008, landings reached 901 short tons (818 metric tons), and ex-vessel price ranged from $0.01 to $1.75 per pound ($0.02 to $3.86 per kilogram), averaging $0.95 per pound ($2.09 per kilogram). This renewed fishing effort for hagfish was also a result of an increased number of displaced fishers, either from fisheries that had seasonal reductions or emergency closures, or who were seeking an additional income source. Buyers were also recruiting fishers by offering traps and equipment to those who would sell hagfish to them.

There is no recreational fishery for Pacific hagfish.

Status of Biological Knowledge

The Pacific hagfish is a member of the Myxinidae (hagfishes) family. Hagfish are cartilaginous fish that lack eyes, jaws, scales and paired fins. Hagfish also have a single nostril and a mouth that contains two parallel rows of pointed, keratinous teeth. These teeth are secured to rasping dental plates. The oral/nasal cavity is surrounded by eight barbells. Considered scavengers, hagfish will feed upon dead fish and marine mammals, or any other animal matter they can find. Hagfish identify food sources through their excellent sense of smell and touch. After identification, hagfish will protract/retract their plates until the food source is secured and consumption begins by entering an existing hole or making one using their dental plates. The hagfish will then enter its food item, if possible, consuming it from the inside. Hagfish were once thought of as parasites due to this behavior. Members of the hagfish family also have mucous producing "slime" glands along each side of the fish's body. When agitated, the hagfish will produce a protein-based mucous that, when mixed with water, produces a thick, viscous slime. This behavior is the reason hagfish are commonly called "slime eels".

Pacific hagfish occur in depths from 30 to 2402 feet (9 to 732 meters) on muddy substrate, but most are caught in depths less than 1800 feet (549 meters). Knowledge of maturation and fecundity is limited, but improving. Studies indicate that females attain sexual maturity around 13 inches (33 centimeters) when they are between 7 and 12 years old. Male sexual maturity knowledge is limited, but males are sexually identifiable at 11 inches (28 centimeters). Males typically will grow to a larger size than females. Females are sexually identifiable at 8 inches (20 centimeters). Hagfish fecundity is low with female hagfish producing 20-30 eggs per reproductive cycle. Female hagfish may contain eggs of various stages of maturity. Reproductive cycle length is not known; however, a female's eggs must come to full term before the next batch of eggs will begin to mature. There is no specific spawning season and female hagfish may have viable eggs at any time during the year. Viable eggs have been observed more frequently in sampled hagfish during fall and winter months.

Larger Pacific hagfish may show characteristics of hermaphroditism or bisexuality. In these rare cases, the hagfish gonad will contain both developing eggs and active spermatogenic follicles.

Status of the Population

Little is known about the status or biomass of Pacific hagfish stocks. Based on landings from the first surge of fishing activity from 1989 to 1991 and the current pulse, which began in 2007, the biomass must be large. A tagging study performed by Nakamura in 1991 suggests that the population density could range from approximately 484,000 to 714,000 hagfish per square mile (1870 to 2760 hagfish per hectare) in suitable habitats and in water depths less than 1200 feet (366 meters), although the estimates were based on samples primarily in the 600 foot (183 meter) depth regime. Recent California Department of Fish and Game (Department) sampling of the fishery has shown hagfish to average about four to five individuals per pound, which would equate to density estimates ranging from approximately 48 to 89 short tons of hagfish per square mile (168 to 311 kilograms per hectare), using Nakamura's data.

Management Considerations

In 1991, at the end of the first surge in fishing activity, the Department enacted several regulatory measures (FGC §8397). In addition to normal licensing, fishers were required to purchase a nontransferable hagfish permit to take hagfish. With the hagfish permit, a general trap permit was not required. Fishers were also required to submit logs documenting their fishing activities. Vessels were limited to 1200 Korean traps or 300 of any other type of trap. Korean and bucket traps are fished in a string and are secured to an anchored, central ground line. The Fish and Game Code was later amended to specify non-Korean traps as the 5-gallon bucket type trap. The requirement for the hagfish permit and associated fee, and the logbook requirement, were repealed in April 1998. Beginning in 1999, vessels were limited to 500 Korean traps or 200 bucket traps (FGC §9001.6).

Currently hagfish fishers and crewmen are required to possess a valid general trap permit. A logbook is required again. Vessels are limited to a maximum of 500 Korean traps or 200 five-gallon bucket style traps. No other fish, other than hagfish, may be possessed or targeted while fishing for hagfish or if hagfish are onboard (FGC §9001.6).

In December 2008, the California Fish and Game Commission authorized the Department to issue experimental gear permits for the use of 40-gallon barrel traps to take hagfish commercially. No more than 40 barrel traps, each with its own float and line, may be used by an individual. This type of gear may reduce potential gear conflicts with trawlers fishing in federal waters and with the Dungeness crab trap fishery. In addition, this gear may produce a better, more marketable catch. As a condition of the permit qualified fishers are required to submit logs of their fishing activity, pay a permit fee and have at least three days of observer coverage to assess the gear. As of March 2009, three permits have been issued.

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Further Reading

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Pacific hagfish commercial landings, 1982-2008.

Year	Pounds	Year	Pounds	Year	Pounds
1982	126	**1991**	303,228	**2000**	69
1983	45	**1992**	405,374	**2001**	44,256
1984	170	**1993**	473	**2002**	109
1985	0	**1994**	1,206	**2003**	0
1986	0	**1995**	72	**2004**	4,466
1987	0	**1996**	182,445	**2005**	119,036
1988	690,655	**1997**	86	**2006**	169,045
1989	2,642,540	**1998**	523	**2007**	1,699,723
1990	4,900,596	**1999**	206	**2008**	1,802,935

Data source: CFIS data, all gear types combined.

4 Thresher Shark, *Alopias vulpinus*

Thresher shark, *Alopias vulpinus*. Photo credit: Dale Sweetnam.

History of the Fishery

The common thresher shark, *Alopias vulpinus*, is the most common commercially landed shark in California. They are primarily caught using large mesh drift gill nets and hook and line gear, but are also caught incidentally with small mesh gill nets and harpoon. Prior to 1977, all sharks were reported in one market category and not separated by species, and it is assumed threshers were caught as bycatch in gears at levels similar or greater than today. The first significant fishery for thresher sharks began the late 1970s to early 1980s when drift gill net fishers began to target them close to the southern California coastline. The fishery expanded rapidly and, because of overfishing concerns, the California Department of Fish and Game (Department) as mandated by the State Legislature began an observer program, monitored landings and implemented a logbook program. A limited entry permit program for drift gill net gear was initiated in 1982, with permits issued to fishers rather than boats to prevent false inflation in value. The drift gill net fishery for thresher sharks peaked in 1981 when 113 drift gill net boats landed nearly 600 tons (544 metric tons). However, total landings using all gears were highest the following year with a total of more than 1700 tons (1542 metric tons) taken by all gears (Figure 4-1).

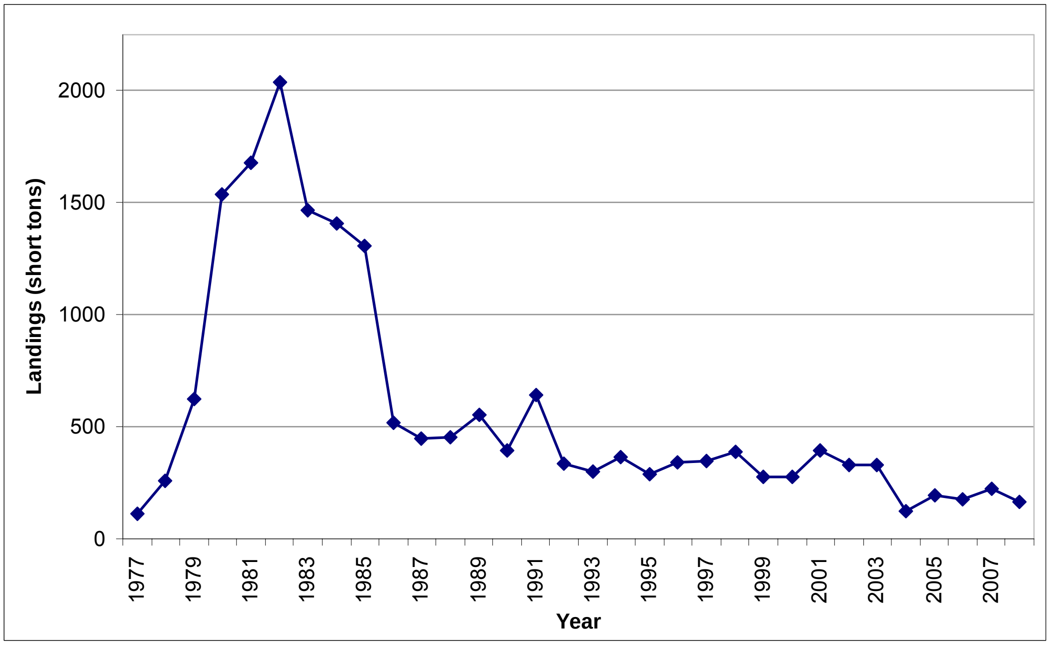

Figure 4-1. Thresher shark commercial landings, 1977-2008. Data source: Department Catch Bulletins (1977-1985) and CFIS data (1986-2008), all gear types combined. Data not available prior to 1977.

By the late 1980s, research monitoring of the commercial landings indicated that entire size classes were no longer being caught. Legislation was enacted establishing a series of time/area closures for the gill net fishery in order to protect the shark resource. The objective of these closures were threefold: 1) to protect large females who moved into the Southern California Bight (SCB) during their pupping season; 2) to prevent interactions with marine mammals, sea turtles and sea birds; and 3) to prevent conflicts with harpoon fisheries. Several revisions to the gill net time and area closures resulted in the fishery being completely closed between February 1 and April 30 and closed within 75 miles (121 kilometers) of the coast from May 1 to August 14 (FGC §8576).

In the early 1980s, drift gill net vessels switched to swordfish as their primary target species. Thresher sharks, along with shortfin mako sharks, were targeted secondarily and landings of threshers began to decline (Figure 4-1). In 1990, a California voter referendum banned gill nets in state waters (within 3 nautical miles; 5.6 kilometers) of shore south of Point Arguello (Santa Barbara County)] in southern California (FGC§8610.2). In 2001, a federal gill net closure was enacted to protect leatherback sea turtles from Point Conception to central Oregon from August 15 through October 31. In addition, during El Niño conditions, the area south of Point Conception is closed to drift gill net fishing August 15 through August 31 and in January to protect loggerhead turtles. These closures have further reduced thresher shark landings, with landings totaling less than 200 short tons (181 metric tons) each year since 2004 (Figure 4-1). At present, the only requirement for purchasing a drift gill net permit is possession of one for the preceding season; there is no landing requirement. Currently, there are 83 drift gill net permittees; however, only about half of those are actively fishing.

Thresher sharks are also taken by other commercial gears including hook and line, small mesh gill nets and harpoon. Small mesh gill nets include set nets targeting California halibut and drift nets targeting barracuda and white seabass. Small mesh drift gill nets [mesh 8 inches (20 centimeters) or smaller] targeting white seabass and barracuda are not required to have a drift gill net permit, however state regulations limit possession to no more than two thresher sharks along with ten barracuda or five white seabass, while federal regulations have a limit of ten highly migratory species (HMS) excepting swordfish (HMS includes albacore, bigeye, bluefin, skipjack and yellowfin tunas; common, big eye and pelagic thresher sharks; shortfin mako shark; blue shark; striped marlin; swordfish; and dorado). In 1996, a state ban on landing detached shark fins became effective for all commercial fishing gears (FGC §7704). Because of their size, threshers are the only exception to this rule; however, the fins must match a corresponding carcass on the vessel.

Thresher sharks have long been a desired species for recreational anglers and are considered a prized fighting fish. California recreational regulations impose a two fish bag limit on thresher sharks. This is cumulative for multi-day trips and most anglers seldom fill bag limits. Boat limits are in effect for multiple anglers per boat; with no more than the bag limit for each of the number of licensed anglers per boat. Again, these limits are seldom filled. If filleted at sea, a one inch patch of skin must be left on the fillets. In recent years, interest in thresher shark has increased as other recreational species become more heavily regulated, and some fishing areas are closed to protect other fish species. Many shark anglers practice a catch and release ethic. However, the survival of these released fish, often caught using a species specific tactic of tail hooking, may be much lower than previously thought. Research is currently underway to determine specific survival rates of tail hooked sharks.

There are two different recreational sampling programs: the Marine Recreational Fisheries Statistical Survey (MRFSS) which sampled from 1980 to 2003 and the California Recreational Fisheries Survey (CRFS) which was initiated by the Department in 2004. Due to changes in the sampling protocol and how the data are used to estimate catch these two surveys are not comparable. The recreational catch of thresher shark, all species combined, from 1980-2003 has been variable; ranging from a high of 4829 fish in 1987 to 461 fish in 1997 (Figure 4-2). This trend has continued during the 2004-2008 period, ranging from 306 fish in 2005 to 4554 fish in 2004 according to CRFS data (Figure 4-3). Recreational thresher shark catches are highest May through August, for both kept and released fish. Most recreational thresher shark catch occurs in the private/rental boat mode [90 percent for the years 1980-2003 (MRFSS data); 84 percent for the years 2004-2008 (CRFS data)] (Figure 4-4). In 58 percent (14/21) of the sampling years between 1980 and 2003, the estimated number of threshers released alive have been greater or equivalent to those kept. Since 2004, estimates of the metric tonnage of fish released alive have been available; in four of the five sampling years the estimated tonnage of those fish released has also been greater or equivalent. Threshers are often taken incidentally while anglers are targeting other species. Those taken in northern California were all incidental to salmon or halibut recreational fishing trips, while in southern California, 69 percent were caught on trips targeting threshers and the rest were caught incidentally on halibut, yellowtail and barred sand bass trips. Commercial passenger fishing vessel (CPFV) logs indicate that the take of thresher sharks aboard their vessels is much less than that taken by anglers fishing from private boats. For the last fifteen years, the take of thresher sharks by CPFV averaged about 40 fish a year with a high of 163 fish during the El Niño of 1993.

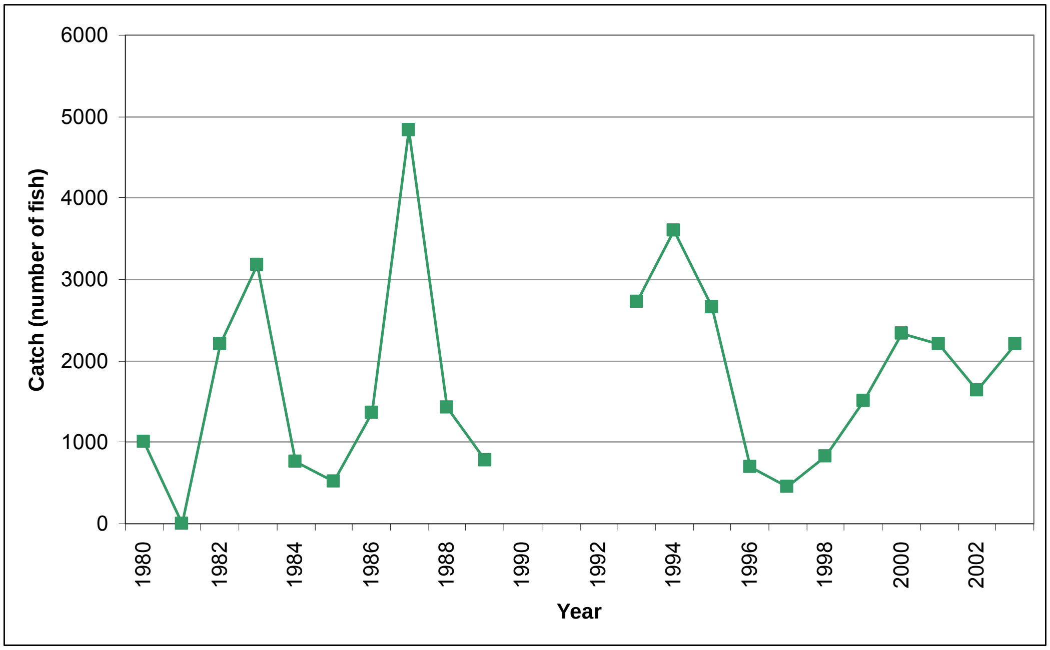

Figure 4-2. Thresher shark recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data not available from 1990-1992. CPFV data not available for central and northern California for 1993-1995.

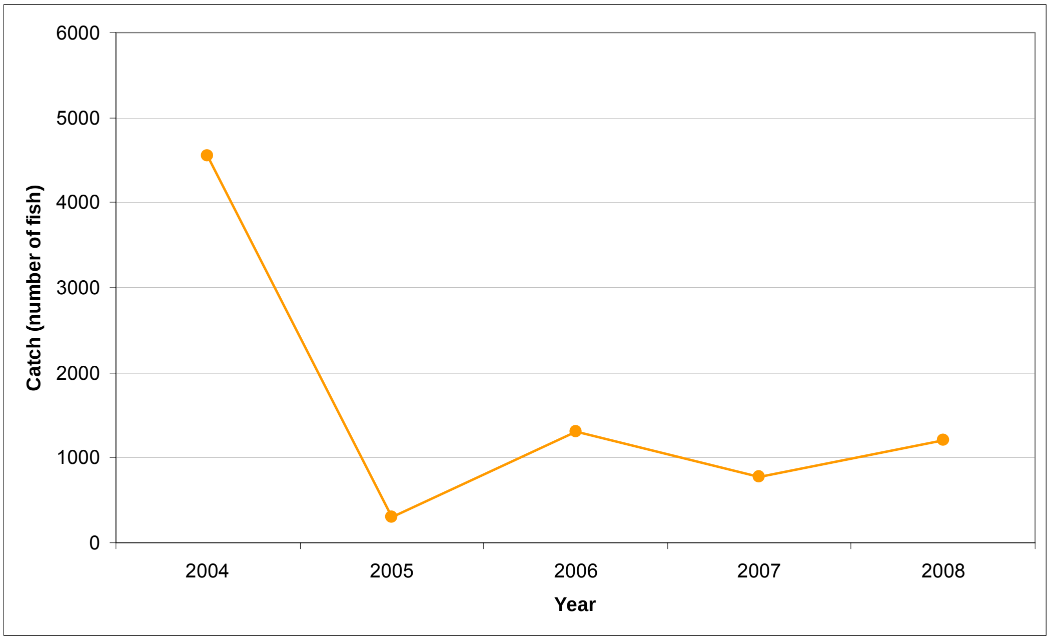

Figure 4-3. Thresher shark recreational catch, 2004-2008. Data source: CRFS data, all fishing modes and gear types combined.

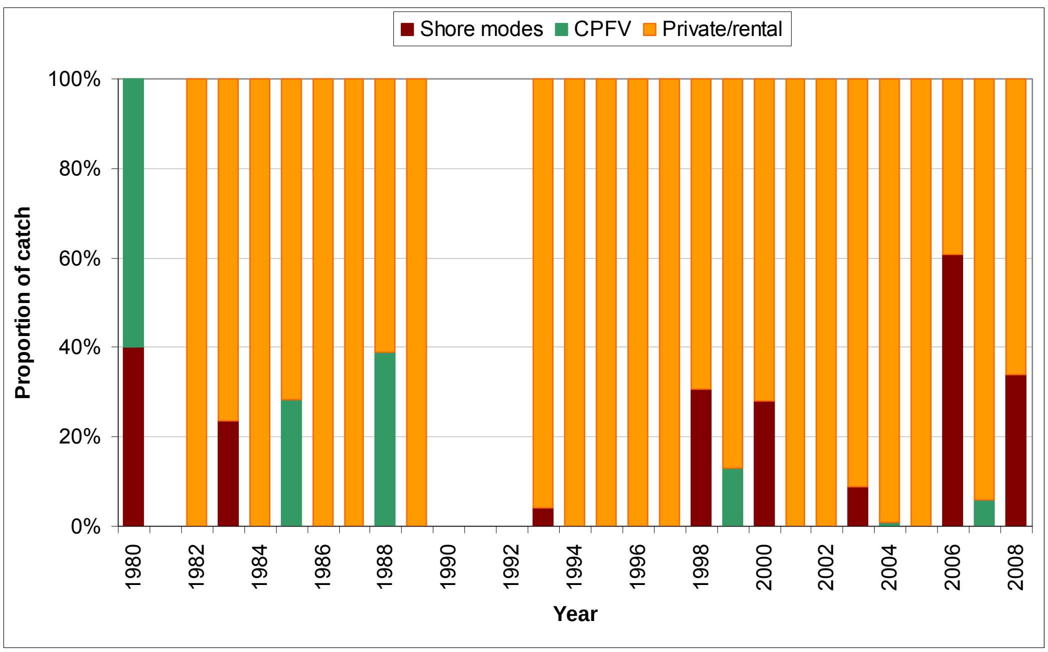

Figure 4-4. Thresher shark recreational catch by fishing mode, 1980-2008. Data source: MRFSS data (1980-2003) and CRFS data (2004-2008), all gear types combined. Data not available from 1990-1992, CPFV data not available for central and northern California for 1993-1995.

Status of Biological Knowledge

Thresher sharks are large pelagic sharks whose most defining characteristic is the enormous upper lobe of the tail, which can be up to half their total length, and is used to stun their prey. Common thresher sharks are dark brown to dark grey dorsally, fading to tan to gold on the sides, and a distinct demarcation to white on the belly. They can be differentiated from two other thresher sharks that occur in California (the bigeye thresher and the pelagic thresher) by the white belly markings extending over the top of the large pectoral fins and a slight bronzy-green iridescence to the skin, which leads markets to sometimes record the species on fish receipts as “green thresher” (as opposed to “brown thresher,” which refers to bigeye). Some also have small white spots on the tips of the pectoral and pelvic fins.

Common thresher sharks have a worldwide distribution in temperate seas and are found in the Mediterranean Sea and the Atlantic, Pacific and Indian Oceans. They tend to be most common over continental shelves, preferring areas of high productivity where concentrations of the small schooling organisms that make up most of their diet are found. Young threshers tend to remain within 3 miles (5 kilometers) of the coast in their early years and as they grow larger, range much farther offshore. Migratory patterns inferred by seasonal catches seem to indicate that adult threshers move north from Baja California in the spring, into the SCB, where “pupping” is thought to occur. The adults then continue north as far as Oregon and Washington by late summer, followed by subadults later in the season. Subadults are known to migrate south again in the wintertime, but it is not known what route is taken south by large adults. The National Marine Fisheries Service-Southwest Fisheries Science Center (NMFS-SWFSC), in cooperation with the Tagging of Pacific Predators program has been conducting a tagging study annually since 2003 using satellite tags on large threshers caught during its annual survey of thresher shark pup abundance. Adults and subadults tagged with conventional and pop off satellite tags have shown a preference for coastal waters, but occasionally venture into offshore waters to depths of more than 1600 feet (500 meters) or greater. Nine of eleven satellite tags deployed during the last 2 years popped up in the SCB within 6 to 8 months.

Thresher shark size at birth has been estimated to be 62 inches (158 centimeters) total length, and can reach a maximum size of 250 inches (636 centimeters) for females and 194 inches (493 centimeters) for males. Recently published work estimates both sexes to reach sexual maturity at an age of 5 years and a length of 119 inches (303 centimeters). The oldest thresher reported was 50 years old.

Thresher sharks feed mostly on small schooling pelagic organisms. A recent study of stomachs from threshers taken in the California drift gill net fishery found that they consumed food from 20 different taxa; including anchovies, Pacific whiting, Pacific mackerel, Pacific sardine, squid and pelagic red crabs. Pacific whiting were the most common food item for thresher sharks caught north of Point Conception, while anchovies were the most common for thresher sharks caught south of Point Conception, especially for juveniles. They are thought to use their large upper lobe of the caudal fin to stun their prey before eating it; this is corroborated by the fact that most threshers caught by conventional hook and line gear are snagged by the tail.

Like other large pelagic sharks, common threshers have been shown to be warm blooded. Thresher sharks caught by long line and by rod and reel were shown to have elevated temperatures in their aerobic swimming musculature, as much as 3 degrees higher than surrounding sea surface temperatures. They are also obligate ram ventilators, meaning that they require forward motion to keep oxygenated water flowing over their gills. They do not survive well on fishing gear which restricts their movement or drags them backwards through the water. The NMFS-SWFSC and the Pfleger Institute of Environmental Research are currently collaborating on research studying thresher shark mortality when taken on conventional hook and line gear using satellite tagging methods. Alternative gears, which have a higher probability of hooking the shark in mouth rather than the tail, are also being studied.

Threshers are ovoviviparous, with gestation period of about 9 months. Eggs are retained in the uterus, where they hatch; the newly-hatched fetuses are oophagous, meaning they feed on excess intrauterine eggs prior to birth. The mother shark then gives live birth to a litter of two to four pups, although in some areas the number may be as high as seven. In the eastern Pacific, the SCB is thought to be a nursery area for thresher sharks. Observers sampling adult females taken in the commercial fishery in early spring found all to be pregnant. The pupping season takes place from April to June, and mating season is thought to follow in late summer to fall. In 2003, the NMFS-SWFSC began investigating the range of thresher shark pup distribution along the coast of southern California, in an attempt to clarify borders of nursery areas and establish an index of juvenile thresher shark abundance. While it is still too early in the study to establish trends in abundance, the juvenile thresher’s patchy distribution makes identifying the nursery areas difficult even though they have been shown to prefer nearshore waters at depths 0 to 150 feet (0 to 46 meters) and nearly all were caught in depths less than 295 feet (90 meters).

The Pacific Fisheries Management Council (PFMC) has identified priority research needs for additional life history information for HMS included in the Highly Migratory Species Fishery Management Plan (HMS FMP). For thresher shark, the research priorities are: 1) identify stock structure and boundaries of the populations, and where they interact with other populations, the seasonal migration patterns for feeding and reproduction and life stages vulnerable to fisheries; 2) determine ages and growth rates, including comparisons to other areas; and 3) determine maturity and reproductive schedules.

Status of Population

Stock assessments for all HMS sharks, including thresher, are also needed but are problematic; fisheries data for sharks are often collected in a manner not suited for use in assessments. Regional Fishery Management Organizations have tended to make tunas and billfish the priority while sharks, even though they are more vulnerable to overfishing because of their slow growth and low reproductive rates, have not received the same attention. This is primarily because of their status as bycatch in other fisheries or that data on sharks are often not separated by species, but lumped together in one market category. Even in California, thresher sharks were not identified by species until 1977. In addition, significant catches of thresher sharks occur in Mexico, and as for all shark fisheries, sample data are scarce and incomplete.

Preliminary assessment analyses indicated west coast drift gill net fishery catch and catch-per-unit-effort were increasing from the lows of the early 1990s; from this it was inferred that the population was recovering. The most recent assessment of thresher shark in 2002 indicated that thresher shark is no longer overfished and recent average landings are about 75 percent of maximum sustainable yield. However the PFMC has recommended that a new stock assessment be a priority.

Management Considerations

The HMS FMP became effective in February 2005, putting thresher shark under federal management, although California regulations were used as a model for most HMS species. The HMS FMP establishes a biennial management cycle, in which measures to be implemented are introduced in June and, if approved, implemented the following April. For thresher sharks, a harvest guideline of 375 short tons (340 metric tons) was established for total commercial and recreational catch.

In June 2008, recommendations were made by the PFMC's HMS Management Team to limit the recreational take of common thresher sharks. Recreational catch had been increasing, due to the recreational public becoming more educated on how to target them, and increasing use of internet websites to disseminate information on fishing areas and thresher shark occurrence. Concerns were raised because much of this catch was occurring during the spring thresher shark pupping season, and many of the fish caught appeared to be pregnant females. Additionally, although many thresher shark anglers advocate catch and release fishing methods, a preliminary study indicated that thresher sharks caught by tail hooking had poor survival rates when released. When added to commercial landings, recreational catches were thought to be approaching the harvest guideline. Prior to PFMC decision making, a series of seminars were conducted to educate anglers on best ways to catch and release thresher sharks. Alternatives proposed included closing the recreational fishery for the same period as the commercial fishery, changing bag limits to one shark per day (thresher only or all HMS sharks), seasonal bag limits using harvest cards or gear modifications.

On further examination of the recent CRFS data, estimates of recreational thresher shark catches were found not to be causing cumulative landings to exceed the harvest guideline (Figure 4-5). Further, an analysis of bag limits showed that few anglers caught limits and a change in the bag limit would likely have little effect on recreational catch. The PFMC decided not to make changes to thresher shark regulations for the 2009-2010 management cycle, but did make a number of recommendations including: 1) continuing outreach to anglers regarding best practices to increase survival of released animals; 2) improving data collection on thresher sharks (especially for private access marinas, and in commercial hook and line and non HMS fisheries); 3) initiating a new stock assessment that incorporates data from Mexico; 4) improving estimates of the number and condition of released fish; 5) investigating further the use of recreational gear modifications to increase survival; and 6) identifying thresher shark nursery areas. CRFS is currently conducting a study involving panels of anglers based in private marinas, and funding for proposals to carry out the other recommendations is currently being pursued from the Marine Recreational Information Program and the California Ocean Protection Council.

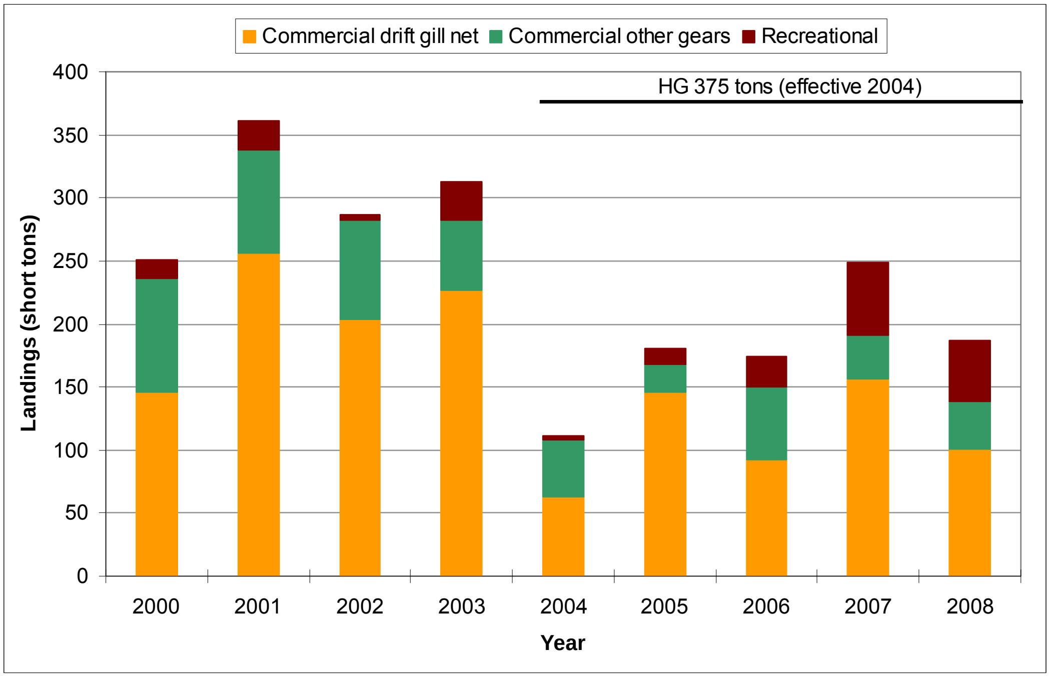

Figure 4-5. Thresher shark landings compared to the harvest guideline (HG), 2000-2008. Commercial drift gill net includes both large mesh offshore drift gill nets targeting swordfish and small mesh drift gill nets targeting white seabass and barracuda. The HG for commercial and recreational fisheries (combined) is 375 short tons (340 metric tons). Data source: Commercial - CFIS data (2000-2008); Recreational - MRFSS (2000-2003) and CRFS (2004-2008), all fishing modes and gear types combined.

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Further Reading

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Thresher shark commercial landings, 1977-2008.

Year	Short tons	Year	Short tons	Year	Short tons
1977	94	**1988**	389	**1999**	238
1978	219	**1989**	471	**2000**	236
1979	533	**1990**	335	**2001**	338
1980	1,309	**1991**	550	**2002**	283
1981	1,431	**1992**	286	**2003**	283
1982	1,738	**1993**	258	**2004**	108
1983	1,252	**1994**	310	**2005**	168
1984	1,203	**1995**	248	**2006**	150
1985	1,117	**1996**	294	**2007**	191
1986	440	**1997**	298	**2008**	138
1987	381	**1998**	333		

Data source: Department Catch Bulletins (1977-1985) and CFIS data (1986-2008), all gear types combined. Data not available prior to 1977.

Thresher shark recreational catch (number of fish) by fishing mode, 1980-2003.					
Year	**Shore modes**	**CPFV**	**Private/ rental**	**Total of all modes**	**Percent private/ rental**
1980	406	607	0	1013	0%
1981	0	0	0	0	--
1982	0	0	2205	2205	100%
1983	747	0	2436	3182	77%
1984	0	0	769	769	100%
1985	0	147	375	523	72%
1986	0	0	1359	1359	100%
1987	0	0	4829	4829	100%
1988	0	554	872	1426	61%
1989	0	0	776	776	100%
1990	--	--	--	--	--
1991	--	--	--	--	--
1992	--	--	--	--	--
1993	116	0	2610	2726	96%
1994	0	0	3600	3600	100%
1995	0	0	2654	2654	100%
1996	0	0	703	703	100%
1997	0	0	461	461	100%
1998	254	0	576	829	69%
1999	0	195	1307	1502	87%
2000	656	0	1685	2341	72%
2001	0	0	2204	2204	100%
2002	0	0	1644	1644	100%
2003	195	0	2012	2207	91%
Average 1980-2003	**113**	**72**	**1575**	**1760**	**90%**

Data source: MRFSS data, all gear types combined. Data not available from 1990-1992. CPFV data not available for central and northern California for 1993-1995.

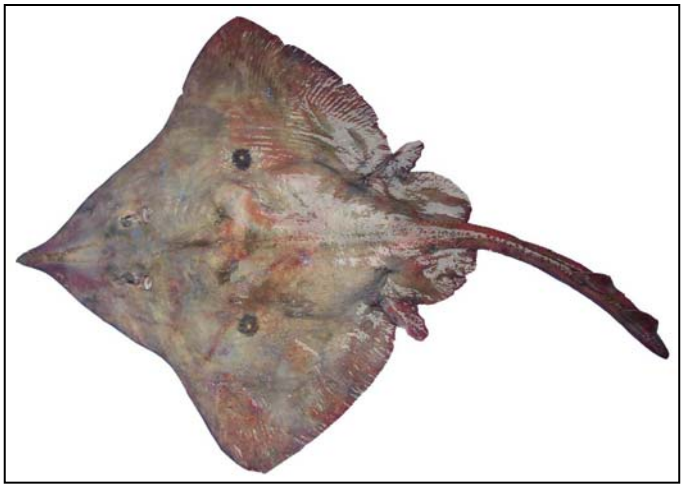
Thresher shark recreational catch by fishing mode, 2004-2008.					
Year	**Shore modes**	**CPFV**	**Private/ rental**	**Total of all modes**	**Percent private/ rental**
2004	0	36	4518	4554	99%
2005	0	0	306	306	100%
2006	797	0	516	1313	39%
2007	0	45	731	776	94%
2008	410	0	708	1118	63%
Average 2004-2008	**241**	**16**	**1356**	**1613**	**84%**

Data source: CRFS data, all gear types combined.

Thresher shark commercial and recreational catch (short tons), 2000-2008, compared to the 375 short ton (340 metric ton) harvest guideline (HG).								
	Commercial DGN (all sizes)		**Commercial Other Gears**		**Recreational (all modes)**		**Total**	
Year	**Tons**	**Percent HG**	**Tons**	**Percent HG**	**Tons**	**Percent HG**	**Tons**	**Percent HG**
2000	146.2	39.0%	89.7	23.9%	15.0	4.0%	250.9	66.9%
2001	256.4	68.4%	81.6	21.8%	22.7	6.1%	360.8	96.2%
2002	203.3	54.2%	79.4	21.2%	3.5	0.9%	286.2	76.3%
2003	226.9	60.5%	55.8	14.9%	30.2	8.1%	312.8	83.4%
2004	63.4	16.9%	44.5	11.9%	3.6	1.0%	111.6	29.7%
2005	145.8	38.9%	21.7	5.8%	12.8	3.4%	180.3	48.1%
2006	92.5	24.7%	57.3	15.3%	25.0	6.7%	174.8	46.6%
2007	156.8	41.8%	34.4	9.2%	57.1	15.2%	248.3	66.2%
2008	100.5	26.8%	37.7	10.1%	39.2	10.5%	177.4	47.3%
Average 2000-2008	154.6	41.2%	55.8	14.9%	24.3	6.5%	234.7	62.6%

Data sources: Commercial - CFIS data (2000-2008). Recreational - MRFSS data (2000-2003) and CFRS data (2004-2008), all fishing modes and gear types combined.

5 Skates and Rays



Longnose skate, *Raja rhina.* Photo credit: Pacific States Marine Fisheries Commission.

History of the Fishery

In California, the earliest fishers for cartilaginous fishes were indigenous people living along the coast. Chinese immigrants fished for assorted coastal rays and sharks in the mid 1800s, mostly in and around San Francisco Bay. Until the mid 1930s, most skates and rays were discarded except in Asian communities where they were consumed.

Skates and rays have not historically been targeted in commercial fisheries, but have primarily been taken incidentally by trawlers in northern and central California. Of the species identified in commercial landings, the most common species are the big skate, *Raja binoculata*, California skate, *Raja inornata*, shovelnose guitarfish, *Rhinobatos productus*, and bat ray, *Myliobatis californica*. This does not reflect actual species composition, however, because the majority of landings are reported as "unspecified skate" or "stingray".

In the past, the primary market has been for just the pectoral fins or "wings" of skates, with only a small portion of skate and ray landings marketed whole. Currently, skates are marketed both whole and as wings. Wings are sold largely in Asian markets as fresh or fresh-frozen, dried, or dehydrated and salted. The carcasses are usually discarded at sea or sometimes sold as bait for trap fisheries. Skates also have been processed for fishmeal, but these ventures failed for economic reasons. Reportedly, rounds punched from skinned wings have been used as an inexpensive substitute for scallops in seafood restaurants and markets.

In the early years of the fishery the majority of skate landings came through central California (Monterey and San Francisco) which accounted for 41 to 100 percent of the annual landings from 1948 through 1989 (72 percent average). Since 1975, the northern California ports (Eureka, Crescent City and Fort Bragg) have become progressively more important for skate landings. In 1995 northern California landings increased dramatically, and has since accounted for 72 to 93 percent of the total landings. Total landings from ports south of Monterey have continued to be relatively insignificant.

Skate landings from 1916 to 1990, which ranged from 50,419 pounds (23 metric tons) in 1944 to 631,420 pounds (286 metric tons) in 1981, comprised 2 to 90 percent of the total elasmobranch landings with an average of 11.8 percent. Rays, which were not identified separately until 1978, were likely included with skate landings prior to 1978. Similar to the shark fishery, skate landings have fluctuated widely throughout the history of the fishery. While a shift to the shark fishery in 1938 resulted in a decrease in skate landings, the variations in catch roughly followed general economic conditions, though oceanographic conditions may also have had a role. Skate landings increased significantly in the mid 1990s. During this period, skate and ray landings increased over ten-fold in California from about 106,163 pounds (48 metric tons) in 1994 to 1,433,211 pounds (650 metric tons) in 1999, with a peak of 3,003,177 pounds (1362 metric tons) in 1997 (Figures 5-1 and 5-2). Landings fell sharply in 2002, corresponding with reduced demand in Asian markets. Over the past seven years, skate and ray landings have averaged about 284,000 pounds (129 metric tons).

The statewide economic value of skate and ray fisheries has been historically small compared to other fisheries. The average annual ex-vessel price for skates and rays ranged from $0.01 to $0.02 per pound ($0.02 to $0.04 per kilogram) from 1958 to 1969. Skate average prices rose from $0.09 per pound in the 1970s to $0.27 per pound in the 1990s ($0.20 to $0.60 per kilogram). From 2000 to 2008, prices averaged $0.33 per pound and reached as high as $10 per pound ($0.73 to $22 per kilogram). The price of rays has fluctuated considerably compared to skates. From the 1970s to 1980s, the average price per pound rose from $0.07 to $1.82 ($0.15 to $4.00 per kilogram), and then dropped to $0.74 in the 1990s ($1.63 per kilogram). Between 2000 and 2008, the average price was $0.68 per pound ($1.50 per kilogram) with a maximum of $50 per pound ($110 per kilogram). The ex-vessel value of skates and rays peaked in 1997 at approximately $525,000, and decreased to $112,000 in 2008. It should be noted that the high price per pound (over $3.00 per pound; $6.61 per kilogram) is for rays sold for research, usually electric rays, and represents less than 0.23 percent of the total landings. The ex-vessel price of skates and rays sold for food is much lower. The apparent increase in skate landings in the 1990s may be attributed to increased landings of previously discarded catch. When the commercial groundfish fishery was divided into limited entry and open access components in 1994, new quotas and regulations were required. The significant reduction of groundfish quotas for both components created more space in boat’s holds to retain non-quota species. Trawl vessels were able to supplement groundfish landings with skate and ray bycatch. It is uncertain whether the effort to utilize the skate and ray resource has increased or if previously discarded catch is simply being retained and landed.

In 2009 new regulations require that longnose skate be sorted from other species upon landing (Title 14, CCR, §189). Previously, skate market categories were limited to only big skate and California skate, though these and other skate and ray species were mostly lumped into the “unspecified skate" market category in the absence of sorting requirements. Under federal regulations, skates had been part of the “other fish” species complex because they had not been thoroughly studied nor received a stock assessment. Longnose skate has been removed from the “other species” complex and assigned species-specific allowable biological catch values for the 2009 and 2010 management cycle. State commercial fishery samplers began sampling the species composition of commercial skate landings in 2009. Current regulations also require all skates be landed whole (FGC §5508, 8042). The possession of skate wings aboard a vessel is prohibited as there are no equivalents or conversion factors established.

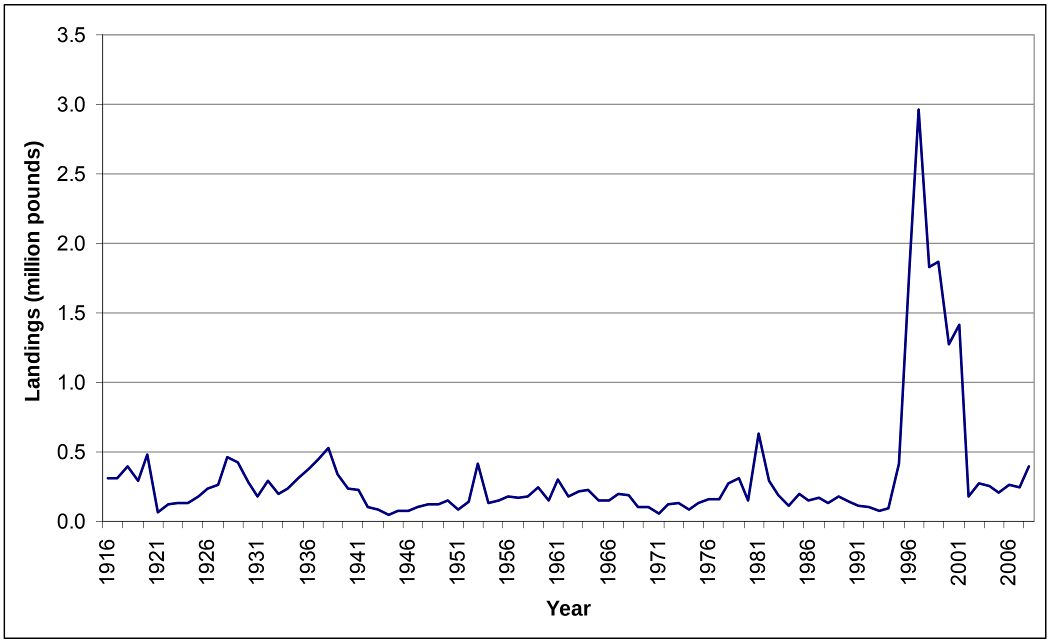


Figure 5-1. Skate commercial landings (all species combined), 1916-2008. Data source: Department catch bulletins (1916-1986) and CFIS data (1987-2008), all gear types combined.

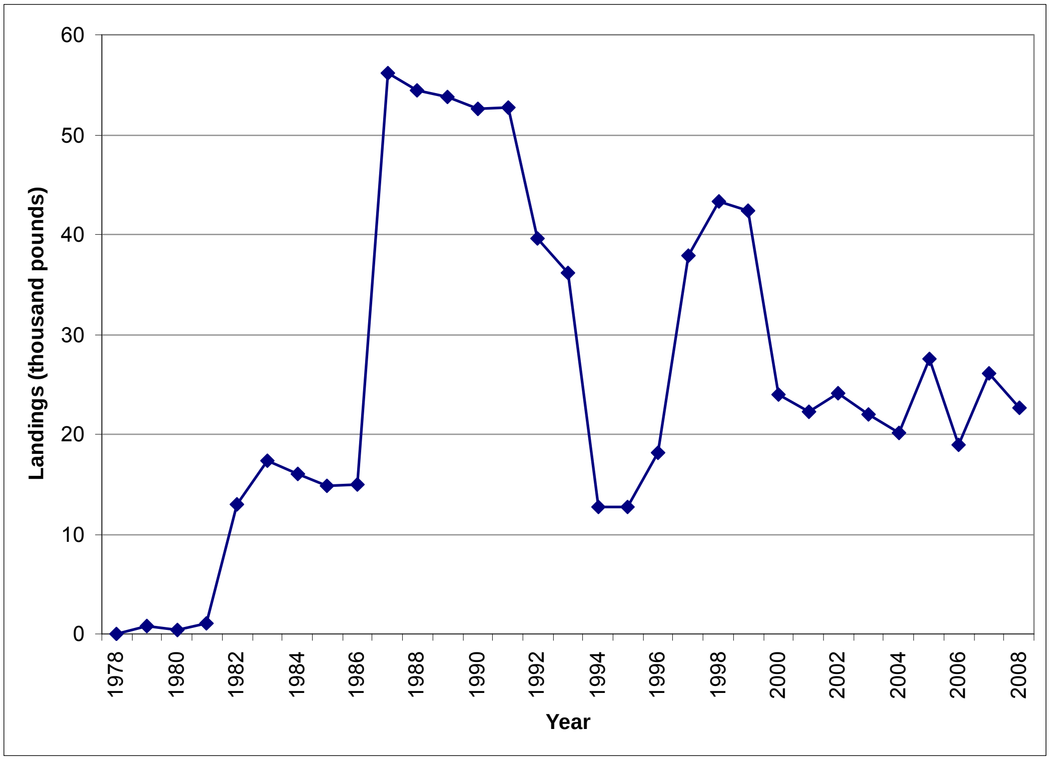


Figure 5-2. Ray commercial landings (all species combined), 1978-2008. Data source: CFIS data, all gear types combined. Data not available prior to 1978.

The recreational fishery for skate and rays is relatively meager. A few of the shallow nearshore species are targeted by small recreational fisheries. Rays dominate the catch (Figures 5-3 and 5-4); the most common species are bat rays, shovelnose guitarfish and thornbacks, *Platyrhinoidis triseriata*.

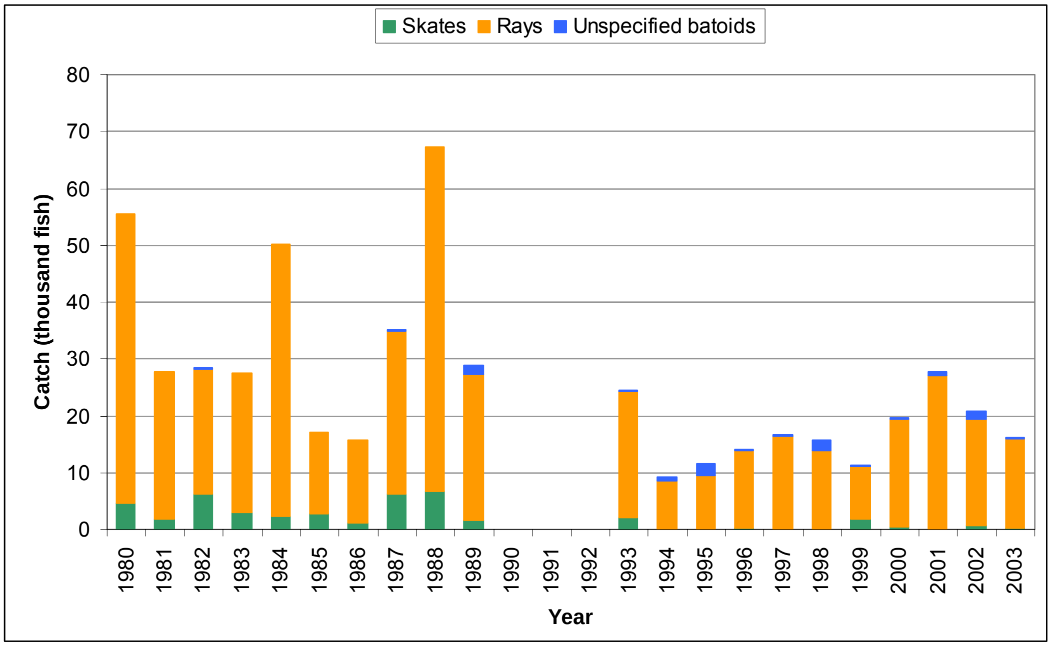


Figure 5-3. Skate and ray recreational catch (all species combined), 1980-2003. Source: MRFSS data, all fishing modes and gear types combined. Data not available from 1990-1992. CPFV data not available for central and northern California for 1993-1995.

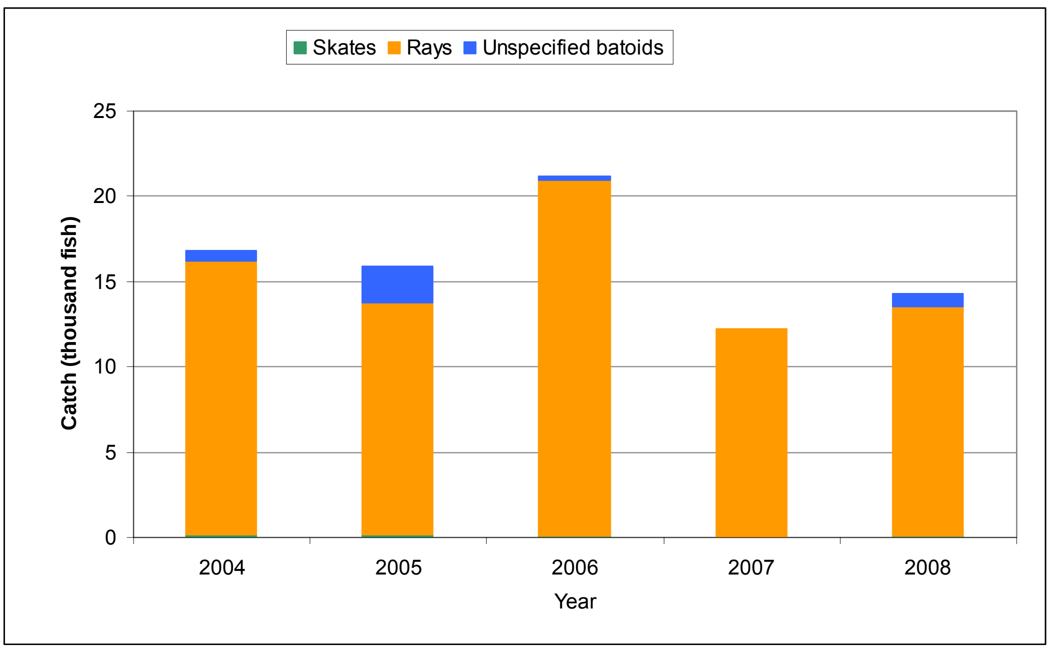


Figure 5-4. Skate and ray recreational catch (all species combined), 2004-2008. Source: CRFS data, all fishing modes and gear types combined.

Status of Biological Knowledge

The skates and rays, also known as batoids, are the largest group of elasmobranchs, comprising about 55 percent of the living cartilaginous fishes. They are often considered flattened sharks, adapted to a benthic lifestyle. Their pectoral fins expand forward and are fused to the head, forming a wide flat disc with five pairs of gill openings completely on the underside. The eyes and spiracles are positioned on the top of the head allowing them to see and respire while partially buried. The mouth is located on the ventral side, an adaptation for feeding on benthic prey. Their dorsal coloration is usually a shade of gray, brown or olive, which may camouflage them with sandy or muddy bottoms.

Batoids are found from the tropics to polar regions in all marine habitats, in shallow bays and estuaries to the open ocean to the deep continental slope in depths over 9500 feet (2895 meters) as well as in some freshwater habitats. Some species are fairly common in California waters; others are known only from a few specimens or are seasonal visitors that appear only during warm summer months or El Niño events. Like most elasmobranchs, the batoids typically have a life history strategy described by a slow growth rate, late onset of sexual maturity and few offspring. Populations with these characteristics are more vulnerable to overfishing.

Like sharks, all batoids have internal fertilization, which occurs in one of two reproductive modes. The skates are oviparous (egg layers), with fertilized eggs protected inside leathery rectangular egg cases that are deposited on the sea floor. Developing embryos are nourished through the attached egg yolk and hatch when it is depleted. Empty egg cases, often called “mermaid’s purses”, sometimes wash ashore and are found by beachgoers. The remaining batoids are all ovoviviparous. Embryos develop within the female, initially relying on an egg yolk for nutrients. After the nutrients have been consumed, embryos ingest or absorb an energy rich histotroph or “uterine milk” produced by the mother. In stingrays, this milk is secreted through hair like filaments called trophonemata. The gestation period for batoids varies widely among species, ranging from 2 months up to 3.5 years. Upon hatching, newborn batoids look like miniature adults.

Most batoids are generalized benthic predators, feeding on a wide variety of worms, mollusks, crustaceans, other invertebrates and fishes. They also employ a broad range of feeding strategies. Electric rays can shock large fishes and swallow them whole. Eagle rays can excavate hard shelled bivalves and use their plate-like teeth to crush them, whereas mantas, the largest of the batoids, filter tiny plankton. In turn, predators of batoids include marine mammals, sharks and other large fishes. For defense, some species have a sharp stinging spine in the tail whereas others have sandpapery denticles or enlarged thorns on the back and tail for protection. Currently, 22 species of skates and rays are known from California waters.

The Skates
Families Rajidae and Arhynchobatidae

The skates are the largest and most diverse group of the batoids, representing more than one-fourth of all living cartilaginous fishes worldwide. Eleven species in three genera are currently known from California waters. The three commercially important skates in California are the big skate, California skate and longnose skate.

Figure 7-4. Longnose skate, *Raja rhina*. Photo credit: Diane Haas.

Skates are characterized by a greatly flattened rhomboid-shaped disc. They often have rows of thorns or denticles on the back and tail, but they do not have stinging spines. There are two small dorsal fins near the end of the slender tail, and the caudal fin is generally weak or absent. They have paired electric organs on either side of the tail that emit weak electric signals. The exact role of these organs is unknown, but they may function in communicating with conspecifics, perhaps for recognizing mates or demonstrating aggression. Adult skates display sexual dimorphism, with males developing bell-shaped discs and rows of hooked thorns along the front and lateral edges (malar and alar thorns) of the disc for copulation. Skates occur worldwide from depths close inshore to nearly 9850 feet (3000 meters).

<u>Big skate</u>

The big skate has a stout, stiff elongated snout, typical of other hardnose skates (Rajidae). It has a diamond shaped disc, weakly notched pelvic fins, and a pair of prominent eyespots on the dorsal surface. Found from the eastern Bering Sea to southern Baja California, it inhabits shallow bays to 2624 feet (800 meters) deep, though it is more common at moderate depths. Big skates have the largest egg cases of any California's skate species, and are the only species to routinely have more than 1 embryo (up to 7) per egg case. They are also the largest skate found in California, growing up to 8 feet (2.4 meters) in length, though they are uncommon over 6 feet (1.8 meters). Maturity in females occurs at a length of 4.3 feet (1.3 meters) and 12 years; males mature at 3.6 feet (1.1 meters) around 10 to 11 years. They feed on polychaete worms, mollusks, crustaceans and benthic fishes. Predators include sevengill sharks and northern elephant seals.

<u>California skate</u>

The California skate has a moderately long, acutely pointed snout and an olive-brown dorsal surface covered with small scattered prickles. It occurs from Washington to southern Baja California. It is a common nearshore species that usually occurs on soft bottoms at depths less than 60 feet (18 meters), but has been reported from 5248 feet (1600 meters) deep. Females grow to about 30 inches (76 centimeters) in length and mature at about 20 inches (52 centimeters); males are slightly smaller. California skates feed on small benthic invertebrates.

<u>Longnose skate</u>

The longnose skate is recognized by its extremely long pointy snout. It ranges from the eastern Bering Sea to southern Baja California. It is found from nearshore to depths over 3500 feet (1069 meters), usually over mud-cobble bottoms near areas with vertical relief. Females reach a length of about 71 inches (180 centimeters), while males reach about 41 inches (105 centimeters). Maturity occurs at 28 to 39 inches (70 to 100 centimeters) and 10 to 12 years in females; males mature around 24 to 29 inches (62 to 74 centimeters) and 10 to 11 years. Longnose skates over 24 inches (60 centimeters) in length feed mostly on bony fishes while smaller skates feed more on crustaceans.

Other hardnose skate species include the Pacific starry skate, *Raja stellulata*, a common nearshore skate covered with small star-shaped prickles, and the broad skate, *Amblyraja badia*, a rare deepwater species found from 2775 to 7616 feet (846 to 2322 meters). The remaining species found in California are the softnose skates (Arhynchobatidae), which are distinguished by a short flexible snout and usually live in deeper waters. These include the Aleutian skate, *Bathyraja aleutica*, fine-spined skate, *B. microtrachys*, and roughtail skate, *B. trachura*. The sandpaper skate, *B. interrupta*, named for its prickly, sandpaper-like dorsal surface, is sometimes known as *B. kincaidii* as it may be a distinct species from the northern Pacific form, but this needs further study. The rare Pacific white skate, *B. spinosissima*, and deepsea skate, *B. abyssicola*, are some of the deepest living of all skate species, found to 9695 feet (2938 meters) and 9528 feet (2904 meters), respectively.

The Guitarfishes and Thornbacks
Families Rhinobatidae and Platyrhinidae

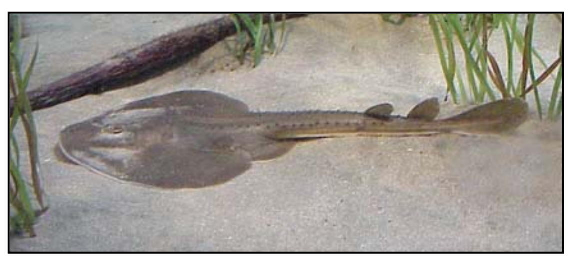


Figure 5-5. Thornback, *Platyrhinoidis triseriata*. Photo credit: Edgar Roberts.

Guitarfishes, named for their similarity in shape to the musical instrument, are easily distinguished from other rays by a flattened, wedge-shaped disc, thick tail, and prominent dorsal fins. Thornbacks share this general shape, but have a more rounded snout (Figure 5-5). Guitarfishes and thornbacks are usually found inshore on or near the bottom in warm-temperate to tropical regions. They are bottom feeders and have rows of small, pebble-like teeth used to prey mainly on invertebrates and small fishes. Three species are found in California waters.

Shovelnose guitarfish

The shovelnose guitarfish has a long pointed snout and a spade-shaped disc that is longer than wide. The dorsal surface is smooth except for a row of thorns extending along the back and tail, and coloration is olive to sandy brown. It ranges from San Francisco south to the Gulf of California, but is rare north of Monterey. This ray is generally a shallow water species found to 43 feet (13 meters) but occurs to depths of 298 feet (91 meters). It is found in shallow coastal waters, bays, sloughs and estuaries; these areas are important for mating and serve as nursery grounds. Shovelnose guitarfish are nomadic, gregarious and often abundant. During the summer pupping season prior to mating, females may outnumber males by as much as 53 to 1. After about a one year gestation, pups 6 to 9 inches (15 to 23 centimeters) long are born, with up to 28 pups per litter. Adult females reach about 5 feet (1.5 meters) in length and weigh around 40 pounds (18 kilograms) while males are smaller. Both sexes mature at around 3 feet (1 meter) in length in southern California, although females mature at 7 years and live to at least 16 years while males mature at 8 years and live to at least 11 years. Shovelnose guitarfish will partially bury themselves in sand or mud but have been observed in sea grass beds. They feed on a variety of crabs, worms, clams and fishes.

Banded guitarfish

The banded guitarfish, *Zapterx exasperata*, has a more rounded disc that is about equal in length and width. Its prickled dorsal surface has a single row of thorns along the back, and its coloration is sandy brown to dark gray with black bars. It reaches about 3 feet (1 meter) in length. Though found to depths of 656 feet (200 meters), it usually inhabits tidepools to 70 feet (21 meters) in rocky reef areas. It ranges from central California to the Gulf of California, but occurs rarely in California.

Thornback

The thornback has a heart-shaped disc and three parallel rows of large hooked thorns that extend along the back and down the narrow tail. The dorsal surface is olive to gray brown in color. Adults reach 36 inches (91 centimeters) in length. They are found from Tomales Bay to the Gulf of California, but are uncommon north of Monterey Bay. These rays are usually common inshore in waters shallower than 20 feet (6 meters) but have been found to 449 feet (137 meters). They inhabit mud and sand bottoms in bays, sloughs, coastal beaches and around kelp forests. Females mature at 19 inches (48 centimeters); males mature at 15 inches (37 centimeters). Newborn thornbacks are just over 4 inches (11 centimeters) long, born in litters of up to 15 pups. Thornbacks feed on benthic invertebrates and small fishes, and they are eaten by white sharks and Northern elephant seals.

The Electric Rays
Family Torpedinidae

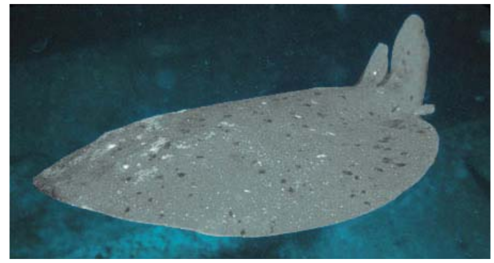


Figure 5-6. Pacific electric ray, *Torpedo californica.* Photo credit: Daniel W. Gotshall.

Electric rays, also called torpedo rays, are characterized by their smooth flabby appearance with an enlarged sub-circular disc, short stout tail and large caudal fin (Figure 5-6). Their most noteworthy characteristic is the pair of specialized kidney-shaped electric organs in the disc, composed of modified muscle cells that are capable of producing a powerful electric shock. Electric rays are found worldwide in temperate to tropical regions, usually in shallow waters but recorded to over 3500 feet (1071 meters). Prey items include crustaceans, cephalopods, worms and fishes. Solitary and nomadic, electric rays are sometimes seen floating effortlessly in the water column. Only one species is known from California waters.

<u>Pacific electric ray</u>

The Pacific electric ray, *Torpedo californica*, is bluish gray in color dorsally, often with irregular black spots, and whitish below. It ranges from northern British Columbia, Canada to central Baja California, Mexico. It occurs on sandy bottoms, rocky reefs and near kelp beds usually at 10 to 100 feet (3 to 30 meters), although one has been observed swimming in the water column at 33 feet (10 meters) over waters 9840 feet (3000 meters) deep. Females reach a length of over 60 inches (137 centimeters), while males reach 36 inches (92 centimeters). Maturity in females occurs at a length of 29 inches (73 centimeters) and 9 years; males mature at 26 inches (65 centimeters) two years earlier. Maximum age is at least 16 years but possibly 24 years. Reproduction may occur biennially in females, with pups 7-9 inches (18-23 centimeters) long born in litters of 17 to 20 pups. Pacific electric rays employ two feeding strategies to capture mainly fish but also invertebrate prey. During the day they are ambush predators, lying partially buried in the sand until immobilizing prey with electric discharges. At night or in low visibility they actively forage in the water column. They can envelope and manipulate prey items towards their mouths with their highly dexterous pectoral fins.

Pacific electric rays can discharge an electric shock of 45 volts or more, so care should be taken when encountering them. The shock is unlikely fatal to humans, however it is strong enough to knock down an adult. Extremely active at night, they will sometimes act aggressively if approached by divers and swim directly at them.

The Stingrays
Families Urolophidae, Myliobatidae, Dasyatidae, Gymnuridae, and Mobulidae

Stingrays, named for the stinging spine in the tail, are most frequently found in warm temperate and tropical waters. In California, some species are relatively common while others only occasionally appear during periods of unusually warm water. They exhibit a remarkable size range from a maximum disc width (wingtip to wingtip) of about

8 inches (20 centimeters) in some stingrays to over 20 feet (6 meters) in the manta ray. They feed on a variety of invertebrates and fishes.

Bat ray

Figure 5-7. Bat ray, *Myliobatis californica.* Photo credit: Daniel W. Gotshall.

The bat ray, *Myliobatis californica*, is a heavy bodied eagle ray with a distinct thick head and long whip-like tail (Figure 5-7). It ranges from northern Oregon to the Gulf of California usually in waters less than 164 feet (50 meters) deep. Seasonally abundant from spring to fall, bat rays are commonly found over mud and sand in bays and sloughs, which are important feeding and nursery grounds. They are also common around rocky reefs and kelp forests. Gestation lasts 9 to 12 months, and pups are 8-12 inches (20-31 centimeters) in disc width at birth. Litter size increases from 2 pups in smaller females up to 12 in larger individuals. Maturity in males occurs at a disc width around 24-26 inches (62-66 centimeters) and 2 to 3 years; females reach maturity at about 35-39 inches (88-100 centimeters) and 5 years. Females grow to larger sizes than males, reaching a maximum disc width of 6 feet (1.8 meters). Females also live much longer, to at least 24 years, while maximum age in males is estimated to be 6 years.

Bat rays feed on a wide variety of benthic invertebrates including abalone, clams, snails, shrimps, crabs, worms, sea cucumbers and brittle stars. They occasionally eat small bony fishes. Divers can often see large pits in the sand left by excavating bat rays. Preventive measures like fencing and trapping have been used to keep bat rays from preying on oyster beds; however, studies have shown that crabs and not bat rays are the culprits. In fact, keeping bat rays away from these areas may do more harm as they are prevented from feeding on these detrimental crabs.

Round stingray

California's most common stingray, the round stingray, *Urobatis halleri*, is small with a nearly round disc. Its short stout tail has a well developed caudal fin and robust serrated spine. Round stingrays are found from Humboldt Bay, California to Panama, and are most abundant south of Point Conception. A benthic species, round stingrays usually occur in shallow nearshore waters less than 50 feet (15 meters) deep, including bays and sloughs, but have been reported to at least 298 feet (91 meters). They occur on soft mud or sand bottom and are often found camouflaged in areas of abundant eelgrass. Round stingrays segregate by age and sex as males and juveniles tend to live in shallow habitats while adult females live in offshore waters deeper than 46 feet (14 meters). During the spring and summer, adult females will move inshore to mate and pup. Most females give birth each year to a litter of 1 to 6 pups after a short 3 month gestation period. Both males and females reach maturity at a disc width of 6 inches (15 centimeters) and 6 years. Males reach a maximum disc width of 10 inches (25 centimeters) and females about 12 inches (31 centimeters). Their diet changes as they mature, with shifting preferences for polychaetes, crabs and bivalves.

Round stingrays are notorious for causing injuries to many beachgoers each year. They congregate in large numbers just off beaches and will sting bathers if stepped on. Although wounds are not fatal, they can be very painful; bathers can usually avoid this danger by shuffling their feet. Attempts have been made to reduce the number of injuries by removing the spines from captured round stingrays. This has been met with limited success as round stingrays can replace their spines every year.

Diamond stingray

The diamond stingray, *Dasyatis dipterura*, and the pelagic stingray, *Pteroplatytrygon violacea*, are members of the largest stingray family, the whiptail rays. The diamond stingray is found in shallow waters to a depth of 230 feet (17 meters) over mud and sand near rocky reefs and kelp forests. It ranges from southern California to northern Chile and the Galapagos. Rare in California waters, it appears more frequently and in greater numbers during periods of warm water. Its maximum reported size is 47 inches (120 centimeters) disc width.

Pelagic stingray

The pelagic stingray is an oceanic species, found from the upper surface to at least 780 feet (238 meters) in depth over very deep water. This migratory stingray is found worldwide in warm temperate and tropical regions, and has been recorded year round in California waters though it is rare north of Monterey Bay. It reaches a maximum disc width of 32 inches (80 centimeters), though stingrays in captivity may grow to 38 inches (96 centimeters). Both the pelagic stingray and diamond stingray have very long stinging spines that are potentially hazardous to humans.

California butterfly ray

The California butterfly ray, *Gymnura marmorata*, is found in warm temperate and tropical waters along sandy beaches and in shallow lagoons. It ranges from southern California to the Gulf of California and Peru. It is identified as the only California ray with a very broad disc that is nearly twice as wide as long, reaching 48 inches (122 centimeters) in females.

Manta

The manta, *Manta birostris*, and the spinetail mobula, *Mobula japanica*, are both found worldwide in warm temperate and tropical regions. These two members of the devil ray family, distinguished by their broad pectoral wings and hornlike cephalic fins, are occasionally found in southern California waters. They are usually seen at the surface swimming individually or in large groups. The manta is the largest known ray, attaining a wing span of at least 22 feet (6.7 meters). The spinetail mobula is smaller, reaching a maximum width of 10.1 feet (3.1 meters). Mantas and mobulas are the only filter feeding batoids. They channel great quantities of water through specialized gill plates and strain out planktonic crustaceans and small fishes.

Status of the Population

There is considerable uncertainty regarding current or past population levels of California's skates and rays. It is unknown how the dramatic increase in landings in the mid 1990s affected the resource. Fishes that were previously discarded, both dead and alive, are now retained and landed. Given the past and potential increase in landings, skates and rays should be closely monitored. The life history of skates and rays is usually described by slow growth, late onset of maturity and low fecundity when compared to bony fishes. These characteristics leave most species vulnerable to overfishing. Decreases in skate and ray landings have already been observed in other regions. In the north Atlantic, fishing pressure has altered the abundance, distribution, and population structure of several skate species and overfishing has apparently occurred.

The first assessment for longnose skate populations off the U.S. west coast was completed in 2008, and represents the only stock assessment for any batoid occurring in California waters. Results of the assessment indicated that the biomass of the longnose skate population has been gradually decreasing from its unfished level in 1915. The estimated 2007 spawning stock biomass was at about 66 percent of the unfished stock level and was above the 25 percent overfishing threshold. The population model suggested a generally low harvest rate for longnose skates. This is expected given that longnose skates, along with other skate species, have not historically supported a directed fishery along the U.S. west coast.

The effect of recreational fisheries on the skate and ray resource is relatively unknown. Surveys of 55 shark derbies between 1951 and 1995 in Elkhorn Slough show that shovelnose guitarfish, which were the second most caught elasmobranch in the 1950s and 1960s, nearly disappeared from the catch by the 1970s. Shovelnose guitarfish declined to only about three percent of the catch by the 1990s, but coincided with an increase in the occurrence and relative abundance of thornbacks. The relative abundance of bat rays steadily increased over the years though the average number caught per derby declined during the last two decades. It is likely that a combination of fishing pressure, habitat alteration and oceanographic conditions influenced elasmobranch abundance and distribution. However, recreational fisheries sampling data show continued catches of bat rays, shovelnose guitarfish and thornbacks. It is difficult to determine the total numbers of skates and rays caught as sampled catch numbers vary considerably from year to year.

Management Considerations

Three species of skate, big skate, California skate and longnose skate, became federally designated groundfish in 1982 when the PFMC adopted the Pacific Coast Groundfish Fishery Management Plan. Prior to 1982, this species was managed by the California Department of Fish and Game (Department) through regulations adopted by the state legislature and the California Fish and Game Commission. All other skate and ray species are managed by the state. The recent longnose skate stock assessment provides a basic foundation for the management of longnose skates; however, the assessment relied on some critical assumptions based on limited supporting data. More research is needed to improve the longnose skate population model and to produce effective management plans for other skate and ray species in California. The information needed includes:

1. Landing data on size, sex and species composition of the recreational and commercial catch.
2. Survival rates for released catch.
3. Life history parameters for many of the species involved, including age determination and age validation studies.
4. Population dynamics including movement. This information will help determine if increased landings of previously discarded catch are altering the impact to the species involved.
5. Genetic studies to determine stock structure.

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Further Reading

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Skate commercial landings (all species combined), 1916-2008.

Year	Pounds	Year	Pounds	Year	Pounds
1916	307,716	**1947**	103,696	**1978**	275,057
1917	314,837	**1948**	119,101	**1979**	309,521
1918	398,031	**1949**	123,464	**1980**	155,216
1919	295,800	**1950**	153,758	**1981**	631,420
1920	479,812	**1951**	84,634	**1982**	287,808
1921	69,932	**1952**	138,716	**1983**	185,690
1922	121,210	**1953**	415,669	**1984**	116,293
1923	134,353	**1954**	136,221	**1985**	195,837
1924	131,137	**1955**	152,622	**1986**	150,125
1925	183,484	**1956**	175,751	**1987**	169,691
1926	232,993	**1957**	171,678	**1988**	127,852
1927	263,715	**1958**	176,896	**1989**	174,838
1928	458,926	**1959**	240,801	**1990**	143,732
1929	427,986	**1960**	146,934	**1991**	113,144
1930	286,390	**1961**	299,317	**1992**	103,469
1931	174,785	**1962**	182,178	**1993**	78,070
1932	292,412	**1963**	216,825	**1994**	93,391
1933	193,711	**1964**	222,705	**1995**	413,278
1934	232,175	**1965**	153,475	**1996**	1,830,076
1935	307,122	**1966**	154,014	**1997**	2,965,274
1936	381,944	**1967**	196,751	**1998**	1,834,740
1937	447,392	**1968**	186,350	**1999**	1,869,295

Skate commercial landings (all species combined), 1916-2008.					
Year	**Pounds**	**Year**	**Pounds**	**Year**	**Pounds**
1938	528,273	**1969**	106,068	**2000**	1,273,491
1939	336,854	**1970**	102,982	**2001**	1,410,925
1940	238,287	**1971**	61,223	**2002**	180,794
1941	224,698	**1972**	118,386	**2003**	275,452
1942	105,691	**1973**	133,433	**2004**	251,939
1943	81,109	**1974**	86,158	**2005**	210,418
1944	50,419	**1975**	135,291	**2006**	268,286
1945	74,009	**1976**	161,137	**2007**	247,495
1946	78,038	**1977**	161,426	**2008**	392,313

Data source: Department catch bulletins (1916-1986) and CFIS data (1987-2008), all gear types combined.

Ray commercial landings (all species combined), 1978-2008.					
Year	**Pounds**	**Year**	**Pounds**	**Year**	**Pounds**
1978	57	**1989**	53,728	**1999**	42,432
1979	839	**1990**	52,633	**2000**	24,018
1980	447	**1991**	52,704	**2001**	22,286
1981	1,100	**1992**	39,663	**2002**	24,163
1982	12,967	**1993**	36,163	**2003**	21,976
1983	17,306	**1994**	12,773	**2004**	20,110
1984	15,969	**1995**	12,740	**2005**	27,590
1985	14,771	**1996**	18,089	**2006**	18,924
1986	14,993	**1997**	37,903	**2007**	26,027
1987	56,143	**1998**	43,288	**2008**	22,672
1988	54,461				

Data source: CFIS data, all gear types combined. Data not available prior to 1978.

Skate and ray recreational catch (all species combined), 1980-2003.			
Year	**Number of fish**	**Year**	**Number of fish**
1980	55,607	**1992**	---
1981	27,700	**1993**	24,558
1982	28,362	**1994**	9,142
1983	27,541	**1995**	11,498
1984	50,077	**1996**	14,125
1985	17,208	**1997**	16,657
1986	15,795	**1998**	15,621
1987	35,115	**1999**	11,375
1988	67,281	**2000**	19,625
1989	28,823	**2001**	27,820
1990	---	**2002**	20,920
1991	---	**2003**	16,162

Data source: MRFSS data, all fishing modes and gear types combined. Data not available from 1990-1992. CPFV data not available for central and northern California for 1993-1995.

Skate and ray recreational catch (all species combined), 2004-2008.	
Year	**Number of fish**
2004	16,852
2005	15,878
2006	21,154
2007	12,211
2008	14,300

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

6 Sturgeons, *Acipenser spp.*

White Sturgeon, *Acipenser transmontanus*. Photo credit: Department.

History of the Fishery

The sturgeon fishery has been of major importance to California historically. Sturgeon remains found in Native American middens in the San Francisco Bay area, Sacramento-San Joaquin Delta and Elkhorn Slough indicate that sturgeon were an important nutrition source for some California native populations. A commercial sturgeon fishery developed in the San Francisco Bay estuary between the 1860s and 1901 to supply the increasing demand for caviar and smoked sturgeon in the eastern United States. White sturgeon, *Acipenser transmontanus*, has been the primary species taken in the commercial and recreational fisheries with green sturgeon, *A. mediostris*, taken in smaller amounts. Gear used in the commercial fishery included gill nets, long lines and snagging hooks. The commercial fishery peaked in 1887 when 1.65 million pounds (748 metric tons) were landed, fell to 0.3 million pounds (136 metric tons) in 1895, and to 0.2 million pounds (91 metric tons) in 1901. Heavy commercial fishing led to serious resource depletion by 1900 and the fishery for sturgeon closed in 1901. The fishery reopened in 1909; however, small catches indicated that the population was still depressed. The commercial and recreational sturgeon fisheries closed in 1917; the commercial fishery closing permanently.

The recreational fishery for sturgeon (white and green combined) was re-established in 1954 with a 40 inch (102 centimeter) total length (TL) minimum size limit, no seasonal closure, and a one fish per day bag limit. A tagging study conducted in 1954 showed that white sturgeon weight increases slowly until the total length reaches 35 inches (89 centimeters) and then varies depending on size. The study also showed the fishery is dependent upon widely spaced strong year classes. This tagging study resulted in a recommendation of a 50 inch (127 centimeter) size limit for both species to provide a buffer stock of larger fish for anglers and to insure maintenance of an adequate spawning stock.

The new size limit was implemented in 1956, the same year snagging sturgeon became illegal—sturgeon may only be taken by angling, which is defined as the fish voluntarily taking the bait or lure in its mouth (Title 14, CCR, §5.80). The minimum size limit returned to 40 inches (201 centimeters) in 1964. Concern over potential depletion of the sturgeon resource in the late 1980s prompted regulation changes starting in 1990 with the implementation of a 72 inch (183 centimeter) TL maximum size limit, creating the first slot size limit regulation for a marine species. The slot size limit protects smaller, juvenile fish as well as larger fish with the highest reproductive capacity. In 1990 the minimum size limit was increased by 2 inches (5 centimeters) each year until 1992 when a minimum size limit of 46 inches (117 centimeters) was reached (Title 14, CCR, §5.80).

In 2006 the National Marine Fisheries Service (NMFS) determined that the North American green sturgeon Southern Distinct Population Segment (DPS), which includes the populations originating from coastal watersheds south of the Eel River, is at risk of extinction in the foreseeable future throughout all or a significant portion of its range and listed the species as Threatened under the Federal Endangered Species Act (ESA). As a result, the California Fish and Game Commission, upon a recommendation by the California Department of Fish and Game (Department), closed the recreational fishery for green sturgeon in 2007 (Title 14, CCR, §5.81).

In 2007, a suite of new recreational fishing regulations were implemented for the white sturgeon fishery to reduce the white sturgeon catch and the bycatch of threatened green sturgeon, and to assist enforcement. The new regulations provide for an annual limit of three white sturgeon, a reduction in the maximum size limit to 66 inches (168 centimeters) TL, a requirement to record all catch on a Sturgeon Fishing Report Card, and a requirement to tag all retained white sturgeon (Title 14, CCR, §5.79 and 5.80).

The report card information will provide fishery-dependent data, and the tagging requirement is intended to help anglers to comply with the annual bag limit. All anglers targeting or retaining sturgeon are required to possess the card, including those anglers that are not required to possess a fishing license, such as anglers under the age of 16 and people fishing from a public pier or fishing on free fishing days. Regulations require anglers that catch and release green sturgeon incidentally while fishing for white sturgeon record their green sturgeon catch on the Sturgeon Fishing Report Card along with any white sturgeon taken (whether kept or released). Anglers are required to return the card to the Department by January 31 of the following year.

Data from the 2007 Sturgeon Fishing Report Card show that approximately 41,000 cards were issued. Of these, 6573 cards were returned by anglers and 1801 cards had data on sturgeon catch. Anglers reported keeping 1399 white sturgeon, and releasing 4612 white sturgeon and 311 green sturgeon. White sturgeon catch was greatest in Suisun Bay, the Sacramento River from Rio Vista to Chipps Island [10 mile (16 kilometer) stretch of river near Suisun Bay], and Montezuma Slough (north of Suisun Bay). Angler reported lengths of retained white sturgeon averaged 55 inches (139 centimeters) TL and ranged from 12 to 68 inches (30 to 172 centimeters). While anglers are not required to provide the length of released white sturgeon, many volunteered such data. The average TL of released white sturgeon was approximately 44 inches (112 centimeters).

Green sturgeon catch was greatest in the Sacramento River from Red Bluff to Colusa (100-mile stretch of river north of Sacramento), and the Sacramento River from Rio Vista to Chipps Island (20-mile stretch of river inland from Suisan Bay). While anglers are not required to provide the length of green sturgeon released, many anglers did provide green sturgeon length information. The reported lengths ranged from 19 to 86 inches (48 to 218 centimeters) and averaged 37 inches (94 centimeters) TL.

Sturgeon is an important target species for some commercial passenger fishing vessels (CPFV) fishing inside San Francisco and San Pablo bays. Some operators specialize in sturgeon fishing, offering passengers sturgeon-only trips. All CPFV operators are required to submit a log of daily fishing activity to the Department. Green and white sturgeon are not differentiated on the CPFV logs and the catch is reported as “sturgeon”. As white sturgeon make up the majority of the total sturgeon recreational catch, it is believed that the CPFV catch of white sturgeon is larger than the green sturgeon catch. Following regulatory changes for white sturgeon beginning in 1990, reported catch by anglers aboard CPFVs decreased compared to catch reported for the 1980s (Figure 6-1).

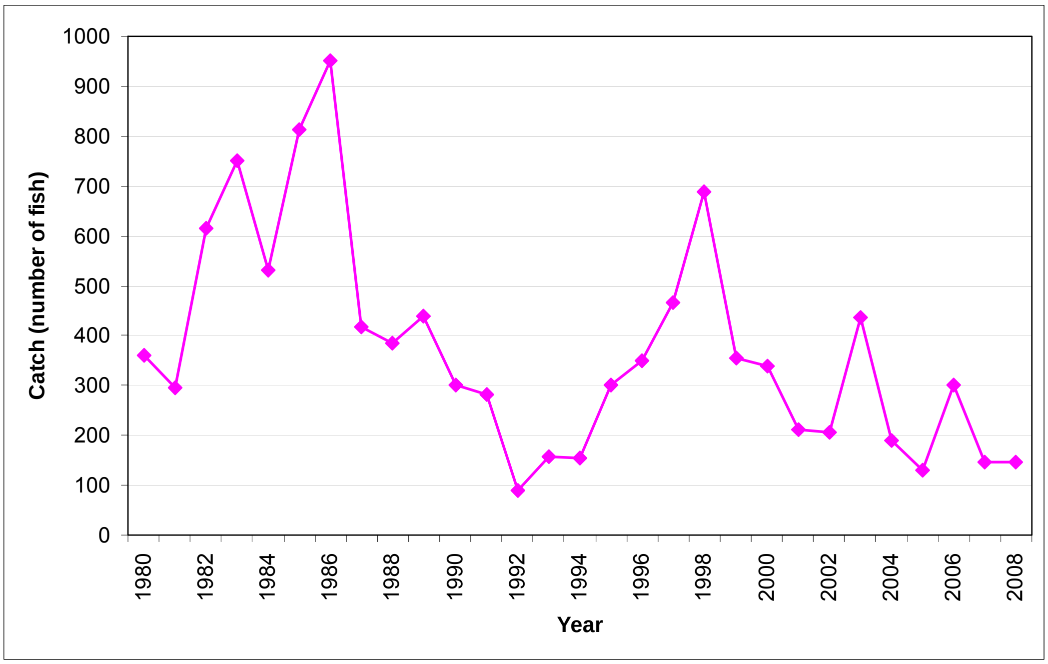

Figure 6-1. Sturgeon commercial passenger fishing vessel (CPFV) catch (all species combined), 1980-2008. Data Source: CPFV logbook data.

Green sturgeon may have been of historical importance to Native Americans living on California’s north coast. While recreational fishing regulations prohibit recreational anglers from taking sturgeon in the rivers of Del Norte, Humboldt and Mendocino counties, a tribal fishery for green sturgeon continues today on the Klamath River in California. These green sturgeon are believed to be from the Northern DPS and are not protected.

Poaching, primarily to supply black market demand for caviar, makes up an unknown yet potentially significant portion of the white sturgeon total catch and is a serious concern. For green sturgeon, poaching represents a real threat to the survival of the species. Undercover operations by Department wardens have resulted in 8 major cases against sturgeon poaching rings since 2003. Recent amendments to FGC

§7370, 12006 and 12157 (Assembly Bill 1187, DeSaulnier 2007) substantially increased the penalty for illegal commercialization of sturgeon and made it easier to establish intent to illegally commercialize sturgeon.

Status of Biological Knowledge

White Sturgeon

White sturgeon are long-lived, slow growing anadromous fish ranging from the Gulf of Alaska to Ensenada, Mexico. Spawning populations have been found only in large rivers from the Sacramento-San Joaquin River system north. In California, white sturgeon are most abundant in the San Francisco Bay estuary. Some white sturgeon move into the Sacramento River Delta and lower Sacramento River during late fall and winter. Some fish move 90 miles (145 kilometers) up the river to the Knights Landing-Hamilton City area (Yolo County) to spawn. Anecdotal information indicates that a small number of adult white sturgeon occur in the San Joaquin River mainstream upstream from the Delta. White sturgeon spawning in the San Joaquin River is suspected to occur in wet, high water years but has never been confirmed. Catches of two unidentified juvenile sturgeon in the Mokelumne River in 2003 could be the first documentation of sturgeon spawning in a San Joaquin River tributary. Spawning may also occur in the Feather River, but has not yet been documented there.

Spawning occurs in the Sacramento River between mid February and late May when water temperatures are 46 to 72°F (8 to 22°C). The spawning season of white sturgeon in the Klamath River is unknown. Little is known about sturgeon spawning behavior. White sturgeon are broadcast spawners in deep holes with fast-moving water. Compared with most freshwater or anadromous fishes, white sturgeon are quite old when they become sexually mature. Age at maturity differs between the sexes – mature males are 9 to 25 years old and 3.6 to 6 feet long (1.1 to 1.8 meters), while mature females are generally 14 to 30 years old and 4.6 to 6.6 feet long (1.4 to 2.0 meters). High natural variability in the size at sexual maturity has been observed, especially among females. Studies suggest that female white sturgeon do not spawn every year; several years may pass between successive spawning by an individual female. One study showed that approximately 50 percent of the males captured were approaching spawning condition for that year, compared with only about 15 percent of the captured females. The female white sturgeon fecundity is impressive; one 9.2 foot, 460 pound (2.8 meters, 209 kilogram) female contained 4.7 million eggs. Smaller females (less than 5 feet; 1.5 meters) may contain 100,000 eggs. Fertilized eggs hatch after 4 to 12 days on the bottom. Larvae stay close to the bottom and rear in both the river and the estuary. Rearing location is at least partly determined by river flow – when freshwater flows are high, more larvae are washed into the estuary.

Young white sturgeon grow rapidly, reaching 17 inches (43 centimeters) TL during the first year. Growth slows after the first year to 1 to 2.5 inches (2.5 to 6 centimeters) per year, reaching the current minimum size limit of 46 inches (117 centimeters) TL after 9 to 16 years. Water temperature and dissolved oxygen concentration have a significant impact on growth. The rapid growth capability of white sturgeon has resulted in aquaculture farm development to raise sturgeon for the caviar and fish meat markets.

Historical records of large white sturgeon indicate fish that may have reached lengths greater than 18 feet long, weighed more than 1800 pounds (549 centimeters, 816 kilograms), and possibly reached 100 years of age. This makes the white sturgeon the largest freshwater fish in North America. The current world record recreationally-caught white sturgeon was a 468 pound (212 kilogram) fish taken from the Carquinez Strait area (inland from San Pablo Bay, Solano County) in 1983.

While the oceanic movements of sturgeon are poorly known, most recoveries from tagging programs in the San Francisco Bay estuary have come from the estuary and its tributaries; a few fish have moved along the Pacific coast and been recovered in Oregon and Washington. One white sturgeon was recently documented with radio telemetry to move between the Klamath River in northern California and the Fraser River in British Columbia, Canada. This fish spent long periods of time in at least two very different river systems (one clear and one highly turbid), making determination of the home river uncertain. Large scale movements of sturgeon outside the home river may have serious implications for stock assessments and management.

Young white sturgeon feed primarily on small crustaceans such as amphipods. As they grow, white sturgeon begin to prey upon a wider variety of benthic invertebrates such as crabs, clams and shrimp. The diet of larger white sturgeon includes fishes and, during winter in San Francisco Bay, herring roe. A diet study of fish caught by anglers aboard CPFVs from 1965 through 1967 in the San Pablo Bay and Carquinez Strait-Lower Suisun Bay areas showed that prey items were closely associated with shallow estuarine mudflat areas. Sturgeon feed by suction with their ventral, protrusible mouths. Dense aggregations of taste buds located on the barbels are believed to assist with food identification.

Very little is known about white sturgeon predators. Larger fish are taken by sea lions. Smaller sturgeon are preyed upon by various fish and perhaps birds. The sturgeon’s five lines of sharp, bony scutes may discourage predators and send them searching for more desirable prey.

White sturgeon may be distinguished from green sturgeon by the number of scutes; white sturgeon have more than 38 scutes along the body and no scutes behind the dorsal fin while green sturgeon have 28-30 scutes along the body and 1 to 2 scutes behind the dorsal fin. White sturgeon have a comparatively short and broad snout, with barbells closer to the end of the snout than to the mouth.

Green Sturgeon

Green sturgeon (Figure 6-2) are long-lived, slow growing, anadromous fish and are the most marine-oriented and widely distributed of the sturgeon species, ranging from the Bering Sea to Ensenada, Mexico. Green sturgeon spend the majority of their lives in nearshore marine waters, bays and estuaries. It is believed that green sturgeon spend much less time in the San Francisco Bay estuary, either as young or adults, than white sturgeon. Spawning populations have been found only in medium sized rivers from the Sacramento-San Joaquin River system northward. Current California spawning areas are believed to include the Klamath River Basin and the Sacramento River. Green sturgeon have been reported from the Feather, Yuba, Bear, Trinity and Eel rivers, but it is unclear if spawning takes place in these rivers. There is no evidence to indicate that green sturgeon were historically present or are currently present in the San Joaquin River upstream from the Delta.

Figure 6-2. Green Sturgeon, *Acipenser medirostris*. Photo credit: Department.

Adult green sturgeon usually migrate from salt water into fresh water beginning in late February. Spawning takes place in the Sacramento River from April-July, peaking in May, and March-July, peaking April-June, in the Klamath River. Green sturgeon spawn less frequently with age. Spawning occurs in deep, fast-moving water in river mainstreams. Little is known about sturgeon spawning behavior. Age at maturity differs between the sexes—first spawning for males occurs at 14 years and at 16 years for females. Fecundity is dependent on the size of the female, ranging from approximately 59,000 to 242,000 eggs per female. These numbers are lower than those for white sturgeon, as green sturgeon are smaller than white sturgeon and green sturgeon eggs are larger than white sturgeon eggs. Fertilized eggs hatch after 4 to 12 days. Larvae stay close to the bottom and are believed to reside and develop in rivers well upstream of estuaries. Young fish grow rapidly, possibly reaching 12 inches (31 centimeters) in the first year. By 9 years an average green sturgeon will be 39 inches (100 centimeters) TL; an average 33 year old fish will be 79 inches (201 centimeters) TL. Juvenile green sturgeon are believed to reside in fresh water for the first one to three years of life, then migrate to the ocean, where they disperse widely until they reach sexual maturity and return to their natal waters to spawn.

Green sturgeon have been reported to reach ages of 60-70 years, and historical accounts report fish up to 350 pounds (159 kilograms). The oldest fish sampled from the Klamath River tribal fishery from 1999 through 2003 were estimated to be about 40 years old; the largest fish was 95 inches (241 centimeters) TL and weighed 160 pounds (73 kilograms).

Young green sturgeon feed primarily on small crustaceans such as amphipods. As they grow, green sturgeon begin to prey upon a wider variety of benthic invertebrates such as crabs, clams and shrimp. The diet of larger sturgeon includes fishes. Sturgeon feed by suction with their ventral, protrusible mouths. Dense aggregations of taste buds located on the barbels are believed to assist with food identification.

Very little is known about green sturgeon predators. Large fish are taken by sea lions. Smaller sturgeon are preyed upon by various fish and perhaps birds. The sturgeon's five lines of sharp, bony scutes may discourage predators and send them in search for more desirable prey.

Green sturgeon may be distinguished from white sturgeon, with which they co-occur, by the number of scutes—green sturgeon have 23-30 scutes along the body and 1-2 scutes behind the dorsal fin; white sturgeon have more than 38 scutes along the body and no scutes behind the dorsal fin. Green sturgeon also have a relatively long snout with barbels closer to the mouth than to the tip of the snout compared to white sturgeon.

Status of the Population

The decline in white sturgeon landings in the commercial fishery that took place in the late 1800s and early 1900s shows the species' vulnerability to overexploitation. The length of time required to reach sexual maturity compared to other freshwater and anadromous species and infrequent spawning by females contribute to this vulnerability. Department tagging studies found that angler harvest rates were high during the 1980s. The relatively high catches in the 1980s renewed concern over possible depletion of the resource and led to angling regulation changes starting in 1990 with the creation of the slot size limit.

White sturgeon abundance in the Sacramento-San Joaquin watershed has varied greatly over time. Angler catch and mark-recapture study information suggest that strong year classes since 1980 have been produced only during 5 of the 10 years when the Sacramento Valley Water Year Index was rated 'wet'. Abundance estimates of white sturgeon in the Sacramento River–San Joaquin River Estuary estimated that approximately 142,000 adults greater than 40 inches (102 centimeters) TL were present in 1997. Spawning biomass has at times been very low due in part to the interaction of harvest and successive years of poor recruitment. Research and monitoring is focused on learning more about the factors affecting year class strength, improving the precision of abundance estimates, understanding out-of-system migrations, and developing the potential to limit harvest through use of a quota.

Management Considerations

NMFS listed the green sturgeon's Southern DPS, which includes the spawning population in the Sacramento River, as Threatened under the ESA on April 7, 2006. The Department considers the green sturgeon a Species of Special Concern. The Northern DPS, which includes all spawning populations north of the Sacramento River, is considered a federal Species of Concern.

The Southern DPS is considered likely to become endangered in the foreseeable future. The determination to list the Southern DPS as federal Threatened was based on a number of risk factors including: information showing that the majority of spawning adults are concentrated into one spawning river, the Sacramento, which increases the risk of extinction due to catastrophic events; and information showing evidence of lost spawning habitat in the Sacramento River above Shasta Dam and in the Feather River above Oroville Dam. Unlike white sturgeon, green sturgeon are present in the upper Sacramento River below Shasta Dam year round and angler bycatch of green sturgeon on spawning grounds may be a cause for concern. Insufficient freshwater flow rates in spawning areas, contaminants, elevated water temperatures and entrainment of individuals into water diversion projects are additional risk sources.

The Northern DPS includes populations in the Rogue, Klamath-Trinity and Eel rivers. The Northern DPS is not considered to be in danger of extinction or likely to become an endangered species in the foreseeable future. The two main spawning populations, in the Rogue and Klamath-Trinity rivers, occupy separate basins, reducing the potential for loss of the DPS through catastrophic events. While harvest has been reduced and green sturgeon in this DPS do not face substantial entrainment loss, there are significant concerns due to lack of information, water flow and temperature issues, and habitat degradation.

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Sturgeon recreational commercial passenger fishing vessel (CPFV) catch (all species combined), 1980-2008.

Year	Number of fish	Year	Number of fish
1980	361	**1995**	300
1981	295	**1996**	349
1982	614	**1997**	466
1983	750	**1998**	688
1984	530	**1999**	354
1985	812	**2000**	339
1986	952	**2001**	212
1987	418	**2002**	207
1988	386	**2003**	436
1989	438	**2004**	191
1990	302	**2005**	130
1991	283	**2006**	301
1992	90	**2007**	147
1993	156	**2008**	147
1994	155		

Data source: CPFV logbook data.

7 Eulachon, *Thaleichthys pacificus*

Eulachon, *Thaleichthys pacificus*. Photo credit: Department.

History of the Fishery

Eulachon, *Thaleichthys pacificus*, is a small anadromous smelt that spawns in the lower reaches of coastal rivers and streams from southeastern Alaska to northern California. Eulachon were called “candlefish” by early explorers due to their high oil content (20 percent by weight), which allowed them to be burned like candles when dried. Nearly all eulachon spawning runs have declined in the last twenty years, especially since the mid 1990s, and in March 2009, the National Marine Fisheries Service (NMFS) proposed listing it as Threatened under the federal Endangered Species Act (ESA).

Although there are reports of 56,000 pounds (25 metric tons) of eulachon sold in the Klamath area circa 1963, official records of smelt commercial landings by species began in 1977. According to the Commercial Fisheries Information System (CFIS), the largest landing of eulachon occurred in 1987 when 3046 pounds (1.4 metric tons) were landed. Since 1990, there have only been two small (each less than 30 pounds; 14 kilograms) commercial landings of eulachon in California.

There is no record of any recreational harvest in California’s ocean fisheries or river hook and line fisheries. Although eulachon supported Native American subsistence dip net fisheries for centuries, and an inland recreational dip net fishery beginning in the 1870s in the Klamath Basin, most of the California dip net fisheries ceased to exist in the late 1980s, coinciding with the decline of noticeable spawning populations in the Klamath River, Mad River and Redwood Creek. To the Yurok Tribe, who reside in the Klamath River Basin, eulachon is considered a “Tribal Trust Species” and still has major cultural significance.

Status of Biological Knowledge

Eulachon are members of the family Osmeridae (true smelts) and are the only species in the genus *Thaleichthys*, which means rich or oily fish. Eulachon range from the Bering Sea to Humboldt Bay, California, and have been observed at depths up to 600 feet (1969 meters). The latest study (1996) conducted by the Yurok tribe found no eulachon in the Klamath River. In the past, the main spawning population in California occurred in the Klamath River with typically smaller runs in the Mad River and Redwood Creek. This spawning population represented the southern most population of the species. In January 2006, a mature male eulachon was caught in a juvenile salmonid monitoring rotary screw trap operation at Knights Landing in the Upper Sacramento

River, indicating that this species is not locally extirpated; however, abundance is very low.

Figure 7-1. Eulachon head showing gill cover with concentric rings and upper jaw length. Photo credit: Department.

Eulachon are the largest of the smelts with mature adults ranging from 7 to 12 inches (17 to 31 centimeters) in length. Their coloration is bluish-brown with fine black speckling on the back and head with silvery sides and belly. They are described as having a thin, long body and a moderately large mouth with an upper jaw bone that extends past the pupil. Striations on the gill cover are prominent and concentric; and the lateral line is complete (Figure 7-1). The pectoral fins extend about two-thirds of the way to the base of the pelvic fins. The first dorsal fin and the anal fin have rays, while the second dorsal fin is adipose (fatty and without rays). Their teeth are small and pointed, with two noticeable canine-like teeth at the top of their mouth.

Although they spawn in the lower reaches of fresh water rivers and streams, eulachon are primarily a marine fish, spending over 95 percent of their lives in ocean waters. In addition, they return to their natal streams, similar to salmonids, although their homing seems to be based more on estuarine water imprinting and is not stream specific. They are broadcast spawners that begin their upstream migration as early as December and peak in March and April. In the Klamath River, adults were usually seen migrating from the mouth of the Klamath to Brooks Riffle (inland 12 miles; 33 kilometers) and occasionally as far upstream as Weitchpec (inland 46 miles; 99 kilometers). They spawned over coarse sand and fine gravel beds with good flowing water. Substantial runs of eulachon on the Klamath River were easily identified by flocks of gulls, increased sea lion activity, and a continuous mass of fish at the water's shoreline.

Eulachon can be sexually mature by age two, but most spawn and die in their third year. A few may live to spawn again in their fourth year, with very few fish making it to year five. However, a recent otolith study suggested that the southern distribution of eulachon is semelparous (spawn only once). During spawning, eulachon may lose (reabsorb) their teeth and the males will develop a pronounced midlateral ridge. The males also develop tubercles (raised growths) on their fins, body and head; tubercle development is not as distinct on the spawning females. The males would typically arrive at the spawning grounds ahead of the females. As the males release their milt, females would lay 25,000 eggs each on average. The fertilized eggs have a double membrane; the outer membrane ruptures and then sticks to the substrate. The larval eulachon hatch in about a month and are washed out to the estuary and nearshore ocean environment. Adult eulachon spend most of their lives in schools between the nearshore and the outer continental shelf environments.

In the ocean, eulachon primarily feed on crustaceans such as euphausiids (krill) and copepods. They are an important part of the diet of many marine mammals, fishes, and birds. Eulachon do not feed in fresh water when they return to spawn.

Status of the Population

Information on the spawning populations in northern California are dependent on direct observations by Yurok tribal members and local biologists. No long term population studies have been conducted; however, it is thought the populations first began declining in the 1970s. Spawning populations were last noticed by Yurok tribal members in the late 1980s.

In 1996, the Yurok Tribal Fisheries Program attempted to sample the eulachon run in the lower Klamath River using dip nets and electrofishing methods. The survey included over 110 hours of survey time and was conducted from early February though early May. No eulachon were sampled in the survey. It appears that the northern California eulachon population has experienced a period of low abundance for over 20 years and may be nearly extirpated from California. Several factors such as changing ocean conditions, dams and water diversions may have led to the decline in spawning populations of eulachon in California; however, these factors have not been studied.

Management Considerations

In 1995, eulachon was designated a state Species of Special Concern by the California Department of Fish and Game which means the species appears to be declining and the population needs to be monitored.

In July of 1999, NMFS received a petition to list the Columbia River eulachon as threatened or endangered. Substantial scientific information was not presented by the petition at that time and additional evaluation of eulachon by state and tribal entities was recommended by NMFS.

In 2000, eulachon was elevated to a federal Species of Concern which signals the species is in serious decline and special management is needed to keep it from being listed as threatened or endangered under the ESA.

In November 2007, NMFS was petitioned to list the southern distribution (in Washington, Oregon and California) of eulachon as threatened or endangered under the ESA. In March 2008, it was determined that substantial scientific information was presented by the petition and a status review of the species was initiated. One year later, the status review of the species was complete and NMFS proposed the listing of eulachon south of the Nass River in British Columbia, Canada, as a federal Threatened species.

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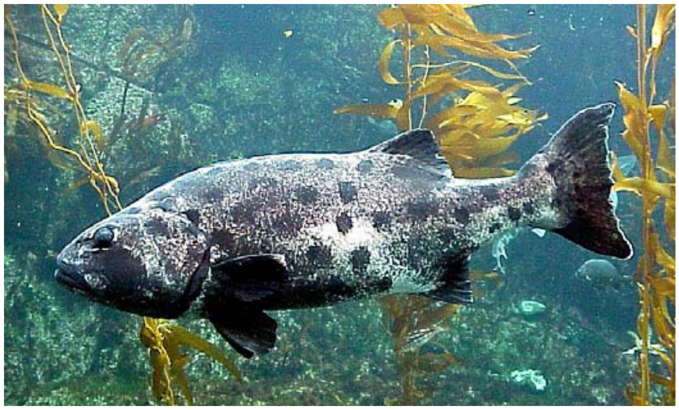
8 Giant Sea Bass, *Stereolepis gigas*



Giant sea bass, *Stereolepis gigas*. Photo credit: Edgar Roberts.

History of the Fishery

The giant sea bass, *Stereolepis gigas*, an apex predator of shallow rocky reefs, is the largest resident bony fish found along the California coast and offshore islands. They range from the southern tip of Baja California, Mexico to Humboldt Bay in northern California and in the northern Gulf of California. Aggregations of both sexes are predominantly found south of Point Conception. Giant sea bass are commonly seen by recreational scuba divers in California along La Jolla, Catalina Island, and Anacapa Island. Because the giant sea bass is slow growing, long lived, and aggregates in large groups, it is susceptible to over fishing. In the past, it was not uncommon for nearly entire aggregations to be eliminated by commercial and recreational fisheries.

Commercial fishing for the giant sea bass began in 1870 in southern California, much earlier than the recreational fishery. In 1932 California commercial landings peaked at more than 254,000 pounds (115 metric tons). Mexican commercial landings peaked at 807,750 pounds (367 metric tons) in 1934 and declined to less than 200,000 pounds (91 metric tons) in 1964. Early commercial fishers used hand lines to catch giant sea bass, but as the resource declined, fishing with hand lines became too inefficient and they changed to gill nets. This technique quickly reduced stock numbers, driving the commercial fishery south into Mexican waters. Commercial and recreational fishing for giant sea bass in Mexico continues today with no restrictions.

The recreational fishery for giant sea bass began in 1895, peaking in California in 1964 and in Mexico in 1973. While a few recreational vessels targeted giant sea bass spawning aggregations, most catches were incidental while targeting other species that occupied the same habitat. With both commercial and recreational fishers targeting these aggregations, the species was depleted to the point that in the late 1970s the fishery nearly disappeared in southern California. In 1981 a law was enacted that prohibits both the recreational and commercial take of giant sea bass in California, with the exception that commercial gill net and trammel net fishers could take and sell two fish per trip (FGC §8380, Title 14, CCR, §28.10). Also, a limit was placed on the amount of giant sea bass that can be taken in Mexican waters and landed in California. These vessels were allowed to land 1000 pounds (450 kilograms) of giant sea bass per trip but only 3000 pounds (1360 kilograms) per year. This law was amended in 1988 to allow only one incidental fish caught in Mexican waters to be landed in California (FGC §8380).

Status of Biological Knowledge

The giant sea bass has been placed in the family Polyprionidae due to its larval similarities with wreckfish. The giant sea bass is a slow growing, long lived species that reaches lengths of more than 7 feet (2.3 meters). The International Game Fish Association all-tackle world record is 563 pound-8 ounce (256 kilograms) fish caught in 1968 off of Anacapa Island, California. There are unconfirmed claims of larger specimens. "The Channels Islands" by Charles F. Holder published in 1910 tells of a giant sea bass taken from the Gulf of California reaching 800 pounds (363 kilograms). However, larger specimens have yet to be confirmed.

Adult giant sea bass occupy rocky habitats near kelp beds, ledges and drop offs at depths of 35 to 130 feet (11 to 40 meters). They may also be found foraging over sandy bottom away from rocky reefs. Juvenile giant sea bass (Figure 8-1) are brick red with irregular rows of black spots on their sides and are found in and near kelp beds and sandy bottom habitats in the depth range of 20 to 70 feet (6 to 21 meters). Adult giant sea bass of both sexes form large aggregations from June through September. Giant sea bass have not been observed spawning in the wild; however, they have been observed spawning in captivity from June through September. This is supported by gonad assessments that also suggest spawning occurs from July through September. Most females mature at 50 to 60 pounds (23 to 27 kilograms) or 7 to 8 years of age, and all females are mature by 100 pounds (45 kilograms) or 11 years of age. Large females are capable of producing an estimated 60 million eggs. After the eggs are deposited and fertilized in the water column they float to the surface, hatching within 36 hours. The developing larvae feed on plankton for their first month before settling on the bottom. It can take 6 years for giant sea bass to reach 30 pounds (14 kilograms), 10 years to reach 100 pounds (45 kilograms), and up to 15 years to reach 150 pounds (68 kilograms).

Figure 8-1. Juvenile giant sea bass.
Photo credit: Edgar Roberts.

Giant sea bass spawning aggregation site selection is poorly understood. It is thought that young giant sea bass learn aggregation site location from older fish. As a result these aggregation sites are used by generations of giant sea bass. Once a local population is depleted their aggregation site permanently disappears. It is unknown how new aggregation sites are selected. Because giant sea bass will continue to aggregate in the same location when kelp is absent, it is assumed that kelp is not the attractant for the location of these aggregations. Little is known of the giant sea bass home range and migration patterns. Researchers began studying giant sea bass movement, behavior, and habitat preference in 2000 using acoustic tags and an array of acoustic receivers around the northern Channel Islands and Catalina Island, as well as the mainland coast. Results of this research show that giant sea bass tagged at Anacapa Island were regularly recorded by receivers off Santa Rosa Island in the north and Catalina Island in the south, as well as Point Dume on the mainland, and that adults can travel more than 50 miles (80 kilometers) among the islands and mainland.

The giant sea bass diet has been quantified by stomach analysis and includes anchovies, sardines, squid, white croaker, jack mackerel, Pacific mackerel, California sheephead, ocean whitefish, sand bass, Pacific bonito, midshipman, stingrays, small sharks, cancer crabs, red crabs, spiny lobster and mantis shrimp. Small giant sea bass feed mainly on small inshore species such as anchovies and sardines.

Status of the Population

Incidental landings of giant sea bass in the commercial fishery, from 1998 to 2008, range from 4238 to 8689 pounds (1924 to 3945 kilograms) per calendar year (Figure 8-2). Giant sea bass incidental recreational catch from 1998 to 2008 range from 0 to 1379 fish per calendar year (Figure 8-3 and 8-4).

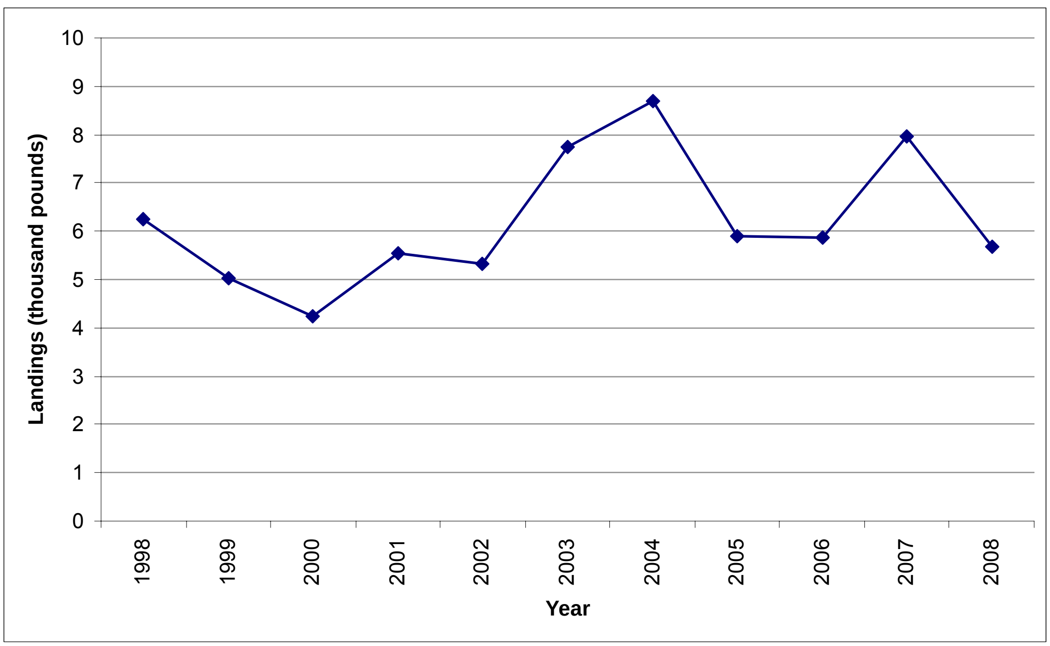


Figure 8-2. Giant sea bass incidental commercial landings, 1998-2008. Data source: CFIS data, all gear types combined.

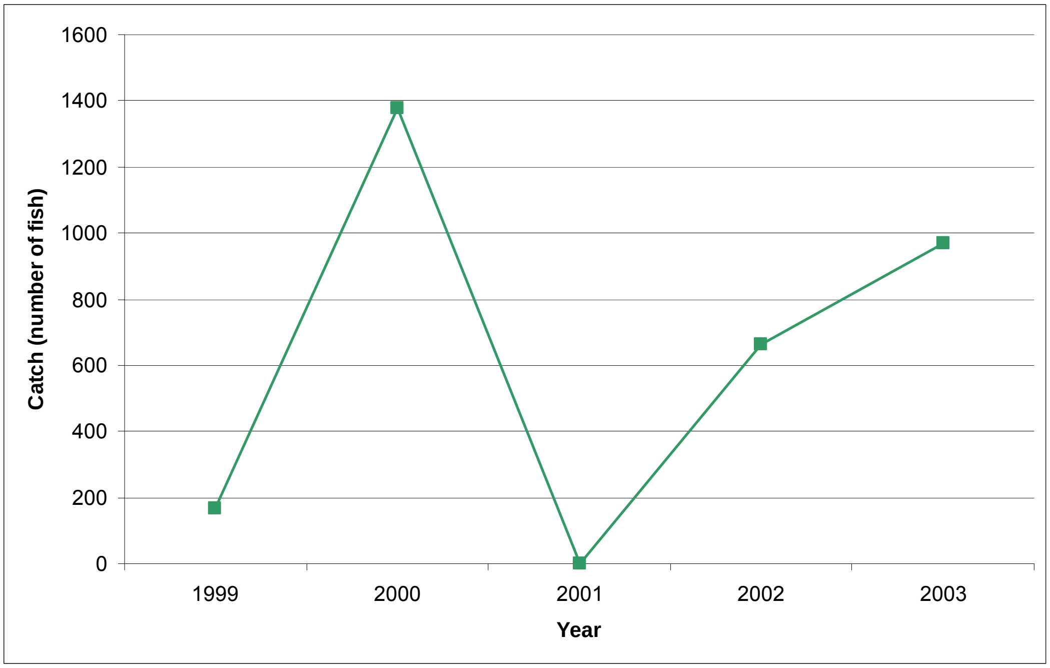


Figure 8-3. Giant sea bass incidental recreational catch, 1998-2003. Data source: MRFSS data, all fishing modes and gear types combined.

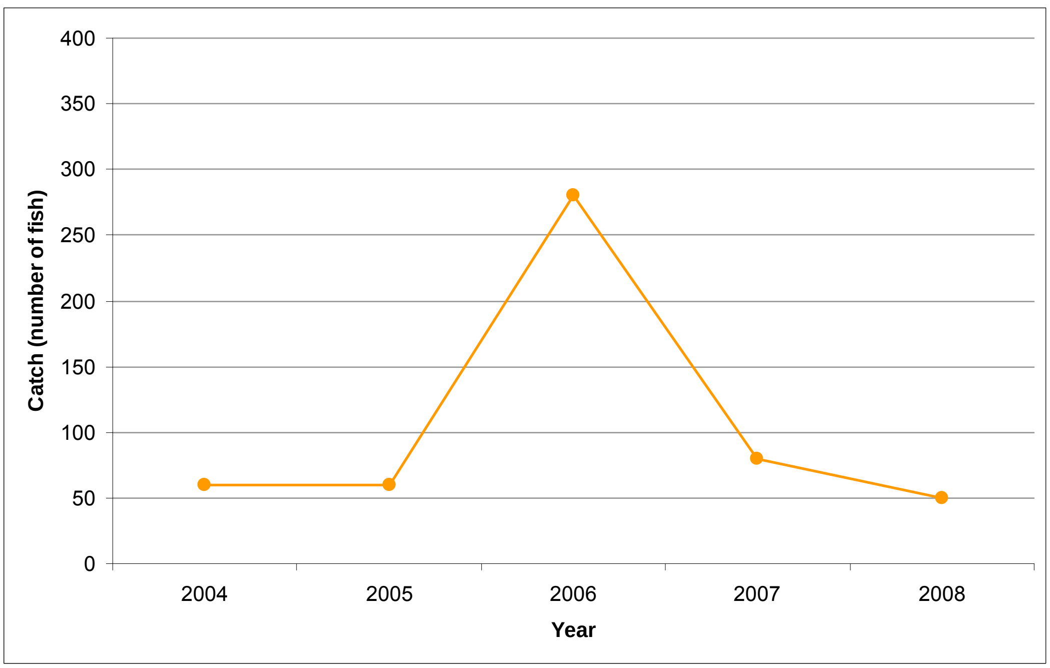


Figure 8-4. Giant sea bass incidental recreational catch, 2004-2008. Data source: CRFS data, all fishing modes and gear types combined.

The International Union for the Conservation of Nature and Natural Resources (IUCN) has designated the giant sea bass as a critically endangered species on the IUCN Red List. The population of the giant sea bass in California continues to be well below historic levels. In 1990, Proposition 132 was passed outlawing the use of gill nets and trammel nets within state waters [within 3 nautical miles (5.6 kilometers) from the mainland, 1 nautical mile (1.8 kilometers) from islands] off southern California beginning in 1994 (FGC §8610.2). The gill net closure displaced the California fishery from the majority of giant sea bass habitat, significantly reducing the incidental catch mortality of giant sea bass in California waters.

The establishment of Marine Protected Areas (MPAs) in locations of giant sea bass aggregations may eliminate catch and release mortality of these enormous reef fish. One study shows a local population of 100 individuals without juvenile recruitment will have 29 individuals after 25 years with natural mortality rate of 6 percent. Adding a 5 percent catch and release mortality will leave only 10 fish after 25 years and 20 percent could cause local extinction in 16 years.

Anecdotal information suggests there has been a gradual increase in giant sea bass numbers over the past few years. Incidental observations by scuba divers have seen an increase in giant sea bass numbers at popular dive locations off La Jolla and at Anacapa and Catalina Islands over the past few years. Scuba surveys conducted by the Van Tuna Research Group, Occidental College, along Palos Verdes Point, beginning in 1974, observed giant sea bass for the first time in 2002 and again in 2003-2004 (Figure 8-5). The Ocean Resources Enhancement and Hatchery Program's (OREHP) gill net monitoring program found a significant increase in giant sea bass catch-per-unit-effort (CPUE) from 1995 to 2004 (Figure 8-6). No scientific research has been conducted on giant sea bass population trends. To date there is still relatively little known of this apex predatory fish.

Hopefully, with the closure of the giant sea bass fishery, elimination of gill nets from the state waters of southern California in 1994, and the implementation of the MPAs within the species home range, the giant sea bass population will rebound after having been severely depleted.

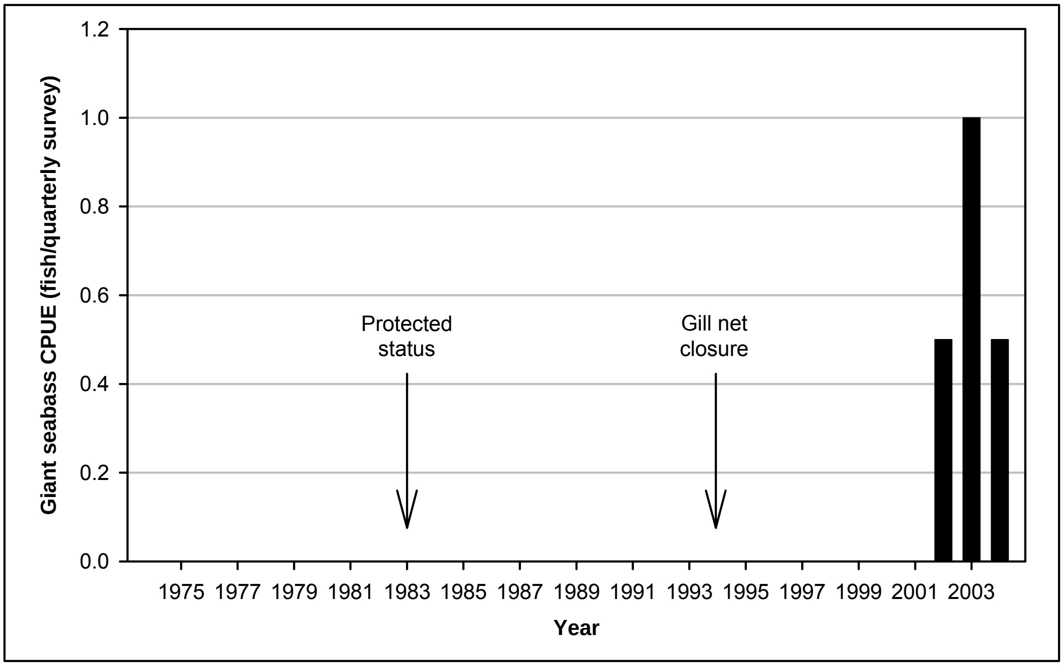


Figure 8-5. Giant sea bass catch-per-unit-effort (CPUE) from quarterly scuba survey, Palos Verdes Point, CA, 1974-2004. Data source: Daniel J. Pondella II, Department of Biology, Occidental College.

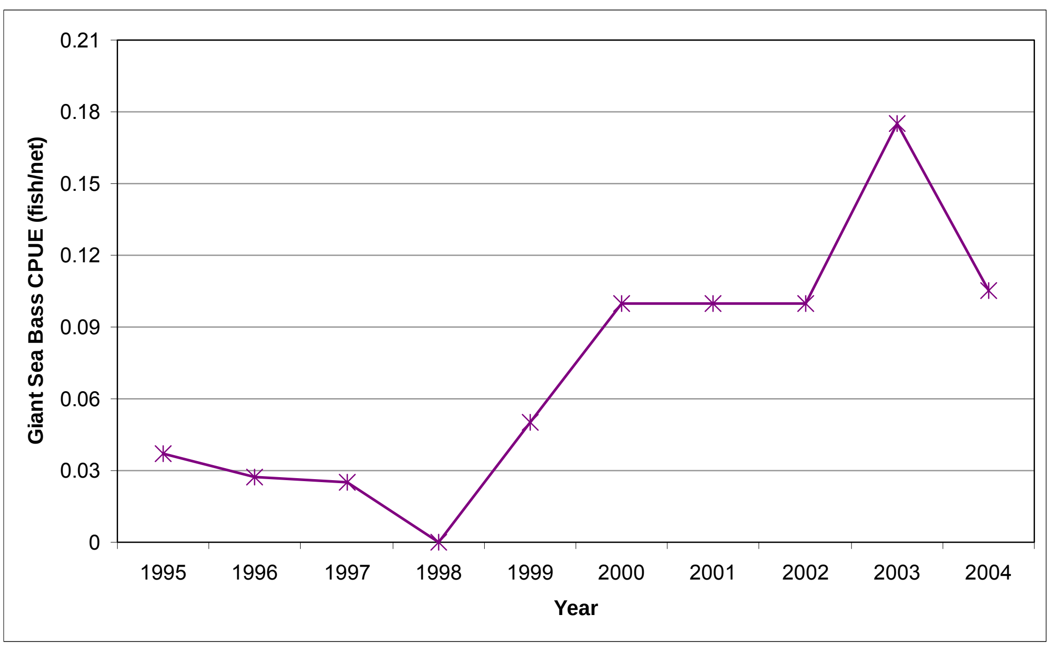


Figure 8-6. Giant sea bass catch-per-unit-effort (CPUE), 1995-2004, from OREHP gill net sampling program. Data source: Daniel J. Pondella II, Department of Biology, Occidental College.

Management Considerations

Current management practices should remain in place. The most important management for protecting the giant sea bass is establishing and maintaining full protection of their aggregation sites to eliminate incidental catch and release mortality.

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Giant sea bass incidental commercial landings, 1998-2008.

Year	Pounds	Year	Pounds
1998	6,238	**2004**	8,689
1999	5,018	**2005**	5,889
2000	4,238	**2006**	5,877
2001	5,530	**2007**	7,952
2002	5,324	**2008**	5,685
2003	7,752		

Data source: CFIS data, all gear types combined.

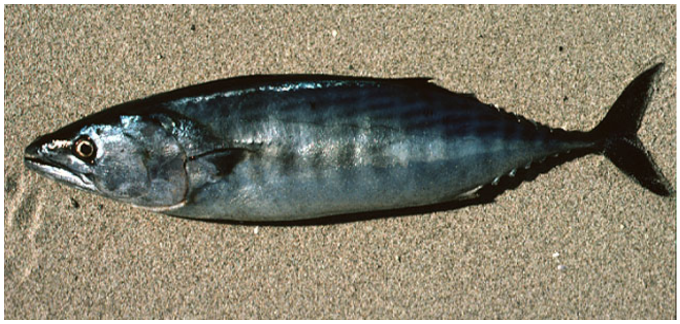
Giant sea bass incidental recreational catch, 1998-2003.	
Year	**Number of fish**
1998	0
1999	166
2000	1,379
2001	0
2002	662
2003	968

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

Giant sea bass incidental recreational catch, 2004-2008.	
Year	**Number of fish**
2004	60
2005	60
2006	280
2007	80
2008	50

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

9 Pacific Bonito, *Sarda chiliensis*



Pacific bonito, *Sarda chiliensis lineolata*. Photo credit: Daniel W. Gotshall.

History of the Fishery

Pacific bonito, *Sarda chiliensis lineolata*, is a component of the commercial purse seine fishery as well as a popular recreational species in southern California. Commercial landings of Pacific bonito have declined steadily since the mid 1980s, but have increased moderately in recent years, from 320 short tons (291 metric tons) in 1997 to 885 short tons (803 metric tons) in 2008 (Figure 9-1). There was a significant increase in landings in 2006 when 2740 short tons (2486 metric tons) were caught by the commercial fishery, but that was an anomaly and not part of the overall trend of recent years. After over 2 decades of low landings, the size of the fleet has decreased from 72 vessels to 59. This smaller fleet is landing fewer loads that are considerably bigger. In 2003, 19 vessels made 38 landings with a CPUE of 0.07 short tons per trip (0.06 metric tons per trip) (Figure 9-1). By 2008, the number of vessels increased to 69 and made 153 landings with a CPUE of 5.8 short tons per trip (5.3 metric tons per trip). The average of the 6 preceding years (1997-2002) was 51 vessels with a CPUE of 1.6 short tons per trip (1.4 metric tons per trip).

The trend over the last 15 years seems to be low landings for most years interspersed with high yield years. Competition with higher valued fisheries was likely part of the decline in landings during the 1980s and 1990s. Increased regulations, decreased stocks and market demand likely contributed to the decline. In 1982, Mexico began restricting foreign vessel access to its nearshore fisheries. Prior to this closure, 50-90 percent of Pacific bonito landed in the United States was caught off the coast of Baja California, Mexico. Now less than 10 percent originates in Mexican waters. Other causes of the fluctuations in landings likely include long term environmental variations in seasonal and local water temperatures, changes in ocean currents and water masses from year to year, strength of recruiting year classes of both predator and prey populations, local availability of prey, effects of pollution on spawning and variable fishing pressure throughout the species' range.

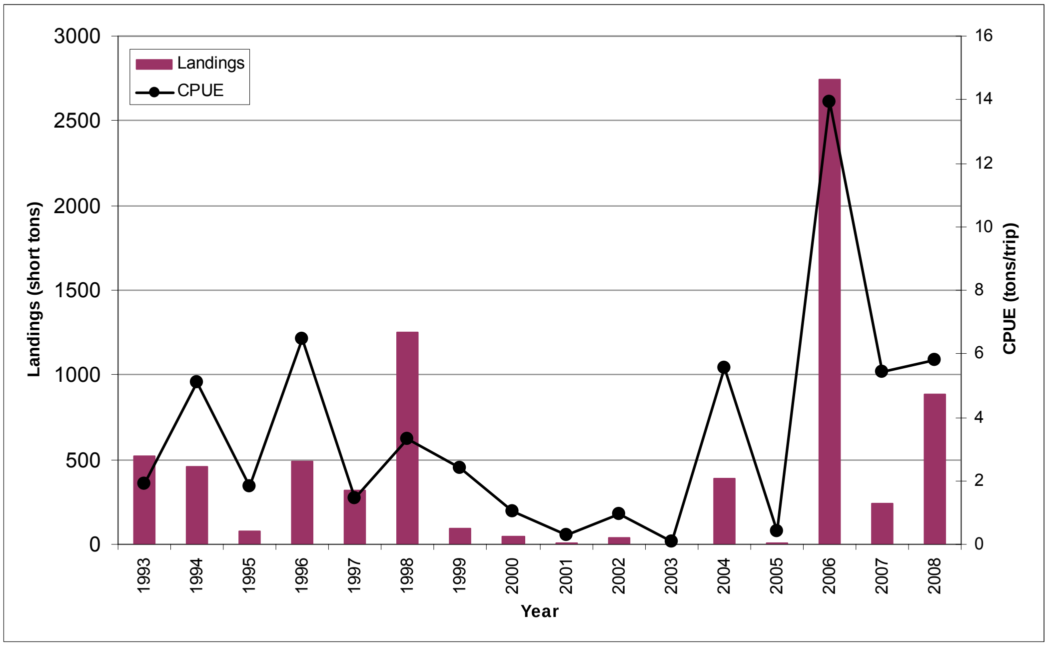


Figure 9-1. Pacific bonito commercial landings and catch-per-unit-effort (CPUE), 1993-2008. Data source: CFIS data, all gear types combined.

Regardless of the reason, lower densities of Pacific bonito in southern California mean that the purse seine fleet will target this species only when large schools are found near the coastline. As a result, the number of vessels landing Pacific bonito can vary dramatically from year to year. The general trend has been a decline from a high of 131 vessels in 1998 to 13 vessels in 2005. The average over the last 15 years is 46 vessels landing Pacific bonito annually. Most of these vessels are not targeting Pacific bonito, but are catching bonito incidental to the target species. In the last three years, 90 percent of the commercial landings have been incidental to other fisheries, and fewer than 10 percent of the vessels active in the fishery each year land over 95 percent of the annual landings.

Pacific bonito is a popular recreational species in southern California, when available. Pacific bonito is a favorite among anglers because they are usually found within 15-20 miles (24-32 kilometers) of the coastline, they fight hard when hooked and are an excellent food fish.

In 1947, the commercial passenger fishing vessel (CPFV) fleet landed only 36,500 fish. After World War II the CPFV industry expanded and the annual landings of Pacific bonito increased to 2.1 million fish in 1961 and reached a peak of 4.6 million fish in 1966. In 1971, CPFV landings dropped to less than 200,000 fish from 1.1 million in 1969. Landings remained low during the 1970s, yielding 100,000 to 650,000 fish annually. The 1980s and 1990s saw another decline with a low of 3300 fish in 1999 (Figure 9-2). Along with reduced catches in the 1990s, the number of anglers and CPUE also declined (Figure 9-3).

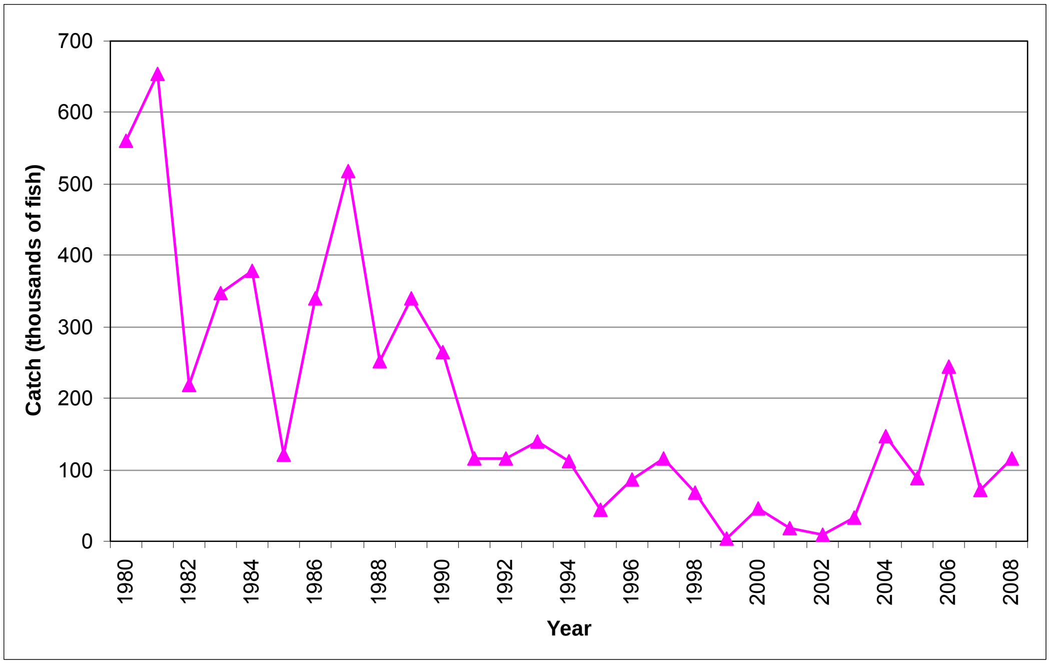


Figure 9-2. Pacific bonito commercial passenger fishing vessel (CPFV) catch, 1980-2008. Data source: CPFV logbook data.

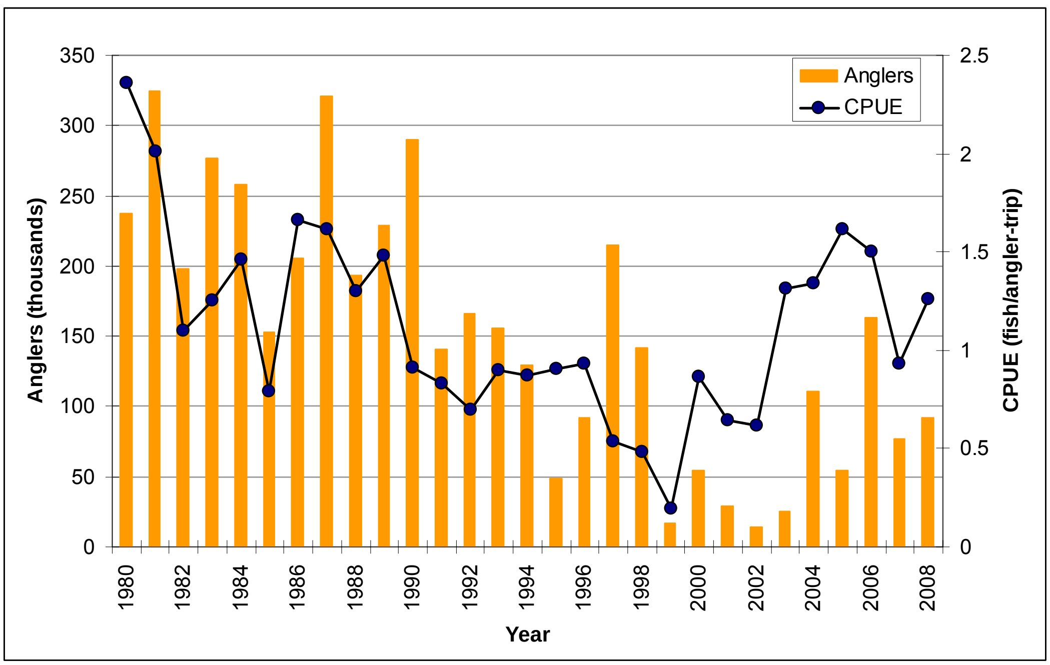


Figure 9-3. Pacific bonito recreational commercial passenger fishing vessel (CPFV) catch-per-unit-effort (CPUE), 1980-2008. Data Source: CPFV logbook data.

There are two different recreational sampling programs: the Marine Recreational Fisheries Statistical Survey (MRFSS) which sampled from 1980 to 2003 and the California Recreational Fisheries Survey (CRFS) which was initiated by the California Department of Fish and Game in 2004. Due to changes in the sampling protocol and how the data are used to estimate catch these two surveys are not comparable.

Recreational catch of Pacific bonito was much higher in the 1980s compared to the 1990s (Figure 9-4) and is likely due to lack of abundance in local waters rather than a reduction in recreational anglers. This trend has continued through 2008 (Figure 9-5). Both MRFSS and CRFS data indicate that Pacific bonito are taken primarily by boat modes (Figures 9-4 and 9-5), with occasional catches from the shore modes, primarily piers and jetties.

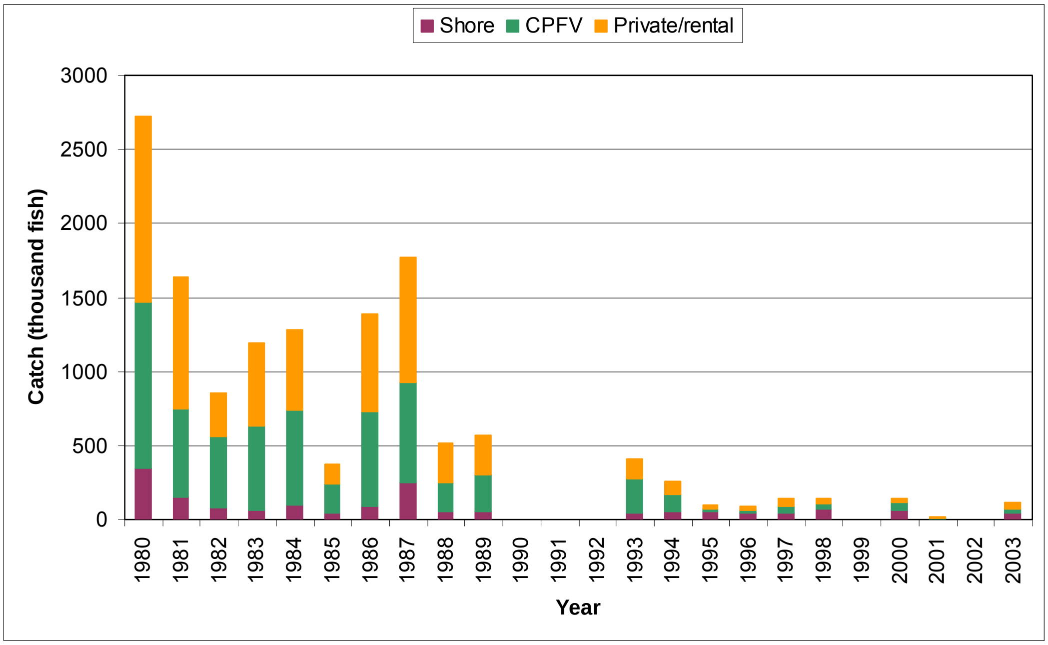


Figure 9-4. Pacific bonito recreational catch by fishing mode, 1980-2003. Data source: MRFSS data, all gear types combined. Data for 1990-1992 is not available. CPFV data not available for central and northern California for 1993-1995.

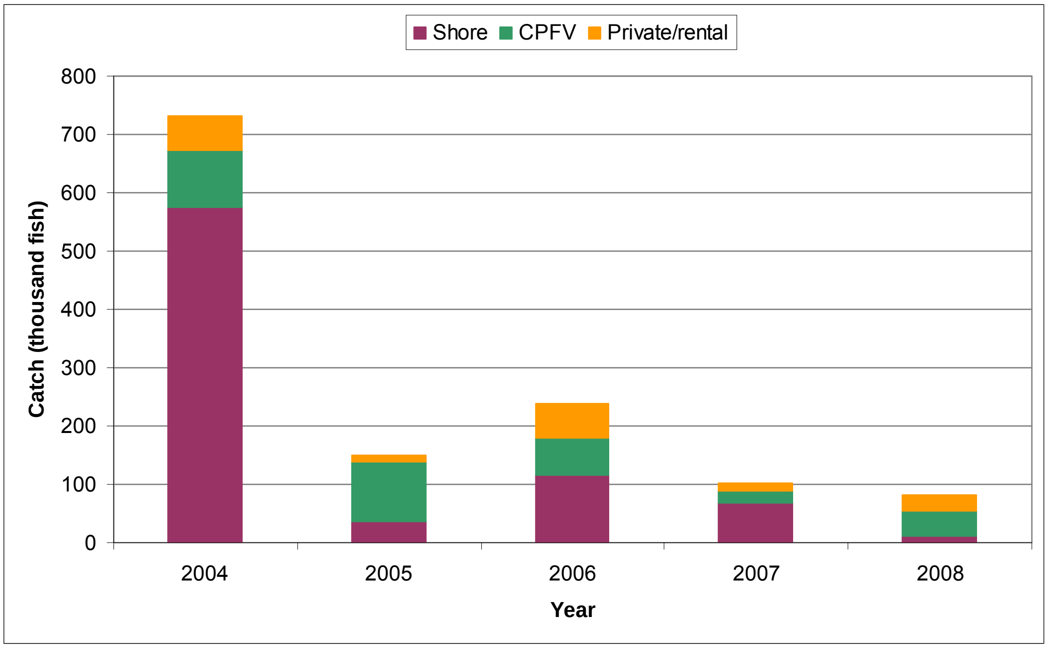


Figure 9-5. Pacific bonito recreational catch by mode, 2004-2008. Data source: CRFS data, all gear types combined.

Status of Biological Knowledge

Pacific bonito are found in the eastern Pacific and are divided into two geographically distinct populations. The California fishery targets the northern sub-species, *Sarda chiliensis lineolata*, which ranges from the Gulf of Alaska to Revillagigedo Island, Mexico [located 240 miles (386 kilometers) southwest of the southern tip of Baja California, Mexico]. This population is centered between southern California and central Baja California, Mexico and moves farther north in warm water years. The southern sub-species, *Sarda chiliensis chiliensis* (Peruvian), is found off the western coast of South America from Colombia to Chile. A different species of bonito is found from the central coast of Mexico to Panama. The separate *S. chiliensis* populations are not different sub-species, but they do have significant physical differences and they are not known to interbreed.

Pacific bonito are a temperate epipelagic schooling fish. They can migrate up to 600 miles (966 kilometers) along the west coast of North America over the continental shelf (to a depth of 120 feet; 37 meters), moving south in the winter and north in the summer. Individuals tagged off Baja California, Mexico have been caught in Santa Barbara. They are most abundant within 15 miles (24 kilometers) of the coast, but can be found several hundred miles out to sea. They are usually caught by California fishers within 50 miles (80 kilometers) of shore in association with kelp beds, around islands and the mainland.

Pacific bonito populations fluctuate on a decadal scale in a similar manner as northern anchovy. These fluctuations are usually associated with warm and cold water periods of the Pacific Decadal Oscillation. Current conditions indicate that the eastern Pacific is in a warm water regime that favors Pacific sardine over northern anchovy. Northern anchovy is a primary prey species for Pacific bonito.

Pacific bonito are associated with temperate water which may impact migration patterns and localized movements. The presence of warm water effluents at power plants in the Southern California Bight have led to year round resident populations that do not migrate to Mexico in the winter months. Tagged fish that are released into these outflows have been recaptured near the release site 3 years later.

Pacific bonito consume approximately 6 percent of their body weight per day. Prey items include northern anchovy and other small forage fish, market squid, euphausiids and others crustaceans and amphipods. Usually fishes are the primary prey items with cephalopods being the next most frequent, but this may change during El Niño events. A California Cooperative Oceanic Fisheries Investigation cruise during the 1983 El Niño event sampled the stomach contents of 41 troll caught Pacific bonito. The composition of the stomach contents was fish and euphausiids. It is speculated that during an El Niño event cephalopods were not available as a prominent prey species.

Pacific bonito are a short lived (less than 6 years), rapid growing species. They can reach 20 inches (51 centimeters) fork length and 4 pounds (1.8 kilograms) in the first year. The average two year old is 25 inches (64 centimeters) and 8 pounds (3.6 kilograms). Six year olds can measure 32-40 inches (81-102 centimeters), though specimens over 36 inches (91 centimeters) and weighing 17-22 pounds (7-10 kilograms) are rare. Males can mature and spawn at one year and 20 inches (51 centimeters). Females are oviparous and will usually spawn more than once per season. A few females will spawn at two years old, but most are at least 27 inches (69 centimeters) long and three years old at first spawning. Most spawning activity occurs within a 3 to 5 month period, being the longest off Baja California, Mexico near the center of their range. Males are ready to spawn before females, who limit the duration of the spawning season. Older fish (greater than three years old) are ready to spawn earlier in the season than younger fish.

The sexes cannot be distinguished using external anatomy, but behavior and coloration during mating is distinct. In aquarium observations spawning females exhibited a unique swim pattern. During courtship males follow directly behind the female fighting for position. They convey interest and an aggressive nature by displaying strong vertical color barring, which is also displayed at feeding time. The successful male and female synchronize their swimming in tight circles while releasing gametes into the seawater where they are fertilized.

Status of the Population

Warm water conditions in the 1980s and 1990s may have affected the availability of the primary prey species (northern anchovy) of Pacific bonito as evidenced by the sporadic catches. Commercial and recreational landings have trended downwards.

This downward trend may be due in part to a shift in effort to more desirable species. It may also be due to changes in distribution and migration of this northern population in response to oceanographic changes that have taken place over the last two decades. Pacific bonito along with other coastal pelagic species (e.g., northern anchovy, Pacific sardine) have natural population fluctuations in response to decadal oceanographic conditions. Additionally, little is known about the take of Pacific bonito off of Baja California, Mexico.

Management Considerations

Pacific bonito is included in the federal Highly Migratory Species Fishery Management Plan as a "monitored species", that means it is not actively managed. Currently, only California statutes and regulations apply to the take of this species. If there is an increase in the take of Pacific bonito, its status could be changed to actively managed. It is legal to target Pacific bonito commercially and recreationally year round.

After the last population assessment in 1982, a minimum size limit of 24 inches (61 centimeters) or 5 pounds (2.3 kilograms) was instituted for both commercial and recreational fisheries. In the recreational fishery there is a 10 fish bag limit and up to 5 undersized fish can be retained (Title 14, CCR, §28.32). Commercial vessels fishing with round haul gear (e.g., purse seine, lampara net) may retain 18 percent or less by number of undersized fish (FGC §8377). When using gill or trammel nets, only 1000 pounds (454 kilograms) or less of undersized Pacific bonito may be retained (FGC §8377).

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Further Reading

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Pacific bonito commercial landings, 1993-2008.

Year	Pounds	Year	Pounds
1993	1,047,606	**2001**	13,005
1994	921,160	**2002**	73,444
1995	157,439	**2003**	5,410
1996	980,471	**2004**	780,209
1997	641,598	**2005**	23,020
1998	2,495,167	**2006**	5,481,546
1999	191,269	**2007**	488,454
2000	96,192	**2008**	1,770,431

Data Source: CFIS data, all gear types combined.

Pacific bonito recreational catch, 1980-1993.							
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	2,721,871	**1986**	1,384,682	**1992**	---	**1998**	138,592
1981	1,638,915	**1987**	1,775,189	**1993**	405,153	**1999**	1,929
1982	850,613	**1988**	514,623	**1994**	258,994	**2000**	145,283
1983	1,192,613	**1989**	569,797	**1995**	94,509	**2001**	15,201
1984	1,282,954	**1990**	---	**1996**	92,087	**2002**	3,116
1985	370,127	**1991**	---	**1997**	144,442	**2003**	114,824

Data Source: MRFSS data, all fishing modes and gear types combined. Data not available for 1990-1992. CPFV data not available for central and northern California for 1993-1995.

Pacific bonito recreational catch, 2004-2008.	
Year	**Number of fish**
2004	732,473
2005	149,580
2006	237,643
2007	101,882
2008	80,883

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

Pacific bonito CPFV catch, 1980-2008.					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	560,508	**1990**	265,263	**2000**	46,820
1981	654,051	**1991**	116,491	**2001**	18,970
1982	218,469	**1992**	115,972	**2002**	8,880
1983	348,050	**1993**	139,569	**2003**	32,942
1984	377,678	**1994**	112,329	**2004**	147,890
1985	120,637	**1995**	44,489	**2005**	87,990
1986	340,480	**1996**	85,583	**2006**	244,179
1987	518,159	**1997**	115,543	**2007**	71,615
1988	251,536	**1998**	68,460	**2008**	117,896
1989	339,382	**1999**	3,301		

Data source: CPFV logbook data.

10 Groundfish: Overview

There are 89 species of marine fish (Table 10-1) included under the Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP) that was adopted by the Pacific Fishery Management Council (PFMC) in 1982. In general, the Groundfish FMP provides for management of bottom dwelling finfish species (including all rockfish and Pacific whiting) that are found within 200 miles (322 kilometers) (exclusive economic zone or EEZ) of the U.S. Pacific coast off Washington, Oregon and California. Of these, only 31 of the species have been assessed. Since 2005, stock assessments have occurred biennially, alternating with regulation development, with an average of 17 species assessed each cycle. Overfished species (currently 7) are assessed or updated with each cycle along with species which have never been assessed or have not been assessed for several years. Only Pacific whiting is assessed each year.

Based on the results of stock assessments, the Groundfish FMP designates a stock to be “healthy,” “precautionary” or “overfished.” According to the Groundfish FMP, healthy stocks maintain more than 40 percent of their estimated unfished spawning stock biomass. Precautionary stocks maintain between 40 and 25 percent of their estimated unfished spawning stock biomass. Federally designated overfished stocks have less than 25 percent of their estimated unfished spawning stock biomass. The Groundfish FMP requires rebuilding plans for all overfished species that place an emphasis on a reasonable likelihood of rebuilding the stock within a specified time period and subsequent management actions designed to avoid fishing pressure upon the overfished species.

The amount of fishing that is allowed is determined using information from the stock assessments, when available, or historic catches. The Acceptable Biological Catch (ABC) is based on the current stock biomass and the fishery exploitation rate, when available. If there is no stock assessment, ABC can be set based on average historic landings. The ABC is the absolute maximum amount of fish that could be taken each year. The Optimum Yield (OY) can be equal to the ABC but is usually less than the ABC due to uncertainty about the stock assessment or historic catch, and can be for a single species or multispecies group. For species listed as precautionary or overfished, the OY is further reduced to allow for rebuilding of the species. When an OY is reached, all fishing for that species or species group must cease. Species which are included in a multispecies OY may also have individual OYs, individual harvest guidelines (HGs), or be included in a HG for a subgroup of the multispecies OY. Unlike OYs, attainment of a HG does not require closing the fishery, but does require review. Groundfish management measures are adopted biennially to keep within the various OYs and HGs. The OY or HG is allocated between the commercial and recreational fisheries, and can be further subdivided by fishing area and/or fishing sector (e.g., limited entry trawl, boat-based anglers).

Table 10-1. Pacific coast groundfish species.

Shallow nearshore species	**Shelf rockfish**	**Slope rockfish**
Black-and-yellow rockfish	● **BOCACCIO**	Aurora rockfish
● Cabezon	● Bronzespotted rockfish	Bank rockfish
● California scorpionfish	● **CANARY ROCKFISH**	● Blackgill rockfish
China rockfish	Chameleon rockfish	● **DARKBLOTCHED ROCKFISH**
● Gopher rockfish	● Chilipepper	● **PACIFIC OCEAN PERCH**
Grass rockfish	● **COWCOD**	Redbanded rockfish
● Kelp greenling	Dusky rockfish	Rougheye rockfish
Kelp rockfish	Dwarf-red rockfish	Sharpchin rockfish
Deep nearshore rockfish	Flag rockfish	Shortraker rockfish
Black rockfish	Freckled rockfish	● Splitnose rockfish
● Blue rockfish	Greenblotched rockfish	Yellowmouth rockfish
Brown rockfish	Greenspotted rockfish	**Flatfish**
Calico rockfish	● Greenstriped rockfish	● Arrowtooth flounder
Copper rockfish	Halfbanded rockfish	Butter sole
Olive rockfish	Harlequin rockfish	Curlfin sole
Quillback rockfish	Honeycomb rockfish	● Dover sole
Treefish	Mexican rockfish	● English sole
Round fish	Pink rockfish	Flathead sole
Finescale codling	Pinkrose rockfish	Pacific sanddab
● Lingcod	Pygmy rockfish	● Petrale sole
Pacific cod	Redstripe rockfish	Rex sole
Pacific rattail	Rosethorn rockfish	Rock sole
● Pacific whiting	Rosy rockfish	Sand sole
Ratfish	● Shortbelly rockfish	● Starry flounder
● Sablefish	Silvergrey rockfish	**Sharks**
	Speckled rockfish	Leopard shark
	Squarespot rockfish	Soupfin shark
Additionally all species of the family Scorpaenidae that occur off Washington, Oregon and California, including those not listed above, are considered groundfish. The Scorpaenidae genera include Sebastes, Scorpaena, Scorpaenodes and Sebastolobus.	Starry rockfish	Spiny dogfish
	Stripetail rockfish	**Skates**
	Swordspine rockfish	Big skate
	Tiger rockfish	California skate
	● Vermilion rockfish	● Longnose skate
	● **WIDOW ROCKFISH**	
	● **YELLOWEYE ROCKFISH**	
	● Yellowtail rockfish	
	● Longspine thornyhead	
	● Shortspine thornyhead	

Notes:
Species in caps have been declared overfished and are currently under rebuilding.
Species with a ● have been assessed.

New state legislation in 1998 enacted the Marine Life Management Act (MLMA) which required the state to take a more precautionary approach to finfish management, delegated the management of finfish in state waters to the California Fish and Game Commission (Commission), and mandated the Commission adopt a Nearshore Fisheries Management Plan (Nearshore FMP) for 19 nearshore species, 16 of which are included in the Groundfish FMP. For the commercial fishery, the Nearshore FMP implemented a regional restricted access fishery for the shallow nearshore species, California sheephead and rock greenling; and a statewide Deeper Nearshore Species Fishery Permit for the deep nearshore rockfish (Table 10-1). Monkeyface prickleback is included in the Nearshore FMP; however, no permit is required to take this species.

California's Nearshore FMP implemented a more precautionary approach to managing nearshore rockfish compared to the federal Groundfish FMP, based on how much is known about a species. In a data moderate situation, a healthy stock is one that maintains more than 60 percent of their estimated unfished spawning stock. Precautionary stocks maintain between 60 and 30 percent of their estimated unfished spawning stock biomass. Overfished stocks have less than 30 percent of their estimated unfished spawning stock biomass. The 19 species in the Nearshore FMP occur primarily in state waters (0-3 miles; 0-5 kilometers), so while the federal government maintains authority over the shallow and deep nearshore species, California is instrumental in developing regulations for these species using the guidelines of the Nearshore FMP.

Groundfish management is complicated because fisheries for many of the species are interrelated, but the various stocks have responded differently to fishing pressure. For example, flatfish populations such as Dover and English soles have been subjected to significant commercial fisheries for decades, yet have not shown the magnitude of decline that has occurred in some of the rockfish populations.

The current status of many rockfish off the west coast is poor, and significant changes in the groundfish fishery have been necessary to address this situation. There are over 60 different species of rockfish in California. Several factors affect the abundance of rockfish and the ability to manage them effectively. Recent analyses have shown that rockfish stocks are not as productive as previously thought. This is due in part to improved information about rockfish life history (such as age, growth and reproduction), better stock assessments and environmental conditions that generally have not been favorable to rockfish reproduction or survival for many years. As a result, rockfish cannot support harvest rates as high as previously thought.

Management is further complicated because the habitats and ranges of many rockfish species overlap, so it is difficult to catch one species without catching other species at the same time. Fishing must be reduced for an entire group of rockfish in order to realize lower catches that are necessary to rebuild overfished stocks. For example, although a few shelf rockfish species such as chilipepper and yellowtail rockfish appear to be comparatively healthy, their allowable harvest has been set at levels below the potential yield to protect the overfished shelf rockfish that tend to be caught with them, such as canary and yelloweye rockfish.

Prior to 2000, the allowable catch of all rockfish in the PFMC's southern management area (most of California) was combined into a single quota. To better align fishing opportunities with the resources that support them, fishery managers grouped rockfish into three new categories: nearshore, shelf, and slope (Table 10-1). In addition, management has been refined by setting individual quotas for a few species, which reduces the aggregate quota for other remaining rockfish species. While this approach lowers the harvest of overfished rockfish species, such as canary and yelloweye rockfish, it also reduces the opportunities for nearshore species that are no longer grouped with certain deepwater species that are typically under harvested. In 2003, the nearshore species group was further subdivided into the shallow and deep nearshore to align quotas with California's new commercial fishery permits for nearshore species.

In 2002, the Rockfish Conservation Areas (RCAs) were created to reduce fishing pressure on the shelf where most of the overfished rockfish species occur. These are depth based closures ranging from 30-50 fathoms and 150-200 fathoms (55-91 meters and 274-366 meters) depending on regional management area, along the California coastline. Bottom fishing is prohibited within the RCA, but provisions allow for some surface fishing as well as transiting through the RCA. In addition to the RCAs, the Cowcod Conservation Area (CCA), a non-depth based closure covering much of the cowcod's habitat, was implemented to protect cowcod, one of the overfished rockfish. These closures have had significant impact on both recreational and commercial fishers.

Commercial fishery

The commercial groundfish fishery primarily targets round fish (Pacific whiting, sablefish), flatfish (Dover sole, Petrale sole) and shelf rockfishes (thornyheads, widow and chilipepper rockfish) (Figure 10-1). Landings of shelf rockfish have declined since 2000 due to catch restrictions aimed at limiting the take of overfished species (e.g., yelloweye and canary rockfish).

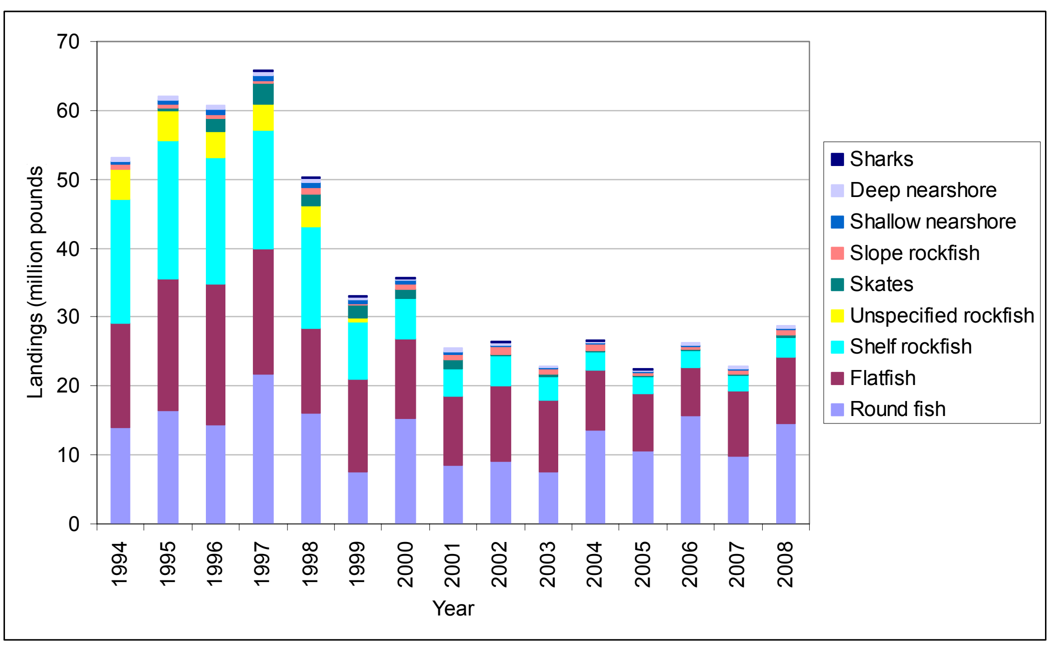

Figure 10-1. Groundfish commercial landings, 1994-2008. Data source: CFIS data, all gear types combined.

The commercial fishery is split into the limited entry (trawl and sablefish long line/trap) and the open access sectors. Trip limits for species or species groups differ between the sectors. Additionally, time and area closures (RCAs, CCA) are used to keep the commercial fishery within the various OYs and HGs.

In 2004, a Vessel Monitoring System (VMS) was implemented; its purpose is to monitor compliance with regards to areas closed to fishing such as the RCAs. Initially, VMS was only required on limited entry vessels fishing in federal waters (2004) but has since expanded to include the open access sector of the groundfish fishery for vessels fishing in federal waters (2008).

Overcapacity is another issue in the groundfish fishery. In 1994, the groundfish trawl and sablefish fixed gear fishery became limited entry fisheries to cap and reduce capacity. However, this did not reduce fleet size enough and further actions were taken. In 2001, a permit stacking program was implemented for the sablefish fixed gear fishery that allows fishers to take additional amounts of catch, depending on how many permits they have. For more information on this program, see the sablefish section of this report.

The PFMC developed and implemented a trawl vessel buyout program in 2003 to help compensate for continued fishery overcapacity. Coastwide, 92 trawl vessels, representing 1/3 of the fleet, took advantage of the vessel buyout program. The upcoming trawl individual quota (IQ) program will address overcapitalization in the remaining groundfish trawl vessels by granting quota shares for species or species groups based on historic landings. These quota shares can be used, leased or sold.

The Pacific whiting fishery is another sector of the groundfish fishery burdened with overcapacity. In 2008, a limited entry program was created for all sectors of the whiting fishery (catchers, catcher-processors and at sea processors). The program was implemented as an interim measure until the groundfish trawl IQ program could be implemented.

In 2000, the PFMC indicated that limiting the open access sector of the commercial groundfish fishery was a priority to limit overcapitalization. In subsequent years, the PFMC looked at a range of alternatives to restrict the fishery with a limited entry permit. After much deliberation, the PFMC adopted a registration only option that will require any vessel participating in groundfish fisheries to register with the National Marine Fisheries Service each year beginning in 2011. This option will provide annual fleet accountability for management tracking while maintaining flexibility for fishery participants.

A total of about 850 businesses in California are directly affected by commercial groundfish catch regulations. Most of the affected businesses are fishing vessels. There are approximately 625 commercial fishing vessels in California that catch and sell groundfish as part of their operations.

Vessels in the limited entry fleet have a federal permit that allows them to harvest larger amounts of groundfish. Consequently, vessels with limited entry permits generally rely heavily on groundfish as a major source of income. There are 191 limited entry vessels in California.

Vessels that land groundfish under open access provisions may or may not depend on groundfish as a major source of income. Many vessels that predominately fish for other species also may inadvertently catch and land groundfish. Although 533 open access vessels landed groundfish in California during 2008, many landed less than 1000 pounds (454 kilograms). A total of 305 open access vessels each landed more than 1000 pounds (454 kilograms) of groundfish during the calendar year. In addition to the commercial fishing fleet, there are approximately 200 wholesale fish buying businesses in California that purchase groundfish from commercial fishing vessels.

The 2008 California commercial groundfish harvest was approximately 28.8 million pounds (13,000 metric tons), with an ex-vessel value of $19.0 million (Figure 10-2). This represents a 43 percent decline in landings and an 11 percent decline in value compared to 1998, before more restrictive regulations became effective. Groundfish production has exhibited a long-term downward trend in landings since the 1990s, mostly due to increased regulations. Although landings have declined significantly over time, the advent of the live fish fishery has kept value fairly stable. The live fish fishery began in the late 1980s targeting nearshore rockfish and cabezon in central California. This fishery has expanded coastwide and now targets some other groundfish species (e.g., lingcod and thornyheads). In 2008, over 1 million pounds (470 metric tons) of live groundfish (3.4 percent of the total groundfish catch) worth $4.2 million dollars were landed in California, primarily thornyheads, deeper nearshore rockfish, sablefish, shallow nearshore rockfish, cabezon and lingcod. For some species, such as cabezon, grass rockfish and treefish, over 90 percent were landed live in 2008 (Figure 10-3).

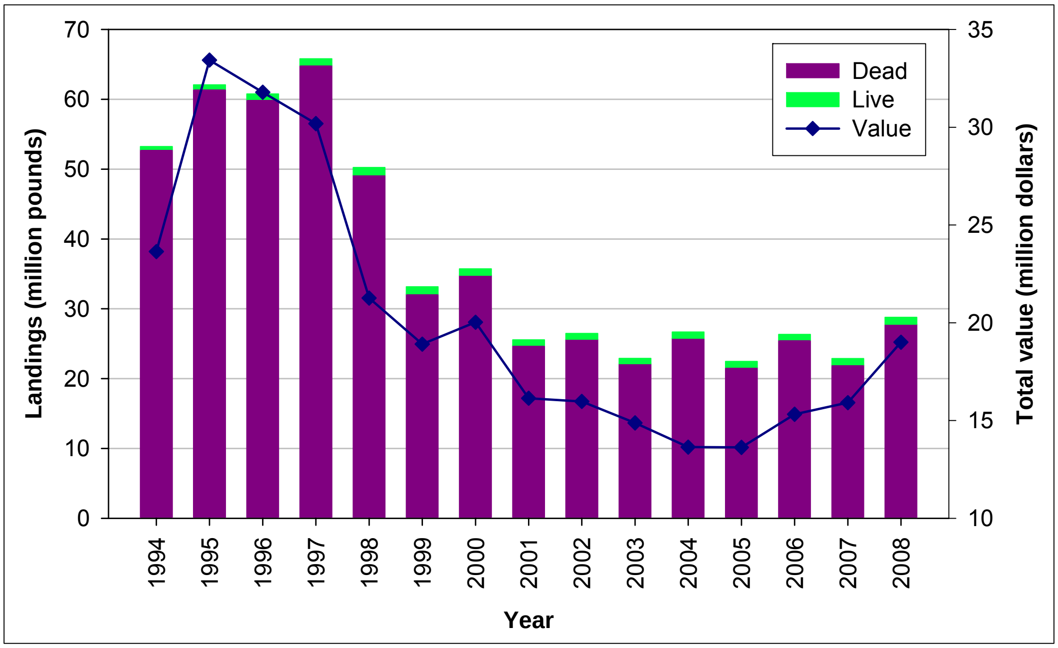

Figure 10-2. Commercial groundfish landings and value, 1994-2008. Data source: CFIS data, all gear types combined.

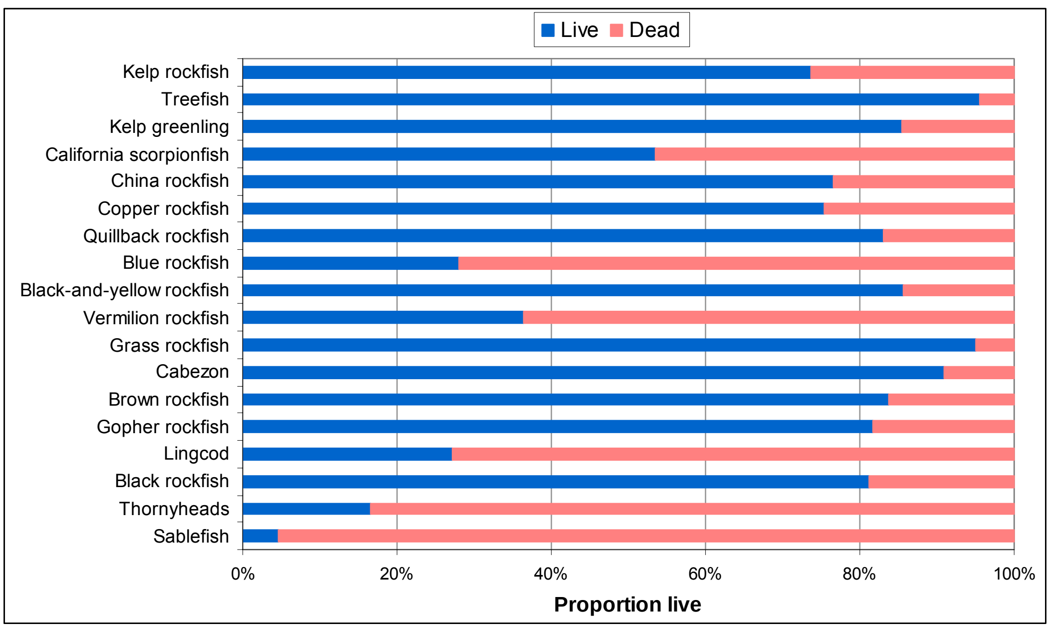

Figure 10-3. Live groundfish commercial landings in 2008. Species are ranked from lowest to highest total landings (live and dead combined). Data source: CFIS data, all gear types combined.

Recreational fishery

The primary groundfish species or species groups caught by recreational anglers are rockfishes, sanddabs, California scorpionfish, lingcod, cabezon and greenlings (Figures 10-4 and 10-5). Within the rockfish category deep nearshore, shelf, shallow nearshore and unspecified rockfish are the primary species groups caught. Groundfish are primarily caught by recreational anglers on boats, with shore-based anglers taking less than 5 percent of the catch. Bag and size limits and time and area closures are the primary means of keeping the recreational fishery within the various OYs and HGs.

There are two different recreational sampling programs: the Marine Recreational Fisheries Statistical Survey (MRFSS) which sampled from 1980 to 2003 and the California Recreational Fisheries Survey (CRFS) which was initiated by the California Department of Fish and Game (Department) in 2004. Due to changes in the sampling protocol and how the data are used to estimate catch these two surveys are not comparable. From 1994 to 2003, recreational groundfish catch was fairly stable based on MRFSS data, although the species composition changed as regulations changed (Figure 10-4). According to CRFS, catch peaked in 2005, declining each year thereafter (Figure 10-5). This is likely do to additional constraints on the recreational fishery.

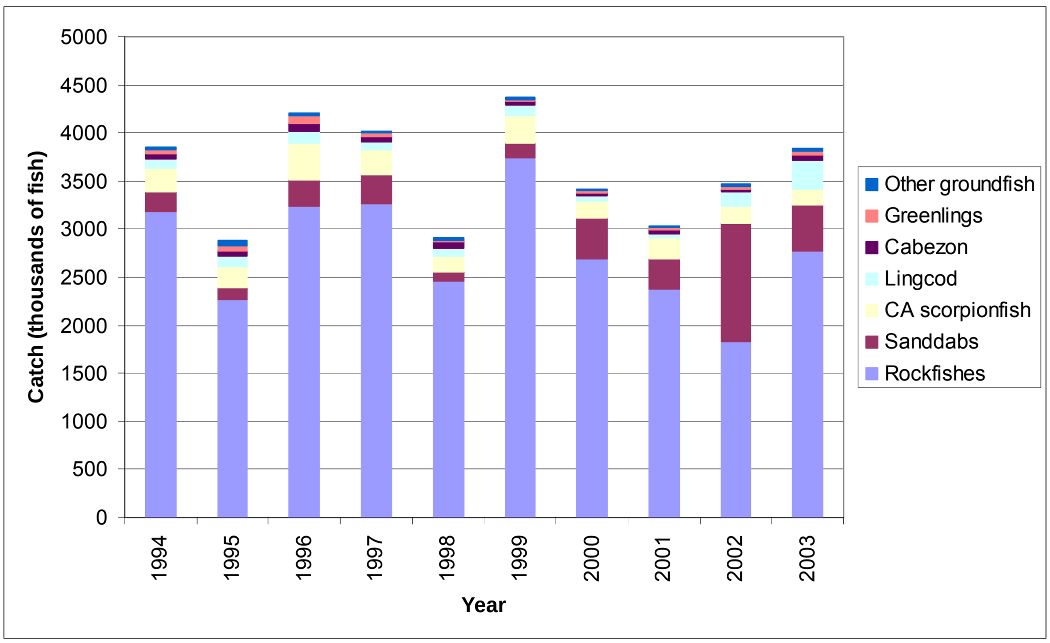

Figure 10-4. Groundfish recreational catch, 1994-2003. Data source: MRFSS data, all fishing modes and gear types combined. CPFV data not available for central and northern California for 1994-1995.

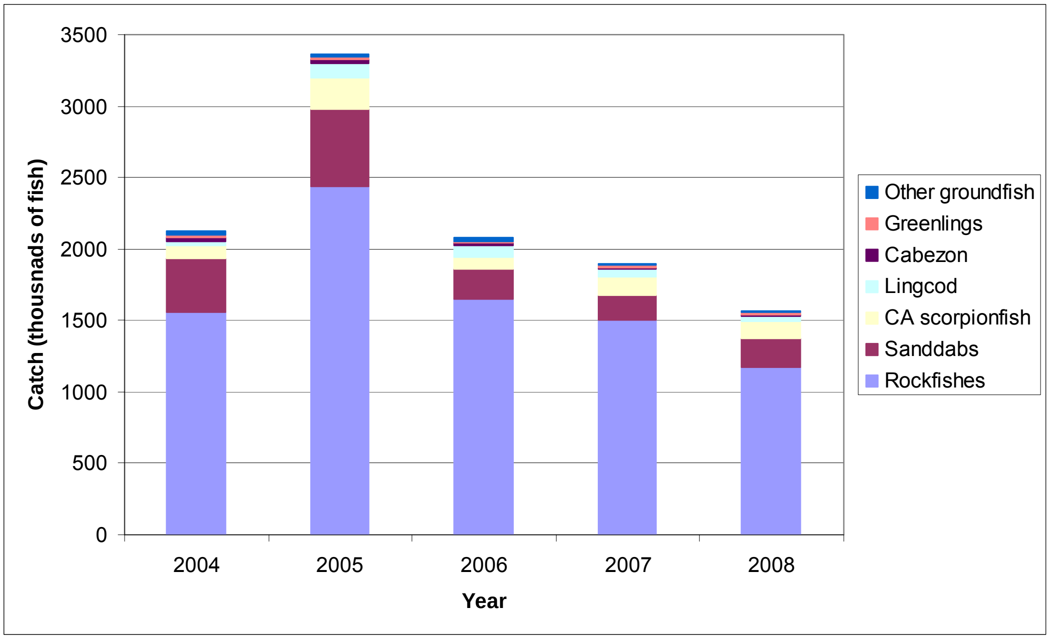

Figure 10-5. Groundfish recreational catch, 2004-2008. Data source: CRFS data, all fishing modes and gear types combined.

In 2000, the first of several major changes to the recreational take of groundfish occurred with the reduction of the rockfish bag limit from 15 fish to 10 fish, all species combined. In 2003, the RCG (rockfish, cabezon and greenlings) complex was established with a 10 fish bag limit, for all species combined. Since 2003, there have been a number of sub-bag limit changes such as allowing only 2 shallow nearshore rockfish within the 10-fish RCG bag limit (established 2003 and repealed in 2004). As of 2008, the 10-fish RCG bag limit includes a sub-bag limit for cabezon (1 fish) and greenlings (2 fish). Additionally, there have been changes to the lingcod bag limits over time (see the lingcod section of this report); the current lingcod bag limit is 2 fish (2008). There are also bag limits for the following groundfish species—leopard shark (3 fish) and soupfin shark (1 fish). The general bag limit of not more than 20 finfish in combination of all species with not more than 10 of any one species applies to the following groundfish—arrowtooth flounder, big skate, butter sole, California skate, curlfin sole, Dover sole, English sole, finescale codling, flathead sole, longnose skate, longspine thornyhead, Pacific cod, Pacific whiting, ratfish, rattail, rex sole, rock sole, sablefish, sand sole, shortspine thornyhead and spiny dogfish. There is no bag limit for Pacific sanddab, Petrale sole and starry flounder.

In 2000, the first size limits for recreationally-caught groundfish were established—cabezon (14 inches), California scorpionfish (10 inches) and greenlings (12 inches). In 2001, the size limit for cabezon was increased to 15 inches where it remains. As of 2008, the only rockfish with a recreational size limit is bocaccio (10 inches). Barotrauma, associated with bringing rockfish up from depth, has precluded the use of size limits on other rockfish species and any species with swim bladders caught in deeper waters. The size limit for lingcod is currently 24 inches (2008), but has changed over time (see the lingcod section of this report). The only other groundfish species with a recreational size limit is leopard shark (36 inches).

In 2000, there were 3 recreational management areas in California. The northern recreational management area [Oregon/California border to Cape Mendocino (Humboldt County)] was open year round. The central recreational management area [Cape Mendocino to Lopez Point (Monterey County)] was closed in March and April for nearshore and shelf rockfish and lingcod and the southern recreational management area (Lopez Point to U.S./Mexico border) was closed in January and February for nearshore and shelf rockfish and lingcod. The first of many actions to limit recreational fishing for groundfish occurred mid-2000 when lingcod was closed for November and December. In 2003, recreational fishing in the central and southern recreational management areas was curtailed with a July–October season. Intense fishing pressure after being off the water for 6 months occurred in some areas. This resulted in early closures for some species due to attaining the HG for overfished species bocaccio and lingcod, as well as nearshore rockfish. In an effort to maximize fishing opportunities, a fourth management area was created in 2004 by splitting the central area into the north-central and south-central recreational management areas. Over the next 4 years, the number of recreational management areas grew from 4 to 6. Depth-based closures also increased culminating with the RCAs in 2003. Associated time and area closures have become more complex as the Department tries to maximize fishing opportunities while protecting overfished species such as yelloweye rockfish. Table 10-2 lists the 2008 time and depth closures for each regional management area.

Table 10-2. Recreational regulations for cabezon, California scorpionfish, greenlings, lingcod and rockfishes in 2008.

Recreational management area	Season	Depth closure
Northern OR/CA border to Cape Mendocino	May-December Lingcod May-November *Closed September 2*	30 fms *Changed to 20 fms*
North-Central Cape Mendocino to Lopez Pt	June-November Lingcod June-November	30 fms *Changed to 20 fms*
The North-Central region was split into two regions effective September 2, 2008:		
North-Central North of Point Arena Cape Mendocino to Pt Arena	*Closed September 2*	20 fms
North-Central South of Point Arena Pt Arena to Pigeon Pt	June-November Lingcod June-November	20 fms
Monterey South-Central Pigeon Pt to Lopez Pt	May-November	40 fms
Morro Bay South-Central Lopez Pt to Pt Conception	May-November	40 fms
Southern Pt Conception to U.S./Mexico border	March-December Lingcod April-November California scorpionfish January-December	60 fms

Note: Inseason changes in *italics*.

Gear restrictions are another tool used to limit groundfish effort. Prior to 2000, there were no gear restrictions. In 2000, recreational anglers targeting rockfish were allow only 1 line with 3 hooks. This was reduced to 1 line with 2 hooks in 2001 where it remains. In 2004, special gear was allowed for the take of Pacific sanddabs when rockfish fishing was closed and in depths where rockfish fishing was not allowed.

The recreational catch of groundfish totaled over 1.5 million fish in 2008, just 22 percent of the total recreational catch. Groundfish made up almost 70 percent of the commercial passenger fishing vessel (CPFV) catch and over 50 percent of the private/rental boat catch in 2008. Some areas, such as the Redwood and Wine CRFS districts, roughly analogous to the Northern and North-Central North of Point Arena recreational groundfish management areas, rely heavily on groundfish species, which represents 59 and 78 percent of the total recreational catch, respectively (Figure 10-6). The South and Channel CRFS districts, roughly analogous to the Southern groundfish recreational management area, do not rely on groundfish.

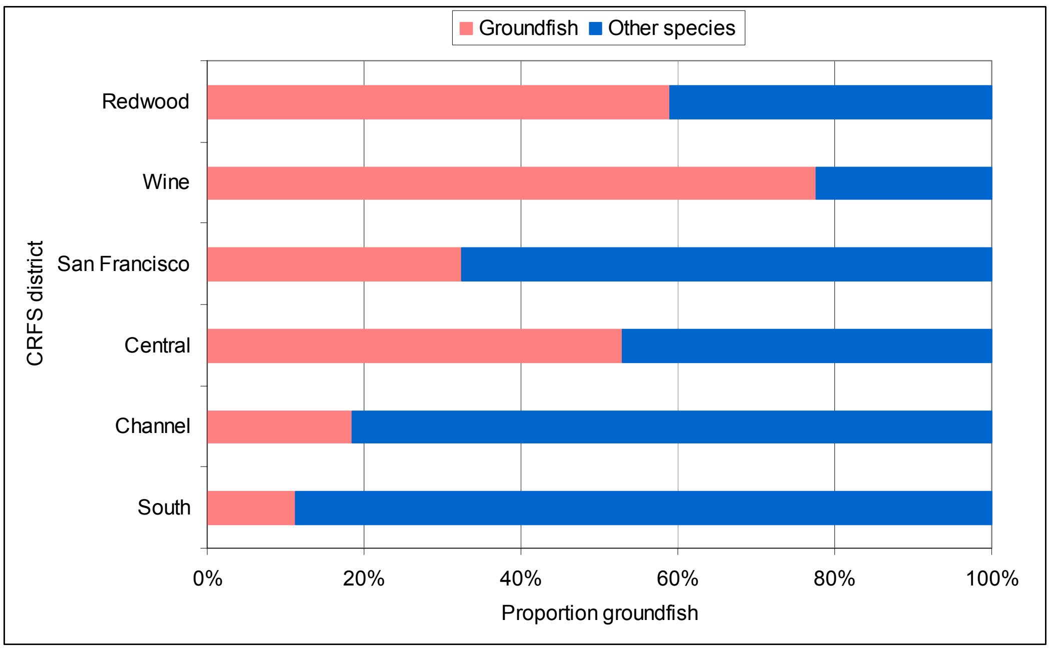

Figure 10-6. Proportion of groundfish taken by recreational anglers in 2008. Data source: CRFS data, all fishing modes and gear types combined.

For more information on groundfish and groundfish management in California go to the Department's Groundfish Central website at http://www.dfg.ca.gov/marine/groundfishcentral/index.asp.

For more information on federal groundfish management go to the PFMC's website at http://www.pcouncil.org/.

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Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Shallow nearshore species							
Black-and-yellow rockfish	5	0	7	889	2,063	23,581	32,017
	$0	$0	$0	$2,960	$5,460	$102,586	$162,925
Cabezon	82,924	193,814	245,230	264,868	372,760	321,207	255,811
	$273,589	$665,683	$837,835	$847,178	$1,224,134	$1,220,517	$1,126,064
California scorpionfish	113,123	90,740	76,444	95,880	112,822	86,683	41,252
	$179,440	$145,764	$113,944	$138,158	$187,812	$202,508	$102,401
China rockfish	67,963	58,156	38,388	47,657	21,837	14,305	12,256
	$124,071	$107,533	$68,191	$102,768	$61,587	$55,403	$59,439
Gopher rockfish	31,337	17,327	12,095	19,368	23,477	93,420	77,842
	$34,998	$35,105	$18,936	$46,601	$66,132	$328,716	$360,635
Grass rockfish	72,601	108,714	93,310	87,793	92,196	59,258	62,825
	$293,418	$505,926	$424,949	$319,413	$444,454	$297,934	$406,955
Kelp greenling	7,599	2,577	5,800	23,118	14,716	32,439	51,019
	$12,611	$4,980	$14,653	$55,180	$51,197	$123,637	$223,099
Kelp rockfish	6,673	5,307	4,297	2,009	1,653	2,976	2,218
	$10,245	$6,061	$7,359	$1,788	$2,392	$9,788	$9,440
Group gopher rockfish	147,069	167,911	221,345	141,795	135,196	28,468	12,059
	$257,142	$342,071	$513,363	$352,017	$355,756	$93,415	$54,483
Group nearshore rockfish	0	0	0	0	0	129	6,550
	$0	$0	$0	$0	$0	$468	$18,333
Deeper nearshore rockfish							
Black rockfish	248,713	244,298	272,928	269,270	188,642	130,194	110,603
	$116,947	$127,998	$149,230	$153,188	$104,438	$98,219	$128,183
Blue rockfish	73,600	40,356	25,311	86,180	92,215	30,393	17,862
	$38,611	$22,872	$14,403	$46,691	$56,986	$24,601	$19,769
Brown rockfish	9,200	3,843	2,729	6,612	13,012	24,502	29,078
	$6,734	$5,243	$3,711	$3,369	$12,490	$41,344	$119,158

Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Deeper nearshore rockfish (continued)							
Copper rockfish	76,857	97,591	141,988	101,053	66,362	35,456	21,821
	$110,714	$136,901	$201,484	$116,907	$84,656	$65,756	$63,492
Olive rockfish	135	564	720	645	1,259	1,218	2,186
	$83	$248	$2,023	$1,363	$4,693	$1,993	$3,185
Quillback rockfish	2,776	11,448	17,936	20,739	26,164	18,030	13,808
	$3,761	$16,457	$35,661	$31,684	$47,970	$55,315	$54,910
Treefish	114	199	1,536	1,744	231	1,960	3,720
	$353	$705	$1,861	$2,693	$1,087	$9,912	$18,702
Group black/blue rockfish	10,309	384	2,226	8,192	2,695	487	48
	$5,545	$404	$1,173	$4,486	$1,414	$449	$144
Group bolina (brown) rockfish	73,926	56,229	97,338	126,021	125,799	112,594	67,501
	$148,668	$109,998	$204,351	$240,937	$262,633	$315,263	$281,376
Group deeper nearshore rockfish	0	0	0	0	0	0	0
	$0	$0	$0	$0	$0	$0	$0
Shelf rockfish							
Bocaccio	1,883,077	1,678,458	1,022,557	600,460	297,478	150,895	54,455
	$730,583	$687,328	$405,653	$237,223	$142,490	$79,635	$38,135
Bronzespotted rockfish	54	627	0	16	137	0	61
	$0	$627	$0	$7	$150	$0	$91
Canary rockfish	205,338	341,969	404,248	477,605	399,487	233,081	34,937
	$145,303	$210,324	$254,793	$308,771	$233,669	$154,894	$34,508
Chameleon rockfish	0	0	0	0	18	0	0
	$0	$0	$0	$0	$0	$0	$0
Chilipepper rockfish	2,682,990	2,819,834	2,749,430	2,802,935	2,052,104	1,943,419	985,916
	$1,143,955	$1,226,671	$1,161,390	$1,121,507	$895,052	$864,839	$600,979
Cowcod	33,596	52,129	34,007	21,625	25,768	6,809	1,622
	$37,036	$59,755	$35,551	$22,935	$35,060	$8,640	$2,364

Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Shelf rockfish (continued)							
Darkblotched rockfish	0	0	10,078	25,513	8,203	1,259	25,149
	$0	$0	$4,600	$9,808	$333	$421	$14,074
Flag rockfish	180	1,005	18	130	170	1	279
	$240	$890	$20	$52	$11	$5	$369
Greenblotched rockfish	0	0	0	0	19	0	477
	$0	$0	$0	$0	$4	$0	$949
Greepspotted rockfish	33,381	15,356	41,785	44,779	27,160	13,523	6,478
	$31,940	$12,399	$38,603	$25,579	$18,973	$13,984	$9,850
Greenstriped rockfish	3,140	4,219	1,529	1,909	7,317	1,781	986
	$1,115	$1,105	$351	$424	$5,322	$1,123	$475
Honeycomb rockfish	0	0	0	0	0	0	0
	$0	$0	$0	$0	$0	$0	$0
Pink rockfish	0	0	0	2	0	0	0
	$0	$0	$0	$0	$0	$0	$0
Pinkrose rockfish	214	0	0	296	3,757	0	0
	$75	$0	$0	$118	$1,669	$0	$0
Rosethorn rockfish	10,157	10,248	15,855	18,792	5,307	1,106	285
	$4,265	$4,576	$8,341	$6,529	$2,028	$801	$333
Rosy rockfish	1,002	202	39	0	8,560	591	297
	$587	$103	$34	$0	$4,047	$206	$167
Shortbelly rockfish	6,195	12,600	61,440	44,888	15,088	17,634	8,710
	$186	$1,957	$5,567	$516	$1,619	$962	$1,033
Speckled rockfish	13	10	4,706	455	1,447	4,975	224
	$10	$10	$1,995	$336	$986	$6,702	$578
Squarespot rockfish	1,413	94	0	0	0	23	0
	$1,197	$41	$0	$0	$0	$23	$0

Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Shelf rockfish (continued)							
Starry rockfish	20,236	5,050	455	148	3,482	2,274	334
	$25,380	$6,766	$644	$167	$4,210	$3,070	$733
Stripetail rockfish	0	0	0	0	0	0	15
	$0	$0	$0	$0	$0	$0	$44
Swordspine rockfish	0	0	1,423	2	0	295	1,778
	$0	$0	$1,399	$0	$0	$7	$1,654
Vermilion rockfish	48,690	46,501	30,819	32,021	22,659	23,293	22,819
	$42,014	$42,285	$28,214	$30,259	$26,252	$35,223	$48,201
Widow rockfish	2,015,399	3,741,581	3,106,827	3,075,859	2,139,872	1,389,652	1,583,435
	$686,705	$1,310,776	$1,028,728	$985,287	$863,419	$593,670	$766,859
Yelloweye rockfish	56,754	66,949	99,667	92,249	38,202	21,106	7,278
	$58,283	$85,871	$132,317	$98,222	$50,752	$36,785	$16,259
Yellowtail rockfish	543,557	533,686	465,389	547,713	755,331	221,937	107,985
	$243,862	$234,233	$205,588	$242,766	$389,267	$119,656	$54,377
Group bocaccio/chilipepper rockfish	0	0	0	542	0	0	0
	$0	$0	$0	$325	$0	$0	$0
Group canary/vermilion rockfish	147	227	33	58	0	164	23
	$117	$204	$30	$123	$0	$148	$44
Group red rockfish	1,354,762	1,044,060	1,225,861	850,384	710,159	242,835	40,291
	$1,219,509	$1,005,099	$1,041,703	$837,280	$658,300	$258,743	$71,156
Group rosefish rockfish	549,425	650,929	594,180	773,483	2,762,585	409,944	192,309
	$143,828	$218,694	$141,456	$176,786	$618,913	$102,876	$58,123
Group shelf rockfish	0	0	0	0	0	0	42,871
	$0	$0	$0	$0	$0	$0	$30,309
Group small rockfish	1,099,744	924,333	1,210,981	1,487,399	1,236,840	288,096	12,359
	$354,120	$288,455	$310,086	$344,935	$338,740	$87,278	$6,696
Longspine thornyhead	944	5,856,667	5,420,006	4,606,366	2,911,494	2,380,198	1,940,774
	$872	$5,830,692	$4,344,592	$3,318,016	$1,914,459	$1,970,876	$1,921,151

Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Shelf rockfish (continued)							
Shortspine thornyhead	179	1,666,441	1,543,123	1,315,231	1,220,855	781,904	636,264
	$251	$1,884,136	$1,423,948	$1,183,418	$1,050,947	$859,307	$883,034
Unspecified thornyheads	7,293,383	502,216	345,041	271,063	107,771	131,487	165,575
	$5,386,609	$528,906	$356,120	$323,301	$138,282	$180,004	$235,428
Slope rockfish							
Aurora rockfish	0	0	0	97	4	0	1,524
	$0	$0	$0	$114	$0	$0	$2,252
Bank rockfish	55,867	106,376	66,639	81,466	451,477	27,166	179,935
	$24,624	$40,808	$27,937	$33,962	$206,602	$12,826	$120,440
Blackgill rockfish	579,005	411,473	479,860	414,246	348,434	77,288	98,928
	$403,339	$272,355	$303,386	$252,377	$232,558	$54,771	$102,412
Pacific ocean perch	323	20	45	0	0	3,426	7,143
	$113	$0	$135	$0	$0	$975	$3,024
Redbanded rockfish	6,138	2,173	1,104	1,480	447	251	10,143
	$4,776	$1,361	$837	$1,330	$359	$218	$10,973
Splitnose rockfish	4,029	18	370	936	89,585	74,081	49,948
	$1,075	$32	$0	$234	$15,723	$20,860	$23,737
Group deepwater red rockfish	2,368	36,572	6,138	4,332	379	0	271
	$928	$17,129	$3,793	$3,375	$178	$0	$509
Group slope rockfish	0	0	0	0	0	0	421,766
	$0	$0	$0	$0	$0	$0	$184,298
Unspecified rockfish	4,329,766	4,329,509	3,851,420	3,859,876	3,019,768	639,803	50,499
	$1,867,569	$1,967,691	$1,684,632	$1,581,950	$1,496,098	$409,053	$69,196
Flatfish							
Arrowtooth flounder	161,936	259,994	110,415	104,739	82,096	94,301	57,646
	$20,888	$31,671	$11,695	$11,034	$9,844	$10,255	$7,424

Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Flatfish (continued)							
Butter sole	262	0	1,897	57	6	55	0
	$105	$0	$1,648	$21	$2	$13	$0
Curlfin sole	211	275	0	5	30	90	0
	$53	$158	$0	$0	$30	$68	$0
Dover sole	9,888,498	13,417,995	14,107,539	11,693,676	7,874,411	8,421,513	7,247,486
	$2,824,487	$4,251,099	$4,012,496	$3,188,756	$2,592,020	$2,718,708	$2,461,483
English sole	1,019,534	1,101,103	1,281,212	1,430,131	940,449	849,836	668,158
	$351,058	$422,201	$472,740	$469,744	$333,267	$290,415	$244,341
Pacific sanddab	91,278	9,908	958	1,041	2,755	24,399	10,446
	$20,735	$1,139	$174	$144	$1,186	$6,312	$3,263
Petrale sole	1,211,845	1,305,154	1,803,549	1,830,750	1,042,039	1,250,534	1,400,696
	$983,260	$1,176,597	$1,589,178	$1,589,478	$972,545	$1,161,064	$1,434,170
Rex sole	1,256,861	1,517,177	1,097,983	1,000,369	637,802	629,453	495,761
	$467,318	$597,717	$401,275	$345,483	$231,525	$238,893	$214,883
Rock sole	8,400	15,691	7,822	20,762	21,506	14,515	16,542
	$3,604	$7,293	$3,350	$8,197	$9,303	$6,386	$7,958
Sand sole	121,880	81,496	137,148	109,918	77,254	60,137	83,862
	$89,499	$64,950	$111,253	$87,241	$56,748	$47,089	$69,805
Starry flounder	33,244	25,580	49,286	94,591	100,303	76,463	47,172
	$15,858	$13,984	$20,805	$41,500	$41,384	$35,059	$25,235
Unspecified sanddabs	1,408,535	1,483,628	1,737,152	2,044,958	1,435,056	2,044,787	1,629,012
	$401,529	$533,211	$583,861	$653,951	$453,041	$662,068	$585,765
Round fish							
Lingcod	1,251,353	1,185,394	1,066,023	1,132,240	331,705	313,284	119,817
	$585,956	$614,933	$574,245	$607,682	$273,627	$293,026	$151,714
Pacific cod	28	4	10	38	47	49	21
	$1	$0	$2	$52	$15	$22	$13

Groundfish commercial landings, 1994-2000.							
Common Name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Round fish (continued)							
Pacific whiting	7,964,783	9,018,285	6,395,184	14,028,191	12,617,919	2,883,014	10,991,514
	$353,655	$456,332	$238,707	$590,661	$385,047	$115,587	$753,993
Sablefish	4,790,1273	6,186,789	6,997,446	6,477,982	3,166,222	4,336,184	4,136,065
	$3,375,080	$7,254,744	$7,254,744	$8,961,132	$6,715,824	$8,501,141	$5,260,841
Spotted ratfish	6	6	0	735	94	415	181
	$0	$0	$0	$74	$0	$163	$18
Sharks							
Leopard shark	27,615	18,660	13,848	20,508	26,219	25,484	23,100
	$19,233	$15,363	$11,032	$18,009	$23,762	$22,834	$21,107
Soupfin shark	79,486	63,911	83,868	84,933	78,530	98,326	58,328
	$57,125	$51,841	$68,727	$77,545	$64,451	$84,493	$48,860
Spiny dogfish	1,221	232	1,320	8,405	14,996	77,752	31,584
	$173	$52	$101	$157	$5,598	$67,657	$11,299
Skates							
Big skate	0	230	0	534	3,592	1,257	19
	$0	$87	$0	$96	$647	$478	$6
California skate	155	0	0	0	0	141	1,782
	$28	$0	$0	$0	$0	$56	$1,254
Unspecified skate	93,236	413,048	1,830,076	2,964,575	1,832,499	1,870,653	1,242,026
	$26,728	$88,364	$390,005	$557,712	$376,151	$285,903	$249,292
Annual pounds	**53,251,723**	**62,066,127**	**60,778,141**	**65,810,335**	**50,239,973**	**33,153,501**	**35,726,569**
Annual value	**$23,640,749**	**$33,435,066**	**$31,786,341**	**$30,179,304**	**$21,260,800**	**$18,900,622**	**$20,025,952**

Data source: CFIS data, all gear types combined.

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Shallow nearshore species								
Black-and-yellow rockfish	19,672	18,897	16,572	23,086	22,679	18,401	22,729	26,592
	$101,620	$97,905	$81,920	$135,475	$146,182	$129,688	$161,382	$191,660
Cabezon	159,438	110,912	87,464	108,532	68,204	62,329	56,063	50,812
	$716,663	$483,897	$415,605	$501,803	$341,814	$343,181	$326,329	$309,730
California scorpionfish	44,038	29,761	11,582	11,034	11,405	5,936	7,847	7,959
	$122,741	$76,754	$32,122	$31,923	$32,670	$17,410	$24,666	$24,826
China rockfish	10,432	12,240	3,438	5,108	6,694	6,581	9,246	8,982
	$55,077	$71,005	$22,612	$32,436	$43,469	$46,663	$67,502	$68,578
Gopher rockfish	96,993	74,458	29,537	34,766	40,461	34,419	44,155	53,532
	$447,772	$364,668	$154,594	$205,276	$262,707	$240,811	$310,662	$392,941
Grass rockfish	51,221	37,396	29,784	30,090	27,930	39,015	41,986	35,070
	$363,743	$277,883	$253,157	$264,263	$255,986	$379,201	$426,698	$364,281
Kelp greenling	23,779	17,817	10,930	4,484	3,840	3,581	3,294	2,973
	$110,430	$85,545	$58,686	$24,632	$22,882	$23,511	$20,638	$20,087
Kelp rockfish	2,151	2,500	2,481	2,088	1,826	1,559	1,008	1,081
	$9,331	$9,603	$11,037	$9,305	$8,913	$9,316	$5,624	$5,901
Group gopher rockfish	4,540	2,809	3,641	3,037	2,924	4,274	1,711	584
	$18,305	$12,875	$18,050	$15,007	$17,241	$29,929	$9,391	$4,611
Group nearshore rockfish	6,250	2,545	420	381	56	1,692	925	1,347
	$8,774	$2,362	$614	$622	$107	$3,318	$1,948	$3,621
Deep nearshore rockfish								
Black rockfish	229,640	203,909	127,176	127,176	166,943	138,241	178,415	217,556
	$252,488	$311,199	$254,928	$254,928	$266,541	$253,445	$356,519	$436,900
Blue rockfish	26,603	38,106	17,003	20,993	35,291	39,674	38,252	24,516
	$30,045	$45,674	$25,347	$31,125	$47,494	$59,245	$54,680	$36,201
Brown rockfish	59,087	47,315	44,164	53,357	49,184	45,505	48,325	53,347
	$255,896	$215,698	$206,602	$291,529	$284,235	$272,004	$294,134	$334,745

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Deep nearshore rockfish (continued)								
Copper rockfish	32,816	28,096	6,595	11,125	11,672	8,335	11,549	12,086
	$114,816	$87,914	$23,563	$45,523	$45,436	$32,414	$45,758	$49,512
Olive rockfish	2,349	1,882	1,583	2,209	2,586	2,585	2,414	1,692
	$3,820	$2,849	$2,074	$3,972	$4,736	$4,553	$4,627	$3,923
Quillback rockfish	26,075	9,919	4,251	3,952	10,627	9,173	14,469	13,594
	$98,772	$37,708	$20,449	$18,904	$52,388	$44,987	$73,770	$70,450
Treefish	3,398	2,690	1,704	1,536	1,763	1,712	2,452	2,129
	$20,276	$15,404	$8,989	$8,732	$13,125	$13,405	$19,573	$19,008
Group black/blue rockfish	1,021	0	131	0	463	0	3	0
	$1,095	$0	$169	$0	$576	$0	$0	$0
Group bolina (brown) rockfish	35,977	17,846	4,897	6,832	8,195	7,049	1,351	274
	$149,217	$78,688	$21,313	$35,149	$47,357	$44,248	$8,882	$1,384
Group deep nearshore rockfish	0	0	0	317	196	791	839	91
	$0	$0	$0	$517	$414	$1,442	$1,517	$231
Shelf rockfish								
Bocaccio	48,127	45,458	1,368	19,293	15,756	10,603	13,334	15,407
	$37,389	$30,924	$1,395	$20,984	$16,825	$15,145	$18,251	$19,183
Bronzespotted rockfish	55	109	0	88	236	206	106	40
	$147	$109	$0	$163	$531	$466	$121	$316
Canary rockfish	31,494	23,854	1,149	2,050	4,608	5,485	2,253	1,780
	$29,193	$11,817	$767	$1,273	$2,911	$3,199	$1,537	$1,381
Chameleon rockfish	29	0	0	18	0	0	0	148
	$29	$0	$0	$36	$0	$0	$0	$444
Chilipepper rockfish	761,726	345,191	38,824	139,623	145,235	95,405	126,546	227,743
	$449,961	$185,011	$17,245	$66,084	$73,877	$58,075	$98,716	$189,378
Cowcod	56	112	8	68	85	0	130	0
	$25	$36	$0	$18	$90	$0	$130	$0

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Shelf rockfish (continued)								
Darkblotched rockfish	38,352	42,533	13,151	75,681	35,483	45,747	90,077	65,257
	$14,412	$19,194	$6,603	$37,935	$20,276	$25,831	$53,657	$38,978
Flag rockfish	65	163	54	541	110	531	340	355
	$119	$275	$59	$1,113	$227	$799	$1,171	$1,066
Greenblotched rockfish	1,094	128	27	744	283	986	1,901	363
	$2,273	$283	$21	$1,166	$436	$1,042	$2,054	$602
Greepspotted rockfish	1,401	1,510	703	641	708	453	1,915	2,764
	$1,954	$1,577	$587	$715	$1,221	$874	$4,556	$3,708
Greenstriped rockfish	626	274	826	219	209	180	40	179
	$842	$104	$1,138	$31	$101	$100	$41	$209
Honeycomb rockfish	0	0	0	10	0	18	4	9
	$0	$0	$0	$21	$0	$0	$4	$1
Pink rockfish	0	48	6	12	74	0	0	0
	$0	$47	$45	$5	$665	$0	$0	$0
Pinkrose rockfish	3	0	0	0	0	0	0	0
	$3	$0	$0	$0	$0	$0	$0	$0
Rosethorn rockfish	511	200	81	89	2	66	5	3
	$998	$395	$178	$194	$3	$187	$45	$4
Rosy rockfish	2,568	6,493	536	419	48	796	1,156	887
	$838	$2,743	$322	$466	$62	$265	$2,852	$2,752
Shortbelly rockfish	11,470	25	1,123	91	0	608	0	0
	$4,039	$0	$778	$9	$0	$0	$0	$0
Speckled rockfish	46	35	64	53	80	646	93	268
	$68	$61	$179	$100	$80	$815	$191	$317
Squarespot rockfish	0	0	424	272	87	0	438	93
	$0	$0	$907	$580	$232	$0	$1,504	$360
Starry rockfish	234	196	47	274	155	280	1,193	1,438
	$371	$383	$66	$670	$353	$678	$4,625	$6,468

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Shelf rockfish (continued)								
Stripetail rockfish	0	0	0	248	0	0	5	0
	$0	$0	$0	$0	$0	$0	$5	$0
Swordspine rockfish	46	0	10	0	0	25	8	7
	$51	$0	$20	$0	$0	$25	$8	$7
Vermilion rockfish	25,314	18,008	13,541	30,730	36,415	34,008	39,677	30,981
	$42,043	$37,678	$31,636	$67,364	$79,989	$83,866	$95,076	$80,383
Widow rockfish	731,293	107,987	10,186	19,085	12,840	18,068	18,230	67,556
	$346,412	$51,858	$5,923	$9,231	$6,382	$15,042	$19,341	$15,198
Yelloweye rockfish	8,457	146	22	43	46	10	401	54
	$19,920	$130	$20	$46	$23	$6	$800	$16
Yellowtail rockfish	91,627	30,760	4,985	20,845	12,857	11,587	11,353	8,080
	$47,032	$16,128	$4,596	$14,565	$10,648	$17,995	$15,595	$8,331
Group bocaccio/ chilipepper rockfish	26	0	0	0	0	0	0	642
	$21	$0	$0	$0	$0	$0	$0	$353
Group canary/vermilion rockfish	5	0	0	0	0	0	0	0
	$24	$0	$0	$0	$0	$0	$0	$0
Group red rockfish	22,700	17,774	35,004	21,630	16,174	13,379	25,533	8,541
	$39,906	$31,111	$23,612	$42,601	$33,958	$22,742	$34,248	$17,434
Group rosefish rockfish	205,179	165,621	373,345	389,224	266,770	309,649	44,944	3,285
	$61,034	$50,063	$106,611	$123,276	$81,992	$91,958	$23,711	$1,495
Group shelf rockfish	26,961	26,495	1,629	5,491	6,865	18,640	14,105	7,378
	$19,907	$15,899	$1,933	$9,058	$12,041	$35,517	$32,103	$22,067
Group small rockfish	7,327	12,635	4,124	5,558	2,452	3,109	143	96
	$5,301	$6,039	$2,819	$2,274	$1,142	$1,455	$74	$31
Longspine thornyhead	1,313,534	2,482,144	1,863,418	1,197,918	1,135,563	1,226,826	1,110,725	1,531,888
	$1,342,917	$2,268,766	$1,387,221	$705,810	$565,008	$739,686	$640,178	$767,828
Shortspine thornyhead	449,425	856,978	860,178	694,548	713,329	708,407	730,950	920,704
	$644,377	$1,271,761	$1,301,200	$1,217,098	$1,393,105	$1,525,266	$1,615,605	$2,086,029

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Shelf rockfish (continued)								
Unspecified thornyheads	104,974	148,798	130,480	91,313	42,834	28,822	19,111	4,655
	$213,221	$197,052	$143,140	$177,692	$79,258	$91,116	$63,188	$16,492
Slope rockfish								
Aurora rockfish	339	825	3,403	920	1,241	876	8,245	1,211
	$634	$1,713	$3,364	$1,202	$885	$797	$3,560	$2,703
Bank rockfish	124,050	439,106	159,600	199,370	36,227	77,489	56,812	183,590
	$74,077	$244,566	$94,682	$119,135	$29,503	$66,255	$63,178	$178,635
Blackgill rockfish	180,305	205,273	395,259	249,678	122,385	148,511	56,044	93,737
	$155,216	$220,371	$408,950	$259,643	$121,624	$165,473	$84,687	$141,409
Pacific ocean perch	2,195	108	0	128	56	721	58	538
	$952	$47	$0	$281	$47	$454	$27	$223
Redbanded rockfish	741	1,585	402	221	3,141	1,079	2,379	734
	$871	$1,721	$520	$211	$2,853	$1,335	$2,384	$1,979
Splitnose rockfish	30,474	40,066	49,847	22,668	1,667	17,605	177,128	188,865
	$12,713	$15,967	$16,424	$9,114	$1,689	$5,872	$61,600	$72,962
Group deepwater red rockfish	0	21	56	354	0	0	0	0
	$0	$47	$126	$347	$0	$0	$0	$0
Group slope rockfish	399,920	411,279	123,185	329,627	158,163	126,204	144,170	171,932
	$200,688	$212,776	$72,395	$174,898	$94,072	$80,475	$88,051	$109,697
Unspecified rockfish	33,704	41,843	21,682	6,135	7,160	7,585	29,891	1,498
	$37,420	$29,164	$13,542	$5,990	$5,905	$9,787	$39,491	$3,310
Flatfish								
Arrowtooth flounder	20,586	64,085	95,708	97,644	95,693	70,134	131,969	98,093
	$2,736	$9,559	$14,513	$10,034	$10,219	$7,429	$13,556	$9,896
Butter sole	1,177	69	0	0	140	157	0	86
	$467	$28	$0	$0	$198	$79	$0	$36
Curlfin sole	0	61	4	0	0	163	11	0
	$0	$29	$4	$0	$0	$52	$6	$0

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Flatfish (continued)								
Dover sole	5,307,234	6,881,731	7,185,492	5,337,785	4,894,492	3,884,339	6,101,575	6,667,414
	$1,875,731	$2,503,923	$2,599,173	$1,969,689	$1,798,577	$1,430,755	$2,380,396	$2,579,456
English sole	927,131	821,953	289,854	677,381	536,400	660,249	398,527	306,598
	$350,407	$301,721	$111,378	$250,613	$182,694	$228,485	$143,123	$110,067
Pacific sanddab	16,989	65	187	3,180	5,131	323	8,956	174
	$5,388	$172	$89	$1,064	$1,334	$323	$5,345	$94
Petrale sole	1,234,980	1,055,574	838,405	1,080,285	1,694,083	1,661,938	2,020,351	2,048,686
	$1,262,768	$924,670	$797,990	$1,109,232	$1,613,531	$1,728,327	$2,122,149	$2,203,405
Rex sole	518,975	633,841	570,787	463,782	469,277	329,588	379,204	314,350
	$231,463	$281,813	$254,616	$191,779	$186,684	$119,537	$132,931	$112,509
Rock sole	15,945	28,494	32,409	28,977	27,834	12,585	11,781	4,707
	$9,101	$15,690	$16,350	$14,496	$14,007	$6,789	$7,149	$2,802
Sand sole	183,661	119,576	80,657	50,388	57,052	16,465	13,989	5,749
	$145,417	$100,826	$68,502	$45,851	$44,850	$15,482	$11,503	$5,749
Starry flounder	91,768	64,615	63,448	74,234	83,938	65,757	29,367	22,866
	$46,149	$33,240	$39,491	$59,302	$67,874	$53,122	$18,453	$14,815
Unspecified sanddabs	1,713,965	1,242,137	1,350,096	785,590	503,737	253,348	347,247	277,711
	$670,896	$478,084	$508,937	$308,724	$238,323	$129,305	$164,506	$129,756
Round fish								
Lingcod	137,002	178,984	115,388	137,703	139,981	141,749	176,177	155,402
	$175,456	$246,966	$184,466	$215,224	$205,402	$204,873	$260,724	$237,181
Pacific cod	798	6	1,314	129	0	0	0	45
	$138	$4	$844	$104	$0	$0	$0	$23
Pacific whiting	5,084,234	6,114,074	3,838,412	10,454,767	6,845,532	11,969,975	6,543,217	10,899,837
	$171,486	$266,219	$170,080	$637,829	$339,695	$1,360,503	$383,730	$1,079,968
Sablefish	3,344,669	2,838,856	3,575,310	3,109,821	3,594,422	3,561,600	3,193,109	3,422,402
	$4,173,748	$3,509,313	$4,719,560	$3,723,153	$4,310,083	$4,888,379	$4,871,286	$6,233,813

Groundfish commercial landings, 2001-2008.								
Common name	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Round fish (continued)								
Spotted ratfish	0	3,458	0	0	2	3	160	5
	$0	$692	$0	$0	$0	$0	$64	$0
Sharks								
Leopard shark	23,210	24,831	17,137	21,864	25,180	20,301	19,958	6,393
	$22,446	$23,993	$15,694	$17,574	$19,891	$28,220	$20,170	$6,101
Soupfin shark	60,298	42,323	43,505	42,138	33,285	40,532	30,228	14,638
	$49,286	$36,397	$40,069	$39,532	$34,732	$40,223	$26,172	$12,559
Spiny dogfish	6,574	36,259	23,749	58,122	16,871	31,737	27,905	98,261
	$978	$7,626	$11,242	$36,136	$3,391	$19,180	$8,227	$36,423
Skates								
Big skate	1,540	0	90	0	0	0	12	167
	$329	$0	$32	$0	$0	$0	$9	$49
California skate	0	0	0	47	0	0	0	26
	$0	$0	$0	$0	$0	$0	$0	$8
Unspecified skate	1,397,954	180,794	275,379	251,845	209,266	268,286	247,483	391,641
	$289,048	$35,444	$62,057	$44,318	$39,337	$47,559	$54,006	$99,545
Annual pounds	**25,560,447**	**26,464,642**	**22,909,273**	**26,667,960**	**22,475,676**	**26,334,870**	**22,897,700**	**28,792,175**
Annual value	**$16,139,755**	**$15,972,722**	**$14,873,309**	**$13,641,404**	**$13,628,257**	**$15,316,421**	**$15,911,762**	**$19,004,591**

Data source: CFIS data, all gear types combined.

Groundfish recreational catch (number of fish), 1994-2003.										
Common name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Shallow nearshore species										
Black-and-yellow rockfish	33,852	26,406	9,564	8,968	13,969	15,810	20,656	17,046	16,377	21,158
Cabezon	47,117	60,075	77,059	54,674	66,551	40,706	31,867	41,456	31,391	59,511
California scorpionfish	252,899	213,018	384,501	256,586	163,517	296,977	175,072	211,181	186,909	173,475
China rockfish	45,537	34,195	30,294	14,155	11,160	23,900	26,627	30,835	22,232	30,416
Gopher rockfish	196,032	86,346	112,597	110,950	105,317	154,879	174,953	288,403	183,689	225,202
Grass rockfish	15,175	14,845	12,380	14,490	13,278	8,147	5,651	23,775	14,460	15,573
Kelp greenling	44,908	48,205	78,473	40,239	23,276	18,098	17,483	25,591	25,697	34,858
Kelp rockfish	61,308	51,927	31,329	30,583	13,433	20,008	18,084	22,253	44,141	45,541
Deep nearshore rockfish										
Black rockfish	300,040	222,109	196,661	152,778	161,786	282,997	230,214	346,179	187,545	735,698
Blue rockfish	428,512	266,618	463,803	764,979	619,300	498,466	311,406	256,500	295,750	444,844
Brown rockfish	63,119	77,297	105,665	116,911	79,660	120,091	101,707	192,572	100,074	206,415
Calico rockfish	6,276	8,055	6,665	5,102	3,816	8,038	1,538	545	453	2,186
Copper rockfish	151,575	64,243	118,736	47,955	60,873	89,955	56,217	42,272	30,097	45,952
Olive rockfish	113,238	58,690	73,482	99,214	82,999	65,458	75,933	119,027	199,638	73,494
Quillback rockfish	5,153	4,135	4,102	5,259	3,367	7,216	8,127	4,392	1,118	12,134
Treefish	34,950	52,915	54,407	17,691	27,057	41,268	14,481	27,738	13,580	13,265
Shelf rockfish										
Bocaccio	177,081	23,962	70,941	110,924	39,997	89,364	141,865	124,017	81,351	8,154
Bronzespotted rockfish	6,544	0	0	2,364	601	304	2,113	0	0	0
Canary rockfish	117,547	138,740	106,868	127,925	33,853	95,515	90,457	39,529	9,130	21,579

Groundfish recreational catch (number of fish), 1994-2003.										
Common name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Shelf rockfish (continued)										
Chilipepper	51,182	28,759	64,381	90,957	8,515	45,372	67,180	57,525	23,161	465
Cowcod	8,153	583	4,547	1,429	1,487	2,692	1,615	0	294	242
Flag rockfish	35,397	18,610	33,283	25,709	23,397	40,455	31,764	19,276	15,818	5,638
Freckled rockfish	0	0	0	0	0	0	0	0	810	0
Greenblotched rockfish	362	3,717	16,215	4,394	3,453	52,295	26,227	18,060	8,923	0
Greenspotted rockfish	150,756	176,427	90,925	64,817	37,814	144,306	96,569	60,173	33,133	1,485
Greenstriped rockfish	35,908	32,004	18,590	15,998	13,585	39,263	32,612	20,579	4,688	245
Halfbanded rockfish	23,954	7,142	27,262	82,779	28,101	32,579	7,395	372	5,897	4,484
Honeycomb rockfish	23,815	27,343	107,193	30,988	35,879	159,623	38,253	13,947	19,017	35,445
Mexican rockfish	0	0	7,292	0	242	1,282	4,327	2,577	244	0
Pink rockfish	1,176	0	0	0	0	1,340	4,215	0	0	0
Pinkrose rockfish	0	0	0	0	0	317	0	0	204	0
Redstripe rockfish	632	0	188	990	159	425	313	0	9	0
Rosethorn rockfish	1,064	156	1,155	1,869	3,480	1,868	1,556	115	647	0
Rosy rockfish	40,833	31,979	107,620	104,178	66,635	113,552	77,583	50,200	7,522	13,601
Shortbelly rockfish	0	0	439	1,353	256	0	0	327	0	0
Slivergrey rockfish	0	0	0	0	0	192	138	0	0	19
Speckled rockfish	76,735	19,876	23,382	41,199	17,780	25,010	12,560	5,451	4,050	2,907
Squarespot rockfish	33,004	14,158	131,858	95,819	53,115	43,653	10,890	1,552	5,640	17,146
Starry rockfish	111,378	42,561	148,256	115,761	62,922	145,742	70,310	51,156	19,719	15,723
Stripetail rockfish	771	0	159	0	0	1,513	0	0	0	0

Groundfish recreational catch (number of fish), 1994-2003.										
Common name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Shelf rockfish (continued)										
Swordspine rockfish	11,284	4,062	722	0	49	1,498	149	0	139	0
Tiger rockfish	592	0	0	0	344	291	0	0	148	252
Vermilion rockfish	271,783	195,499	252,511	90,894	120,205	262,932	199,477	138,760	198,047	382,247
Widow rockfish	9,529	9,566	41,023	57,920	49,108	37,038	15,763	13,647	3,776	1,394
Yelloweye rockfish	11,678	7,486	7,328	8,716	4,966	8,122	5,475	3,594	1,116	3,411
Yellowtail rockfish	86,234	66,094	196,910	598,807	171,157	326,041	198,487	86,674	46,231	35,748
Shortspine thornyhead	748	2,322	85	0	0	240	0	0	694	159
Slope rockfish										
Aurora rockfish	949	0	0	0	0	0	0	873	0	0
Bank rockfish	61,163	621	54,307	18,700	6,966	13,244	2,880	822	314	1,872
Blackgill rockfish	0	2,050	0	0	0	171	0	0	5,070	42
Darkblotched rockfish	0	0	136	0	0	0	0	0	0	0
Pacific ocean perch	1,265	0	427	1,614	0	0	0	2,092	566	862
Redbanded rockfish	316	0	0	0	0	360	0	0	0	0
Rougheye rockfish	3,583	156	414	2,676	244	0	0	225	139	180
Sharpchin rockfish	0	0	0	0	0	0	0	0	39	0
Splitnose rockfish	660	0	274	0	312	53	0	0	0	246
Unspecified rockfish	370,581	443,572	506,146	183,057	476,189	714,907	505,865	294,195	223,719	349,568
Round fish										
Lingcod	96,643	108,854	122,112	89,509	73,507	102,994	52,421	41,544	148,739	297,309

Groundfish recreational catch (number of fish), 1994-2003.										
Common name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Round fish (continued)										
Pacific cod	632	0	0	0	0	0	0	0	0	0
Pacific whiting	1,265	583	2,857	935	0	2,845	247	0	710	0
Sablefish	0	0	341	0	0	271	442	179	6,210	631
Spotted ratfish	0	0	0	0	0	0	221	0	0	0
Walleye pollock	109	0	0	0	0	0	0	0	0	246
Flatfish										
Butter sole	0	0	661	0	0	86	0	0	0	0
Curlfin sole	0	0	0	0	0	0	352	0	0	19
English sole	4	0	0	0	0	0	0	0	0	0
Pacific sanddab	194,622	101,435	273,692	285,950	89,771	141,231	422,624	302,792	1,088,153	350,311
Petrale sole	217	977	665	542	0	145	351	547	274	273
Rock sole	397	1,208	1,150	486	138	1,033	2,193	1,148	566	2,896
Sand sole	1,375	1,124	251	577	552	208	657	1,901	2,008	4,318
Starry flounder	2,875	5,769	2,822	5,499	14,353	8,998	6,599	4,295	4,549	4,716
Unspecified sanddab	20,460	32,416	13,644	6,307	15,506	10,010	12,365	23,975	141,139	137,448
Sharks										
Leopard shark	14,705	37,105	11,444	8,990	10,006	8,258	5,638	10,064	7,906	10,652
Soupfin shark	0	1,199	143	0	0	1,150	508	0	27	387
Spiny dogfish	4,881	9,434	5,402	1,517	2,247	3,728	2,680	2,258	3,971	5,638
Skates										
Big skate	0	0	0	0	0	0	0	0	662	206

Groundfish recreational catch (number of fish), 1994-2003.										
Common name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Skates (continued)										
California skate	0	0	297	0	0	536	0	0	24	0
Longnose skate	0	0	0	0	0	257	391	0	0	0
Unspecified groundfish	5,011	2,073	0	323	0	0	0	69	0	0
Annual catch	3,869,549	2,888,703	4,216,035	4,023,004	2,916,246	4,375,319	3,423,744	3,044,276	3,478,343	3,857,879

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

Groundfish recreational catch (number of fish), 2004-2008.					
Common name	**2004**	**2005**	**2006**	**2007**	**2008**
Shallow nearshore species					
Black-and-yellow rockfish	10,656	9,484	7,395	7,429	12,390
Cabezon	23,492	29,987	14,487	12,068	12,090
California scorpionfish	90,162	219,096	85,089	136,150	121,522
China rockfish	14,405	22,668	20,311	20,551	23,667
Gopher rockfish	97,377	116,601	106,965	84,125	96,154
Grass rockfish	13,853	14,167	29,044	14,249	13,450
Kelp greenling	23,576	23,576	23,576	23,576	23,576
Kelp rockfish	9,253	13,927	11,961	14,419	10,907
Deep nearshore rockfish					
Black rockfish	166,016	218,689	214,653	155,950	175,585
Blue rockfish	342,442	568,033	531,533	256,887	175,761
Brown rockfish	50,887	134,469	105,785	92,215	76,305
Calico rockfish	1,891	5,099	433	1,001	1,035

Groundfish recreational catch (number of fish), 2004-2008.					
Common name	**2004**	**2005**	**2006**	**2007**	**2008**
Deep nearshore rockfish (continued)					
Copper rockfish	34,603	67,639	53,860	74,897	61,932
Olive rockfish	79,322	131,687	73,593	69,338	57,371
Quillback rockfish	4,111	5,495	10,579	12,709	5,009
Treefish	10,671	21,550	7,631	14,282	10,826
Shelf rockfish					
Bocaccio	54,588	82,224	36,779	49,307	33,250
Bronzespotted rockfish	3	0	0	0	0
Canary rockfish	15,882	4,670	10,324	8,370	2,520
Chilipepper	15,408	23,878	4,552	14,511	9,178
Cowcod	439	203	21	189	133
Flag rockfish	17,709	33,613	9,393	19,654	14,368
Freckled rockfish	17	131	54	238	239
Greenblotched rockfish	3,220	5,134	3,108	1,007	570
Greenspotted rockfish	38,787	62,395	18,475	33,874	27,072
Greenstriped rockfish	929	3,166	1,692	1,999	2,922
Halfbanded rockfish	5,848	11,192	2,206	2,772	7,405
Honeycomb rockfish	19,502	55,392	10,981	20,222	20,707
Mexican rockfish	21	213	9	29	33
Rosethorn rockfish	24	82	0	0	12
Rosy rockfish	28,890	31,631	14,332	35,245	28,308
Speckled rockfish	16,784	26,255	7,193	11,762	12,310

Groundfish recreational catch (number of fish), 2004-2008.					
Common name	**2004**	**2005**	**2006**	**2007**	**2008**
Shelf rockfish (continued)					
Squarespot rockfish	16,335	25,804	5,834	9,874	13,205
Starry rockfish	31,587	73,498	30,954	66,540	49,940
Stripetail rockfish	518	124	5	1,552	5
Swordspine rockfish	0	396	59	137	0
Tiger rockfish	0	33	176	348	40
Vermilion rockfish	250,584	343,077	174,507	180,783	99,065
Widow rockfish	26,838	6,939	5,011	11,756	7,076
Yelloweye rockfish	632	824	704	2,750	598
Yellowtail rockfish	26,850	36,856	38,865	112,035	42,507
Longspine thornyhead	0	0	0	6	0
Shortspine thornyhead	2	0	49	0	0
Slope rockfish					
Bank rockfish	1,246	3,123	77	181	161
Blackgill rockfish	4	0	0	0	0
Unspecified rockfish	150,752	275,084	101,674	103,328	85,379
Round fish					
Lingcod	30,909	72,085	82,881	49,912	30,477
Pacific whiting	201	71	39	32	35
Sablefish	2	259	12	6	14
Flatfish					
Butter sole	0	15	25	81	0

Groundfish recreational catch (number of fish), 2004-2008.					
Common name	**2004**	**2005**	**2006**	**2007**	**2008**
Flatfish (continued)					
Curlfin sole	4	0	0	0	8
Dover sole	0	0	0	36	6
English sole	206	13	21	6	0
Pacific sanddab	344,518	365,983	191,537	138,403	190,334
Petrale sole	538	558	867	1,315	612
Rex sole	0	0	6	0	0
Rock sole	781	1,319	742	802	678
Sand sole	2,275	134	96	229	178
Starry flounder	4,022	4,864	1,749	663	1,463
Unspecified sanddab	27,611	174,740	17,376	27,229	12,431
Sharks					
Leopard shark	13,837	7,561	20,735	4,682	5,877
Soupfin shark	0	1,337	60	32	43
Spiny dogfish	1,329	1,051	1,998	1,241	825
Skates					
Big skate	43	9	33	0	53
California skate	0	140	13	13	25
Longnose skate	145	0	39	0	0
Unspecified groundfish	0	71	0	0	0
Annual catch	2,122,539	3,370,187	2,092,808	1,903,058	1,577,126

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

11 Spiny Dogfish, *Squalus acanthias*

Spiny dogfish, *Squalus acanthias*. Photo credit: David A. Ebert.

History of the Fishery

The spiny dogfish, *Squalus acanthias*, known also as the piked dogfish, has long been targeted by recreational and commercial fishers in California. Over the past 90 years, there has been great fluctuation in the demand, use, gear used and annual landings of this shark species in California.

Compared to most other shark species, commercial landings and trade of spiny dogfish is well documented due to its long history of utilization in California. At the beginning of the 20th century, sharks comprised a minor meat fishery in California; very few Californians wanted to eat shark. Spiny dogfish have small fins and were not routinely caught for their fins. A small number were harvested for their hides, although this was a labor intensive process. As a common bycatch species, spiny dogfish fetched $5 per ton in reduction fisheries to make fertilizer. Many commercial trawlers despise this species for feeding on their targeted fish and ruining their nets—spiny dogfish roll into circles, thrash about, and have rough skin and spined dorsal fins that make them very difficult to remove from trawl nets. In effect, they were harvested just to remove them from the ocean so as not to destroy any more nets. When it was used, spiny dogfish meat was widely passed off as other, more lucrative species such as California halibut and white seabass. According to California Department of Fish and Game (Department) landings data the annual commercial shark harvest during the years 1930 through 1936 averaged 588,373 pounds (267 metric tons).

A brief but intense commercial fishery for spiny dogfish occurred in the late 1930s, secondarily to the soupfin shark fishery. A new market for sharks suddenly developed with the discovery that livers of soupfin shark, and to a lesser extent, spiny dogfish, have unusually high levels of vitamin A. At the time, vitamin A could not be synthesized and a shark liver gold rush ensued. By 1939, 600 vessels were fishing for sharks along the California coast using gill nets, otter trawls or any means necessary. Starting at around $40 per ton of livers, shark liver dramatically rose in value to $2000 per ton in 1941. This is the equivalent of one shark being worth about $50 today. Not surprisingly, total shark landings increased over eight times between 1937 and 1938, but in 1942 fell to less than half the total landed in 1941. These changes are so great that even data gaps and inaccuracies cannot conceal the events that took place in the fishery. A great increase in landings happened—the annual shark harvest during the years 1937 though 1941 averaged 6.6 million pounds (3000 metric tons) although the actual proportion of spiny dogfish is unknown due to non-specific shark sorting (see below). In the years following 1941, a decrease in total landings occurred in spite of increased fishing effort encouraged by high liver prices. Hence, this latter change may reflect a decrease in abundance of spiny dogfish and soupfin shark. The annual shark harvest during the years 1942 through 1950 averaged 2.4 million pounds (1074 metric tons). The shark liver bonanza halted with the advent of synthetic vitamins and the onset of World War II, and shark landings fell to pre-bonanza levels by 1950.

Commercial sorting of sharks by species was not required by law until relatively recently. The spiny dogfish was known as “grayfish” in the 1930s, and was granted a market code in 1931, but landings were not effectively sorted until the late 1960s. No distinction was made between shark species in the landings before 1937, and only soupfin shark data became available in 1941. From 1941 through 1950, soupfin shark made up 53 percent of the total shark landings by weight, and spiny dogfish probably accounted for a large part of the remainder. Inaccuracies in the landings data arose due to the variations in the marketing practices of the fishers. In the earlier years, sharks were cleaned at sea and only the carcasses were delivered to the markets as “unidentified shark”. Then later, many livers were landed without a corresponding carcass. For instance, in 1948, 100,000 pounds (45 metric tons) of shark livers were landed, the corresponding species unknown.

According to commercial data from Department, spiny dogfish landings have varied greatly since active sorting began in 1969 (Figure 11-1). From 1969 to 1976, landings were relatively low at a yearly average of 6749 pounds (3 metric tons); however many spiny dogfish were probably not sorted into their specific market category and were instead landed as “unidentified shark”. Landings were the highest from 1977 through 1979, and peaked in 1978 at 439,991 pounds (159 metric tons). Between 1989 and 1997, commercial landings were quite low, but slowly increased to 98,261 pounds (45 metric tons) in 2008. Although many factors can affect total landings, probable influences are regulatory changes in other commercial fisheries such as groundfish and salmon, sorting requirements and the demand in foreign markets.

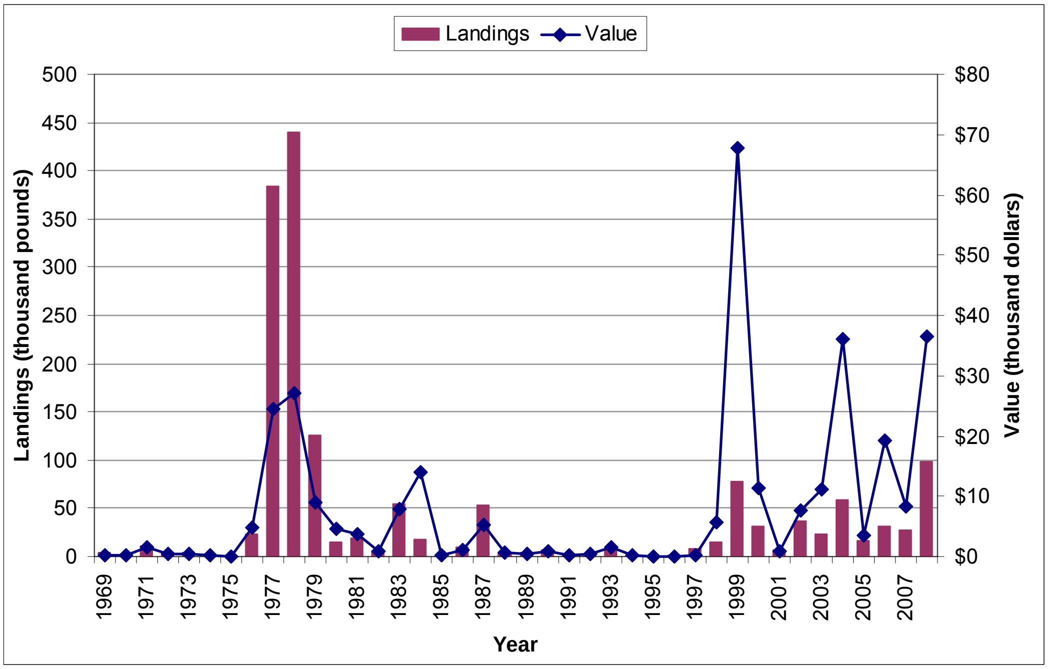

Figure 11-1. Spiny dogfish commercial landings and value, 1969-2008. Data source: CFIS data, all gear types combined. Data not available prior to 1969.

The spiny dogfish in the eastern north Pacific is currently harvested for exportation to Europe, Australia, South America and Japan where the meat is consumed by humans or made into fishmeal for aquaculture. The gear types used to land spiny dogfish are trawl, gill net, and hook and line (e.g. long line). Commercial fishery catch-per-unit-effort (CPUE, in pounds per trip) show that trawl gears have the highest success, followed closely by gill net, with hook and line gear being the least successful (Figures 11-2 and 11-3). Markets favor mature females due to their large size. Fins may be utilized in China, but are of relatively low value because of their small size. Some spiny dogfish are embalmed and processed for science education.

In recent years, the commercial market price for spiny dogfish has been low, between $0.25 and $0.40 per pound ($0.55 to $0.88 per kilogram), with only a modest increase from 1970s prices of $0.10 to $0.20 per pound ($0.22 to $0.44 per kilogram). Currently, the commercial sector lands a majority of the spiny dogfish total catch at 17,905 pounds (8 metric tons) in 2007 and 98,261 pounds (45 metric tons) in 2008, compared to the recreational sector at 11,423 pounds (5 metric tons) in 2007 and 6428 pounds (3 metric tons) in 2008. The 2008 commercial ex-vessel value of spiny dogfish is estimated at $36,423 (Figure 11-1).

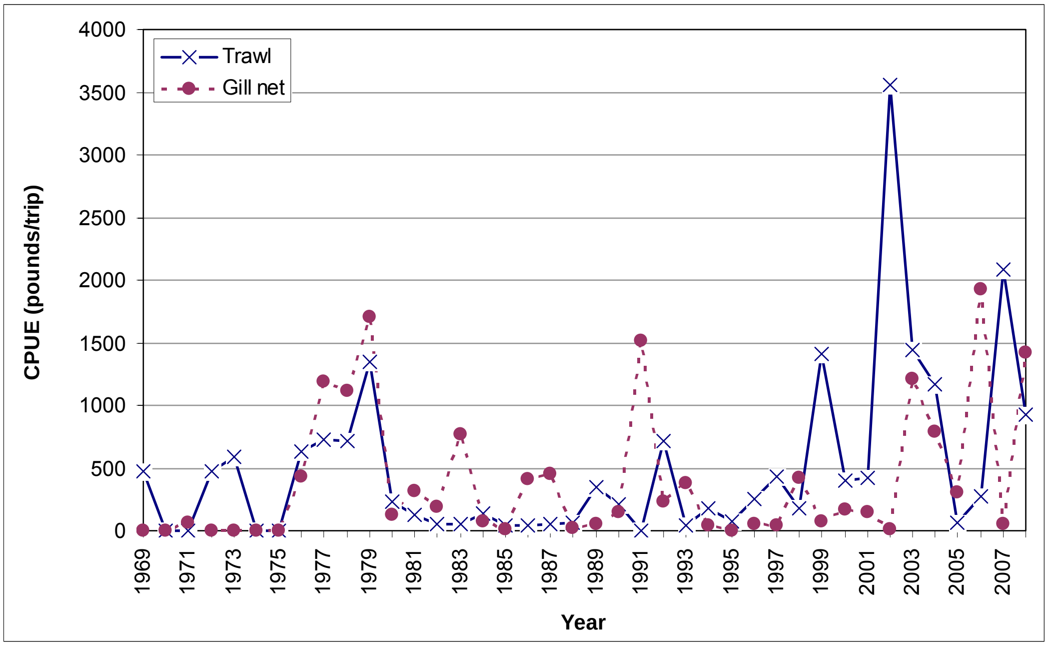

Figure 11-2. Spiny dogfish trawl and gill net catch-per-unit-effort (CPUE), 1969-2008. Data source: CFIS data. Data not available prior to 1969.

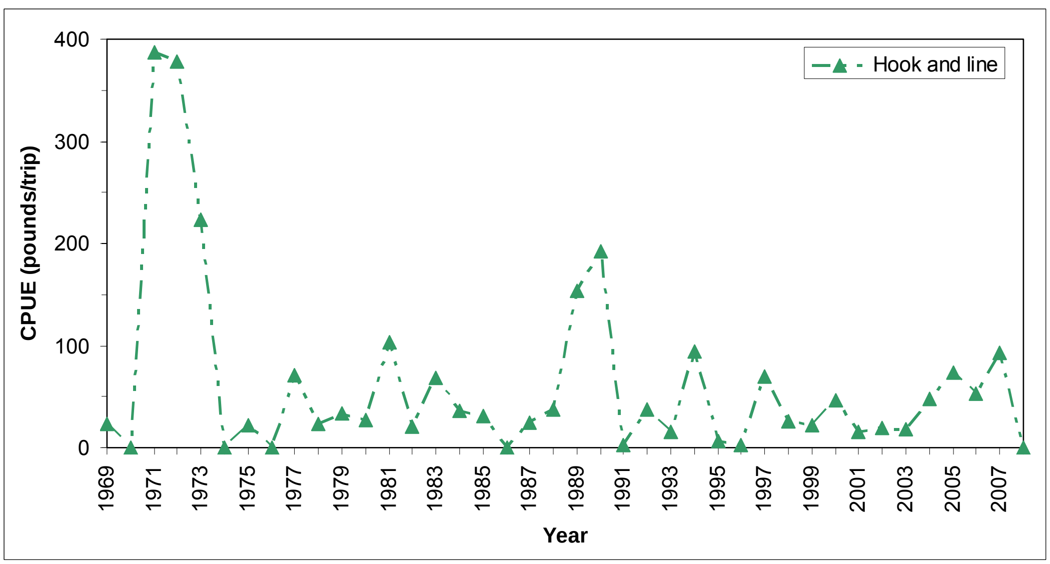

Figure 11-3. Spiny dogfish commercial hook and line catch-per-unit-effort (CPUE), 1969-2008. Data source: CFIS data. Data not available prior to 1969.

Generally, recreational anglers in California do not target the spiny dogfish; however, due to its voracious feeding nature, it is frequently caught incidentally and considered a nuisance by many recreational anglers. Nevertheless, spiny dogfish make up a significant portion of the recreational fishery catch in southern California and in the San Francisco Bay area. In the recreational fishery, it is taken primarily by hook and line gear and has been landed in the following fishing modes: private/rental boats, commercial passenger fishing vessels (CPFVs), and man-made structures. Beaches and banks tend to be too shallow, thereby minimizing catch for this fishing mode.

There are two different recreational sampling programs: the Marine Recreational Fisheries Statistical Survey (MRFSS) which sampled from 1980 to 2003 and the California Recreational Fisheries Survey (CRFS) which was initiated by the Department in 2004. Due to changes in the sampling protocol and how the data are used to estimate catch these two surveys are not comparable. A review of the MRFSS data show the average annual catch of spiny dogfish from the period of 1980-1989 was 25,331 fish (Figure 11-4) and the average weight during this period was 4.2 pounds (1.9 kilograms). The average annual catch declined by 80 percent to 5065 fish from the period of 1993-2003 (note: no data available for the years 1990-1992) but the average weight during this period was quite a bit larger, at 6.8 pounds (3.1 kilograms). Catch peaked in 1980 at just fewer than 58,000 fish; the worst year for recreational spiny dogfish harvest was 1997 at 1517 fish. From 1980 through 2003, for the years where data are available, a majority (71 percent) of spiny dogfish were landed in southern California. The spiny dogfish is quite a common species encountered on southern California CPFVs. From 1986 through 1989, spiny dogfish ranked tenth in total number of fish caught onboard CPFVs at Bolsa Chica Artificial Reef.

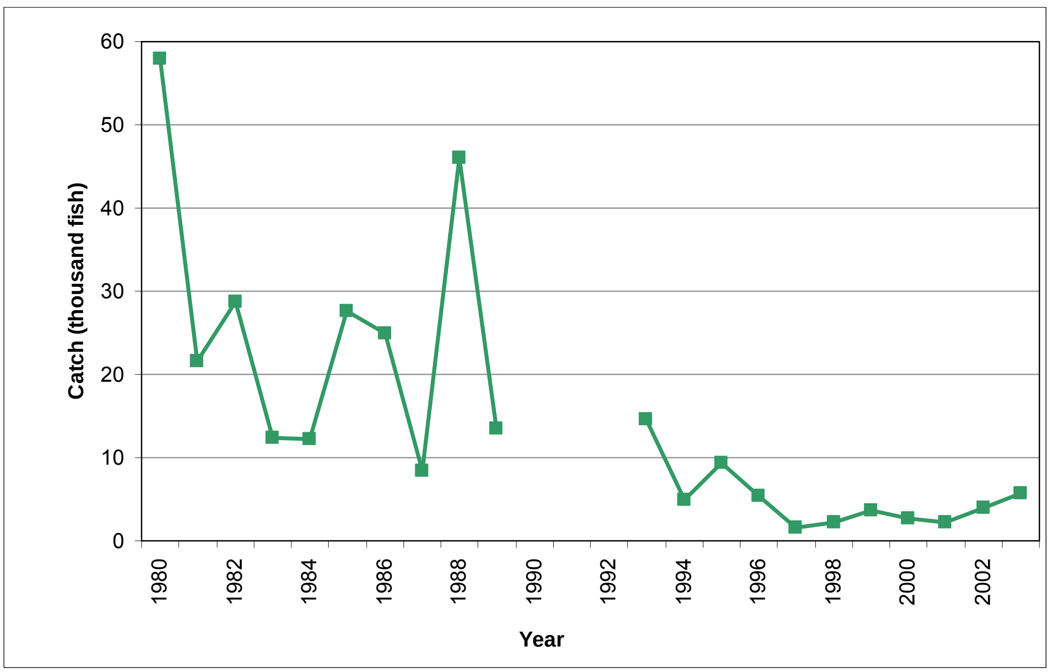

Figure 11-4. Spiny dogfish recreational catch, 1980-2003. Data source: MRFSS data, all fishing modes and gear types combined. Data not available for 1990 through 1992. CPFV data not available for central and northern California for 1993-1995.

The California Recreational Fisheries Survey (CRFS) data show spiny dogfish Catch has fluctuated between 825 and 1998 fish per year since 2004 (Figure 11-5). The average weight per shark since 2004 was 6.4 pounds (2.9 kilograms); and a majority of the catch came from private/rental boats (50 percent), followed by man-made structures (29 percent), and CPFVs (20 percent). CRFS data (2004-2008) show spiny dogfish ranked 53rd statewide as the most commonly caught species from all boat modes (private/rental and CPFV combined). A majority of the 2004-2008 spiny dogfish recreational catch (76 percent) was landed in the port complexes of San Francisco, Los Angeles, and San Diego; very few fish were landed north of Point Arena (Mendocino County).

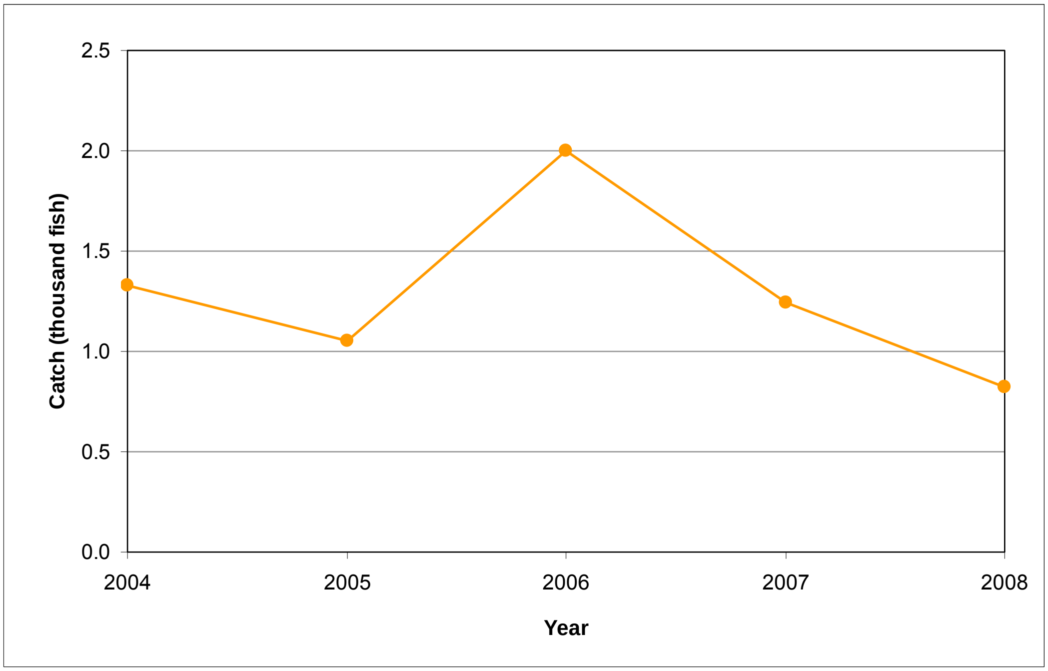

Figure 11-5. Spiny dogfish recreational catch, 2004-2008. Data source: CRFS data, all fishing modes and gear types combined.

Recreational fishery CPUE, an indicator of fish abundance based on MRFSS and CRFS sample data, has varied greatly since 1980, with the 2008 figure (in amount of fish caught per 100 angler hours) similar to the early 1980s (Figure 11-6).

According to CPFV logbook data available from 1948 to present, CPFV spiny dogfish catch varied greatly from over 1500 fish in 1975 and 1980 to 15 fish in 2008 (Figure 11-7). Since the spiny dogfish is a schooling species, catch is highly dependent on whether the vessel drifts into a school. According to the CPFV logbook data, the 1940s was not a time for catching spiny dogfish onboard CPFVs. Either the species was still recovering from the shark liver boom, or perhaps anglers were not interested in keeping these fish (released fish were not recorded until 1994). Relative to the 1980s and early 1990s, there has been a notable decline in fish landed and CPUE of spiny dogfish in the late 1990s and 2000s (Figure 11-8). From 1981 through 1993, the average number of spiny dogfish landed was 430 fish, with an average CPUE of 0.31 fish/100 angler-hours. From 1994 through 2008, the average number of spiny dogfish landed was 141 fish, with a CPUE of 0.08 fish/100 angler hours. This decline for CPFV CPUE could be due to changes in overall recreational fishing regulations since 1998.

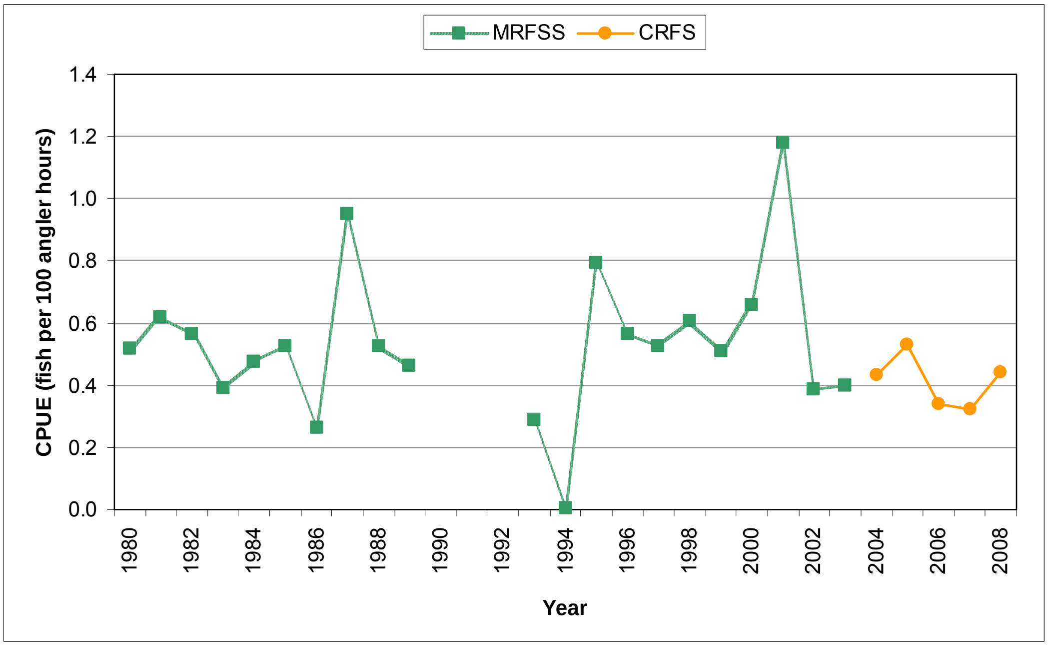

Figure 11-6. Spiny dogfish recreational catch-per-unit-effort (CPUE) for boat modes (private/rental and CPFV), 1980-2008. Data source: MRFSS (1980-2003) and CRFS (2004-2008). Data not available for 1990 through 1992. CPFV data not available for central and northern California for 1993-1995.

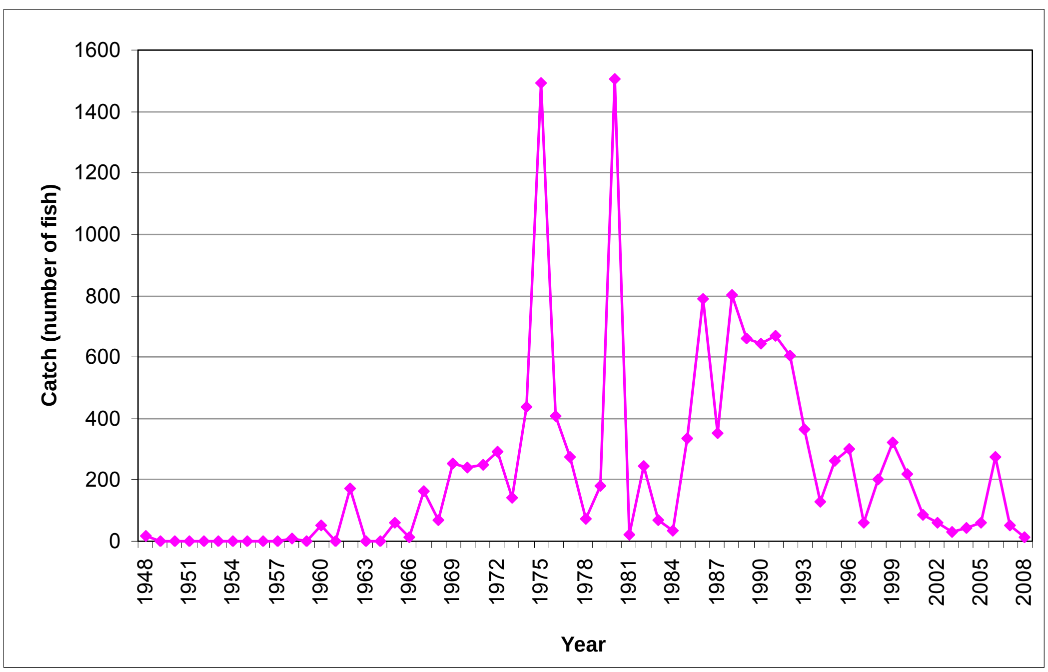

Figure 11-7. Spiny dogfish commercial passenger fishing vessel (CPFV) catch, 1948-2008. Data source: CPFV logbook data. Data not available prior to 1948.

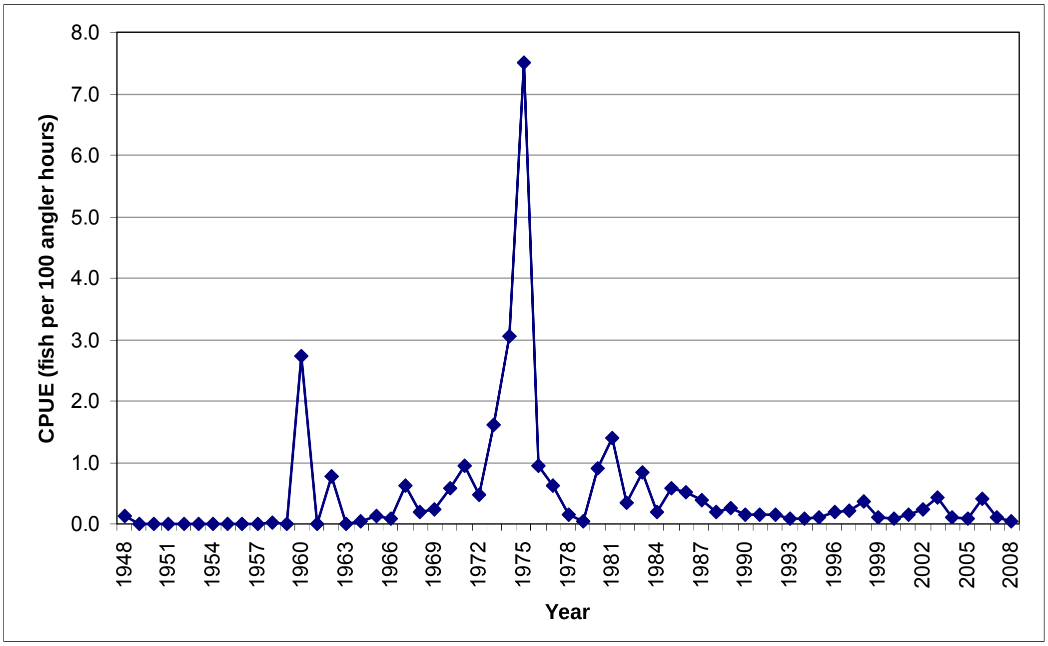

Figure 11-8. Spiny dogfish commercial passenger fishing vessel (CPFV) catch-per-unit-effort (CPUE), 1948-2008. Data source: CPFV logbook data. Data not available prior to 1948.

Status of Biological Knowledge

The spiny dogfish occurs worldwide on the continental shelf, from the intertidal to the shelf-slope boundary, in temperate and boreal waters. In the eastern North Pacific, the geographical range of the spiny dogfish extends from the Gulf of Alaska southward to San Martin Island (southern Baja California, Mexico). This species is extremely abundant in waters off British Columbia, Canada and Washington state, but declines in abundance southward along the Oregon and California coasts. Spiny dogfish prefer colder waters (45-59°F; 7-15°C), often making migrations to follow this optimal temperature gradient. Spiny dogfish have been observed from the surface down to a depth of 4055 feet (1236 meters), but fishery data as well as National Marine Fisheries Service (NMFS) fishery-independent shelf surveys show that the highest catch rates occur in 180-600 feet (55-183 meters).

Although frequently observed as a solitary species, this gregarious shark forms large localized schools of hundreds if not thousands of individuals of uniform size and sex. Spiny dogfish can travel long distances. An extensive tagging project found that spiny dogfish tagged off the west coast of Canada migrate as far as the coasts of Japan and Mexico.

The spiny dogfish is a moderately large species of squaloid shark, reaching a maximum size of 51 inches (130 centimeters) in the eastern Pacific. It reaches maturity between 14-35 years of age; males reach maturity at a younger age, but females live longer and grow larger than males. The maximum age estimated for this species is at least 30-40 years but potentially up to 100 years. This species is extremely slow growing, at about 0.6-1.4 inches (1.5-3.6 centimeters) per year. It displays one of the lowest population growth rates calculated for any shark species: 2.3 percent annual rate of population increase from maximum sustainable yield in the eastern North Pacific.

Reproduction in the spiny dogfish is well documented. This species displays aplacental viviparity (i.e. ovoviviparity; live young without a yolk sac placenta) and no parental care. The breeding season is between September and January. The gestation period of the spiny dogfish is the longest documented in any vertebrate, 18-24 months. Mature females give birth every two years and large schools of pregnant females have been documented. Birth occurs in the midwater zone in depths of 541-1178 feet (165-359 meters). Pup size at birth is between 8.7 and 13.0 inches (22-33 centimeters). Litters average between 2 and 12 pups with larger females having larger litters. The young tend to occupy a pelagic habitat, but as they mature, they shift to a more demersal lifestyle.

The spiny dogfish is a top level predator and it is a highly active, voracious, opportunistic feeder that preys upon squids, crabs, shrimps, sea cucumbers, jellyfish and combjellies, and bony fish such as herring, smelt, rockfishes, sardines, and almost any fish smaller than itself. Fish become a more important part of their diet as the spiny dogfish grow larger. Most of the diet of juveniles consists of small invertebrates, whereas the adults prey largely on benthic organisms. They are preyed upon by a variety of shark species, including sixgill, sevengill, leopard, and white sharks, and by some marine mammals. This shark is not dangerous to humans other than the occasional injury to anglers by their sharp teeth and mildly toxic dorsal fin spines.

In California, the highest levels of contaminants in marine fishes usually occur in coastal southern California and San Francisco Bay. In a 1975-1981 comparison of fish contamination in southern California coastal areas, the highest values of dichlorodiphenyl trichloroethane (DDT) and its isomers and metabolites in muscle tissue were in the spiny dogfish (200 parts per million). Polychlorinated biphenyls (PCBs) in muscle and liver tissue were also the highest in the spiny dogfish (14.8 parts per million). Since inputs of contaminants from all sources have decreased in recent years, concentrations of contaminants in water, sediments, and marine organisms have also decreased.

Status of the Population

Currently, there is no fishery stock assessment approved for management purposes on the west coast. Washington is the only west coast state with a directed spiny dogfish fishery, mostly in Puget Sound, where, in 1955 the spiny dogfish population was considered to be nearly fully utilized. The Washington Department of Fish and Wildlife (WDFW) was scheduled to lead a 2009 assessment, however the majority of studies conducted thus far are for the waters of Puget Sound, Washington or Vancouver, Canada. There is a lack of west coast spiny dogfish biological data, specifically, age and size composition data. In late 2008, the Pacific Fishery Management Council (PFMC) discussed the issue and decided to postpone the assessment until 2011 to allow WDFW time to collect more data.

Some stock assessment scientists believe that the Puget Sound sub-stock has been overfished, and some indicators (e.g. CPUE) support this with catches at historic lows. Fishery and population trend data indicate that populations in the North Pacific qualify the spiny dogfish for inclusion in the International Union for the Conservation of Nature (IUCN) Red List of threatened species. The spiny dogfish has already been declared as overfished on the east coast. At the global level, the spiny dogfish is categorized in the IUCN Red List as “near threatened”. Since foreign markets are, in most cases, the driving economic force behind spiny dogfish fisheries around the world, unregulated international trade is the main threat to the species.

It is unknown how the population off California fares today. The spiny dogfish was most likely overfished by the end of the 1940s, but the population has had many years to recover from the shark liver fishery boom of the 1930s and 1940s.

Management Considerations

The spiny dogfish became a federally designated groundfish in 1982 when the 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 Department through regulations adopted by the state legislature and the California Fish and Game Commission.

There is no directed commercial fishery for spiny dogfish in California. Federally, it is included in the Other Fish category in Pacific coast groundfish management. Since 2006, the spiny dogfish has been managed with separate trip limits but there is no set allocation or optimum yield (OY), as no stock assessment has been completed. Although the U.S. and Canada conduct cooperative surveys for northeast Pacific spiny dogfish, there is no coordinated, international management for the stock.

Even in the absence of a formal assessment, life history information indicates the spiny dogfish is easily overfished. The spiny dogfish is long lived, slow growing and late maturing, with a very slow metabolic rate, limited reproductive capacity and a low population growth rate. Furthermore, fishers preferentially target the large, often pregnant, females whose aggregating habit and predictable migration patterns make it relatively easy to obtain high catches.

In late 2005, the PFMC raised concern that existing measures are inadequate for effectively managing spiny dogfish. Future management measures may include removing spiny dogfish from the Other Fish category and setting an acceptable biological catch and OY. There is also concern over the amount of spiny dogfish harvested as bycatch in other directed fisheries. Because it occurs in many areas where gill nets, long lines, and trawls are used, these gears catch spiny dogfish incidentally. Gears with small mesh size may take immature individuals. The U.S. Northeast Regional Stock Assessment Review Committee assessed the relative importance of spiny dogfish bycatch for the period 1968-2002 and estimated that average discards were more than double the average catch. Fortunately, spiny dogfish are rather tenacious and post release survival tends to be high from trawls, hook and line gear, and handling stress.

Before the PFMC considers moving forward with management measures for spiny dogfish on the west coast, additional information is necessary, including an assessment of the status of the stock. The WDFW is prepared to lead the 2011 stock assessment and is in contact with representatives from academia and state and federal agencies to share and review spiny dogfish biological and fishery data. Any genetic stock differences are unknown at this time, so a successful assessment needs to take into account the trans-boundary nature of the spiny dogfish stock. At this time, it is unknown how a west coast stock assessment will affect spiny dogfish management in California.

The PFMC and the Department continue to coordinate efforts to manage spiny dogfish. The Department uses area closures (e.g. marine protected areas) and the general bag limit of no more than 10 fish (Title 14, CCR, §28.51) to regulate the recreational fishery. For the commercial fishery, license and permit regulations, gear restrictions, area closures, depth restrictions and trip limits are used for management purposes. Depending on a future stock assessment outcome, management recommendations for spiny dogfish may include minimum size restrictions and a smaller daily bag limit for the recreational fishery, and more conservative trip limits and bycatch quotas for the commercial fishery.

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Further Reading

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Spiny dogfish commercial landings, 1969-2008.

Year	Pounds	Value	Year	Pounds	Value	Year	Pounds	Value
1969	3,554	$213	**1983**	54,704	$7,906	**1997**	8,405	$157
1970	1,466	$287	**1984**	17,181	$14,040	**1998**	14,996	$5,598
1971	10,262	$1,577	**1985**	1,000	$165	**1999**	77,752	$67,657
1972	4,345	$466	**1986**	9,558	$1,175	**2000**	31,584	$11,299
1973	4,672	$360	**1987**	53,935	$5,207	**2001**	6,574	$978
1974	879	$307	**1988**	3,773	$611	**2002**	36,259	$7,626
1975	179	$59	**1989**	3,430	$452	**2003**	23,749	$11,242
1976	22,697	$4,765	**1990**	6,873	$896	**2004**	58,122	$36,136
1977	384,177	$24,505	**1991**	1,523	$228	**2005**	16,871	$3,391
1978	439,991	$27,026	**1992**	3,350	$392	**2006**	31,737	$19,180
1979	125,489	$8,890	**1993**	6,230	$1,583	**2007**	27,905	$8,227
1980	15,280	$4,537	**1994**	1,221	$173	**2008**	98,261	$36,423
1981	19,250	$3,817	**1995**	232	$52			
1982	5,744	$909	**1996**	1,320	$101			

Data source: CFIS data, all gear types combined. Data not available prior to 1969.

Spiny dogfish commercial CPUE (pounds/trip), 1969-2008.

Year	Trawl	Gill net	Hook and line	Year	Trawl	Gill net	Hook and line
1969	471	0	23	**1989**	352	56	153
1970	0	0	0	**1990**	214	148	192
1971	0	60	388	**1991**	0	1516	2
1972	474	0	378	**1992**	714	233	37

Spiny dogfish commercial CPUE (pounds/trip), 1969-2008.							
Year	**Trawl**	**Gill net**	**Hook and line**	**Year**	**Trawl**	**Gill net**	**Hook and line**
1973	585	0	224	**1993**	44	380	16
1974	0	0	0	**1994**	180	41	95
1975	0	0	22	**1995**	69	0	7
1976	631	436	0	**1996**	253	49	3
1977	724	1189	70	**1997**	435	47	70
1978	719	1115	23	**1998**	176	423	25
1979	1344	1709	34	**1999**	1410	72	23
1980	232	126	27	**2000**	399	167	47
1981	126	313	104	**2001**	421	142	16
1982	56	194	20	**2002**	3553	13	19
1983	51	769	69	**2003**	1444	1208	18
1984	135	75	36	**2004**	1168	790	48
1985	40	16	31	**2005**	63	310	74
1986	47	415	0	**2006**	273	1928	53
1987	52	455	25	**2007**	2081	50	93
1988	59	23	37	**2008**	925	1418	0

Data source: CFIS data. Data not available prior to 1969.

Spiny dogfish recreational catch, 1980-2003.							
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	57,988	**1986**	24,955	**1992**	---	**1998**	2,247
1981	21,565	**1987**	8,455	**1993**	14,536	**1999**	3,728
1982	28,764	**1988**	45,992	**1994**	4,881	**2000**	2,680
1983	12,326	**1989**	13,505	**1995**	9,434	**2001**	2,258
1984	12,183	**1990**	---	**1996**	5,402	**2002**	3,971
1985	27,575	**1991**	---	**1997**	1,517	**2003**	5,638

Data source: MRFSS data, all fishing modes and gear types combined. Data not available for 1990-1992. CPFV data not available for central and northern California for 1993-1995.

Spiny dogfish recreational catch, 2004-2008.	
Year	**Number of fish**
2004	1,329
2005	1,051
2006	1,998
2007	1,241
2008	825

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

Spiny dogfish commercial passenger fishing vessel (CPFV) catch, 1940-2008.

Year	Number of fish	Year	Number of fish	Year	Number of fish	Year	Number of fish
1948	19	**1964**	1	**1980**	1506	**1996**	302
1949	0	**1965**	61	**1981**	23	**1997**	61
1950	0	**1966**	12	**1982**	246	**1998**	202
1951	0	**1967**	161	**1983**	69	**1999**	323
1952	0	**1968**	67	**1984**	35	**2000**	219
1953	0	**1969**	252	**1985**	333	**2001**	85
1954	0	**1970**	241	**1986**	788	**2002**	62
1955	0	**1971**	248	**1987**	353	**2003**	29
1956	0	**1972**	293	**1988**	803	**2004**	44
1957	0	**1973**	141	**1989**	660	**2005**	58
1958	10	**1974**	436	**1990**	643	**2006**	273
1959	0	**1975**	1494	**1991**	671	**2007**	53
1960	50	**1976**	408	**1992**	604	**2008**	15
1961	0	**1977**	274	**1993**	366		
1962	172	**1978**	74	**1994**	129		
1963	0	**1979**	181	**1995**	261		

Data source: CPFV logbook data. Data not available prior to 1948.

Spiny dogfish recreational boat mode (private/rental and CPFV) CPUE (fish/100 angler hours), 1980-2008.							
Year	**CPUE**	**Year**	**CPUE**	**Year**	**CPUE**	**Year**	**CPUE**
1980	0.52	**1988**	0.53	**1996**	0.56	**2004**	0.43
1981	0.62	**1989**	0.46	**1997**	0.53	**2005**	0.53
1982	0.57	**1990**	---	**1998**	0.61	**2006**	0.34
1983	0.39	**1991**	---	**1999**	0.51	**2007**	0.32
1984	0.48	**1992**	---	**2000**	0.66	**2008**	0.44
1985	0.53	**1993**	0.29	**2001**	1.18		
1986	0.26	**1994**	0.01	**2002**	0.38		
1987	0.95	**1995**	0.79	**2003**	0.40		

Data source: MRFS (1980-2003) and CRFS (2004-2008) data, all gear types combined. Data not available for 1990-1992. CPFV data not available for central and northern California for 1993-1995.

Spiny dogfish CPFV CPUE (fish/100 angler hours), 1948-2008.							
Year	**CPUE**	**Year**	**CPUE**	**Year**	**CPUE**	**Year**	**CPUE**
1948	0.1	**1964**	0.0	**1980**	0.9	**1996**	0.2
1949	0.0	**1965**	0.1	**1981**	1.4	**1997**	0.2
1950	0.0	**1966**	0.1	**1982**	0.3	**1998**	0.4
1951	0.0	**1967**	0.6	**1983**	0.8	**1999**	0.1
1952	0.0	**1968**	0.2	**1984**	0.2	**2000**	0.1
1953	0.0	**1969**	0.2	**1985**	0.6	**2001**	0.1
1954	0.0	**1970**	0.6	**1986**	0.5	**2002**	0.2
1955	0.0	**1971**	1.0	**1987**	0.4	**2003**	0.4
1956	0.0	**1972**	0.5	**1988**	0.2	**2004**	0.1
1957	0.0	**1973**	1.6	**1989**	0.3	**2005**	0.1
1958	0.0	**1974**	3.1	**1990**	0.2	**2006**	0.4
1959	0.0	**1975**	7.5	**1991**	0.1	**2007**	0.1
1960	2.7	**1976**	0.9	**1992**	0.2	**2008**	0.1
1961	0.0	**1977**	0.6	**1993**	0.1		
1962	0.8	**1978**	0.1	**1994**	0.1		
1963	0.0	**1979**	0.1	**1995**	0.1		

Data source: CPFV logbook data. Data not available prior to 1948.

12 Black Rockfish, *Sebastes melanops*

Black rockfish, *Sebastes melanops*. Photo credit: Edgar Roberts.

History of the Fishery

The black rockfish, *Sebastes melanops*, is an important recreational and commercial species in the nearshore rockfish group, particularly in areas north of San Francisco.

Black rockfish are an important commercial nearshore species in California, specifically in the Crescent City port complex; 74 percent, by weight, of all black rockfish were landed there over the past decade. Black rockfish are recorded specifically in the market category “black rockfish” on landing receipts, but some black rockfish may also be recorded in other market categories such as “blue rockfish” or “rockfish, group black/blue.” Conversely, due to similarity in appearance, blue rockfish are sometimes recorded as “black rockfish” on landing receipts.

Black rockfish are part of the deeper nearshore species complex composed of black, blue, brown, calico, copper, olive, quillback and treefish rockfishes. Since 2003, a Deeper Nearshore Species Fishery Permit (DNSFP) has been required to take deeper nearshore species. Black rockfish are caught primarily using hook and line gears, with marginal amounts caught in traps. In the past, black rockfish were also caught using trawl gear or gill nets. Since 1998, commercial landings of black rockfish made up approximately 52 percent of deeper nearshore rockfish species landings by weight. Commercial landings of black rockfish fluctuated between 110,603 pounds (50 metric tons) and 229,640 pounds (104 metric tons) from 1998 to 2008 (Figure 12-1) but showed no distinct trend. Many of the decreases in annual landings correspond to changes in management structure, as discussed below in Management Considerations. Annual ex-vessel value for black rockfish ranged between $98,219 in 1999 to $436,900 (Figure 12-1) in 2008 even though landings of black rockfish have not increased overall.

During the last decade, the live fish fishery for nearshore species has expanded drastically, especially for black rockfish (Figure 12-2). Black rockfish are a fairly hearty fish that can withstand the stresses of being caught and transported to the end destination. Fish landed live often command a premium price (sometimes over $8.00 per pound; $17.60 per kilogram) which contributed to the increase in ex-vessel value over the last decade despite no increasing trend in landings (Figure 12-1). Beginning in

2002 and continuing through 2008, more than half of all landings of black rockfish are of live fish (Figure 12-2).

Figure 12-1. Black rockfish commercial landings and value, 1998-2008. Data source: CFIS data, all gear types combined.

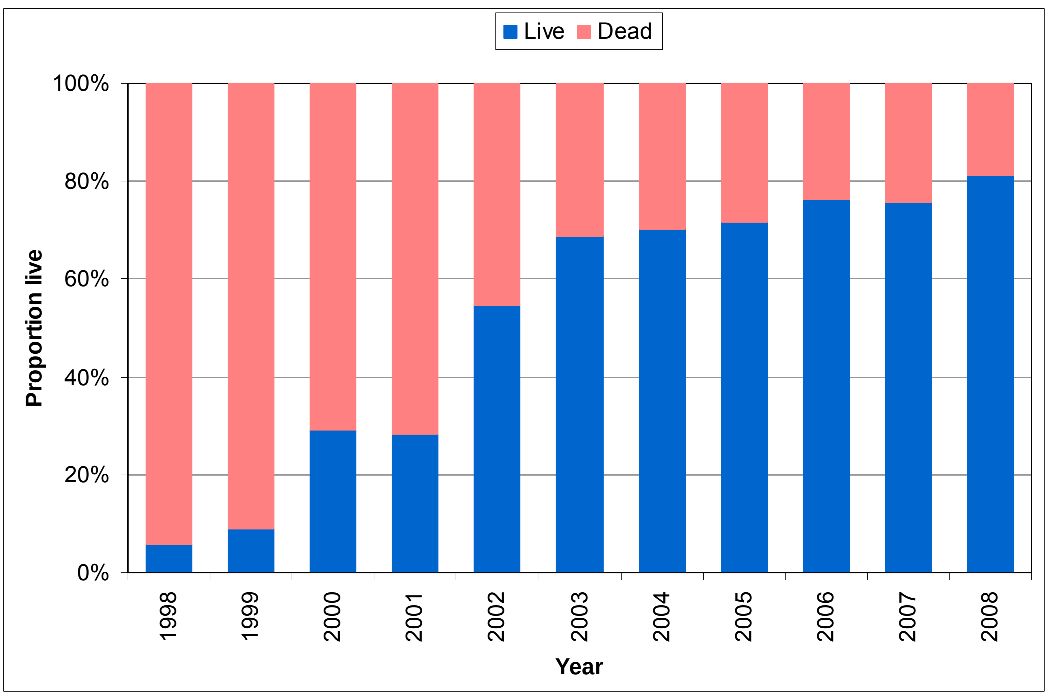

Figure 12-2. Proportion of black rockfish landed live in the commercial fishery, 1998-2008. Data source: CFIS data, all gear types combined.

Recreationally, black rockfish are considered a primary target species due to their size and relative abundance along the central and northern parts of the California coast. Recreational fishery surveys collect data from California's recreational fisheries, the Marine Recreational Fishery Statistical Survey (MRFSS)—from 1980 to 2003, and the California Recreational Fishery Survey (CRFS)—begun in 2004 and ongoing. Due to changes in the sampling protocol and how the data are used to estimate catch these two surveys are not comparable. Data from the MRFSS program show that estimates of black rockfish from 1998 through 2003 ranged from 161,000 to 736,000 fish kept (Figure 12-3) although the high estimate for 2003 is considered questionable. Recreational landings data for black rockfish from 2004 to 2008 (CRFS data) show a range of 156,000 to 218,700 fish landed annually with the lowest catch in 2007 and the highest catch in 2005 (Figure 12-4).

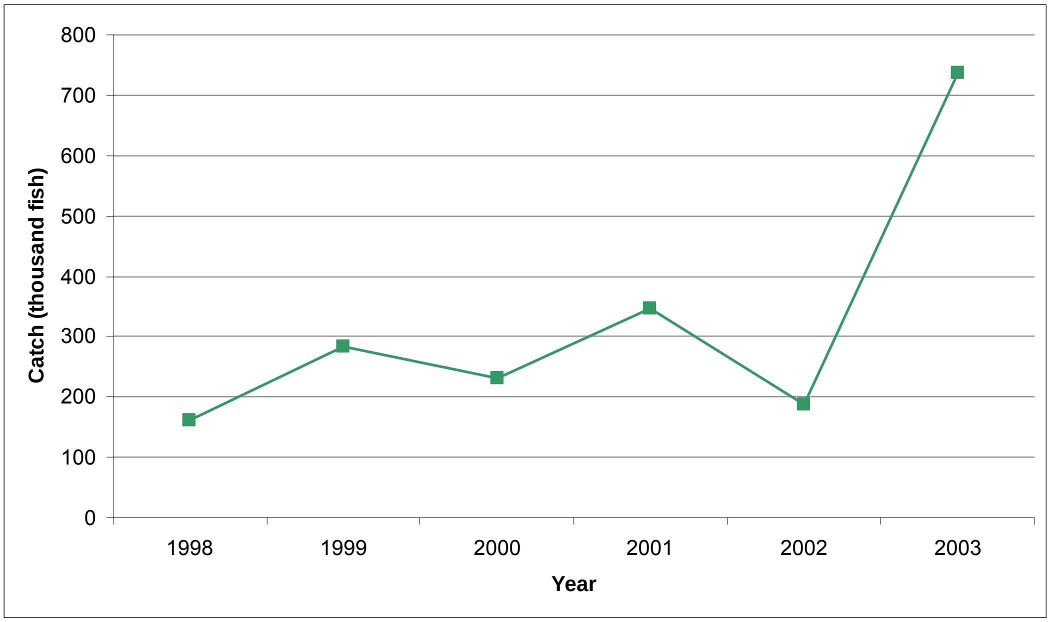

Figure 12-3. Black rockfish recreational catch, 1998-2003. Data source: MRFSS data, all fishing modes and gear types combined.

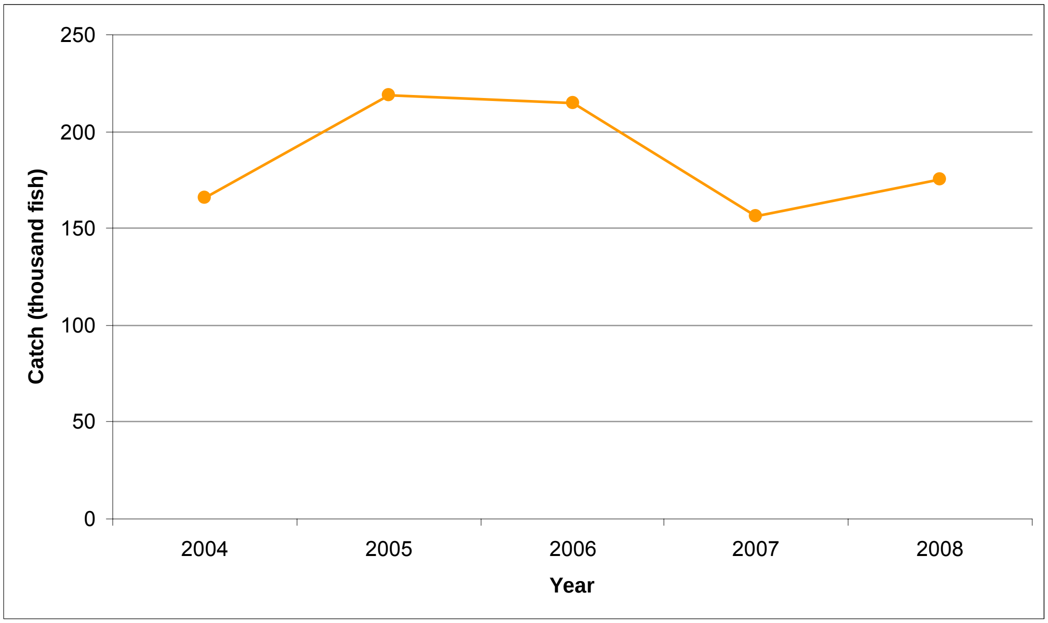

Figure 12-4. Black rockfish recreational catch, 2004-2008. Data source: CRFS data, all fishing modes and gear types combined.

Black rockfish are landed in the following modes of the recreational fishery: private/rental boats (63 percent), commercial passenger fishing vessels (CPFVs) (33 percent), beaches and banks (2 percent), and man made structures (2 percent). Catch estimates from 2004 to 2008 were distributed from north to south as follows: Del Norte and Humboldt counties (44 percent), Mendocino County and Shelter Cove (15 percent), Sonoma and San Mateo counties (32 percent), and from Santa Cruz to San Luis Obispo counties (9 percent). Black rockfish were not landed south of Point Conception.

The CPFV logbook did not list individual rockfish species until 2005; prior to that it only listed unspecified rockfish. However, when black rockfish began being reported in the CPFV logbook data in 2005, 23,374 fish were reportedly landed; catch peaked in 2007 with 65,771 black rockfish reportedly landed (Figure 12-5).

Recreational catch of black rockfish has decreased by 22 percent from 2005 to 2008 (Figure 12-4), mostly due to changes in management and season structure, as discussed in the Management Considerations section below. The average length of retained fish from 1998 to 2008 (MRFSS and CRFS data) is 13.2 inches (33.5 centimeters) with no increasing or decreasing trends in overall average length of retained fish (Figure 12-6).

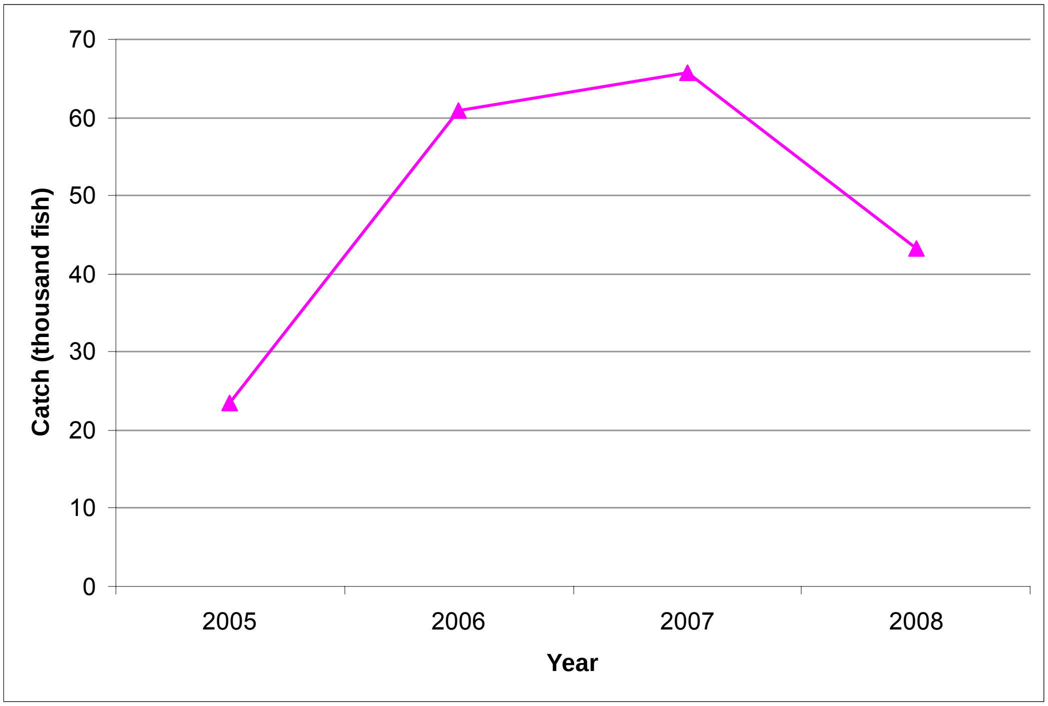

Figure 12-5. Black rockfish commercial passenger fishing vessel (CPFV) catch, 2005-2008. Data Source: CPFV logbook data.

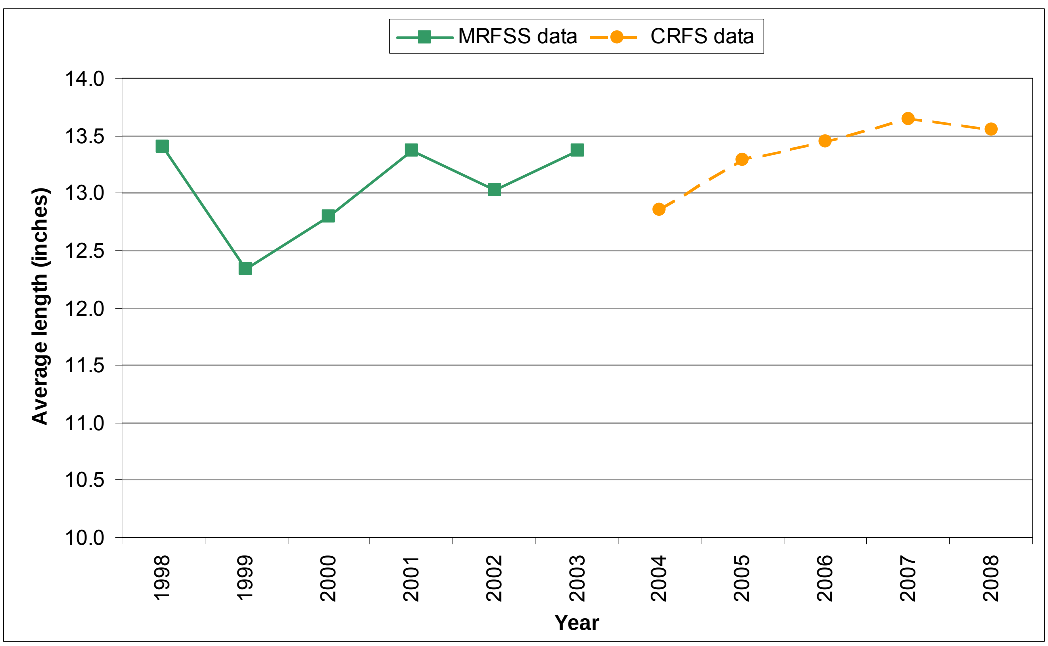

Figure 12-6. Black rockfish average length for the recreational fishery, 1998-2008. Data source: MRFSS (1998-2003) and CRFS (2004-2008) data, all fishing modes and gear types combined.

Status of Biological Knowledge

Black rockfish are found from Amchitka Island (Aleutian Islands, western Alaska) to Huntington Beach (southern California) but are uncommon south of Santa Cruz, California. They occur in depths ranging from 0 to 1200 feet (0 to 366 meters) but most often are found in waters shallower than 180 feet (55 meters). Black rockfish frequently occur in schools, sometimes schooling with blue, yellowtail, widow, or dusky rockfishes, but may also be found resting on or near rocky bottoms.

Male black rockfish transfer their sperm to the females in July and August, and the females store the sperm until their eggs mature, usually between September and November. Larval release occurs from January through May; individual females produce between 125,000 and 1,200,000 eggs per season. Larvae are pelagic until they are four to six months old, or 1 to 1.5 inches in length (3 to 4 centimeters), at which time they settle out of the plankton and inhabit nearshore intertidal and estuarine areas generally shallower than 65 feet (20 meters). Juvenile and adult black rockfish primarily feed on crab megalops larvae, amphipods, isopods and other fishes (including other rockfish). As they grow larger, black rockfish tend to inhabit deeper waters, but may frequent shallower depths in the summer months. Black rockfish grow quickly, with most individuals having entered the fishery by the time they are 3 to 4 years old, or 10 to 11.5 inches (25 to 29 centimeters) in length. Half the population will be mature at 6 to 7 years of age, or 14 inches (36 centimeters) in males and 16 inches (41 centimeters) in females. Males reach a maximum size earlier than females and mature at a smaller size and younger age. Females grow larger than males with maturity of all females occurring by 9 years of age, or 17 inches (43 centimeters). The largest recorded black rockfish was 27.6 inches (69 centimeters) and 11 pounds (5 kilograms). Black rockfish have been known to live up to 50 years.

Black rockfish are often confused with blue rockfish because they are similar in appearance. Features that distinguish black rockfish from blue rockfish include the former's relatively large mouth with the maxilla extending behind the eye, a rounded anal fin, black speckling on the dorsal fin, and a wide light grey area along the lateral line.

Limited tagging studies in California, and more recent tagging studies in Oregon, have shown black rockfish generally have relatively small home territories, although several individuals have been recaptured tens or even hundreds of miles from the original tagging location. A study published in 2008 gives insight to vertical migration in black rockfish on a daily and yearly basis. The study also suggests black rockfish maintain their swim bladder at a smaller volume than neutral presumably to avoid the detrimental effects that rapid decompression in shallow depths can produce.

Status of the Population

There have been two recent stock assessments for black rockfish occurring off the coast of California and Oregon: the first in 2003, followed by one in 2007. Despite the population dipping into the "precautionary zone" (defined below), both recent assessments found the current black rockfish stock to be healthy. The 2007 assessment estimated current spawning stock biomass was about 70.9 percent of the unfished size. While the results of the stock assessments apply to black rockfish in both Oregon and California, much of the data analyzed in the assessments were from Oregon samples as California had very little fishery-dependent or -independent life history data. Future stock assessments for black rockfish would benefit from having additional length and age data as well as more comprehensive recreational and commercial catch records for California.

Management Considerations

Black rockfish are currently managed under joint jurisdiction by the California Department of Fish and Game (Department) and the federal Pacific Fishery Management Council (PFMC). Prior to 1982, black rockfish was managed under state jurisdiction by the Department along with the California Fish and Game Commission, and the state legislature. Black rockfish was designated a federal groundfish in 1982 when the PFMC implemented the Groundfish Fishery Management Plan. Since 2003, black rockfish may only be harvested commercially by a fishery participant in possession of a state Deeper Nearshore Species Fishery Permit.

Prior to the year 2000, the PFMC managed black rockfish as part of the “other rockfish” complex and did not assign a separate Allowable Biological Catch (ABC) or Optimum Yield (OY) for black rockfish. In an effort to control fishing pressure, beginning in the year 2000, and continuing through 2003, PFMC assigned an ABC value for black rockfish landed north of 40° 10' North Latitude [near Cape Mendocino (Humboldt County)], but allowed black rockfish landed south of 40° 10' North Latitude to continue being managed as part of the “other rockfish” complex. In 2004, PFMC established a management line for black rockfish at the border between Oregon and Washington and assigned separate ABC and OY values for the two areas (Washington is assigned the northern portion and Oregon and California share the southern portion). There is a further division of the southern section of the OY into harvest guidelines (HGs): north of 40° 10' North Latitude (Washington/Oregon border to Cape Mendocino, Humboldt County) which is shared through a formal agreement between California and Oregon, and south of 40° 10' North Latitude (Cape Mendocino to the U.S./Mexico border).

Commercial catch is managed by use of season, area, depth and gear restrictions, and bimonthly trip limits. Black rockfish are closed to commercial fishing south of 40° 10' North Latitude during March and April, but open year round north of 40° 10' North Latitude. Depth constraints keep commercial nearshore fishers in fairly shallow waters (less than 180 feet; 55 meters) to avoid impacts to yelloweye rockfish and other overfished species. Recreational catch is managed by the use of seasons, area, gear and depth restrictions, and bag limits. The recreational groundfish season length differs from region to region with the most restrictive season lengths in the northern part of the state [fishery may be open only three months of the year north of Point Arena (Mendocino County)] and the most lenient season lengths in the southern region of the state [fishery is open nine months south of Point Conception (San Luis Obispo County)]. Daily bag limits for the rockfish, cabezon and greenling complex were decreased to 10 fish, in combination, in 2000. More recent regulatory actions include the adoption of marine protected areas (MPAs) along the central California coast which may offer some protection to black rockfish. Under the current management structure, the recreational and/or commercial fisheries for nearshore groundfish (including black rockfish) may be closed early if the projected catch is expected to attain or surpass the ABC, OY or HG prior to the end of the season.

To further California's black rockfish management efforts in the future, more comprehensive life history and landings data from commercial and recreational fisheries are desirable.

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Black rockfish commercial landings and value, 1998-2008.					
Year	**Pounds**	**Value**	**Year**	**Pounds**	**Value**
1998	188,642	$104,438	**2004**	127,176	$254,928
1999	130,194	$98,219	**2005**	166,943	$266,541
2000	110,603	$128,183	**2006**	138,241	$253,445
2001	229,640	$252,488	**2007**	178,415	$356,519
2002	203,909	$311,199	**2008**	217,556	$436,900
2003	127,176	$254,928			

Data Source: CFIS data, all gear types combined.

Black rockfish recreational catch, 1998-2003.	
Year	**Number of fish**
1998	161,786
1999	282,997
2000	230,214
2001	346,179
2002	187,545
2003	735,698

Data Source: MRFSS data, all fishing modes and gear types combined.

Black rockfish recreational catch, 2004-2008.	
Year	**Number of fish**
2004	166,016
2005	218,689
2006	214,653
2007	155,950
2008	175,585

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

Black rockfish CPFV catch, 2005-2008.	
Year	**Number of fish**
2005	23,374
2006	60,899
2007	65,771
2008	42,924

Data source: CFPV logbook data.

13 Yelloweye Rockfish, *Sebastes ruberrimus*

Adult yelloweye rockfish (*Sebastes ruberrimus*). Photo credit: Janna Nichols.

History of the Fishery

Yelloweye rockfish, *Sebastes ruberrimus*, are highly prized by both commercial and recreational fishers in California for their large size, beauty and table fare quality. Starting in 2001, yelloweye rockfish were designated as overfished (current stock size is 40 percent or less of the unfished stock size) and as a result increased regulations for the recreational and commercial fisheries were put in place to reduce the catch of yelloweye rockfish. By 2003, yelloweye rockfish were not allowed to be retained by either recreational or commercial fishers and are only taken as bycatch.

Species specific commercial landing data for yelloweye rockfish are not available prior to 1969 when it was given its own market category; before then, all species of rockfish were grouped together under the general term of “rockfish.” The peak of commercial landings for yelloweye rockfish occurred in 1971, when 1,568,000 pounds (712 metric tons) were landed in California (Figure 13-1).

Historically, a majority of commercially caught yelloweye rockfish were landed in the ports of Fields Landing and Eureka (Humboldt County). Commercial ports in Morro Bay, Fort Bragg, and Crescent City (San Luis Obispo, Mendocino and Del Norte counties, respectively) rounded out the top five ports in total landings since 1969. The gears most commonly used to catch yelloweye rockfish in the commercial fishery were trawl nets, set long lines, and simple hook and line equipment, accounting for 88 percent of the yelloweye rockfish caught since 1969. The highest value from the commercial yelloweye rockfish fishery occurred in 1979 totaling $345,969.

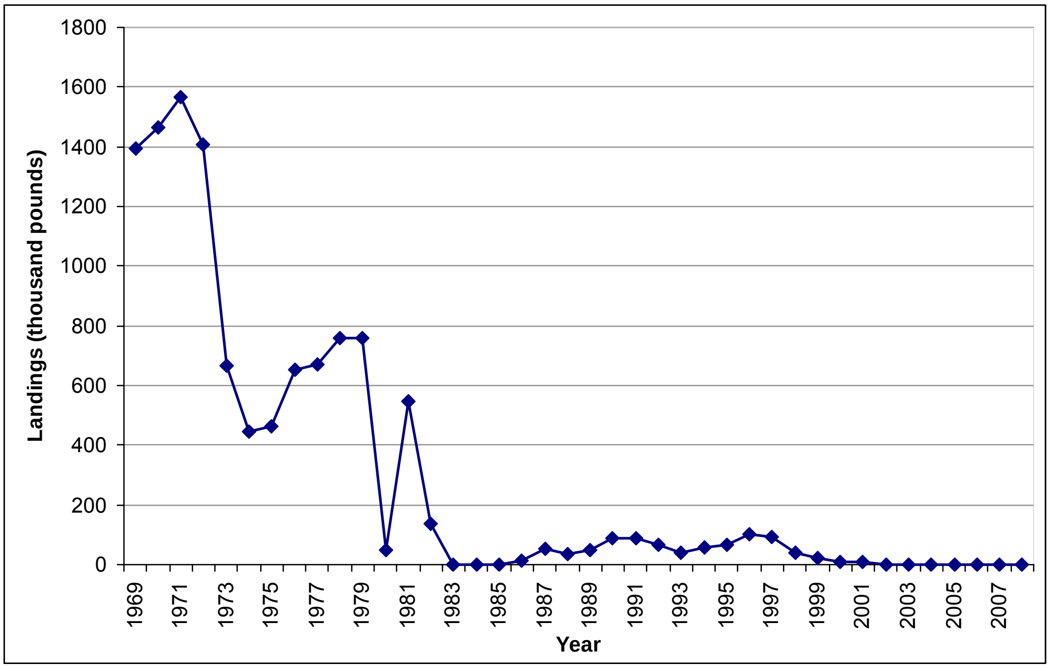

Figure 13-1. Yelloweye rockfish commercial landings, 1969-2008. Data Source: CFIS data. Data not available prior to 1969.

Consistent recorded data for the recreational yelloweye rockfish fishery began in 1980. Similar to the commercial data, the recreational fishery data for yelloweye rockfish prior to 1980 were grouped into a general rockfish category. Since 1980, there have been two different recreational sampling programs: the Marine Recreational Fisheries Statistical Survey (MRFSS) (1980-2003) and the California Recreational Fisheries Survey (CRFS) (2004-2008). Due to changes in the sampling protocol and how the data are used to estimate landings these two surveys are not comparable. An evaluation of the Marine Recreational Fishery Statistical Survey (MRFSS) from 1980-2003 showed yelloweye rockfish catch peaked in 1985 with an estimated 275,578 pounds (125 metric tons) of fish landed (Figure 13-2). Yelloweye rockfish catch decreased significantly after the no retention regulation for yelloweye rockfish was put in place in 2003. Additionally, depth management restrictions were created in the form of Rockfish Conservation Areas (RCAs). The RCA depth closures prevented commercial and recreational fishing for groundfish on the shelf between 30-50 fathoms and 150-200 fathoms (55-91 meters and 274-366 meters), depending on regional management area, along the California coastline. The depth closures include prime yelloweye rockfish habitat, thus limiting the catch of yelloweye rockfish along with other shelf species. The largest estimate of incidental recreational catch reported in the CRFS data (2004-2008) occurred in 2007 with an estimated 8313 pounds (4 metric tons) (Figure 13-3).

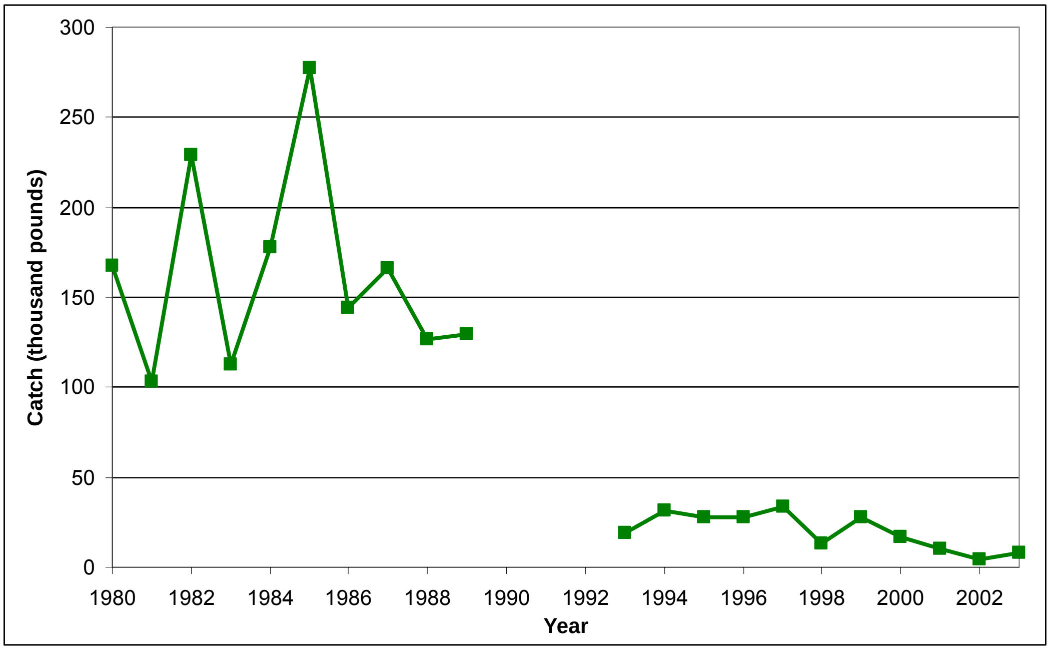

Figure 13-2. Yelloweye rockfish recreational catch, 1980-2003. Data Source: MRFSS data, all fishing modes and gear types combined. Data not available for 1990 through 1992. CPFV data not available for central and northern California for 1993-1995.

According to CRFS, in recent years a majority of the yelloweye rockfish were landed from Point Arena (Mendocino County) to the California/Oregon border. In addition, CRFS estimates show that approximately 99 percent of the total harvested catch came from boat modes [commercial passenger fishing vessels (CPFV) and private/rental boats]. The CPFV fleet caught 50 percent of the total yelloweye rockfish since 1980 with private/rental boats catching 49 percent. The primary reason for such high catch values from boat based anglers is the average depth range for the species, which often makes them inaccessible to shore based anglers.

An evaluation of the average length and average weight of yelloweye rockfish from the recreational fishery shows a gradual trend of decreasing size and length from 1980 to 2002. Conversely, the trends for both size and length from 2003 to 2008 show a slight increase (Figures 13-4 and 13-5). The average length for the past 28 years is approximately 16.5 inches (41.7 centimeters). The average weight for the same time period is 3.5 pounds (1.6 kilograms). Due to catch restrictions since 2002, catch-per-unit-effort (CPUE) data for the recreational fishery no longer accurately reflect the real changes in population abundance, and discard estimates are highly uncertain.

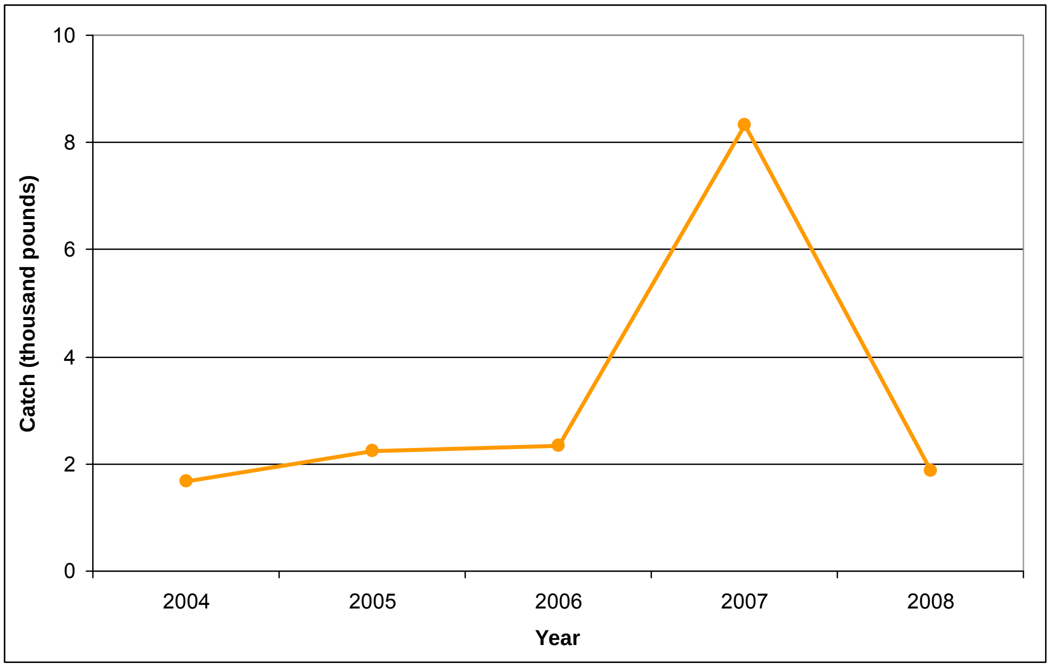

Figure 13-3. Yelloweye rockfish recreational catch, 2004-2008. Data Source: CRFS data, all fishing modes and gear types combined.

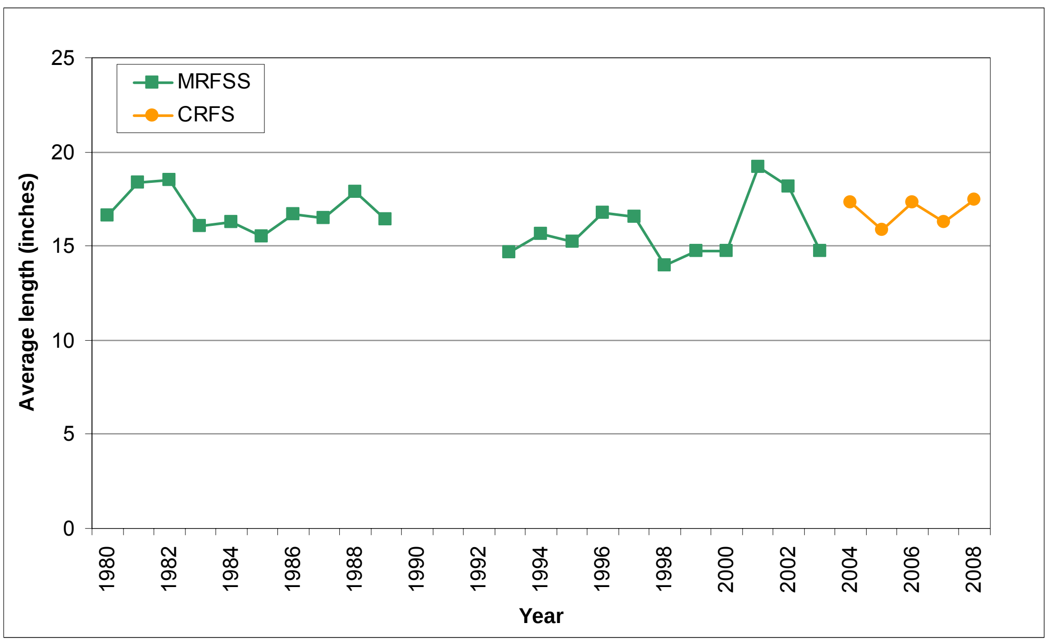

Figure 13-4: Yelloweye rockfish average length for the recreational fishery, 1980-2008. Data source: MRFSS (1980-2003) and CRFS (2004-2008) data, all fishing modes and gear types combined. Data not available for 1990 through 1992. CPFV data not available for central and northern California for 1993-1995.

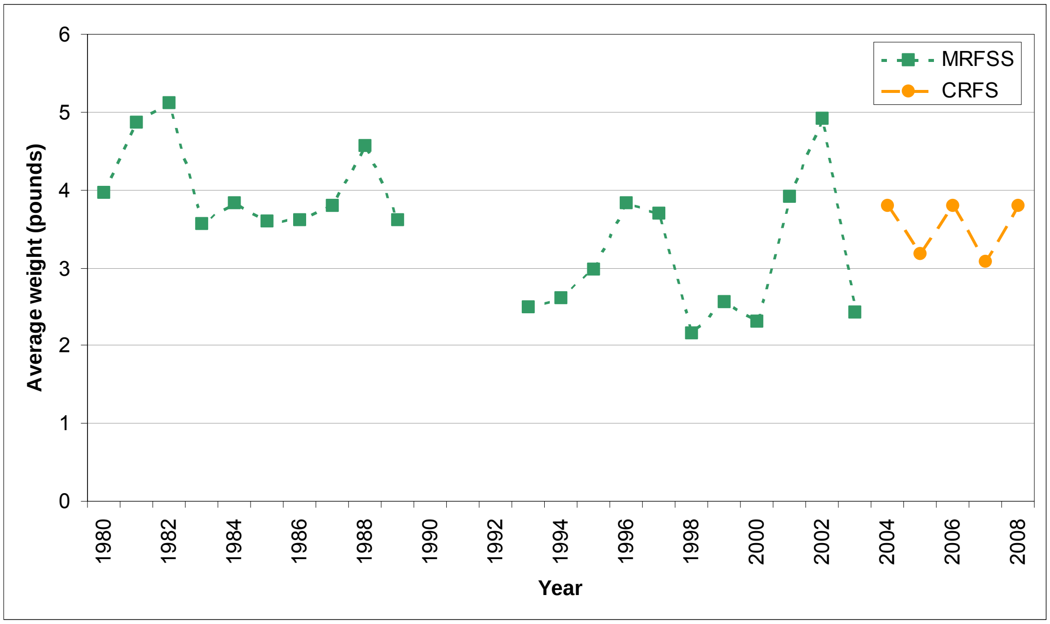

Figure 13-5: Yelloweye rockfish average weight for the recreational fishery, 1980-2008. Data source: MRFSS (1980-2003) and CRFS (2004-2008) data, all fishing modes and gear types combined. Data not available for 1990 through 1992. CPFV data not available for the central and northern California for 1993-1995.

Status of Biological Knowledge

Zoologist Frank Cramer first identified yelloweye rockfish in 1895. As with many fish species, the yelloweye rockfish has several common names including red-turkey rockfish, goldeneye rockfish, Pacific red snapper, red cod and yellowbelly among others. They are easily identified by their deep red to orange body color and distinctive bright yellow eyes. Coloration in juvenile yelloweye rockfish consists of a deep red body color with bright white to yellow horizontal stripes running the length of the body (Figure 13-6).

Figure 13-6. Juvenile yelloweye rockfish. Photo credit: Andy Murch.

When yelloweye rockfish mature into adults their color lightens, the stripes disappear and the fin tips turn black. They have an extremely long lifespan with some specimens aged up to 120 years. Yelloweye rockfish are also late maturing fish, becoming sexually mature at approximately 20 to 22 years of age. The primary food sources for these opportunistic feeders consist of other rockfish, herring, crab and shrimp. Their range extends from the Aleutian Islands off the coast of Alaska to the northern portion of Baja California, Mexico. It is generally accepted that the stock structure consists of a single coastwide population. Spawning for yelloweye rockfish occurs in late fall or early winter.

Females have the ability to retain sperm internally and wait to fertilize the eggs later. Yelloweye rockfish are ovoviviparous (meaning the eggs hatch inside of the mother and are born live as larvae later), the young larvae do not emerge until May or June. Yelloweye rockfish are commonly found near high relief rocky areas both inshore and offshore, such as reefs with high rugosity, offshore pinnacles and steep cliffs. They are most common inshore at depths of 60 to 1800 feet (18 to 548 meters).

Status of the Population

In 2001, the first yelloweye rockfish stock assessment was completed assessing the status of the stock from Lopez Point (Monterey County) to the California/Oregon border. The assessment also modeled the status of the stock along the Oregon coast; Washington state was not included in the assessment due to data limitations. The assessment concluded that the stock status for Northern California was approximately 7 percent of the unfished spawning biomass, and 13 percent of unfished biomass off the coast of Oregon. As a result, yelloweye rockfish were declared overfished by the National Marine Fisheries Service (NMFS) in 2002. The 2001 stock assessment for yelloweye rockfish was updated in 2002 and 2005 and was expanded coastwide (U.S./Canada border to the U.S./Mexico border). In 2006, a new assessment of yelloweye rockfish (updated in 2007) was completed, estimating that the spawning biomass for the entire west coast of the United States was approximately 16 percent of the unfished spawning biomass. The 2006 yelloweye rockfish rebuilding plan states that rebuilding the stock to a point where it is sustainable would take approximately 75 years (2084).

Management Considerations

Yelloweye rockfish became a federally designated groundfish in 1982 after the Pacific Fisheries Management Council (PFMC) adopted the Pacific Coast Groundfish Fishery Management Plan. Since then yelloweye rockfish are managed under the joint jurisdiction of the state and the federal governments. Prior to 1982, this species was managed by California Department of Fish and Game (Department) through regulations adopted by the state legislature and the California Fish and Game Commission. Beginning in 1983, the Department along with PFMC began managing the entire rockfish fishery as the *Sebastes* complex. Yelloweye rockfish were a part of the *Sebastes* complex until 2000 when the complex was separated into three depth based groups. These groups consisted of nearshore, shelf and slope rockfish. This allowed for fine scale managing and proportioning of rockfish stocks for the commercial and recreational sectors. Up until 2002, yelloweye rockfish were managed as part of the shelf rockfish group. After the 2002 stock assessment, yelloweye rockfish were managed using their own coastwide Acceptable Biological Catch (ABC), optimum yield (OY), and harvest guideline (HG). In the case of overfished species, the OY level is adjusted to rebuild the species population to a sustainable level while considering impacts of low harvest levels on fishing communities. Strict management measures in state and federal waters were adopted for both the commercial and recreational sectors that prohibit retention (allow only bycatch) in order to rebuild the stock as quickly as possible.

The 2006 yelloweye rockfish rebuilding plan specified a harvest “ramp down” strategy before resuming a constant coastwide HG (15 short tons; 14 metric tons) in 2011. The ramp down strategy involved a gradually declining HG from 25 to 15 short tons (23 to 14 metric tons) during the years 2007 to 2010. The strategy was adopted by the PFMC in 2006 to mitigate impacts of a more severe reduction on the commercial and recreational fisheries that would occur without the ramp down approach. This ramp down period is being used to work with commercial and recreational constituents and develop additional yelloweye rockfish protection measures. In addition, it provided an opportunity for coastal communities to prepare for anticipated economic losses due to shortened rockfish seasons. In 2007, the California recreational HG for yelloweye rockfish was exceeded despite early closures for the Northern and North-Central groundfish management areas that compromise the area from California/Oregon border to Point Arena. The Department implemented a new methodology in 2008 to track the recreational catch of overfished species including yelloweye rockfish. The new tracking system reduced the time needed to initiate and implement emergency inseason regulatory changes. In 2008, the new tracking system indicated the HG for the recreational yelloweye rockfish fishery would once again be exceeded if the season continued at the current rate. Since most of the yelloweye rockfish were caught in northern California, an emergency closure was instituted in September 2008 from the California/Oregon border to Point Arena. These closures prevented stock rebuilding from being jeopardized by keeping the catch within the OY.

The Department and PFMC are working together to develop and adopt various management measures to keep the catch of yelloweye rockfish within the designated OY and rebuild the population. Examples of management measures for the recreational sector include area closures, depth restrictions, and bag limits. For the commercial fishery, license and permit regulations, gear restrictions, seasonal and area closures, and depth restrictions are used.

The previous yelloweye rockfish stock assessments and updates are considered data poor. Additional data are needed to strengthen stock assessments in the future. Sex-specific age and length information from both the recreational and commercial fishery would be extremely useful. Lastly, the development of ongoing non-lethal fishery-independent studies is needed to determine the changes that are occurring in stock abundance and location and how they may relate to environmental factors, without contributing to stock mortality.

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Further Reading

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Yelloweye rockfish commercial landings and value, 1969-2008.

Year	Pounds	Value	Year	Pounds	Value
1969	1,396,144	$91,588	**1989**	49,631	$32,630
1970	1,466,606	$110,436	**1990**	86,607	$70,064
1971	1,567,622	$119,342	**1991**	86,866	$70,305
1972	1,408,373	$125,412	**1992**	64,620	$50,875
1973	665,361	$99,643	**1993**	40,158	$33,669
1974	445,630	$88,859	**1994**	56,754	$58,283
1975	462,003	$109,293	**1995**	66,949	$85,871
1976	651,610	$182,306	**1996**	99,667	$132,317
1977	672,337	$225,448	**1997**	92,249	$98,222
1978	760,206	$302,653	**1998**	38,202	$50,752
1979	757,324	$345,969	**1999**	21,106	$36,785
1980	49,093	$20,760	**2000**	7,278	$16,259
1981	547,551	$279,725	**2001**	8,457	$19,920

Yelloweye rockfish commercial landings and value, 1969-2008.					
Year	**Pounds**	**Value**	**Year**	**Pounds**	**Value**
1982	138,968	$29,961	**2002**	146	$130
1983	1,986	$468	**2003**	22	$20
1984	659	$235	**2004**	43	$46
1985	848	$243	**2005**	46	$23
1986	11,558	$8,828	**2006**	10	$6
1987	51,291	$31,779	**2007**	401	$800
1988	35,670	$22,627	**2008**	54	$16

Data source: CFIS data, all gear types combined. Data not available prior to 1969.

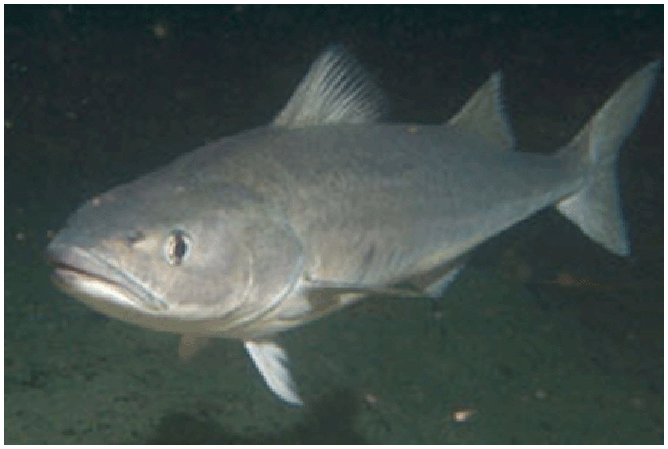
Yelloweye rockfish recreational catch, 1980-2003.			
Year	**Pounds**	**Year**	**Pounds**
1980	167,327	**1992**	---
1981	103,474	**1993**	18,663
1982	228,810	**1994**	31,756
1983	112,415	**1995**	27,690
1984	178,124	**1996**	27,510
1985	277,370	**1997**	33,352
1986	144,347	**1998**	12,829
1987	165,781	**1999**	27,753
1988	126,815	**2000**	16,601
1989	129,357	**2001**	10,171
1990	---	**2002**	4,582
1991	---	**2003**	8,098

Data source: MRFSS data, all fishing modes and gear types combined. Data not available for 1990-1992. CPFV data not available for central and northern California for 1993-1995.

Yelloweye rockfish recreational catch, 2004-2008.			
Year	**Pounds**	**Year**	**Pounds**
2004	1,665	**2007**	8,314
2005	2,239	**2008**	1,871
2006	2,336		

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

14 Sablefish, *Anoplopoma fimbria*



Sablefish, *Anoplopoma fimbria*. Photo credit: Wade Smith.

History of the Fishery

Since the early 1900s, *Anoplopoma fimbria*, more commonly known as sablefish or blackcod, has been commercially harvested in great quantities from California waters. The California Department of Fish and Game (Department) began recording commercial landings in 1916; during that year sablefish accounted for 83,623 pounds (38 metric tons). Between 1916 and 1941 the average annual landings of sablefish was 897,484 pounds (407 metric tons) with a range of 83,623 to 2,848,672 pounds (38 to 1293 metric tons). Beginning in 1942, an increase in landings occurred when 1,972,522 pounds (896 metric tons) were recorded. This trend continued over the next few years reaching 6,262,397 pounds (2843 metric tons) by 1945. This surge was not unique to sablefish as other commercial fisheries experienced a strong market demand during and shortly after World War II. Since 1945, the sablefish fishery continued to grow gradually before a significant increase during the 1970s (Figure 14-1).

At various times in the past, long line, trawl or trap gears were used to land the majority of sablefish. Longline was the dominant gear type prior to 1969 and then consistently accounted for about 20 percent of the landings from 1969 to 1973 and 1980 to 2008. In general, trawl gear accounted for 66 percent of annual landings from 1969 to 1973, while trap gear accounted for only 2 percent of landings. From 1974 to 1979 trap landings increased in importance; these years had very high landings including 1979 when 396 vessels landed 28.6 million pounds (12,972 metric tons) valued at $6.7 million dollars (Figure 14-2); 57 percent taken with trap gear and 36 percent with trawl gear. The shift away from trawl gear would be short lived; from 1980 until 2008 the trawl fishery continued to dominate landings averaging 58 percent annually, while trap gear averaged about 20 percent of annual landings from 1980 to 2008.

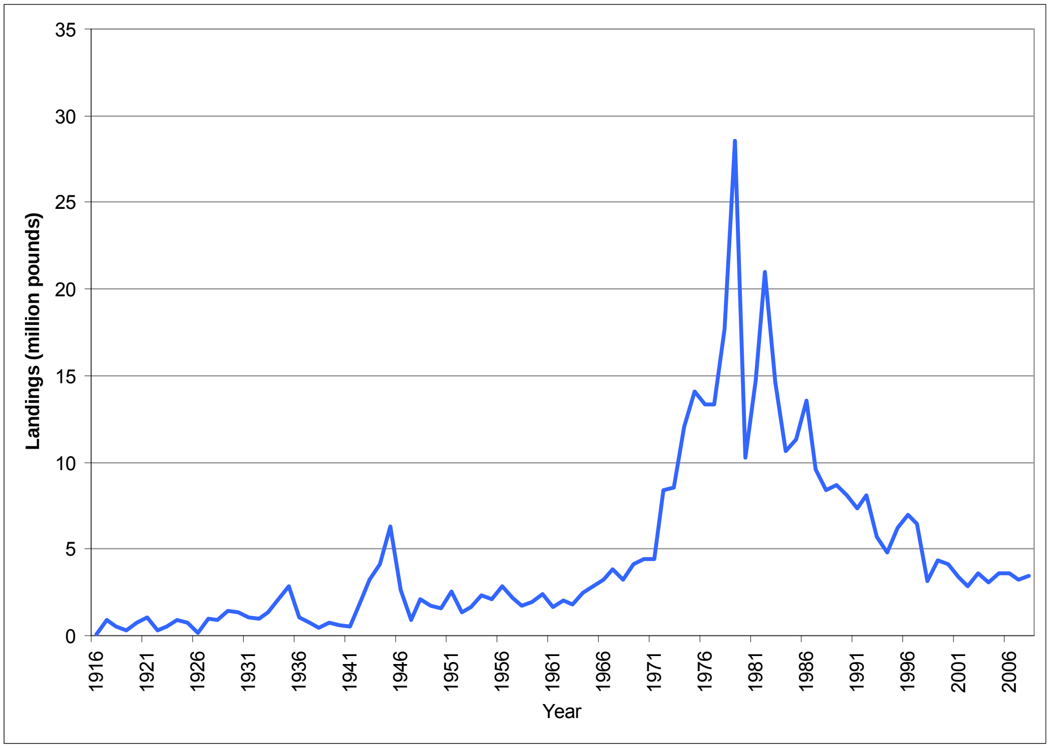


Figure 14-1. Sablefish commercial landings, 1916-2008. Data source: Department catch bulletins (1916-1968) and CFIS data (1969-2008), all gear types combined.

From the 1970s to present day, changes in management authority and regulations to restrict the sablefish fishery were implemented that shifted the dynamics of the fishery. The explosion of the fishery during the 1970s has been attributed to foreign fishing fleets from the former Soviet Republic, Japan and the Republic of Korea, and heavy market demand for foreign export to Asia. Partly to quell further foreign fishing pressure and also to prevent overfishing, the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) of 1976 established a fishery conservation zone (later changed to the U.S. Exclusive Economic Zone or EEZ) which extended control of U.S. waters from 3 to 200 miles (5 to 322 kilometers). The Magnuson-Stevens Act also created the Pacific Fishery Management Council (PFMC) to oversee the development and implementation of fisheries management on the Pacific west coast. This process set the stage for the sablefish fishery to experience many changes during the next 30 years.

In response to the development of improved fishing technology, the PFMC adopted the Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP) in 1982, which covers almost 90 species, including sablefish. The Groundfish FMP imposed trip limits on the fishery to prevent exceeding the Allowable Biological Catch (ABC). Trip limit regulations would facilitate a downward trend in sablefish landings. By 1987, the sablefish ABC was allocated between the trawl and non-trawl fleets. This resulted in derby style management throughout the 1990s resulting in high fishing pressure during very short seasons. In response to substantial harvesting capacity (Figure 14-2) that exceeded the sustainability of the entire groundfish fishery, in 1994 the PFMC adopted and implemented Amendment 6 of the Groundfish FMP requiring vessel owners using trawl, long line and trap gear to hold a federal limited entry permit to catch and retain all groundfish species including sablefish. All other gears utilized for groundfish were able to continue harvesting under an open access system. This process diversified the fleet into the limited entry and open access sectors with an average of 79 percent of the landings coming from the limited entry sector during 1994-2008 (Figure 14-3). The refinement of harvest limits, trip and landing frequency limits, mesh size requirements for trawl gear, size limits, and separate allocations between sectors began to shape the fishery into its present form.

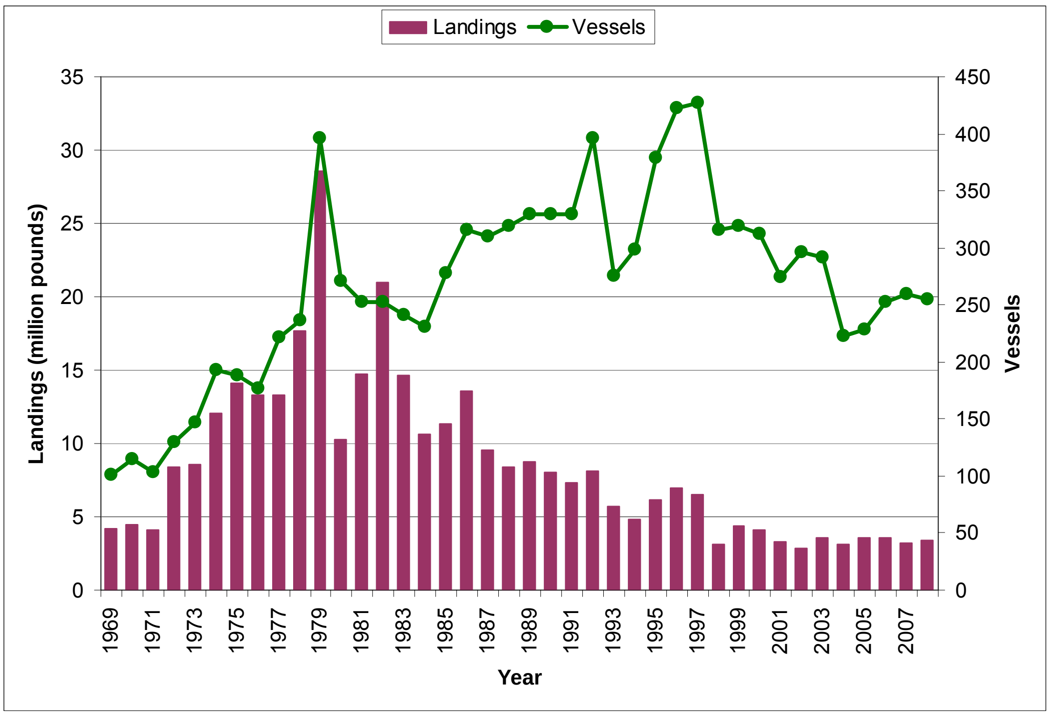


Figure 14-2. Sablefish commercial landings and participating vessels, 1969-2008. Data source: CFIS data, all gear types combined.

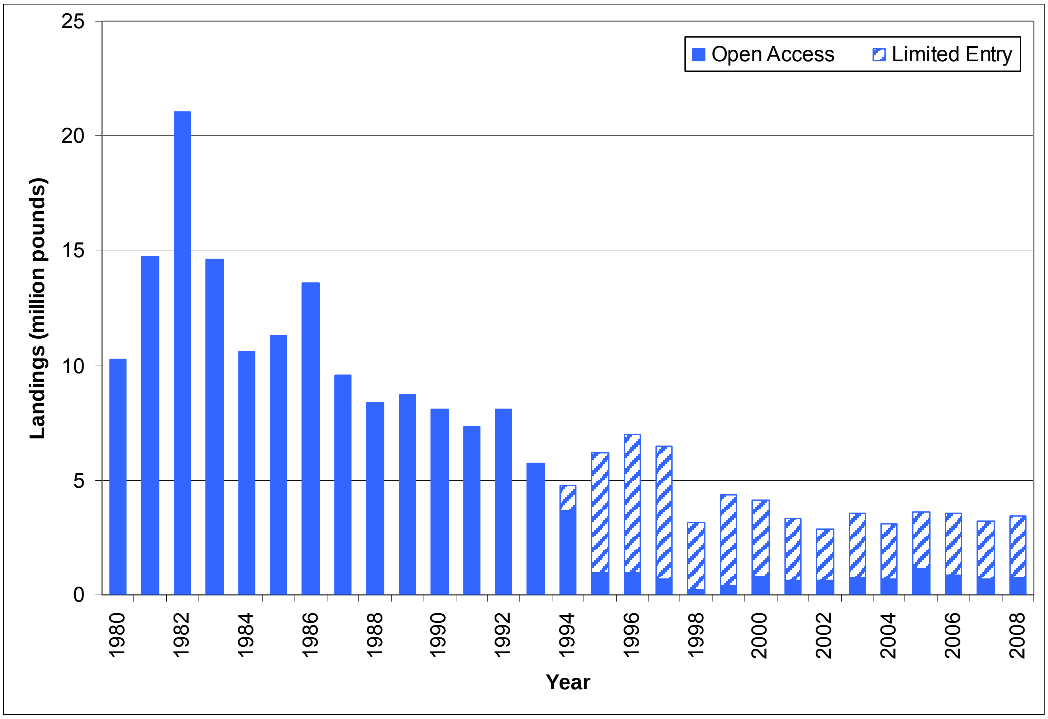


Figure 14-3. Sablefish commercial landings by fishing sector, 1980-2008. Data source: CFIS data, all gear types combined.

These management tools began to stabilize the sablefish fishery maintaining an average annual take of 4.2 million pounds (1900 metric tons) during 1994-2008. During this time period, deepwater species, such as sablefish, were predominately taken with trawl gear, averaging 54 percent of total landings. Interestingly, during the same time period as annual landings were decreasing due to additional restrictions to the fishery, the value increased totaling $6.2 million dollars in 2008 (Figure 14-4). This increase in value can be attributed to the increased landing of live sablefish. Live fish often command a much higher price per pound from market dealers. Since 1994, annual landings of live sablefish have experienced a substantial upward trend, going from less than 10,000 pounds (5 metric tons) in 1994 and 1995 to just over 160,000 pounds (73 metric tons) in 2007 valued at $410,000 (Figure 14-5). Although the live component of the fishery averages only 4 percent of the entire fleets' ex-vessel value, this growth demonstrates how the sablefish fishery continues to diversify and evolve through regulatory change and economic pressures. Despite challenges, such as inflated fuel prices that reached unprecedented levels in 2007 and 2008, the sablefish fishery remains one of the most valuable groundfish fisheries in California.

There is no recreational fishery for sablefish due to its deeper water distribution.

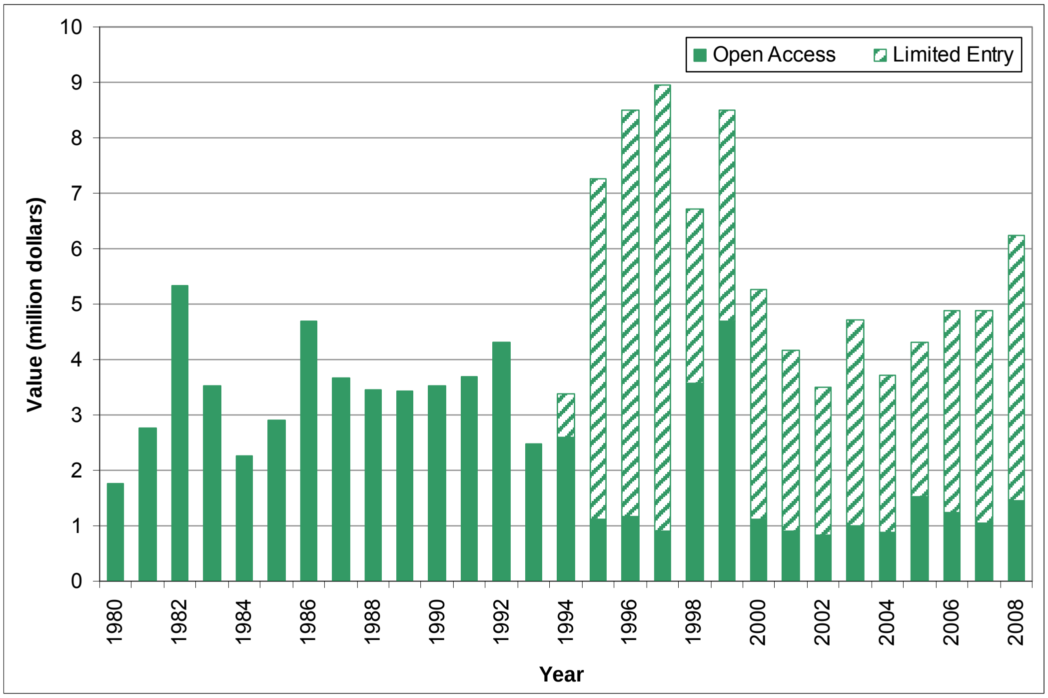


Figure 14-4. Sablefish commercial value by fishing sector, 1980-2008. Data source: CFIS data, all gear types combined.

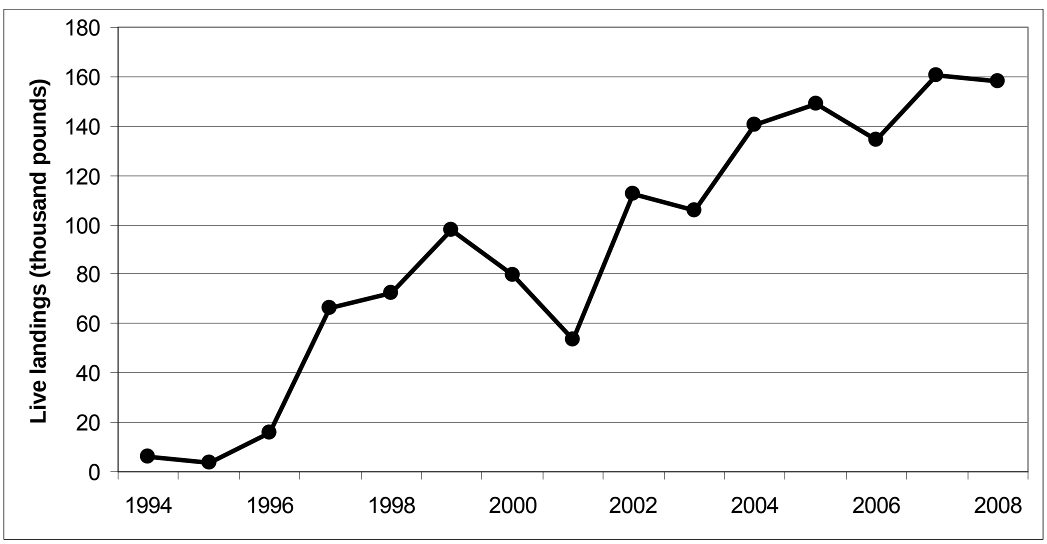


Figure 14-5. Live sablefish commercial landings, 1994-2008. Data source: CFIS data, all gear types combined.

Status of the Biological Knowledge

Sablefish belong to the taxonomic class of ray-finned fish which includes skillfish. Sablefish can grow to 3-4 feet (91-122 centimeters) in length and are blackish-gray in color. The dark color earned them the common name of blackcod, widely used among commercial fishers. The geographic distribution of sablefish ranges from southern Baja California, Mexico to the northern stretches of the Bering Sea in Alaska. Sablefish spawn during winter months, laying eggs in water generally deeper than 1000 feet (300 meters). Eggs become more buoyant as they mature bringing them closer to the surface. These first few months of larval life are imperative to survivorship and are highly dependent on oceanic conditions to provide nutrients. Once hatched, juvenile sablefish will remain within inshore waters until reaching maturity, between 4 and 6 years, at which time they migrate offshore to deep water (greater than 1600 feet; 500 meters). They are commonly found on muddy bottoms and can be found as deep as 6500 feet (2000 meters). Examination of otoliths to determine age has confirmed that sablefish, much like other species of groundfish, are long lived and slow growing after maturity and both sexes reach maximum growth around age 10. Females grow larger and live longer than males; the largest female included in the most recent stock assessment measured 40 inches (102 centimeters) and was estimated to be between 80 and 92 years old. The largest male, at 35 inches (91 centimeters) was estimated to be 68 years old. Based on fishing depth information the older sablefish are caught in deeper water. As adults, carnivorous sablefish are effective predators that target crustaceans, cephalopods and other fish. Conversely, sablefish are preyed on by other fishes and marine mammals, such as Pacific cod, Pacific halibut, spiny dogfish, elephant seals, harbor seals and California sea lions.

Status of the Population

In 2007, a stock assessment was conducted on sablefish. For the first time, the geographic stock (or population) considered by the assessment ranged from the U.S./Canadian border to Point Conception, California (San Luis Obispo County). This differed from previous assessments which ended at Lopez Point (Monterey County). The results of the stock assessment indicate that the sablefish population may be supported by fewer, less frequent, strong year classes rather than by a greater number of “average” strength year classes. This is likely due to the fact that sablefish recruitment is strongly dependent on favorable oceanic conditions that provide nutrients during early larval stages. The stock assessment authors recommended that further research be conducted in order to evaluate alternative methods for incorporating environmental information into the modeling process.

The results of the 2007 stock assessment concluded that the spawning stock biomass of the sablefish population is currently at 207 million pounds (93,900 metric tons) which represents 38.3 percent of the unfished stock size. This is a relative improvement from the previous 2005 assessment but is dependent on strong 1999 and 2000 year class recruitment. Harvest limits for 2009 and 2010 were set conservatively so the stock will not be fully dependent on these strong recruitment year classes. It should be noted that 1999 and 2000 were considered strong recruitment years for other groundfish species including lingcod, bocaccio and cabezon. For the current 2009-2010 management cycle, the Pacific coastwide sablefish optimum yield (OY) increased modestly from 13 million pounds (5934 metric tons) in 2008 to 18.6 million (8423 metric tons) in 2009.

Management Considerations

Sablefish are currently managed under joint jurisdiction by the federal PFMC and the Department. Prior to 1982, sablefish was managed under state jurisdiction by the Department along with the California Fish and Game Commission, and the state legislature. Sablefish was designated a federal groundfish in 1982 when the PFMC implemented the Groundfish FMP. Following the 1994 creation of the federal limited entry permit program, the PFMC adopted Amendment 14 to the Groundfish FMP in 2001 adding another major management change to the sablefish fishery. This amendment, known as the “tier program” replaced the derby style fishery by creating permit stacking in the limited entry fixed gear (long line and trap) sector (hence “tiers”) which allows permittees to take multiple trip limits based on the number of permits stacked on a vessel. For the fixed gear sector, the tiered program has resulted in extended fishing seasons and has allowed commercial fishers greater flexibility and efficiency during the fishing season by maximizing individual business strategies and promoting safety.

In the early 2000s, a significant change to all groundfish fisheries occurred in response to the growing declaration of overfished groundfish species. Because these overfished species co-occur with many other healthy groundfish species, trip limit restrictions were implemented in specific species groups to reduce the take of overfished species. Additionally, in 2002 depth management restrictions were created in the form of Rockfish Conservation Areas (RCAs). The RCA depth closures prevented commercial and recreational fishing for groundfish on the shelf between 30-50 fathoms and 150-200 fathoms (55-91 meters and 274-366 meters), depending on regional management area, along the California coastline. In some areas, this process pushed commercial fishers further outside of their normal fishing grounds.

Due to the increased need to monitor the effectiveness of RCAs and protect overfished species, a federal Vessel Monitoring System (VMS) program was implemented. This program required Global Positioning Systems equipment to be installed on any vessel intending to target groundfish species in or transiting through federal waters with groundfish onboard. Because sablefish fishing grounds are in deep water seaward of the RCA, almost the entire fleet complied as a result—the only exception would be deep water canyons inside state waters. In 2004, VMS was implemented for the limited entry sector (both fixed gear and trawl) and by early 2008 was required within the open access sector as well.

Beginning in 1998, the PFMC began looking more closely at the open access sector of the groundfish fishery—sablefish compose a significant component of the open access fishery. Historically, the open access fishery experienced high variation in participation from fishers and was intermittently utilized. In 2000, the Groundfish Strategic Plan identified the open access fishery as being overcapitalized and made permitting that sector a priority. In subsequent years, the PFMC looked at a range of alternatives to restrict the fishery with a limited entry permit. After much deliberation, the PFMC adopted a registration only option that will require any vessel participating in groundfish fisheries to register with the National Marine Fisheries Service each year beginning in 2011. This option will provide annual fleet accountability for management tracking while maintaining flexibility for fishery participants. This is particularly important for sablefish because the open access sablefish fishery has been used as an alternative fishery in years when salmon are not available.

In the near future, all fixed gear groundfish fisheries will be required to maintain a logbook. It is anticipated this information will be instrumental in calculating effort and can be used in making management decisions.

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Further Reading

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Sablefish commercial landings and value, 1980-2008.

Year	Dead (pounds)	Live (pounds)	Total (pounds)	Value
1980	10,284,920	0	10,284,920	$1,763,395
1981	14,727,473	0	14,727,473	$2,764,070
1982	21,018,966	0	21,018,966	$5,323,652
1983	14,613,390	0	14,613,390	$3,531,071
1984	10,633,319	0	10,633,319	$2,253,646
1985	11,306,064	0	11,306,064	$2,897,656
1986	13,585,933	0	13,585,933	$4,695,310
1987	9,585,595	0	9,585,595	$3,670,009
1988	8,360,438	0	8,360,438	$3,449,234
1989	8,720,361	0	8,720,361	$3,424,398
1990	8,070,375	0	8,070,375	$3,512,553
1991	7,353,503	0	7,353,503	$3,681,681
1992	8,098,798	0	8,098,798	$4,318,290
1993	5,720,045	0	5,720,045	$2,481,213
1994	4,784,144	6,129	4,790,273	$3,375,080
1995	6,183,154	3,635	6,186,789	$7,254,744
1996	6,981,661	15,785	6,997,446	$8,505,608
1997	6,411,701	66,281	6,477,982	$8,961,132
1998	3,094,214	72,108	3,166,322	$6,715,824
1999	4,238,004	98,181	4,336,184	$8,501,141
2000	4,056,350	79,715	4,136,065	$5,260,841
2001	3,291,323	53,346	3,344,669	$4,173,748
2002	2,726,528	112,328	2,838,856	$3,509,313
2003	3,469,774	105,536	3,575,310	$4,719,560

Sablefish commercial landings and value, 1980-2008.				
Year	**Dead (pounds)**	**Live (pounds)**	**Total (pounds)**	**Value**
2004	2,969,247	140,574	3,109,821	$3,723,153
2005	3,445,402	149,020	3,594,422	$4,310,083
2006	3,426,912	134,687	3,561,600	$4,888,379
2007	3,032,639	160,470	3,193,109	$4,871,286
2008	3,264,320	158,042	3,422,402	$6,233,813

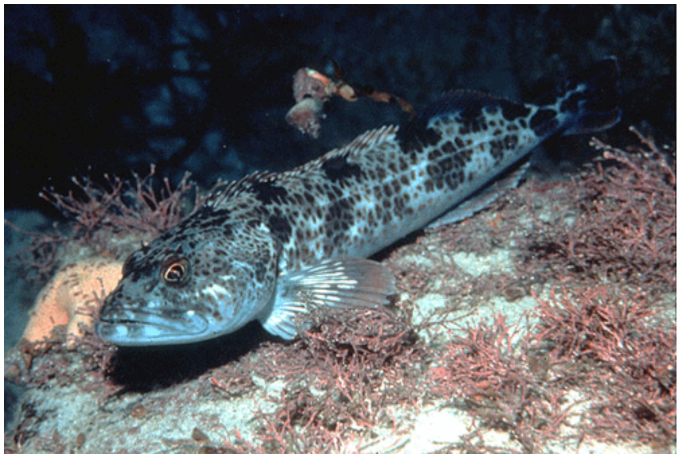
Data Source: CFIS data.

Sablefish commercial landings by fishing sector, 1980-2008.			
Year	**Open access pounds**	**Limited entry pounds**	**Total pounds**
1980	10,284,920	0	10,284,920
1981	14,727,473	0	14,727,473
1982	21,018,966	0	21,018,966
1983	14,613,390	0	14,613,390
1984	10,633,319	0	10,633,319
1985	11,306,064	0	11,306,064
1986	13,585,933	0	13,585,933
1987	9,585,595	0	9,585,595
1988	8,360,438	0	8,360,438
1989	8,720,361	0	8,720,361
1990	8,070,375	0	8,070,375
1991	7,342,150	0	7,342,150
1992	8,078,145	0	8,078,145
1993	5,720,285	0	5,720,285
1994	3,697,677	1,089,671	4,787,348
1995	956,483	5,230,404	6,186,887
1996	963,884	6,034,312	6,998,196
1997	659,585	5,822,716	6,482,300
1998	222,663	2,943,460	3,166,123
1999	401,235	3,936,011	4,337,246
2000	780,045	3,354,801	4,134,846

Sablefish commercial landings by fishing sector, 1980-2008.			
Year	**Open access pounds**	**Limited entry pounds**	**Total pounds**
2001	649,499	2,694,975	3,344,474
2002	610,256	2,228,599	2,838,856
2003	744,985	2,829,703	3,574,688
2004	673,667	2,432,502	3,106,169
2005	1,126,288	2,468,353	3,594,642
2006	852,154	2,704,238	3,556,392
2007	666,852	2,523,583	3,190,436
2008	722,016	2,700,386	3,422,402

Data Source: CFIS data.

15 Lingcod, *Ophiodon elongatus*



Lingcod, *Ophiodon elongatus*. Photo credit: Daniel W. Gotshall.

History of the Fishery

Lingcod, *Ophiodon elongatus*, is an important commercial and recreational species of the Pacific coast of the United States. As a nearshore species, it has been fished by inhabitants along the coastline of California for thousands of years, serving an important role in the diet along with shellfish. More recently, lingcod has been a California commercial fishery since the early 1900s. The lingcod fishery showed a general upward trend ranging from 0.5 million to 2 million pounds (225 to 900 metric tons) in landings since records began in 1916 to a rapid rise during the 1970s, with the growth of the west coast trawl fishery. Commercial landings have been variable, but was greatest between 1970 and 1990 (except for a drop in the mid 1980s), with peak landings of nearly 4 million pounds (1800 metric tons) landed in 1974. Landings decreased in the last decade due to management restrictions beginning in the 1990s, with catch levels consistently under 0.5 million pounds (225 metric tons) (Figures 15-1, 15-2). During the 2000s, annual landings averaged only 145,000 pounds (65 metric tons) with an average value of $209,000 (Figure 15-3).

The average price per pound increased from $0.23 in 1980 to $1.56 in 2008 ($0.50 to $3.44 per kilogram), mainly due to the increased value of the live fish market that began in the mid 1990s (Figure 15-3). From 1998 to 2008, the value of lingcod sold live has comprised a growing share of total lingcod market value; in 1993 live fish represented 1 percent of total commercial lingcod landings, increasing to a range from 32 percent in 1998 to 57 percent in 2003. Prior to the mid 1980s, trawl gear was the predominate gear used to catch lingcod. Fishing strategies changed as the live fish fishery expanded and currently trawl and hook and line gear are used equally. A minor portion of lingcod are taken with gill nets.

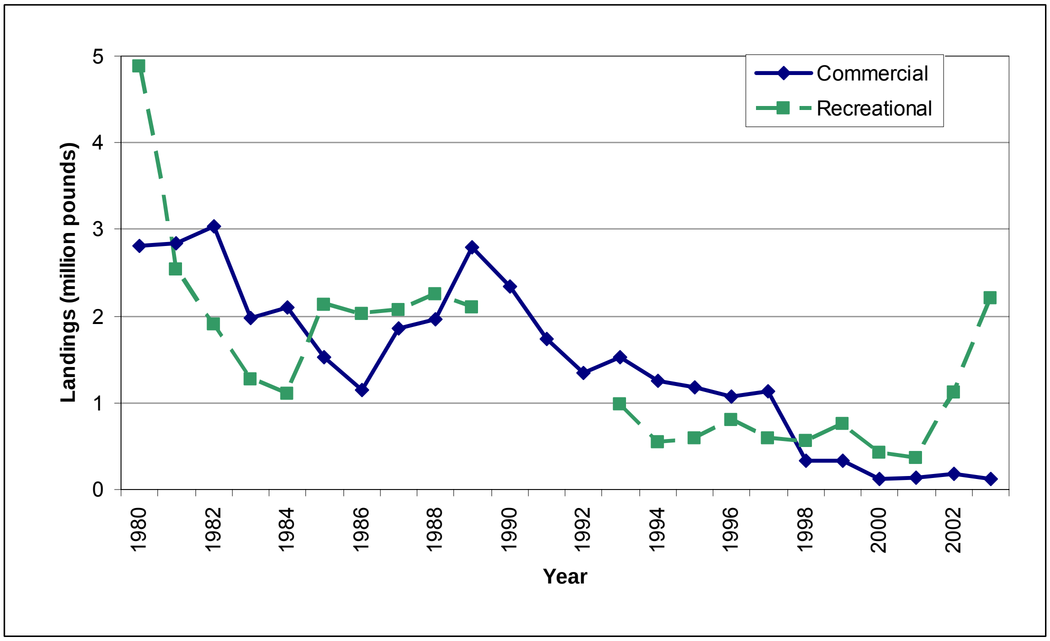


Figure 15-1. Lingcod commercial and recreational landings, 1980-2003. Data Sources: Commercial - CFIS data, all gear types combined. Recreational - MRFSS data, all fishing modes and gear types combined. Data not available for 1990-1992. CPFV data not available for central and northern California for 1993-1995.

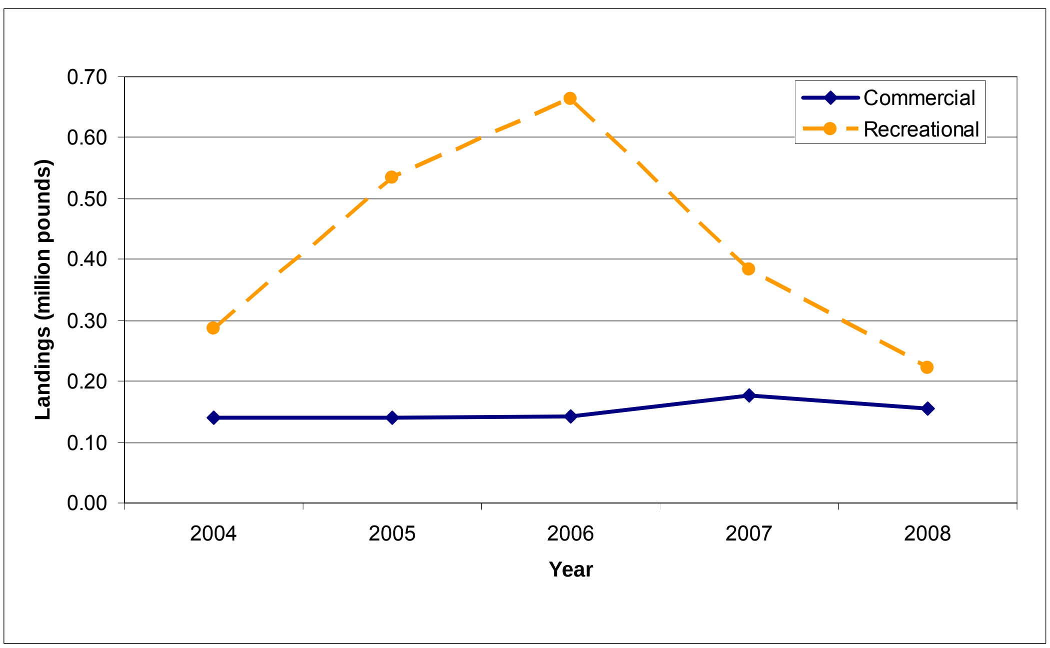


Figure 15-2. Lingcod commercial and recreational landings, 2004-2008. Data Sources: Commercial - CFIS data, all gear types combined. Recreational - CRFS data, all fishing modes and gear types combined.

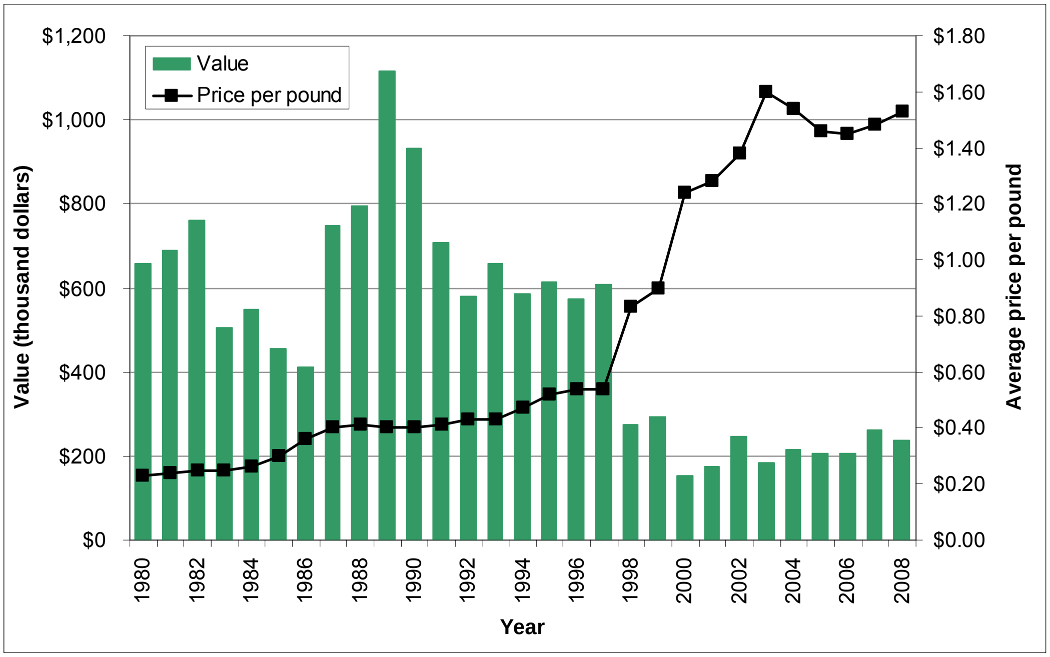


Figure 15-3. Lingcod ex-vessel value and average price per pound, 1980-2008. Data Source: CFIS data, all gear types combined.

Lingcod have been caught recreationally in California since the 1920s, and are now a significant portion of the recreational fishery. Since 1980, there have been two different recreational sampling programs: the Marine Recreational Fisheries Statistical Survey (MRFSS) (1980-2003) and the California Recreational Fisheries Survey (CRFS) (2004-2008). Due to changes in the sampling protocol and how the data are used to estimate landings these two surveys are not comparable. An analysis of MRFSS data (1980-2003) shows lingcod as the third-ranking species among all recreationally caught species in landed weight, averaging 5.6 percent of the total recreational catch for that time period. For 2004-2008, CRFS data rates lingcod as the fifth highest species by weight, at 4.7 percent of the total recreational catch. They are a large, sporting fish that are considered tasty. Most are taken using hook and line (sometimes inadvertently caught fishing for salmon), and some are caught by spearfishing. From 1980 to 2003, 95 percent of lingcod caught were taken by boat modes [commercial passenger fishing vessels (CPFV) and private/rental boats], and for 2004-2008, 97 percent of lingcod were taken by boat mode. Private boat landings were predominant over those from CPFVs, 72 percent to 28 percent from 1980-2003, and 56 percent to 44 percent from 2004-2008.

Since 1980, CPFV catch of lingcod (based on CPFV logbook data; Figure 15-4) has been on a downward trend that may be a result of recreational bag and minimum size limits imposed starting in 1980 (Table 15-1) and exacerbated by the severely restricted harvest guidelines implemented when lingcod was declared overfished in 2000. The CPFV catch from 2000 to 2008 has been highly variable, ranging from 10,652 fish in 2000 to 44,198 fish in 2003. For all recreational modes, both MRFSS (2000 to 2003) and CRFS recreational catch data (2004 to 2008) have also been variable. MRFSS catch ranged from a low of 357,976 pounds (162 metric tons) in 2001 to a high of 2,202,913 pounds (1000 metric tons) in 2003 (Figure 15-1), while CRFS catch ranged from a high of 662,752 pounds (301 metric tons) in 2006 to a low of 222,920 pounds (101 metric tons) in 2008 (Figure 15-2).

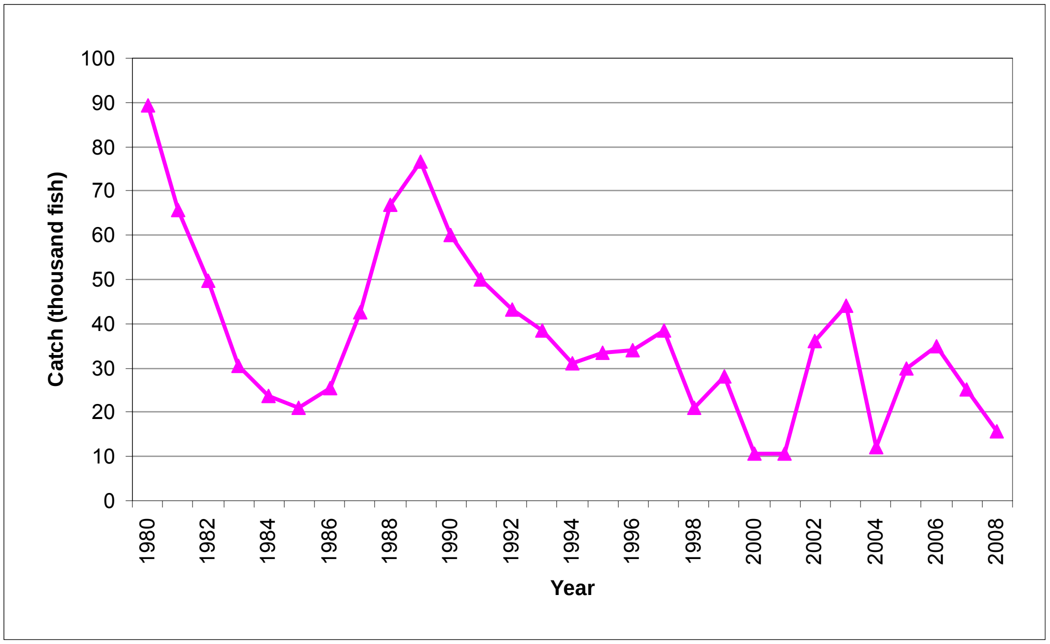


Figure 15-4. Lingcod commercial passenger fishing vessel (CPFV) catch, 1980-2008. Data source: CPFV logbook data.

Table 15-1. History of changes to California recreational lingcod bag and minimum size limits.

Year	Bag limit	Minimum size (inches)
Prior to 1980	10	--
1980	5	--
1981	5	22
1998	3	24
1999	2	24
2000	2	26
2002	2	24
2004	1*	30*
2005 to present	2	24

* Inseason change became effective April 1.

Since 1999, MRFSS and CRFS records show total recreational catch estimates exceeding commercial catch every year (Figures 15-1 and 15-2). In 2004, recreational catch accounted for 65 percent of the total coastwide lingcod catch. This shift away from the opposite pattern of greater commercial landings in the 1970s is attributable to both the recent management restrictions imposed on the commercial fishery (see Management Considerations, below) and increased effort from the recreational sector. An analysis of historical recreational catch data indicates a 65 percent increase in recreational effort (primarily boat modes) between the years 1958 to 1961 and 1981 to 1986, although effort decreased by about 20 percent between 1981 to 1986.

Both average weights and lengths for the lingcod recreational fishery have demonstrated similar trends since 1980, except for a spike in average weights between 1997 to 2001, and a peak in 2004 (Figure 15-5). The increase in lengths beginning in 1997 may be due to the increase in the minimum size limit from 22 to 24 inches in 1996 (Table 15-1). The peak average length of 28.3 inches (72 centimeters) in 2004 is likely due to the April 1 inseason increase of the minimum length size limit to 30 inches (76.2 centimeters), returning to the 24 inch (71.1 centimeters) size limit the following year.

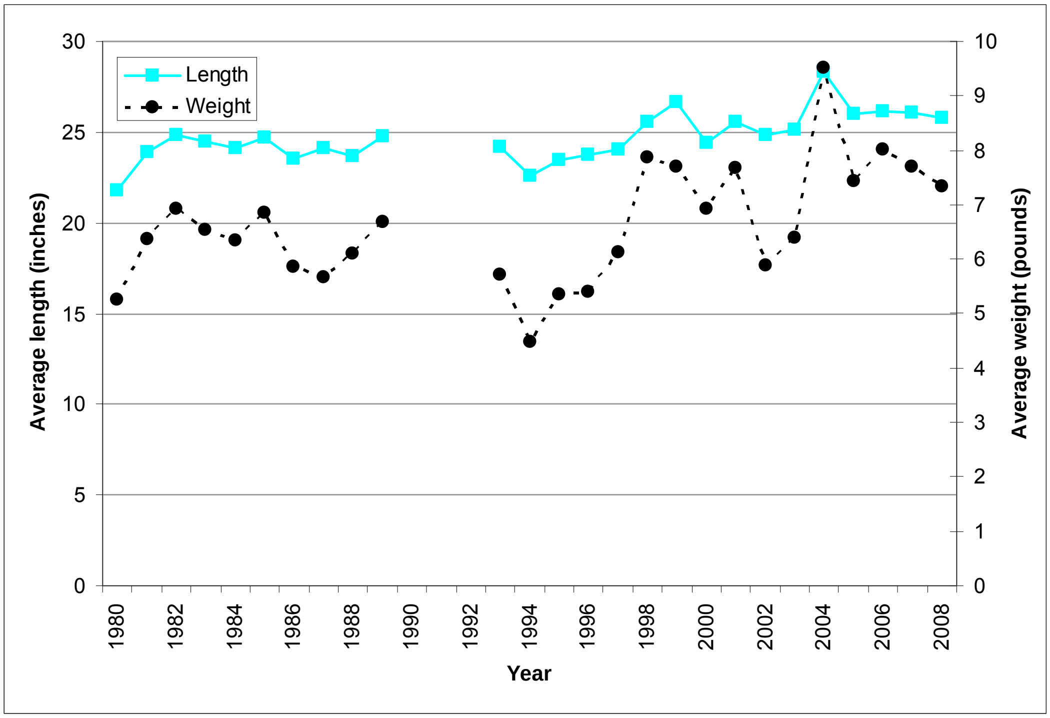


Figure 15-5. Lingcod recreational catch average yearly length and weight, 1980-2008. Data source: MRFSS (1980-2003) and CRFS (2004-2008) sampler examined data, all fishing modes and gear types combined. Data not available for 1990-1992. CPFV data not available for central and northern California for 1993-1995.

The declining catch-per-unit-effort (CPUE) in the commercial fishery since 1980 (Figure 15-6) reflects the decreasing biomass of the stock according to the 2005 stock assessment. The non trawl peak for years 1985-1989 may be attributable to the increased use of gill nets those years, with a relatively higher CPUE from this gear type.

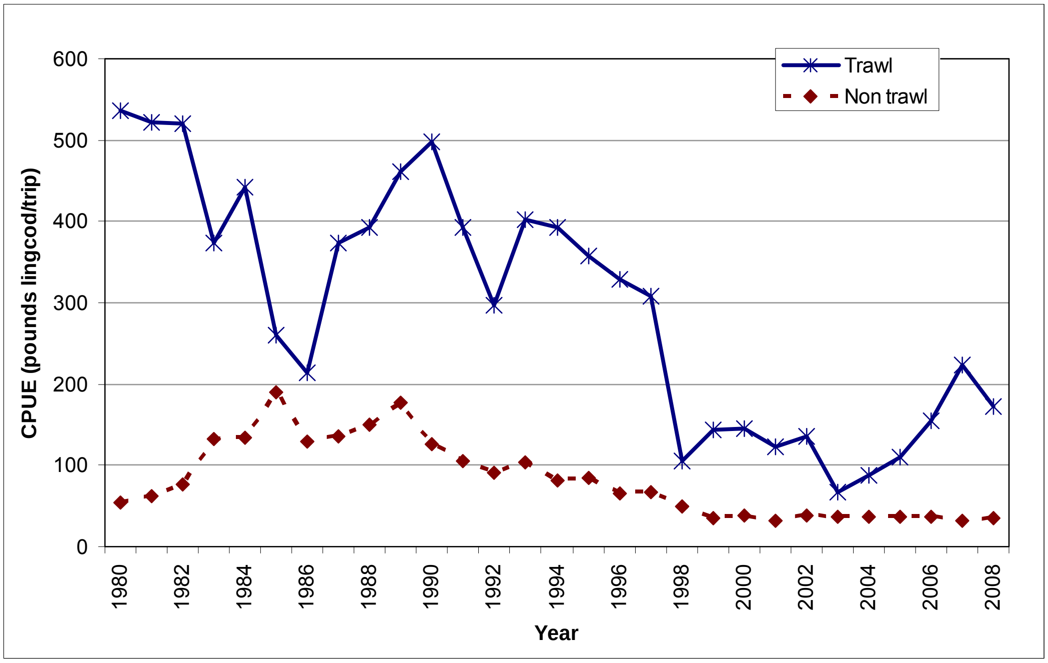


Figure 15-6. Lingcod commercial catch-per-unit-effort (CPUE), 1980-2008, for trawl and non trawl gear types. Data source: CFIS data.

The sharp CPUE increases in both the recreational fishery as a whole and the CPFV fishery in 2002 and 2003 (Figures 15-7 and 15-8) are due to much higher numbers of fish landed, as fishing effort remained about the same as previous years. In 2002 and 2003, CPFVs landed an estimated 58,784 and 35,269 fish, respectively, compared to 12,141 fish in 2001. Similarly, in 2002 and 2003, private boats landed 88,062 and 254,741 fish, compared to 26,719 fish in 2001. These increases may partly be explained by higher numbers of fish available, beginning in 1999, when the stock began to rebound, according to the latest stock assessment. The decline in CPUE in 2004 may be due to a decrease in the bag limit and significant increase in minimum size limit that year, although CPUE has remained low after those regulatory changes were rescinded in 2005 (Table 15-1).

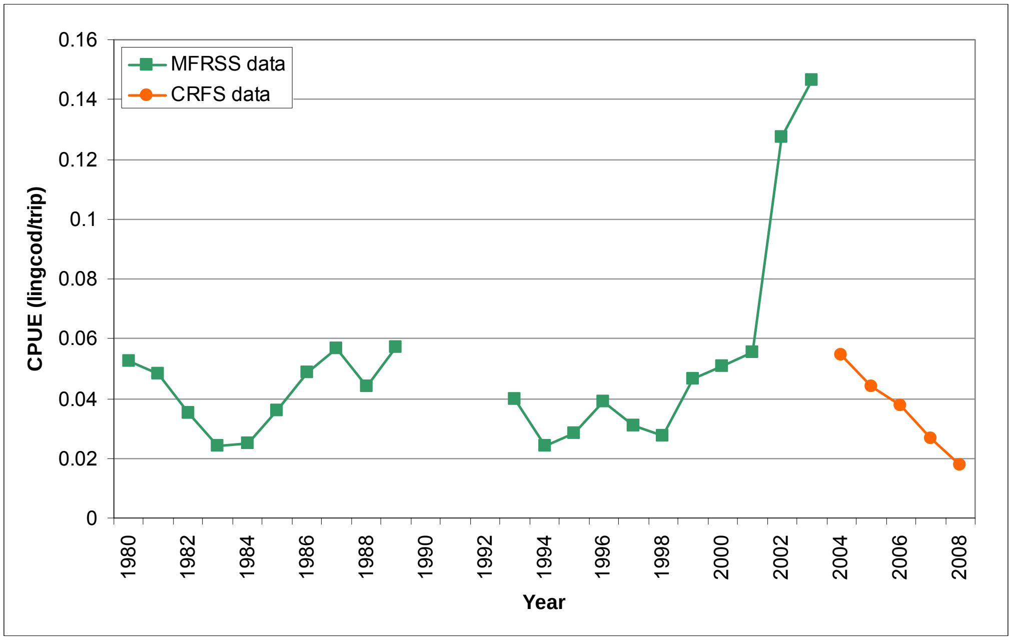


Figure 15-7. Lingcod recreational catch-per-unit-effort (CPUE), 1980-2008. Data sources: MRFSS (1980-2003) and CRFS data (2004-2008), all fishing modes and gear types combined. Data not available from 1990-1992. CPFV data not available for northern and central California for 1993-1995.

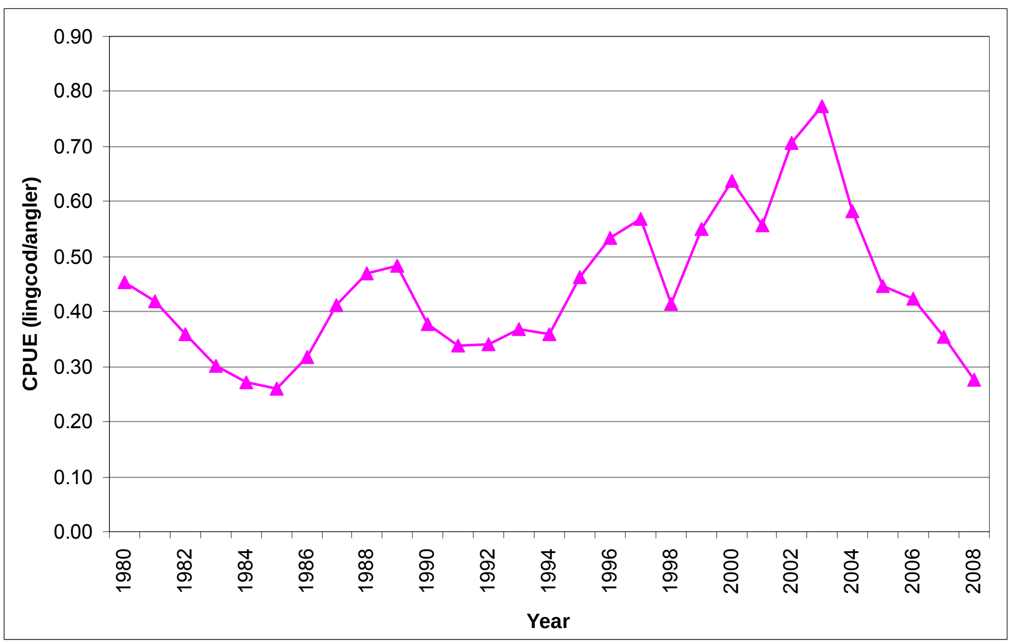


Figure 15-8. Lingcod commercial passenger fishing vessel (CPFV) catch-per-unit-effort (CPUE), 1980-2008. Data source: CPFV logbook data.

Status of Biological Knowledge

Lingcod is a nearshore, demersal species inhabiting Pacific waters from northern Baja California, Mexico to Kodiak Island, Alaska. The areas of greatest abundance are off British Columbia and Washington, with numbers tapering off sharply south of Santa Barbara, California. They are the largest members of the Hexagrammidae (greenlings) family, although recent molecular work indicates they belong in the Cottidae (sculpins) family, being especially close to cabezon. Lingcod are the lone members of the genus *Ophiodon*, which is derived from the Greek words for snake and tooth, referring to its large teeth. The species name *elongatus* is from Latin and refers to its long body. Coloration can range from a mottled dark brown to grey, blue or green. A dorsal fin runs the length of the back, notched into two sections, and the anal fin runs from mid-belly to the tail.

Spawning season is during the fall, from November to early March in California. This is preceded by a spawning migration to nearshore areas when males seek out territories where soccer ball sized egg masses, called nests (or clutches), are deposited. The nests are found on hard substrates in rocky areas, where there is sufficient current to oxygenate the eggs. Additional factors important to lingcod embryo development and hatching are salinity, temperature and light. Mature females spend little time at the spawning grounds; after laying eggs, they leave the nest site and show a lack of nest site fidelity between seasons. Males show high nest site fidelity between seasons, and often will fertilize multiple nests within and between seasons. The polygamous behavior by both sexes serves to maximize genetic diversity.

After spawning, males will strongly defend the nests from predation, including aggressively striking at baits and lures. Males will also remain at nests in the presence of spear fishers. This behavior leaves lingcod populations especially vulnerable at this time, as mortality of nest guarding males leads to not only loss of reproductive potential of the fish, but likely mortality of the undefended egg mass (although unguarded nests may be taken over by new males). Predators of lingcod eggs include other fishes such as rockfish, kelp greenling and cabezon, and by invertebrates such as echinoderms, urchins and gastropods. After 5-11 weeks of incubation, lingcod eggs typically hatch in March or April at a size of about 0.33 inches (0.8 centimeters). Larvae move to the water column for three months, attaining a size of about 3 inches (8 centimeters) feeding on copepods, amphipods and euphausiids. They then settle into nearshore estuarine areas, eelgrass and kelp beds, and subtidal zones with sand and mud substrates. Benthic juvenile prey items include fishes such as flatfishes, herring and crustaceans. As they grow larger they move to deeper areas in rocky reef and kelp bed habitats where adults reside, usually ranging from 30-330 feet (10-100 meters). Laboratory and tagging studies show juvenile lingcod seek more structurally complex environments as they grow, as the costs of lack of protection in open areas (and increasing conspicuousness with size) increase compared to the benefits of growth while foraging. Juveniles are susceptible as prey for marine mammals, seabirds and other lingcod, while adult lingcod generally escape most predation due to their large size. Adult lingcod are ambush predators, using their large mouths and sharp teeth.

They lie in wait for prey, primarily fish but also invertebrates such as crab, squid or octopus.

Growth of lingcod is rapid, reaching 12 inches (30 centimeters) in length the first year. Males reach sexual maturity at 2 years and 18 inches in length (45 centimeters), and females at 3-5 years and 24-36 inches in length (61-75 centimeters). Both sexes grow at the same rate until age 2, when females start to grow faster than males. Maximum age is about 20 years for females at 48 inches (120 centimeters) and 14 years for males at 36 inches (90 centimeters). Fecundity for females ranges from about 40,000 to 500,000 eggs, depending on the size of the fish. Considered a hardy species, lingcod lack a swimbladder and do not suffer decompression injuries when discarded after catch. Discard mortality is primarily due to handling, especially during the time between catch and release, so mortality calculations must account for shipboard handling procedures. Lingcod are generally sedentary, with tagging studies showing that lingcod movement patterns reflect high site fidelity, with established residences from which foraging trips are made. The exception would be during spawning season, when there is migration to spawning grounds at more inshore areas.

Status of the Population

The first lingcod stock assessment provided to the Pacific Fishery Management Council (PFMC) was in 1986. Subsequent assessments for northern and southern areas of its range in 1997 and 1999, respectively, determined stock status at less than 10 percent of unfished size. As a result, the PFMC declared lingcod an overfished stock in 1999. A stock is considered overfished when the stock size is 40 percent or less of the unfished stock size. Since 2000, lingcod stock assessments have considered the coastwide stock as a whole, consisting of a northern (U.S./Canada border to Cape Blanco, OR) and southern (Cape Blanco, OR to U.S./Mexico border) stock. The most recent stock assessment from 2005 estimated the coastwide spawning biomass at 64 percent of unfished level, with the northern stock at 87 percent and the southern stock at 24 percent. Since lingcod are managed coastwide, the PFMC proclaimed the lingcod stock to be fully rebuilt four years ahead of the target rebuilding year of 2009. The recent relatively healthy stock estimates for the northern stock are due to large year classes in 1999 and 2000. However, uncertainty remains over the status of the southern stock due to the sparseness of fishery catch at age data. Also, management actions concerning both minimum size and commercial trip limits have limited the utility of fishery data regarding stock recruitment and as indices of abundance.

Management Considerations

With the adoption of the Pacific Coast Groundfish Fishery Management Plan by the PFMC in 1982, lingcod became a federally managed groundfish species. 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 (Department) through regulations adopted by the state legislature and the California Fish and Game Commission.

The 2005 stock assessment, as mentioned above, resulted in the coastwide stock being declared fully rebuilt. However, since concern remained over the status of the southern portion of the stock, California still manages the southern stock conservatively to promote its rebuilding through strict management measures.

To achieve the greatly reduced harvest levels needed to accomplish management targets and to rebuild the stock on schedule, numerous fishing restrictions were implemented on the commercial and recreational fisheries. Both sectors are subject to a spawning closure. Beginning in 1995, commercial trawl trip limits were imposed; these have become more restrictive as yearly harvest targets have decreased and the need arose to protect yelloweye rockfish, another overfished species. Monthly trip limits of 20,000 pounds (9 metric tons) in 1995 dropped to less than 1000 pounds (454 kilograms) per two month period beginning in 2003, and more recently to less than an average of 300 pounds (136 kilograms) per two month period in 2009. A commercial minimum size limit of 22 inches (56 centimeters) was instituted in 1995, and increased to 24 inches (61 centimeters) in 1998—where it remains.

The recreational bag and size limits have changed repeatedly since 1980 in an effort to maintain catches below recreational allocations (Table 15-1). To protect lingcod populations during the spawning season, seasonal closures were implemented in 2000 for the months of November and December, as well as early months of the year, for areas south of Cape Mendocino (Humboldt County). This pattern of closures has continued since, with various months closed in different years (at a minimum December has been closed statewide since 2005, and January and February closed south of Point Conception).

Recent work using mitochondrial DNA has shown that while there are enough migrants among west coast lingcod populations to effectively homogenize the stock genetically, there are too few migrants to impact fishery management, leaving the populations effectively isolated and subject to localized overfishing. Thus, effects of overfishing can have serious consequences for local populations, as long range larval transport will not be able to rebuild depleted areas. This supports a regional management approach, as exemplified by the use of recreational management areas in California, begun in 2000.

Future research on lingcod is needed regarding age structure and recruitment, especially for the southern stock. The historical data for the southern stock is much sparser compared to that of the northern stock, contributing to the greater uncertainty over its status. Fishery-independent surveys over time and geographic area for both regions are necessary to inform future assessments and management decisions.

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Lingcod commercial landings and value, 1980-2008.

Year	Pounds (thousands)	Value	Average price	Year	Pounds (thousands)	Value	Average price
1980	2,811	$658,177	$0.23	**1995**	1,185	$614,933	$0.52
1981	2,840	$689,042	$0.24	**1996**	1,066	$574,245	$0.54
1982	3,038	$761,568	$0.25	**1997**	1,132	$607,682	$0.54
1983	1,977	$503,918	$0.25	**1998**	331	$273,627	$0.83
1984	2,095	$550,118	$0.26	**1999**	326	$293,026	$0.90
1985	1,531	$456,195	$0.30	**2000**	123	$151,714	$1.24
1986	1,154	$411,486	$0.36	**2001**	137	$175,456	$1.28
1987	1,859	$747,178	$0.40	**2002**	179	$246,966	$1.38
1988	1,960	$794,786	$0.41	**2003**	116	$184,466	$1.60
1989	2,791	$1,116,462	$0.40	**2004**	140	$215,224	$1.54

Lingcod commercial landings and value, 1980-2008.							
Year	**Pounds (thousands)**	**Value**	**Average price**	**Year**	**Pounds (thousands)**	**Value**	**Average price**
1990	2,346	$933,045	$0.40	**2005**	141	$205,402	$1.46
1991	1,736	$706,379	$0.41	**2006**	142	$204,873	$1.45
1992	1,352	$578,537	$0.43	**2007**	176	$260,724	$1.48
1993	1,520	$658,856	$0.43	**2008**	154	$237,181	$1.56
1994	1,251	$585,956	$0.47				

Data Source: CFIS data, all gear types combined.

Lingcod recreational catch, 1980-2003.					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	626,945	**1988**	315,314	**1996**	122,112
1981	347,431	**1989**	291,979	**1997**	89,509
1982	243,986	**1990**	---	**1998**	73,507
1983	168,410	**1991**	---	**1999**	102,994
1984	158,046	**1992**	---	**2000**	52,421
1985	237,083	**1993**	159,635	**2001**	41,544
1986	265,880	**1994**	96,643	**2002**	148,739
1987	287,314	**1995**	108,854	**2003**	297,309

Data source: MRFSS data, all fishing modes and gear types combined. Data not available from 1990-1992. CPFV data not available for central and northern California for 1993-1995.

Lingcod recreational catch, 2004-2008.	
Year	**Number of fish**
2004	30,909
2005	72,085
2006	82,881
2007	49,912
2008	30,477

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

Lingcod CPFV catch, 1980-2008.					
Year	**Number of fish**	**Year**	**Number of fish**	**Year**	**Number of fish**
1980	89,349	**1990**	60,047	**2000**	10,689
1981	65,604	**1991**	50,111	**2001**	10,652
1982	49,775	**1992**	43,260	**2002**	35,981
1983	30,543	**1993**	38,324	**2003**	44,198
1984	23,797	**1994**	31,112	**2004**	12,001
1985	20,911	**1995**	33,355	**2005**	29,871
1986	25,588	**1996**	34,005	**2006**	34,805
1987	42,518	**1997**	38,441	**2007**	25,269
1988	66,778	**1998**	20,873	**2008**	15,616
1989	76,749	**1999**	28,246		

Data source: CPFV logbook data.

16 Eelgrass, *Zostera marina*

Eelgrass, *Zostera marina*: (left) a close-up photo of eelgrass blades; (right) an eelgrass meadow in Humboldt Bay. Photo Credit: UC Sea Grant Extension, Eureka/Annie Eicher.

Introduction

Seagrasses, a group of about sixty species, are unique amongst flowering plants in that they have adapted to live immersed in seawater. Seagrasses grow in shallow marine bays and estuaries around the world and form the basis of a specialized coastal and estuarine habitat of great ecological value. One of the seagrasses that is widely distributed throughout temperate estuaries of both coasts is the native eelgrass, *Zostera marina*. Along the west coast, eelgrass is found from southeastern Alaska to southern Baja California, Mexico.

Eelgrass beds are important ecological communities of shallow bays and estuaries because of the multiple ecosystem values that they provide. Eelgrass is a major source of primary production in nearshore marine systems, supplying detrital-based food chains. In addition, several organisms directly graze upon it, thus contributing to the system at multiple trophic levels. For example, certain waterbirds feed directly on the eelgrass plants, such as brant geese that use eelgrass almost exclusively as a food resource. Eelgrass meadows are also of vital importance as habitat and have an important role in the life cycle of many ecologically and economically important aquatic species by serving as nursery areas. In California bays and estuaries north of Monterey, eelgrass provides spawning habitat for Pacific herring. Eelgrass beds provide habitat for juvenile fish including Pacific salmonids, lingcod, and rockfish, and invertebrate species such as Dungeness crab.

In addition to the habitat and resource values that eelgrass provides, it also functions to trap and remove suspended particles, thus improving water clarity, reduces erosion by providing sediment stabilization, adds oxygen to the surrounding water, and cycles nutrients. Extensive eelgrass canopies absorb wave shock, thereby protecting adjacent shorelines.

Worldwide there has been a decline in eelgrass abundance over the past 20 to 30 years, which concerns natural resource managers. These changes have been attributed to increased anthropogenic effects, such as coastal development, dredging, pollution, fishing practices and boating activities. Besides human disturbances, declines in eelgrass communities have been caused by outbreaks of disease, particularly by the eelgrass wasting disease during the 1930s on the Atlantic coasts of both Europe and the United States. The disease resulted in the loss of over 90 percent of the North Atlantic eelgrass population, which had a catastrophic effect on estuarine productivity. There was a drastic reduction in brant geese populations, as well as the disappearance of the scallop fishery. In addition, it resulted in the only known case of extinction of a marine gastropod, the eelgrass limpet. Wasting disease continues to affect eelgrass beds in North America and Europe with variable degrees of loss; however, none to date have been as catastrophic as the outbreak in the 1930s.

In response to the decline, the importance of eelgrass communities has been realized and they have received increasing attention from scientists and natural resource managers. There has been an increase in protection through management practices throughout the world. In the United States, eelgrass habitat is protected by federal and state law under their respective Clean Water Acts; the Magnuson-Stevens Fishery Conservation and Management Act; the California Coastal Act; and Title 14, California Code of Regulations. According to these laws and regulations, any activities which may potentially impact eelgrass habitat must mitigate for those impacts. This requires mitigation for harmful impacts to existing eelgrass beds as well as potential eelgrass habitat.

Status of Biological Knowledge

Some of the earliest research on seagrasses occurred with the native eelgrass. To gain a better understanding of this vital estuarine habitat, there has been a major increase in research into the detection and assessment of eelgrass threats. Researchers on both coasts have collected an array of information on plant data over a several year period. Additionally, measurements of eelgrass standing stock have been conducted throughout the Northern Hemisphere including the west coast of North America.

The distribution of eelgrass within bay and estuarine systems is defined by several variables, including light, temperature, salinity, substrate, wave exposure, currents and nutrient availability. Eelgrass forms extensive meadows in soft-bottom habitats from the low intertidal to depths of about 20 feet (6 meters), and from sheltered areas to exposed coasts. In southern California, eelgrass has been reported to occur as deep as 98 feet (30 meters). Optimum temperatures for eelgrass growth seem to lie between 50 and 68°F (10 and 20°C). However, eelgrass is known to survive with a lower tolerance level of 21°F (-6°C) and an upper level of 104.9°F (40.5°C). Eelgrass is a euryhaline species (able to live in a wide range of salinities) that is capable of growing near stream mouths when the water is fresh at low tide, but does not grow in persistent fresh water. A salinity range of 10 to 30 parts per thousand is optimum for growth.

Eelgrass morphology consists of horizontal rhizomes that are buried in substrate and long leafy shoots that extend vertically in the water column. Shoots typically consist of three to five ribbon-like leaves. Leaf lengths can vary from less than 1.5 feet (0.5 meters) to nearly 13 feet (4 meters) and leaf width ranges from 0.05 to 0.5 inches (1.5 to 12 millimeters). Eelgrass colonizes substrate ranging from firm sand to soft mud. Leaf growth is very rapid—typically 0.2 inches/day (5 millimeters/day) and in some circumstances growth can reach 0.4 inches/day (10 millimeters/day). This high productivity results in large biomass input into the ecosystem, fueling dynamic energy systems.

Not only does eelgrass provide high ecosystem value, but it also is used as an indicator of estuarine health because it responds to environmental factors by changing in distribution and abundance. Because of the susceptibility of eelgrass to stresses such as pollution, it is used as one of the five sensitive indicators of pollution in the NOAA National Estuarine Eutrophication Assessment. Eelgrass requires some of the highest light levels of any plant group worldwide which means it is acutely responsive to water clarity changes.

Status of the Population

Eelgrass is found in the nearshore waters of every continent except Antarctica. In California, eelgrass is found to some degree in all of the larger bays and estuaries, including Humboldt Bay, Tomales Bay, Drakes Estero, San Francisco Bay, Monterey Bay, Morro Bay, San Diego Bay and Mission Bay. Additionally, eelgrass is established in several of the smaller estuarine embayments along the state's coastline.

Humboldt Bay

In Humboldt Bay, eelgrass is the dominant macrophyte of the shallow subtidal and lower intertidal zones. The eelgrass beds here represent the third largest eelgrass meadows found along the west coast and host over 60 percent of the total brant goose population each year. Eelgrass contributes more than 40 percent of the primary production in the bay, indicating that it is quite likely the most important primary producer.

The seasonal and temporal fluctuation in distribution and standing stock of eelgrass was studied in Humboldt Bay for two years from 2001 to 2003. For the purpose of the study, the bay was divided into three regions, North Bay, Central Bay and South Bay. Total distribution was determined using aerial photography and on the ground verification with handheld GPS. Aerial imagery showed large continuous eelgrass meadows in North and South Bays with narrow bands along Central Bay. The total areal distribution of eelgrass in Humboldt Bay was determined to be 4670 acres (1890 hectares), which represents a substantial portion of California's eelgrass population (approximately 41 percent).

Eelgrass density in South Bay is greater and shoot lengths are shorter compared to North Bay. The population in Central Bay is intermediate in density and shoot length. Factors such as weather variability, flushing rate, temperature and turbidity, or differences in the genetic composition of Humboldt Bay eelgrass may account for differences in shoot density, but need to be investigated further. Given Humboldt Bay's large eelgrass population and the role it serves in the bay's ecology, there is little doubt that it warrants specific management efforts to understand the dynamics of this important and valuable resource.

Tomales Bay

Eelgrass is the dominant marine flora in Tomales Bay and the primary spawning habitat for the Pacific herring, thus eelgrass distribution and density data are essential for calculating Pacific herring spawning population estimates. Bay-wide eelgrass surveys were conducted in 1987, 1992, 1993 and 1994 with eelgrass distribution along the entire 12 mile (20 kilometer) length of the bay estimated at 965 acres (391 hectares), 654 acres (265 hectares), 884 acres (358 hectares) and 865 acres (350 hectares), respectively, for those years. Many of the eelgrass beds are intertidal, becoming completely exposed during low tides. Eelgrass distribution is relatively stable from year to year; however, density is highly variable and can fluctuate seasonally.

San Francisco Bay

A comprehensive baywide eelgrass survey was completed in 2003 to identify and map existing eelgrass beds and identify conditions under which eelgrass can occur throughout San Francisco Bay. Eelgrass surveys were conducted from June to October using both acoustic and aerial survey methods. Survey techniques utilized a combination of aerial visual surveys, photography, side-scan sonar, single-beam sonar and diver ground-truthing to search for eelgrass beds.

The coverage area of eelgrass in San Francisco Bay was determined to be 2881 acres (1166 hectares), which represents approximately 1 percent of the total area of the bay. While the eelgrass resources here account for only a small portion of the total bay habitat, San Francisco Bay ranks second only to Humboldt in eelgrass coverage.

The largest eelgrass bed with 1505 acres (605 hectares) was located between Point Pinole and Point San Pablo north of the Richmond-San Rafael Bridge. The second largest bed with 437 acres (177 hectares) was found in Richardson Bay near Sausalito in Marin County. The majority of eelgrass was located on the east shoreline between Point Pinole and Bayfarm Island.

San Francisco Bay is greatly impacted by human development, thus an estimated one third of the historic extent of the eelgrass in the bay has been lost. Extremely high turbidity has resulted in reduced light penetration and may be the principle cause of the decline of eelgrass in San Francisco Bay.

Central California

The eelgrass beds within Monterey Bay are limited to the estuarine environment of Elkhorn Slough and its entrance to the bay. These areas make up a total of approximately 50 to 75 acres (20 to 31 hectares) of eelgrass habitat. Eelgrass remains the dominant plant in the beds of Morro Bay. The beds there are the largest and least impacted of any in the southern portion of the state. Nevertheless, there are wide fluctuations in areal extent. By 1997, eelgrass distribution reached an historic low of 50 total acres (20 hectares). Further studies in 1998 showed an improvement in eelgrass distribution ranging from 81 to 120 acres (33 to 49 hectares), depending on the season of survey. A recent study conducted by the Morro Bay National Estuary Program found that eelgrass distribution had increased in the bay since the late 1990s. Total eelgrass in coverage in 2006 and 2007 was estimated at 288 acres (117 hectares) and 347 acres (140 hectares), respectively.

Southern California

In southern California, coastal wetlands are more heavily impacted by human alteration than those in northern California, thus approximately 90 percent of this habitat has been lost. Recent estimates reveal that 40 percent of the world's population lives within 60 miles (96 kilometers) of the coastline. As coastal use and development continues, it seems unavoidable that coastal habitats will continue to experience adverse stress.

Historical records suggest that eelgrass was a predominant plant species in the state's south coast estuaries. However, the majority of southern California's remaining eelgrass habitat exists primarily due to replanting or recolonization of eelgrass beds in new or historic locations.

Eelgrass bed communities exist in Los Angeles Harbor, Huntington Harbor, Channel Islands and in adjacent coastal areas. Many of these have been established through transplant activities associated with specific development mitigation requirements. Due primarily to suitable light conditions, many of the reestablished areas have met their intended mitigation goals. However, some reestablishment attempts have been unsuccessful.

Small Coastal Estuaries

It is likely that at one time eelgrass predominated along the seaward edge of many of the small estuaries along the coast. Today, due to human alterations, such as channelization, dredging, development and upstream disturbances that cause increased turbidity and siltation, eelgrass is limited to a few such ecosystems. Remnant populations are documented within California's north coast estuaries that remain open to seawater influence year round, such as the Big River estuary (Mendocino County) where eelgrass forms large beds along muddy banks within the first 3 miles (5 kilometers) of the estuary, and the Albion River Estuary (Mendocino County), which also has a well-established eelgrass community.

Management Considerations

In order to standardize and maintain a consistent policy regarding mitigating adverse impacts to eelgrass resources in southern California, the Southern California Eelgrass Mitigation Policy (Policy) was developed by federal and state resource agencies (National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, and the California Department of Fish and Game (Department). The Policy provides a basis for consistent recommendations for projects that may affect existing eelgrass resources. The Department's future management goals for eelgrass include:

1. Carry out and maintain a comprehensive eelgrass inventory for the state.
2. Develop a Northern California Eelgrass Mitigation and Monitoring Policy in collaboration with NMFS.
3. Include maintenance of plant stock genetic diversity as an important parameter within eelgrass mitigation plan requirements.
4. Evaluate the potential impacts of anticipated sea level rise and coastal erosion on eelgrass bed communities. Because the natural, often gently sloping shorelines around many of California's bays have been replaced by revetments, a study of the potential loss of eelgrass habitat due to the lack of intertidal refuge from increased water depth and reduced light penetration should be undertaken. The results of such a study would then be added to the analyses of potential impacts and preparations for the anticipated rise in sea level.

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Further Reading

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17 Aquaculture: Overview

The commercial culturing of marine species in California is limited primarily to the production of shellfish such as abalone, clams, mussels and oysters. While the culturing of finfish for enhancement purposes is well established in California, commercial culturing has been limited in scale and remains focused on solving technical questions through research. The commercial production of most cultured shellfish has remained about the same or declined slightly from recent peaks in the last 6 years. Oyster production is down from a peak in 1994, clam production has leveled off from a peak in 2004, mussel production is down but has leveled off from a recent peak in 2002, and abalone production is down slightly but has leveled off from a historical peak in 2004. In several instances, demand exceeded production and the declines reflected several ongoing challenges faced by these industries in their efforts to maintain production. More information on production levels can be found in the specific sections that follow.

Developing and maintaining production of cultured marine species is still influenced by technical problems, in some cases in spite of a well-established production history. Fledgling industries, such as those engaged in scallop and finfish production, face technical challenges in developing breeding and rearing techniques. Many technical problems are being solved and there is now interest in developing a commercial offshore aquaculture demonstration project in southern California. Several species that are established in California waters have been raised in captivity and have good market appeal. As marine capture fisheries reach their limits of production, farming of marine finfish is one means of providing consumers with high quality seafood.

Environmental change or disease impacts also present technical challenges in maintaining production to the well-established industries, such as oyster and abalone culture. Human-caused changes in water quality, for example, present significant challenges to culture facilities that are sited in bays and estuaries. In order to address product safety concerns in these areas, the production of filter-feeding bivalves such as mussels, oysters, and clams are often subject to lengthy closures or depuration (removal of contaminants) requirements. The presence of a shellfish aquaculture facility or lease in an area can, as a consequence, provide a contamination early-warning system for recreational harvest of shellfish and an assessment of the water quality conditions in the general area.

Passage of the 1993 Shellfish Protection Act mandated the formation of local Technical Advisory Committees to assist the Regional Water Boards in remediating water quality in impacted bays and estuaries and thus reducing the number of days closed to shellfish harvesting. With the exception of concerns related to the accumulation of biotoxins, changes in water quality do not present significant technical challenges in the culturing of scallops because of the tendency in that industry to site in offshore areas. Natural changes in water quality have also hampered shellfish production. Much of the recent decline in production can be attributed to El Niño related impacts, particularly in the culturing of oysters, mussels and abalone. A broader discussion of these technical challenges can be found in the specific sections that follow this overview.

Development of a technical response to disease, and conforming to regulatory requirements related to disease control have both influenced production in the oyster and abalone industry and have influenced the success of white seabass enhancement efforts. Oyster production in Tomales Bay, for example, continues to be influenced by a significant complex summertime mortality syndrome influenced by environmental factors and a viral oyster pathogen. Abalone production has been influenced by mortality from withering syndrome and hampered by regulatory requirements intended to prevent the spread of an exotic parasitic worm. Through cooperative efforts between growers and regulators, the parasitic worm has been controlled and may be nearly eradicated from state waters. Large numbers of juvenile white seabass propagated for enhancement purposes have been destroyed to address disease concerns. In each instance, the industry made positive contributions to cooperative efforts among resource agency disease management researchers.

Many California shellfish growers, primarily oyster growers, are facing problems in obtaining adequate supplies of seed. In response, the industry is modifying grow out systems, looking at new sources of seed from outside of the state or bioeconomic region, and examining the feasibility of developing new hatchery facilities within the state.

Environmental laws and regulations have impacted the growth and expansion of established industries such as oysters and abalone but have also impacted developing industries such finfish culture. The recent passage of the California Sustainable Oceans Act of 2006 provided a framework for managing marine finfish aquaculture within state waters. However, passage of the federal National Offshore Aquaculture Act (2005, 2007) has been delayed and there is currently no comprehensive federal framework for regulating offshore aquaculture. California has begun to provide that framework by registering offshore farms in federal waters that will allow a period of experimentation and innovation to begin. The Sustainable Oceans Act also mandated that a Programmatic Environmental Impact Report (PEIR) be prepared. This document, which can be used for project level environmental documents, will provide a framework for managing finfish aquaculture in state waters and address siting and best management practices for existing shellfish culture and future finfish culture.

Taken as a whole, the industry has ardent entrepreneurial support, has great economic potential, and has been a source of significant positive societal benefit. The California legislature supports the development of aquaculture. However, there are numerous other stakeholders that use and enjoy California coastal and marine areas. The aquaculture industry must integrate into the multi-stakeholder arena that also includes an evolving system of national marine sanctuaries and state marine protected areas. The oyster industry, for example, is part of California's cultural heritage. Oyster growers can responsibly farm shellfish with minimal adverse environmental impacts and can even help improve coastal environments by providing ecosystem services such as filtering water and by providing refuge and feeding areas for aquatic organisms. The beneficial roles aquaculture can play need to be highlighted and broadly publicized.

If not conducted in a resource-sensitive manner, aquaculture can also cause negative environmental impacts, by introducing exotic species, by introducing or contributing to the spread of disease, or by altering the natural systems within which production facilities are located. The key to achieving the positive aspects of aquaculture while minimizing negative ones rests in how effectively the industry, the research community and regulatory agencies can work together. Cooperation among these groups is bringing California closer to eradicating an abalone parasitic worm inadvertently introduced from South Africa. To further foster collaboration and communication, the California Department of Fish and Game has established the Aquaculture Development Committee and the Aquaculture Disease Committee with members from the industry, state and federal regulatory agencies and non-governmental organizations.

Industry leaders are now focusing on developing best management practices to ensure that shellfish culture does not impact the health of ecosystems upon which they depend. Marine finfish culture offshore is solving technical problems and has demonstrated encouraging projections on economic viability. A common goal will be to ensure that the industry achieves its successes with due regard for California's living resources in resource sensitive ways without having to do so under an undue regulatory burden. The State has the mechanisms in place to achieve that goal by developing partnerships and establishing trust through effective communication among the industry, the regulatory agencies and the general public.

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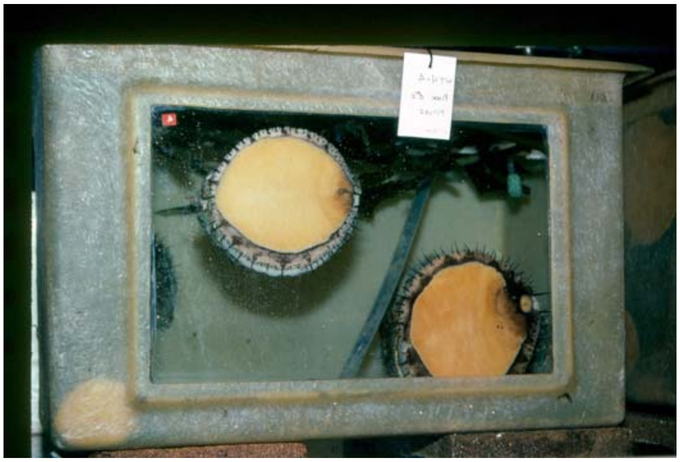
18 Culture of Abalone, *Haliotis spp*.



Red abalone (*Haliotis rufescens*) cultivated at the Department's Granite Canyon Laboratory. Photo credit: Peter Haaker.

History

Pioneering efforts to mass cultivate abalone in California began about 35 years ago. Three abalone species, red (*Haliotis rufescens*), green (*H. fulgens*), and pink (*H. corrugata*) have been farmed, and research into cultivation techniques has been conducted on black (*H. cracherodii*) and white abalone (*H. sorenseni*). The red abalone, however, is the mainstay of the industry and comprises more than 95 percent of total production.

Abalone are grown in either land based tanks or in cages suspended in the water column. The cages are typically tethered to a raft but have also been suspended beneath a wharf. Aquaculturists that operate these in-water systems typically obtain small seed abalone from land based hatcheries for grow out.

In a typical hatchery operation, ripe broodstock abalone are induced to spawn using hydrogen peroxide or ultraviolet light treated seawater. Fertilized eggs that successfully develop to the veliger swimming stage are transferred to flow through larval rearing tanks. In about 6 days at 59ºF (15ºC), larvae are ready to settle from the planktonic to the benthic stage. They are transferred to nursery tanks, and commence to feed on diatoms. After six months of growth, 0.5 inch (13 millimeter) abalone are then transferred to larger tanks. At this point, the abalone begin feeding on macroalgae. An additional 6 to 8 months are required before they reach the size where they are transferred to grow out tanks or in-water systems. After growing in these tanks or in-water systems for 20 months or longer, they attain the typical 3 to 4 inch (76 to 101 millimeter) shell length preferred by the market.

The number of participants in the abalone industry and their total production were correlated over time prior to the first peak in production in 1997 (Figure 18-1). Following this peak, production declined and then increased as the number of industry participants declined. In 1991, 15 registered abalone aquaculturists in California produced an estimated 175,000 pounds (79 metric tons) of abalone in the shell worth $2.3 million. By 1996, 27 registered abalone aquaculturists produced over 292,000 pounds (132 metric tons) of product. Participation then declined slightly to 22 aquaculturists in 1998 while production increased to an industry high of 395,890 pounds (180 metric tons) of product valued at $5.3 million. Only 13 of the 22 abalone aquaculturists registered in 1998 were actively producing abalone and most of the production came from 4 or 5 growers. As of 2008, the number of industry participants has shrunk to total of 7 growers, with 3 to 4 large growers producing most of the state's cultured abalone. Production is expected to remain around 500,000 pounds (227 metric tons) per year but the global financial downturn and greatly increased production and competition from foreign abalone producers will force the industry to pull back from the export markets and develop more lucrative domestic markets.

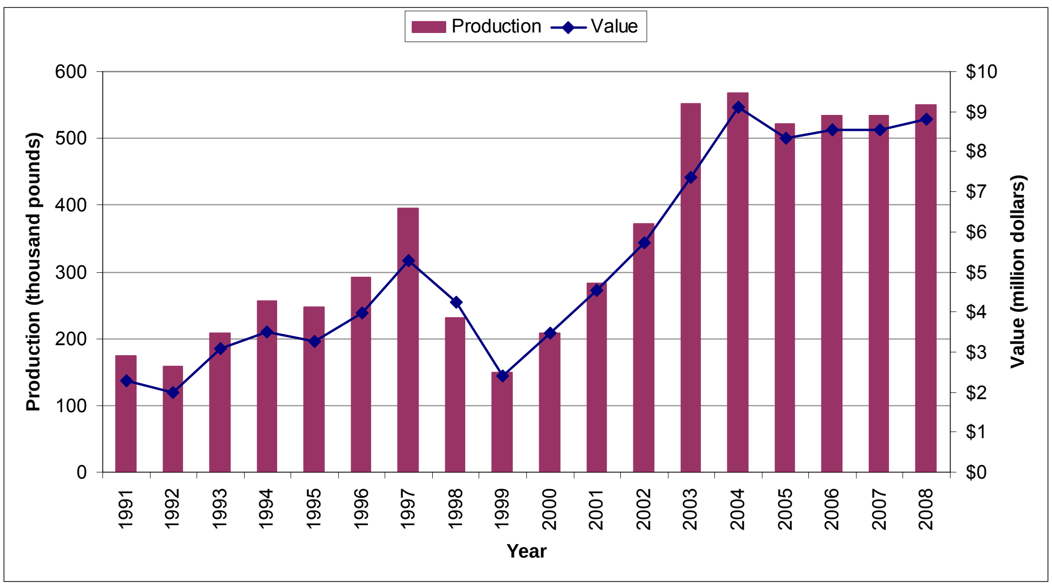


Figure 18-1. Abalone production and value, 1991-2008. Data Source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database. Production includes human consumption only; value includes both seed production and human consumption.

The long term decline in participation and two-year drop in production after 1997 are attributable, at least in part, to disease impacts exacerbated to some extent by a significant El Niño event. Until recently, cultivated abalone had been considered relatively disease free. The bacterium *Vibrio sp*. infected larval cultures, but it was typically suppressed by using filtered, ultraviolet treated seawater. That perspective changed with the introduction of a parasitic sabellid polychaete worm from South Africa. By the mid 1990s, the parasite had spread to virtually every abalone aquaculture facility in the state. The worm induces the infested abalone to form a tube for it out of nacreous (shell) material. With heavy infestations, the abalone shell is brittle and very deformed and abalone growth is stunted. Impacts to the industry included loss from voluntary stock destruction and reduced income from marketing deformed product. Cooperative efforts by the industry, the California Department of Fish and Game

(Department), and Sea Grant-sponsored university researchers have almost completely eradicated the parasitic worm from California.

Unfortunately, the industry also started experiencing elevated losses of cultured product from withering syndrome (WS) during this same time frame. This disease is characterized by a drastic shrinkage of the abalone's foot. The disease has been shown to be caused by a unique bacterium or Rickettsiales-like prokaryote that infects cells lining the gut, and is now sometimes referred to as 'abalone rickettsiosis'. Abalone can be infected by the bacterium without showing clinical signs of disease, especially in cooler water temperatures. For example, in one study no farmed red abalone infected with the causative agent of WS and held at 58°F (15°C) for nine months experienced mortality or signs of disease, while 33 percent of corresponding animals held at 65°F (18°C) died while showing signs of the disease. Similarly, during the 1997-1998 El Niño event, many facilities experienced elevated water temperatures that triggered WS, resulting in elevated mortality in their cultured stock. Research has shown that the disease can be controlled by oral or bath administration of the antibiotic oxytetracycline, but this is generally practical only for treating small numbers of important animals such as broodstock.

In September 2007, a large red tide event caused by the dinoflagellate *Cochlodinium sp.* led to large scale mortality at one facility. Toxic algal blooms have become more common in nearshore waters off of California in recent years. The dinoflagellate impacted the abalone by causing gill damage and by also lowering the amount of dissolved oxygen in the seawater. Growers working with a number of agencies and groups that monitor oceanographic and weather patterns were able to successfully predict another red tide event and avoid potential mortality by lowering the cages containing abalone to the bottom where dissolved oxygen was high and concentrations of toxic algae were low.

The dedicated entrepreneurs at the core of this industry have achieved their successes despite these challenges and interest in abalone aquaculture remains high, prompted in part by the closure of the commercial abalone fishery in 1997. Presently, abalone are available to meet market demands only through importation or the purchase of cultured abalone (Table 17-1). Consequently, there is a high market demand and a good price to growers for the farmed product. The large amount of illegally harvested wild abalone remains a problem worldwide since this product is sold at a reduced price impacting the legal wild harvest and cultured abalone sectors. In 2002, the Department estimated the illegal commercial take of abalone to be 265,000 pounds (120 metric tons) per year. In South Africa the illegal take is so large that if poaching continues at the current rate, abalone there may be fished to extinction.

Table 17-1. World Abalone Production (short tons live weight) for the years 2004 and 2005.			
Country	**Culture**	**Legal Harvest**	**Illegal Harvest**
China	4960		
Taiwan	3307		
South Africa	661	261	2039
Japan	220	2425	591
USA	287	0	132
Australia	320	5653	1102
Chile	220		
Mexico	55	1175	606
New Zealand	3	1188	441
Other	33	487	121
Total	10,067	11,189	5033
Grand Total: 26,290 short tons (live weight)			

Data source: Trends in World Production, Rodney Roberts, Paua Industry Council, New Zealand, 2005.

A more recent positive development in abalone aquaculture is the production of cultured abalone pearls. The product is produced by inserting a nucleus into the abalone. Given time, nacre is laid over the nucleus to form a semi-spherical pearl that has all the lustrous hues of the shell interior. Once extracted, these pearls are set in jewelry and the meat is processed for sale to restaurant trade as either a fresh or frozen product.

Status of Biological Knowledge

A considerable amount of research on abalone aquaculture has been accomplished by the private sector, particularly with respect to systems design and overall technology. University and Department scientists have also made major contributions. Sea Grant-funded research has greatly increased our understanding of abalone developmental biology. Spawning induction procedures, larval settlement inducers and larval rearing systems were developed by researchers funded through this program. Sea Grant-funded research has also contributed significantly to our understanding of abalone diseases.

The Department began abalone culture investigations in 1971 at its Granite Canyon Laboratory near Monterey. That effort led to the development of a flow through larval rearing system and the development of a flush-fill tank system that was adopted by the industry. The Department subsequently developed a pilot production hatchery at Granite Canyon that provided training opportunities and resulted in the production of seed abalone for enhancement research.

The Department's Shellfish Health Laboratory in Bodega Bay has expanded our knowledge of the biology of the parasitic sabellid worm contributing significantly to the success that has been achieved in the cooperative eradication efforts. The laboratory also identified the causative agent for WS and has conducted extensive research into questions related to transmission and control of this pathogen.

Two principle areas for research, nutrition and genetics, may provide significant benefits to the industry in the future. Prepared diets have been developed and are being used widely for juvenile stages. However, most prepared feeds are expensive and not readily accepted by adult abalone in comparison to giant kelp. Recently one of the Monterey growers has been working with California Sea Grant looking at raising red algae as a food supplement and studying its effect on growth rate, shell color and product taste. Results are promising at feed rates of just 6 percent of the diet. Less progress has been made in genetics research. Most growers use a selection process where broodstock is selected based on growth rates. Wild broodstock is also used to maintain genetic diversity in cultured stocks. Some research has been done with triploidy (3 sets of chromosomes) as a means of enhancing abalone growth rates. While encouraging, the results have not been applied broadly within the industry. Recent successful research on the cryopreservation of abalone sperm may greatly benefit controlled breeding programs to assist the development of strains of red abalone that are optimized for domestic production.

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Abalone production and value, 1991-2008.					
Year	**Pounds**	**Value**	**Year**	**Pounds**	**Value**
1991	175,000	$2,275,000	**2000**	208,300	$3,466,088
1992	157,900	$1,976,000	**2001**	283,000	$4,528,000
1993	208,589	$3,072,358	**2002**	372,577	$5,728,593
1994	256,582	$3,500,541	**2003**	551,600	$7,373,600
1995	248,050	$3,256,251	**2004**	568,793	$9,100,688
1996	292,000	$3,971,177	**2005**	522,000	$8,352,000
1997	395,891	$5,280,910	**2006**	535,000	$8,560,000
1998	231,442	$4,246,607	**2007**	535,000	$8,560,000
1999	150,000	$2,398,457	**2008**	551,000	$8,816,000

Data Source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database. Production includes human consumption only; value includes both seed production and human consumption.

19 Culture of Clams

Manila clam, *Venerupis philippinarum*. Credit: Department of Fisheries and Oceans, Canada.

History

The Manila clam, *Venerupis philippinarum*, was unintentionally introduced to the west coast with imports of Japanese oyster seed in the 1930s, and has since become an important species to the aquaculture industry in California. Also known as the Japanese littleneck clam, this species has become naturalized throughout the Pacific coast and is harvested recreationally. The culture of clams in California began in 1981, but production levels were relatively low until the mid 1990s (Figure 19-1) according to the California Department of Fish and Game's (Department) aquaculture harvest survey database. While British Columbia, Canada and Washington State are the largest commercial producers of adult Manila clams, California is a leading supplier of clam seed worldwide.

Culture of Manila clams begins at hatcheries where broodstock animals are brought into reproductive condition.   Broodstock can be selected for faster growth rates by choosing animals that have widely spaced growth rings, or a particular color variation might be selected for to identify the farm of origin. Clams are conditioned by maintaining them in tanks filled with heated water around 64°F (18°C). In addition to water temperature, the quality and availability of food plays a critical role in reproductive success. Cultured algae can be used to supplement naturally occurring food in the water. The conditioning process can take 6 to 9 weeks when conducted outside of the natural breeding season, and the amount of time needed for conditioning decreases as summer approaches. Once the clams have been conditioned, eggs or sperm can be introduced to the tank to induce spawning.

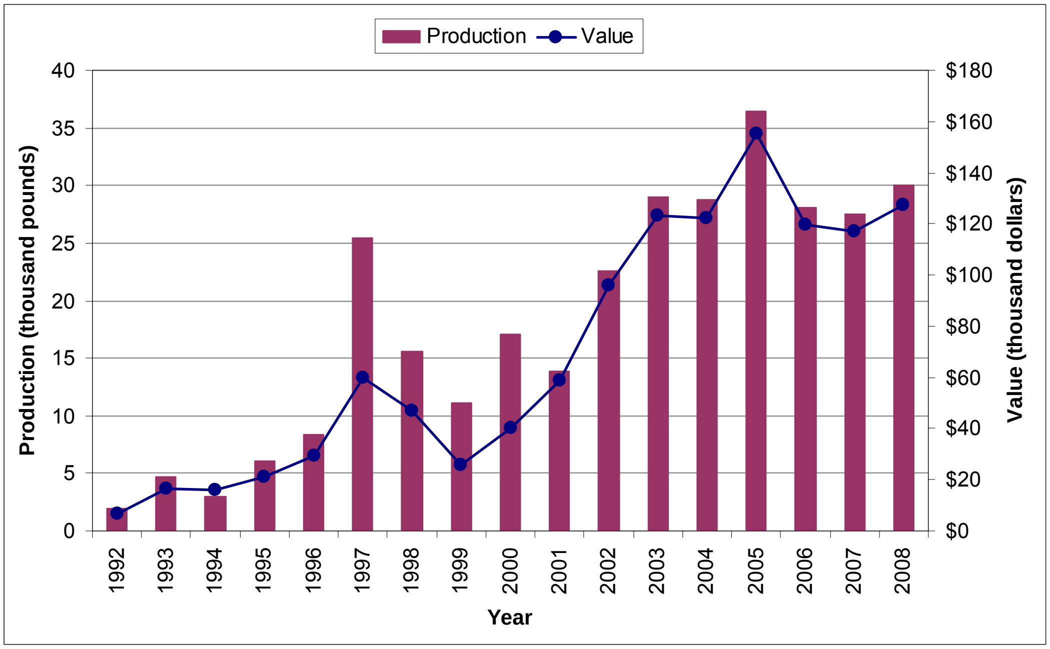

Figure 19-1. Adult Manila clam production and value, 1992-2008. Data source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database. This graph does not include clam seed values.

There are no hatcheries that rear Manila clam larvae in California; certified disease-free larvae are imported from Hawaii, Oregon and Washington. The larvae are cultured in floating upweller systems (FLUPSYs) or suspended trays covered in mesh netting until they are between 0.08-0.39 inches (0.2-1.0 centimeters); it is at this point in development that they become clam seed. FLUPSYs are raft-type structures that house a series of trays or containers that hold the clam larvae. Water is forced upwards through the trays with the tides or through mechanical methods. In 2008, over $1.1 million worth of clam seed was sold by California seed producers.

Figure 19-2. Mesh grow out bags filled with Manila clam seed in Tomales Bay. Photo credit: Thomas O. Moore.

Clam seed is purchased by growers at either 0.16 inches (0.41 centimeters) or 0.24 inches (0.61 centimeters), and is placed in plastic mesh bags with 0.13 inch (0.33 millimeter) or 0.25 inch (0.64 millimeter) mesh, respectively. If smaller seed is used, the clams are transferred to the larger mesh bags when they grow to an appropriate size (greater than 0.25 inches; 0.64 centimeters). Pea gravel and pieces of crushed oyster shell are placed in the bags as substrate for the small clams to attach themselves. The bags are placed into shallow trenches to allow some of the sandy bottom to cover and protect the developing clams. Mud is placed on each of the four corners of the bags to weigh them down (Figure 19-2). The grow out process takes approximately 2 years from the time the clams are placed in the 0.25 inch mesh bags after which time they are manually harvested. The clams are sold in the shell by the pound and cost roughly $5.00 for a bag of 40 to 50 individuals. Demand for cultured clams far outpaces the supply as available space severely limits the amount that can be produced. Because clams take years to reach market size, shellfish growers often practice polyculture (the culture of multiple species in the same space) using other species such as the Pacific oyster.

Outside of California, instead of using mesh bags, small clams are spread at specific densities along prepared subtidal plots and then covered with plastic mesh to inhibit predation. The ends of the mesh are secured using wood stakes, rebar, or may simply be dug into the substrate itself. Experimental plots using this method are being tested in California.

Status of Biological Knowledge

On the Pacific coast, Manila clams range from British Columbia, Canada to southern California. The Manila clam has separate sexes and is a broadcast spawner. They reach maturity at around 0.8 inches (2.0 centimeters), and naturally spawn during the spring when sea temperature rises. Spawning can also be induced when clams are exposed to the gametes of another clam. Fertilized eggs develop into free-swimming larvae within 24 hours. These veliger larvae are able to swim and eat using a ciliated structure called the velum. The Manila clam enters the pediveliger stage after about two weeks at which point it can crawl with its foot as well as swim with the velum. The developing clam then searches for suitable substrate with which to attach itself via byssal threads. At this point, the clam loses the velum, but can still move using its muscular foot.

Age and growth rate can be determined using the annual rings on the shell. The legal size for recreational harvest of 1.5 inches (3.8 centimeters) is reached after 3 to 4 years. Growth rates vary by location, but can also differ greatly between individuals in the same area.

Manila clams prefer habitat higher in the intertidal zone and at shallower depths than native clams, which makes them more susceptible to mortality from extreme temperature variations. Because they are filter feeders, clam health can be affected by poor water quality. In addition, low salinity caused by heavy rains or flooding can lead to large scale mortality events.

Viral or bacterial infections caused by organisms such as *Vibrio sp.*, *Rickettsia sp.* and *Perkinsus sp.* can occur; however, Manila clams in California experience negligible mortality due to disease. Natural predators of the Manila clam include fish, birds, sea stars, rays, crabs and gastropods. For California shellfish growers, loss of product due to predators can lead to serious economic consequences. Predator nets are effective; however, they are unable to protect against larval forms of sea stars and crabs, which can easily pass through the mesh.

The introduced European green crab, *Carcinus maenas*, has been especially detrimental as crab larvae can settle inside the mesh grow out bags and are difficult to remove. Altering grow out methods can reduce the losses caused by green crab predation. Growers may attempt to time the transfer of clams to larger mesh size bags around crab larval set times to reduce the amount of settling inside the bags.

Management Considerations

Expansion of adult clam culture in California is limited by the amount of suitable habitat available to farmers. In addition, mechanized harvesting methods and the process of gravelling are not being used due to possible negative impacts to benthic communities. Disease monitoring should continue to be a priority for cultured species. Changing oceanographic conditions as well as harmful algal blooms could also present serious consequences for shellfish culture in the future.

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Further Reading

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Adult Manila clam production and value, 1992-2008.					
Year	**Pounds**	**Value**	**Year**	**Pounds**	**Value**
1992	1,900	$6,650	**2001**	13,825	$58,756
1993	4,664	$16,323	**2002**	22,545	$95,816
1994	2,930	$16,240	**2003**	29,026	$123,361
1995	6,070	$21,245	**2004**	28,799	$122,396
1996	8,330	$29,155	**2005**	36,489	$155,078
1997	25,393	$59,674	**2006**	28,096	$119,408
1998	15,604	$46,813	**2007**	27,491	$116,837
1999	11,070	$26,014	**2008**	29,980	$127,416
2000	17,080	$40,138			

Data source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database. This table does not include clam seed values.

20 Culture of Mussels (*Mytilus spp.*) and Mussel Fisheries

A bed of sea mussels, *Mytilus californianus*, in the intertidal zone at Trinidad State Beach (Humboldt County). Photo credit: John Mello.

History

The use of mussels of the genus *Mytilus* for food in California extends back over 10,000 years as they are the most common shellfish found in island and coastal middens. More recently, mussels have fluctuated in importance in California's commercial and recreational shellfish fisheries for food and bait since the early 1900s. The extent of the recreational harvest has largely remained unknown but commercial landings have been recorded since 1916. Experiments in culturing wild seed stock and in developing hatchery and grow out methods in the 1980s have greatly increased the importance of aquacultural mussel production, particularly the Mediterranean mussel, *Mytilus galloprovincialis*, which occurs primarily in southern and south central California. A related species, the Baltic mussel, *M. trossulus*, is recreationally harvested in northern California and hybrids of the two species are commonly found between Cape Mendocino (Humboldt County) and Monterey Bay.

The California mussel, *M. californianus*, is of minor economic importance in California at present, though it is taken by recreational harvesters. It is primarily used as bait along the west coast, but in the 1980s, wild harvested sea mussels, highly esteemed by gourmet chefs in Oregon, were sold to fine restaurants in Portland. More recently, landings of sea mussels for food have been negligible.

Between 1916 and 1927, the commercial fishery landed a total of over 470,000 pounds (213 metric tons) of mussels, ranging from 9000 pounds (4 metric tons) to 69,000 pounds (31 metric tons) per year in California. After 1927, most areas were closed to harvest by the California Department of Health Services [now Department of Public Health (DPH)] due to a major outbreak that year of paralytic shellfish poisoning. Mussel landings declined to 1600 pounds (7 metric tons) in 1928 and stayed depressed until 1972, when a record 111,000 pounds (50 metric tons) were landed, primarily for bait. Bait sales continued to be the most significant type of commercial activity for mussels until improved methods of harvesting wild stocks were developed, new culture methods were adopted, and west coast markets began developing for this tasty shellfish in the early 1980s. After the development of the aquaculture industry for mussels, commercial landings of mussels became a minor part of total mussel production and have dropped to below 1000 pounds (0.5 metric tons) in 2007 and 2008 (Figure 20-1).

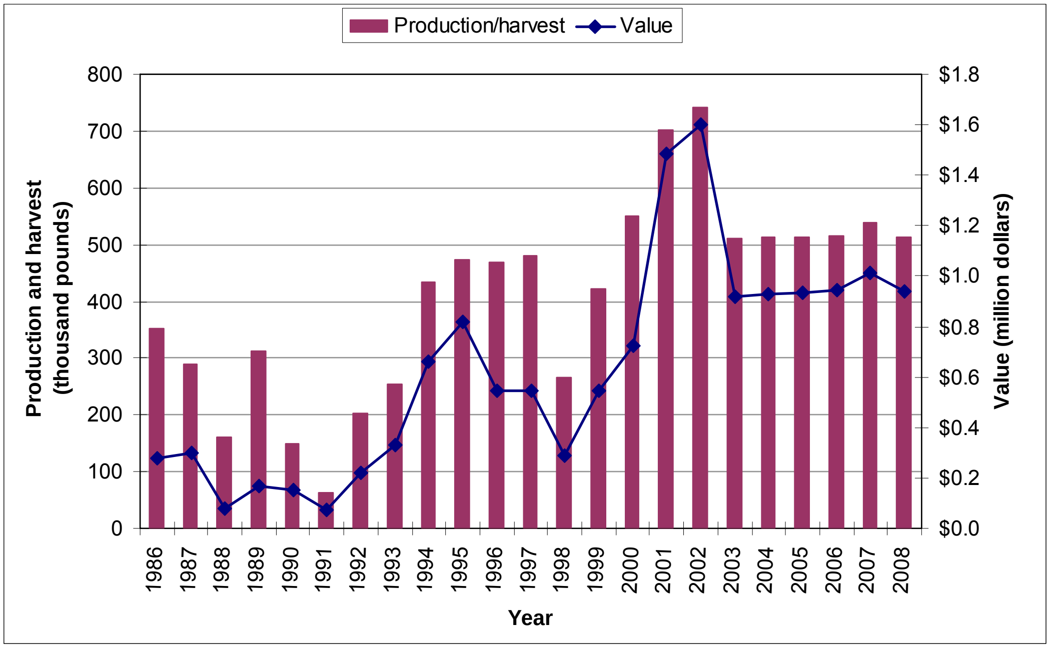

Figure 20-1. Mussel production, harvest and value (cultured mussels and commercially harvested wild mussels), 1986-2008. Data Source: Production - California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database. Harvest - CFIS data, all gear types combined.

Research on harvesting naturally set Mediterranean mussels from offshore oil production platforms for food was initiated in the Santa Barbara Channel in 1979. Divers routinely removed fouling organisms from the submerged support structures of offshore platforms at considerable expense to oil companies. An ecological consulting firm, hired to suggest ways to control the biofouling, found that various stages of the succession of organisms included settlement and growth of edible mussels, both Mediterranean and California. Recognizing the potential for food production and increasing market demand for high quality shellfish, the owners of the firm contracted with various offshore oil companies to test the feasibility of harvesting and marketing the mussels. The harvest of mussels from oil platforms became significant in the 1980s but because of internal problems, the harvesting company stopped production in recent years. While mussels taken from oil platforms have been counted as a component of aquaculture mussel production, this source of mussels might be more properly categorized as part of the commercial fishery landings. Although the structures are man made, they are not designed nor intended for aquaculture purposes.

Experimental mussel, oyster and clam culture also began in 1983 in Aqua Hedionda Lagoon near Carlsbad. Taking advantage of excellent natural mussel settlement in the lagoon and relatively fast growth of juveniles, the shellfish firm began to culture mussels in 1985. It obtained a 5 acre lease for use of the lagoon and began a commercial operation following modified Italian long line techniques. Mussel seed was placed in a tubular net “stocking” designed specifically for mussel growing (Figure 20-2). The stocking or “reste” was originally imported from Italy, but is now available to growers from U.S. suppliers. The stockings were suspended from long lines 50 yards long and supported by small buoys to keep the stockings off the bottom. Mussel production at the Carlsbad farm peaked in 1989, second only to the offshore platform harvest in the Santa Barbara Channel. However, the following year DPH decertified the shellfish growing area due to rising coliform counts in the lagoon. Production ceased in 1990 and remained static until a certified depuration system, required by the state, was put into operation in 1992.

Figure 20-2. Cultured mussels grown on aquaculture sock lines. Credit: Department of Fisheries and Oceans Canada.

In 1985, approximately 104,000 pounds (47 metric tons) of mussels were harvested, primarily from offshore platforms, but by this time a farm in Tomales Bay also had begun to utilize European long line methods to grow mussels. Over the next 7 years, three to five other Tomales Bay oyster growers diversified into mussel production. These growers utilized wild caught and hatchery reared seed, with the latter being relied upon more in the late 1980s, as natural recruitment during this period was often erratic and unreliable. After a brief period of expansion, several Tomales Bay growers ceased all but minimal production in the mid 1990s to concentrate on oyster culture. By the fall of 2000, only one company was producing commercial quantities of mussels and this trend continued until 2008 with sporadic production by one other company. These mussels are sold exclusively to local restaurants around Tomales Bay. At least 3 other growers have the capability to produce commercial quantities and one had begun in 2008 to scale up their operations using the Bouchot culture technique which originated in France in the 13th century. This technique uses tubular mesh nets with mussel seed inside that are wound around tall poles set in rows into the seabed. With the current increased demand and price, this grower plans to sell to the wholesale market rather than restaurants.

On California’s north coast, an oyster grower operating in Mad River Slough, a tributary to Humboldt Bay, began farming mussels in 1992 using the floating raft culture method. Seed mussels, attached to a line inside flexible plastic mesh netting, are suspended from the raft during grow out. Cultured mussels from Humboldt Bay were initially used, but since the mid 1990s, wild juvenile mussels collected from the bay were the primary source of seed. The mature mussels were sold locally at farmers' markets and restaurants. One other Humboldt Bay operation began experimenting with mussel grow out in 2001, using wild seed stock and following the raft culture method used in Mad River Slough. However, as of 2008, no aquaculturists are raising mussels in Humboldt Bay.

The total state mussel production tripled in 1986, reaching more than 334,000 pounds (152 metric tons) (Figure 20-1), with over 90 percent harvested from platforms in the Santa Barbara Channel and the remainder from Tomales Bay. Statewide production dropped slightly in 1987 to approximately 286,000 pounds (130 metric tons) and decreased further in 1988 to 151,000 pounds (68 metric tons), due to major winter storms, which dislodged market-ready mussels from platform structures. Production jumped to over 300,000 pounds (136 metric tons) in 1989 but dropped to 130,000 pounds (59 metric tons) in 1990 when a major producer ceased production, continuing a slide in 1991 to a low of only 47,000 pounds (21 metric tons).

During the next six years (1992 through 1997), with the major producer back in production, increasing harvest from offshore platforms in the Santa Barbara Channel, and steady production in Tomales Bay, the statewide total rose from 187,000 pounds (85 metric tons) to 472,000 pounds (214 metric tons). Strong winter storms following warm El Niño seawater conditions in the fall of 1997 caused havoc to mussel production throughout the state the following year. An economically devastating drop in production of nearly 50 percent, to 256,000 pounds (116 metric tons), occurred in 1998. One of the large southern California growers stated that spawning and recruitment were both affected by these events. A colder water regime in 1999-2000 improved the recruitment situation and harvests increased. Combined harvests from producers and offshore oil platforms pushed production to a new record high of 740,000 pounds (336 metric tons) in 2002. In the period from 2003 to 2008 loss of offshore platform harvest has reduced annual production to slightly over 500,000 pounds (227 metric tons). Recently a new grower in the Santa Barbara area has expanded mussel production on a nearshore open ocean lease. Significant losses due to sea duck predation on mussels, a problem for mussel growers in Tomales Bay as well, has limited Santa Barbara production as of 2008.

Mussels harvested during the five years between 1986 and 1990 provided an average annual return of $188,000 to California growers. Steady expansion of production during the following five years (1991 to 1995) increased statewide annual returns to $412,500. While production and return to growers dipped in 1998 due to El Niño conditions, the five year period from 1996 to 2000 still saw an increase in return to producers of $524,500 annually (Figure 20-1). Annual mussel production reached a historic peak in 2002, boosting annual returns to $1.2 million. Following the 2002 peak in production, oil platform harvest ceased and as of 2008, has not been a component of state production. Production stabilized during the period 2006 to 2008 with annual returns averaging $965,000.

The wholesale price did not change significantly until the late 1990s. The prior 15 years saw the price range from $1.10 to $1.25 per pound ($2.43 to $2.76 per kilogram). Competition with low priced imported mussels kept the price low, reducing the profit margin for state producers. Increased public acceptance of mussels as a quality shellfish food item has led to increased demand and allowed state producers to raise wholesale prices, as the price of imported mussels rose. Wholesale prices have averaged over $1.80 per pound ($3.97 per kilogram) since 2000. Retail/restaurant prices have increased from $2.00 in 1990, to $2.25 in 2000, to around $3.00 per pound as of 2008 ($4.41, $4.96, and $6.62 per kilogram, respectively). Direct sale prices have always been higher to the public at farmers markets and retail shellfish outlets with the price varying between $2.50 per pound in southern California and $4.00 or more per pound in northern California ($5.51 and $8.82 per kilogram, respectively).

California growers continue to face strong competition from mussels imported from eastern Canada, New Zealand, Mexico, Maine and Washington state due to the advent of low cost air transport for fresh shellfish and individual flash freezing methods. Competing on the world market is a challenge to California producers because of the massive production of mussels in China, Korea, New Zealand, Australia and other Pacific Rim countries. All but one company in Tomales Bay ceased or minimized their mussel operations, citing competition from low cost imported mussels as the reason. Expansion of the industry is dependent on the maintenance of clean growing areas, a supportive regulatory environment, aggressive marketing and dependable sources of seed. Climatic and oceanographic events have also had significant impacts on the economic health of this industry.

Until 1986, all mussels grown commercially in California were set or collected as wild spatfall or natural seed. In 1985, a cooperative effort was initiated by a Humboldt County shellfish nurseryman to produce the first commercial quantities of hatchery reared mussel seed on the west coast. Growers utilized a variety of substrates and set the spat (seed) at different densities. A wide range of results, from zero survival to excellent survival and growth were reported. The five participating growers in Tomales Bay purchased larger (0.5 to 1.0 inch; 1.3 to 2.5 centimeters) seed, which could be grown to market size in 6 to 9 months. The methods of growing out seed evolved and matured in Tomales Bay and in the Puget Sound area of Washington state but were not proven on a commercial scale in south central and southern California until the late 1990s. Growers there now use a combination of wild and hatchery seed. As of 2008, no in-state source of cultured mussel seed is currently available and growers now must purchase seed from out of state hatcheries. Availability of hatchery mussel seed is a limiting factor for producers when capture of natural spatfall is limited or fails.

Predation on maturing mussels by surf scoters and other sea ducks and predation on small natural-set seed by schools of surfperch, has over time proved burdensome to most of the shellfish growers who were concentrating on oysters as their primary product. However, recent market interest and increased prices for mussels has led to the use of some innovative and successful techniques by producers in Tomales Bay and Santa Barbara to foil the duck and fish predators.

Both southern and northern California mussel companies also must cope with water quality fluctuations, especially in nearshore areas or embayments. One south coast aquaculturist has built a depuration system for bivalve shellfish, one of the first in

California. The grower has been able to use a protected lagoon to grow mussels, which are relayed to the onshore depuration system prior to sale. By utilizing seawater treated with ultraviolet light to eliminate harmful bacteria, the grower can produce wholesome, high quality mussels.

Status of Biological Knowledge

Early studies of California mussels identified the blue mussel, *M. edulis*, as a common species, but genetic studies utilizing protein electrophoresis in the late 1980s showed that there were two forms of mussels on the west coast that are distinct from the blue mussel and morphometrically similar. One of these forms is electrophoretically indistinguishable from the Mediterranean mussel which is known to have recently colonized many disparate shores around the world. The other form was designated the Baltic mussel, which was originally described from specimens collected in Oregon but is also found in eastern Canada and the Baltic Sea. Along eastern Pacific shores it is found from Alaska to central California. The two forms occur together and hybridize with one another. Several genetic studies in the late 1990s have confirmed that the Mediterranean mussel is found principally south of the Monterey Peninsula and the Baltic mussel is found primarily north of Cape Mendocino (Humboldt County). A zone of hybridization has been documented between these two distinct coastal features but studies using DNA markers have found hybrids as far north as Whidbey Island, Washington (near Seattle) and as far south as San Diego Bay.

The hybridization and geographic range issues regarding the Baltic mussel in central and northern California confound the interpretation of earlier life history studies of mussels taxonomically classified as blue mussel, but, regardless of the taxonomic issue, all mussels share many common biological traits as they are all members of the bivalve class Pelecypoda (hatchet feet). Mussels have separate sexes, though some hermaphrodism occurs. There is evidence that changes in water temperatures, physical stimulation (such as disturbance by winter storms), variation in light levels, or phytoplankton blooms may stimulate spawning.

Spawning in the California mussel occurs throughout the year at a very low level, with peaks in July and December but reproductive output can be up to eightfold greater for sites south of Point Conception relative to more northerly sites. The spawning and recruitment of the Mediterranean mussel also occurs year round, although it is heaviest in February, March and April and again in September and October in southern California. Mussels reaching 1.6 inches (4.1 centimeters) in shell length are found to have gonads in various stages of development and are able to spawn.

When spawning occurs in the natural environment, eggs and sperm are discharged through the excurrent chamber and fertilization takes place in the open ocean or estuary. Within 24 hours, the embryo develops into free-swimming trochophore larva that grows into a more advanced veliger stage, again, within 24 hours. The development of the ciliated velum (approximately 48 hours after fertilization) gives the larvae more control in swimming and in gathering food. The veliger is also known as the “straight-hinge” stage, denoting the appearance of the first shell. In two to three weeks, veligers begin metamorphosis, a stage preceded by the development of an eyespot (a photosensitive organ) and a foot. This is the pediveliger stage, during which the veliger changes from a swimming larva to a bottom dwelling juvenile mussel or spat.

Newly settled mussels attach to substrates with proteinaceous threads (byssus or byssal threads) that are secreted by the postlarvae. Young mussels have the unique ability to detach their byssus, crawl to a different location, or drift away in a current to seek a more favorable substrate, and reattach. This trait is considered to be a significant problem for growers, as postlarvae have disappeared from various substrates soon after placement in open water.

Growth rates of both the Mediterranean mussel and the California mussel have been reported to be at least 0.25 inch (0.64 centimeters) per month and as high as 0.5 inch (1.3 centimeters) per month in the Santa Barbara Channel. Growth rate is influenced primarily by the quantity and quality of food, rather than temperature and mussels achieved a 2 inch (5 centimeter) shell length in 6 to 8 months.

Food consumed by mussels includes dinoflagellates, organic particles, small diatoms, zoospores, protozoa, unicellular algae, bacteria and detritus. Phytoplankton is considered to be the main food item providing energy for rapid growth.

Competition for space is an important factor influencing growth and survival of mussels, both in wild and cultured populations. Mytilids of the same and different species compete for limited space in the rocky intertidal and subtidal growing areas. Cultured mussels on artificial substrates also can become overcrowded if seed stocking densities are too high. Crowding causes instability of mussel masses and, when coupled with high current speeds, turbulence and drifting materials, losses frequently occur. Barnacles and sea anemones also compete for space with mussels.

Changes in climate could negatively affect mussel beds, particularly in southern California. Mussel beds have been found to have high numbers of associated organisms but recent studies indicate a dramatic decline in community diversity which might be attributed to climate change. Compared to the mid 1970s and 1980s, mussel beds in southern California have declined in mussel cover, biomass, and bed thickness but similar changes have not been detected in mussel beds of central and northern California.

Predators of mussel species are abundant. They include sea stars, muricid gastropods and crabs. The surf scoter, the black oystercatcher, shiner surfperch and the sea otter are also important predators in coastal waters. The lower limit of mussel populations in the intertidal zone is determined by the activities of predators, primarily seastars of the genus *Pisaster*. Mussel populations on oil rigs occur much deeper than is typical for coastal reefs and are thought to be protected from sea stars by dense populations of sea anemones occurring below the mussel zone.

Mussels are used in California and other parts of the world as sentinel species in “mussel watch” programs to monitor various organic and inorganic pollutants. As filter feeders, mussels also ingest and concentrate toxin producing species of phytoplankton that periodically bloom along the Pacific coast. The DPH utilizes mussels as biotoxin indicators in a statewide monitoring program staffed by volunteers. A statewide annual quarantine on recreational harvest is imposed between May 1 and October 31 when the probability of toxic phytoplankton uptake in mussels is high. However, commercially grown and commercially harvested wild mussels may continue to be harvested during this period as long as constant testing assures that only a safe, wholesome and nontoxic product is available to the consumer.

Management Considerations

It is recommended that large scale commercial harvesting of wild mussels be prohibited because of the potential for damage to a delicate and highly productive rocky intertidal community. Any harvesting that is done should be size selective and leave a layer of mussels intact. The presence of mussels greatly increases the diversity of rocky intertidal communities but mussel beds can be damaged by human activity. Mussel cover has been negatively impacted by foot traffic and removal of mussels for food or bait in southern California. Large gaps in mussel beds greater than 32 square feet (3 square meters) can take decades to fully recover.

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Further Reading

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Mussel production, harvest and value (cultured mussels and commercially harvested wild mussels), 1986-2008.

	Culture		Harvest		Total	
Year	**Pounds**	**Value**	**Pounds**	**Value**	**Pounds**	**Value**
1986	334,617	$267,693	16,953	$10,282	351,570	$277,975
1987	286,689	$298,157	1,577	$934	288,266	$299,091
1988	151,399	$70,941	9,203	$5,503	160,602	$76,444
1989	302,958	$164,640	9,619	$5,800	312,577	$170,440
1990	130,867	$139,834	17,928	$10,757	148,795	$150,591
1991	47,468	$65,671	15,953	$9,572	63,421	$75,243
1992	187,945	$210,417	14,214	$8,528	202,159	$218,945
1993	241,534	$325,583	11,567	$6,916	253,101	$332,499
1994	421,980	$652,175	12,417	$7,490	434,397	$659,665
1995	458,955	$808,383	13,986	$10,440	472,941	$818,823
1996	458,252	$535,160	11,231	$8,541	469,483	$543,701
1997	471,556	$536,952	8,690	$6,714	480,246	$543,666
1998	255,967	$284,153	9,064	$6,732	265,031	$290,885
1999	413,697	$541,920	7,785	$5,385	421,482	$547,305
2000	545,692	$723,936	4,603	$1,510	550,295	$725,446
2001	699,079	$1,485,418	2,729	$1,513	701,808	$1,486,931
2002	736,457	$1,601,299	4,522	$1,356	740,979	$1,602,655
2003	506,307	$918,921	4,711	$1,263	511,018	$920,184
2004	508,416	$926,088	3,575	$936	511,991	$927,024

Mussel production, harvest and value (cultured mussels and commercially harvested wild mussels), 1986-2008.						
	Culture		Harvest		Total	
Year	**Pounds**	**Value**	**Pounds**	**Value**	**Pounds**	**Value**
2005	511,460	$934,365	2,033	$1,939	513,493	$936,304
2006	514,378	$943,134	1,620	$73	515,998	$943,207
2007	537,127	$1,011,381	997	$215	538,124	$1,011,596
2008	513,720	$941,160	440	$65	514,160	$941,225

Data Source: Production - California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database. Harvest - CFIS data, all gear types combined.

21 Culture of Oysters

The native oyster, *Ostrea conchaphila*, growing in a rocky intertidal area of San Francisco Bay. Photo credit: Thomas O. Moore.

History

California's oyster fishery and oyster aquaculture industry have had a rich and colorful tradition. Native Americans harvested the oyster resource for thousands of years before Spanish, Tsarist Russian and European settlers occupied the west coast. A substantial commercial oyster fishery began in the 1850s, when settlers from the east coast attracted to California by the prospect of gold and new opportunities created larger markets for oysters. The increased population and market pressure for oysters had an immediate impact on the state's shellfish resources. The only available oyster was the native oyster (*Ostrea conchaphila*; previously *O. lurida*; also called Olympia oyster in the Pacific northwest), which was intensively fished, causing a rapid decline in the natural population. In response, native oysters were transported from Shoalwater Bay, Washington (Willapa Bay) and later from other bays in the Pacific northwest and Mexico, representing the initial attempts at oyster culture on the west coast. Oysters were transplanted into San Francisco Bay, where they were maintained on oyster beds and then marketed throughout central California. The Shoalwater Bay trade of native oysters dominated the California market from 1850 through 1869. Market demand for a larger, half shell product stimulated experiments in transporting the eastern oyster, *Crassostrea virginica*, from the Atlantic states to the west coast. Several failed attempts were made to establish transport of the eastern oyster to California by sailing ships. Successful transport of oysters was achieved only after the completion of the transcontinental railroad. Shipments of juvenile and market sized oysters were transported by rail in barrels of sawdust and ice and transplanted into San Francisco Bay. Cool summer water temperatures, however, prevented successful natural reproduction of the eastern oyster.

Transcontinental trade for eastern oyster seed was established in 1875. Small, 1 inch seed was transplanted in San Francisco Bay for further growth. The Shoalwater Bay trade for native oysters was gradually terminated, and from 1872 until the early 1900s California's San Francisco Bay eastern oyster industry was the largest oyster industry on the west coast. Maximum production was reached in 1899 with an estimated 2.5 million pounds (1135 metric tons) of oyster meat.

With California's population and industrial growth came a degradation of water quality in San Francisco Bay. By 1908 eastern oyster production had fallen by 50 percent. By 1921 oyster meat quality declined to the extent that shipments of seed from the east coast were terminated, and by 1939 the last of the San Francisco Bay oysters were commercially harvested. Oysters were still transported and held in Tomales Bay until they could be marketed in San Francisco, but the industry based on the eastern oyster did not recover. The industry and state began reexamining earlier experimental plantings using the Pacific oyster, *Crassostrea gigas*, which originated in Japan. The California Department of Fish and Game (Department) and commercial growers conducted experimental plantings of Pacific oysters in Tomales Bay and Elkhorn Slough in 1929. Experimental plantings continued in a number of bays, including Drakes Estero, Bodega Lagoon, and Morro, Newport and San Francisco bays throughout the 1930s. Humboldt Bay was excluded from plantings while the Department tried to reestablish natural populations of native oysters. Several Pacific oyster plantings proved successful, demonstrating that imported Pacific oyster seed could be grown commercially in California. Shipments of seed from Japan were made through the 1930s, suspended from 1940 through 1946, and increased significantly in 1947. The imported seed was inspected in Japan by both Department personnel and commercial producers prior to shipment. Department personnel examined the shell for organisms considered harmful if introduced into state waters.

Boxes containing oyster shell with attached young oysters (spat or seed) were transported by ship in wooden crates kept moist with seawater. With the influx of seed oysters, the industry began its recovery in California and on the west coast. The Department lifted its restriction on Pacific oyster seed in Humboldt Bay in 1953, and in the next thirty years the California industry showed rapid growth with production centered in Humboldt Bay, Drakes Estero, Tomales Bay, Elkhorn Slough and Morro Bay.

The west coast oyster industry initiated other significant changes in the early 1980s which have had a significant impact on the industry nationally. These changes include the development of U.S.-based shellfish hatcheries for the domestic production of Pacific oyster seed, and the ability to ship advanced hatchery produced oyster larvae (swimming stage) to grow out sites where the larvae are placed in tanks containing cleaned shell and heated seawater for spat production. In this process called remote setting, the larvae settle on clean oyster or scallop shell, called mother shell or cultch, attach and metamorphose into the more familiar flat young oyster called spat. Spatted cultch ultimately results in about 9 to 13 market-sized oysters clustered on remnants of the old mother shell.

Another hatchery product is cultchless oyster seed that are grown out as individual oysters exclusively for the half shell market. Cultchless seed are produced by setting the larvae on sand or finely crushed oyster shell resulting in unattached, individual oysters. Many California growers purchase cultchless seed from California based advanced seed producers. These producers receive small cultchless seed from a hatchery, and then use floating upweller systems (FLUPSY) to hold the seed in flow through containers receiving bay water containing algae. FLUPSYs are raft-type structures that house a series of trays or containers that hold the oyster larvae. Water is forced upwards through the trays with the tides or through mechanical methods. The oyster seed increases in size and is more easily handled in the larger mesh bags used by the end producer. Individual growers are also adopting and expanding their own land based FLUPSYs and downwellers to cut the cost of seed and assume the responsibility of early seed growth. All oysters grown in California currently are produced from seed obtained from hatcheries located in Washington, Oregon and Hawaii.

The hatchery systems primarily produce two species of Pacific oysters: the Pacific oyster and the Kumamoto oyster, *Crassostrea sikamea*, which also originated in Japan and does not reproduce in California's cooler summertime water. Other less prominent species produced by hatcheries have included the European oyster, *Ostrea edulis*, and some eastern oyster. The ability to ship oyster larvae long distances and set the spat at the grow out areas has significantly reduced the cost of seed. The last shipment of Japanese seed to California was in 1989.

The level of oyster production within the various bays has fluctuated throughout the years, primarily because of water quality, each bay's ability to produce good standing crops of algae on which oysters feed, the adequacy of selected sites, summer mortality events and the financial viability of the various oyster operations. All growing areas are classified and certified by the California Department of Public Health (DPH), based on health related water quality standards established and regulated by the Interstate Shellfish Sanitation Conference and the National Shellfish Sanitation Program. Water bottom and offshore grow out areas are leased from the State through the California Fish and Game Commission, local Harbor and Recreation Districts, or belong to private corporations.

The industry uses a variety of oyster culture methods depending on the targeted market, the physical characteristics of the production bay and the need to protect the younger oysters from predators such as bat rays, rock crabs and drills (predatory snails). Culture methods are also influenced by factors such as substrate type, current velocity, tidal range and phytoplankton productivity. California oysters are grown from spat to market size in about 13 to 18 months, depending on the bay and the culture method used.

California oyster production is currently centered in six areas: Arcata Bay located in the North Humboldt Bay complex, Tomales Bay, Drakes Estero, Morro Bay, Santa Barbara offshore waters and Agua Hedionda Lagoon in Carlsbad. Morro Bay oyster production had declined in recent years; however a new grower has once again increased production to near former levels. Grow out techniques used in Morro Bay include bottom, rack and bag, floating bag and stake culture. Former shellfish producers in the Santa Barbara Channel used a system of long lines with attached bags of European oysters suspended from offshore rafts in the deep waters but have discontinued production in recent years. Current production by a new grower in Santa Barbara offshore waters uses Pacific oysters and Mediterranean mussels on submerged long lines. Shellfish producers also culture cultchless oysters in Agua Hedionda Lagoon using long lines with suspended trays.

Humboldt Bay growers have used a variety of oyster culture methods, with bottom culture of Pacific oysters being the most common until the mid 1990s when they began moving to off-bottom culture. For bottom culture, cultch with attached spat was spread over leased areas in the bay, the oysters were grown to about 4 inches and are then harvested by hand picking and hydraulic dredge. Because of environmental concerns and the impact of hydraulic dredging on eelgrass, growers transitioned to off-bottom, long line and rack and bag culture of the Pacific oyster and also the Kumamoto oyster. The Kumamoto oyster derives a higher market price as non-shucked shellstock, and Pacific oysters are primarily used for the shucked oyster market with a small amount sold as single non-shucked oysters.

Long line culture primarily consists of a series of notched PVC pipes set in the substrate with twisted line stretched over the apex of the pipes (Figure 21-1). Spatted cultch is inserted at intervals between the strands of the line which hold the growing oysters above the substrate. The lines containing the clustered oysters are harvested on a flood tide, thereby reducing disturbance to the substrate or associated eelgrass. Other forms of off-bottom culture include bags of cultchless oysters supported by low racks and floating oyster bags attached to long lines.

Figure 21-1. Oyster cultch on long lines in Humboldt Bay (Humboldt County). Photo credit: Thomas O. Moore.

Drakes Estero has one of the largest off-bottom, rack culture systems along the west coast. Like all off-bottom culture, the method is used to avoid predators, use more of the water column, and avoid siltation that occurs when the oysters rest on the substrate. The rack culture system uses spatted mother shells strung on short lines with a tube spacer separating each mother shell. The short lines are hung in an inverted U shape over the horizontal rails of wooden racks set in the bay. Two other growing methods using cultchless single oysters are used in Drakes Estero.

Tomales Bay growers also use a variety of off-bottom techniques including rack and bag, stick and bag, and bag and long line culture. Rack and bag culture uses cultchless seed that is first grown in trays, upwellers and downwellers, or floating, rotating, mesh cylinders (Figure 21-2). After initial growth, the small oysters are transferred to a series of different sized mesh bags positioned on low racks in the bay.

Figure 21-2. Oysters in bags on racks in Tomales Bay **(**Marin County). Photo credit: Thomas O. Moore.

Bag and long line culture use cultchless seed in mesh bags attached to an anchored line which can be floated to suspend the bags vertically in the water or can be used to secure the bags on a stable, hard bottom, intertidal area (Figure 21-3). Bags can also be maintained horizontally at the surface using floats. To maintain the prime oyster shape for the half shell market, the bags must be moved frequently to prevent the individual oysters from growing together and resulting in an irregular shape.

Figure 21-3. Workers placing oyster bags on ground lines in Drakes Estero (Marin County). Photo credit: Thomas O. Moore.

Total annual oyster production for California has fluctuated throughout the industry's history, reflecting cyclic shellfish mortalities caused by summer mortality syndrome (SMS), availability of seed oysters, economic conditions, and the financial stability of individual companies. With the advent of hatchery technology and remote setting of oyster seed, the industry demonstrated significant growth from the mid 1980s to a second post 1960s peak in the mid 1990s (Figure 21-4). Reduced production after 1994 directly reflects several industry setbacks, which include financial restructuring after the 1990s recession, extended bay harvest closures due to sanitary degradation and oil spills, recurrence of cyclic SMS and most recently a shortage of hatchery produced seed. Several of these factors have been resolved but oyster seed supply remains a major issue due to consolidation of commercial hatchery businesses and shortages of seed due to disease issues in those hatcheries. Production increases are expected as the industry works around these challenges.

The overall statewide value of cultured oysters is calculated by converting all types of oyster products to a common denominator of shucked pounds of oysters expressed as packed weight. Packed weight is estimated to be 15.5 percent of live weight for Pacific oyster and 10.9 percent for eastern oyster. Shucked gallons are calculated as 8.6 pounds/gallon (1.03 kilograms/liter) for Pacific oyster and 8.5 pounds/gallon (1.04 kilograms/liter) for eastern oyster. Cultchless oysters, Kumamoto oyster and a large portion of Pacific oyster are sold as shellstock. The majority of total production in recent years is primarily Pacific oysters and to a much lesser extent, Kumamoto oysters. Annual eastern oyster production peaked in 2005 with production over 7500 pounds (3400 kilograms). However, seed availability has limited plantings since then and production in 2008 was estimated to be just over 2000 pounds (900 kilograms).

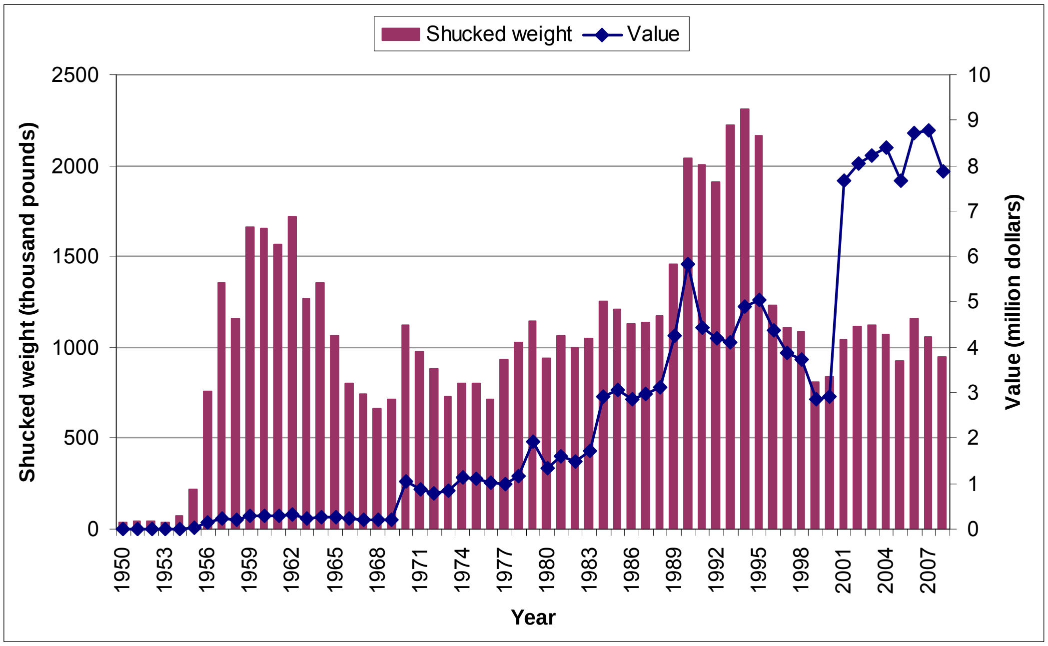

Figure 21-4. Oyster production and value, all species combined, 1950-2008. Data Source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database.

It is difficult to place a good estimate on the value of the California oyster industry. Market demand and price have increased over time with a change in products, such as the trend in California from shucked and jarred oysters to single oysters for the half shell trade. The Department contacts growers to obtain an estimate of the retail and/or wholesale price for that business's products. Confidentiality issues can prevent the release of production information. The large increase in the value of the oyster production seen in 2001 and following years was the result of permission to release previously confidential information (Figure 21-4).

Oyster products are marketed as shucked meat in gallons and 10 ounce jars, and as shellstock for the half shell and barbecue markets. The shucked product is marketed as small (200/gallon; 53/liter), medium (140/gallon; 37/liter), and large (100/gallon; 26/liter). Shellstock is marketed as small (2.5-3.5 inches; 6.4-8.6 centimeters), medium (3.5-4.5 inches; 8.6-11.4 centimeters), large (4.5+ inches; 11.4+ centimeters) sold by the dozen, and clusters (attached, mixed). The demand for oyster products far exceeds the state's production level, and the majority of shellfish products consumed in the state are imported from the Pacific northwest and the Atlantic and Gulf states. California's product is considered prime, and its production areas are among the best in the country.

The DPH has regulatory responsibility over shellfish product safety and periodically conducts sanitary surveys with the U.S. Food and Drug Administration under worst case scenarios to determine growing area sanitation conditions. Two essential programs are the monitoring of the bays for indications of contamination, including human sewage, and for the occurrence of natural biotoxins such as paralytic shellfish poison produced by toxic phytoplankton. The programs are designed to provide a safe product for the consumer and an early warning system for people recreationally harvesting shellfish in noncommercial areas. The water and meat quality monitoring programs conducted by the DPH also provide an assessment of the biological condition of the bays, which is essential information used by all agencies to prevent a reoccurrence of events which led to the contamination of San Francisco Bay.

Status of Biological Knowledge

Oysters are bivalve mollusks that exhibit a variety of sizes, shapes, shell textures and colors, and vary in their mode of reproduction. These biological and physical features influence where they grow and how they reproduce, which in turn influence commercial aspects such as culture practices and marketing strategy. The depth of the shell cup and the shape of the oyster influence market price of shellstock. Individual oysters conform to the shape of the substrate to which they are attached and are therefore highly variable in shape. In addition, shell shape, texture, and color are all influenced by the oyster's genetics and physical environment such as salinity, attachment substrate, crowding by other oysters and food. They feed on phytoplankton and nutrient-bearing detritus by pumping water over their gills, filtering the food material and passing it into the mouth.

All oysters have a typical molluscan trochophore larva that develops into a veliger larva capable of filtering food, swimming and selecting a suitable substrate for attachment. The microscopic veliger settles, cements its left valve to the substrate and undergoes metamorphosis into an oyster spat. For the rest of its life the attached spat will compete for space and nutrients and, if it survives, will grow into the adult form. The five oysters now found in California belong to the family Ostreidae. They represent two groups characterized by biological variations, including different modes of reproduction and dispersal of young. The temperature at which the oysters will spawn and the rate of larval development and growth depend on a variety of factors, including species, genetics and latitude of the breeding population. Natural spawning is also influenced by lunar periodicity and tides.

The native and European oysters are rhythmical consecutive hermaphrodites; they can change sex either annually or at closer intervals. In their first year they are strongly protandric; the first expression of sex at maturity is male. They may become female in the same year or in the following year if environmental conditions are good and food is plentiful. They are also larviparous (brooders); fertilization of eggs is internal, and the larvae are held for a period of time before release. Mature, egg-carrying females spawn at about 59-63°F (15-17°C). The eggs are released into the female's own mantle cavity and are fertilized as she takes in water containing the male's sperm. When the eggs hatch, the veliger larvae are held by the gill blades and incubate for about 10 days before release. Once expelled, the advanced larvae swim freely and feed on phytoplankton before settlement and metamorphosis (native 14-18 days; European 10-14 days).

The Pacific, Kumamoto and eastern oysters are alternative hermaphrodites; sex change occurs, but its timing is erratic. They have a tendency for protandry in their first year, but the tendency is not as strong as that of native and European oysters. They are oviparous (broadcast spawners); the eggs are immediately released and fertilization takes place in the environment. Mature, egg carrying females spawn at about 63-77°F (17-25°C) depending on the species, variety and latitude. Water temperatures required to establish a natural population are higher than those consistently found in California. Since spawning and successful reproduction rarely take place in California, the oysters are spawned and reared in shellfish hatcheries at about 77°F (25°C). The eggs hatch into free swimming trochophores, then become veliger larvae. Within 3 to 5 days these larvae settle, attach to a substrate and metamorphose to spat.

The native oyster is California's only indigenous oyster species and occurs along the Pacific coast from Sitka, Alaska to Cape San Lucas, Baja California, Mexico. The largest concentrations occur in the Pacific northwest along the coast of Washington's Puget Sound and in Willapa Bay. Although still grown commercially in Washington in specially constructed beds, natural concentrations are not abundant enough to support commercial endeavors. Populations of the native oyster are still relatively low in California. Some protection of existing populations is provided by recreational fishing regulations, which allow a daily harvest of 35 native oysters under the general invertebrate bag limit. The adult is about 2-3 inches (5-7 centimeters) in length and more often irregular in shape (Figure 21-5). Shell textures vary from smooth to rough with concentric growth lines, and the exterior has purple-brown to brown axial bands. The two shell valves are symmetrical; their interior is shades of olive green and can have a metallic sheen. The internal shell's muscle scar in adults is usually centrally located and unpigmented.

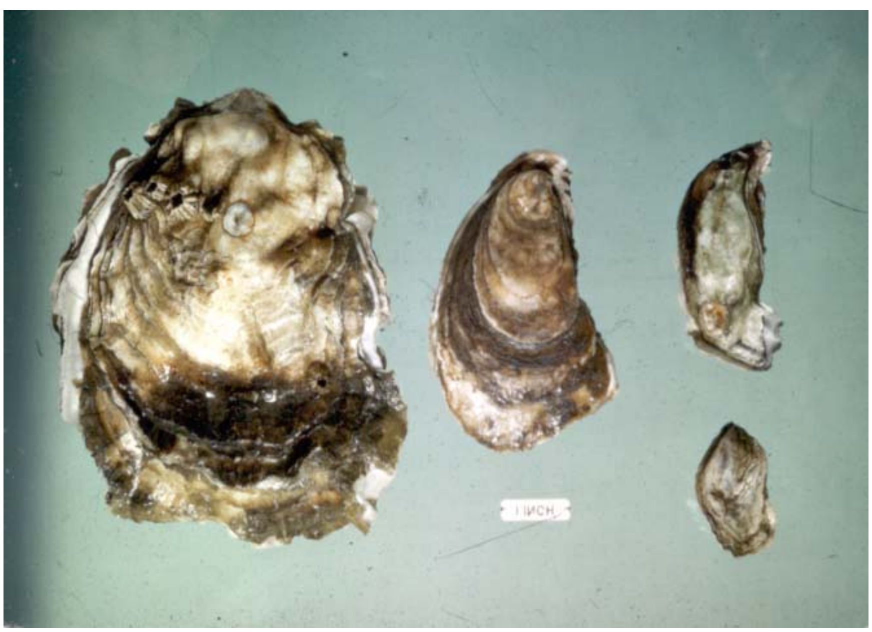

Figure 21-5. Species of oysters grown in California. Left, Pacific oyster; center, eastern oyster; upper right, Kumamoto oyster; lower right, native oyster. Credit: Department.

The native oyster is found in many of California's coastal inlets and bays, especially on hard substrate located on mud flats and gravel bars near the mouths of small rivers and streams. It cannot withstand high temperatures or frost when exposed, and does not survive low salinity or turbid water. The natural beds are located in the subtidal zone of bays, where the oyster is better protected from both prolonged hot summer surface water temperatures and extreme cold winter water conditions. The oysters are often found attached to rocky outcroppings or other structures that offer protection from rays and other predatory fish.

Adult European oysters are about 3-4 inches (8-10 centimeters) in length, with a poorly developed beak that gives the valves an oval to round shape. The left or attachment valve is larger and more deeply cupped than the right valve, with 20 to 30 ribs and irregular, concentric lamellae. The upper, smaller valve is flat, with numerous concentric lamellae but no ribs. The hinge ligament consists of three parts: a middle, flat part on the left valve and two projections on the right. The internal valves are white, and the muscle scar is eccentrically positioned and unpigmented.

Adult eastern oysters may vary in length from 2-6 inches (5-15 centimeters) (Figure 21-5). The shells are asymmetrical, highly variable in texture and shape, and greatly influenced by environmental conditions. The external shell is usually a shade of gray, and the internal valves white with a variable colored muscle scar, usually deep purple. The left valve is longer than the right, not deeply cupped, and the beak is usually elongated and strongly curved. The shell margins are usually straight or only slightly undulating, and the inner margins of the valves are smooth.

The adult Pacific oyster ranges from about 4-6 inches (10-15 centimeters) in length (Figure 21-5). The shell is coarse, with widely spaced concentric lamella and ridges. The shell is thinner than that of eastern oysters, yet more deeply cupped. The Miyagi is the principal variety of Pacific oyster grown on the west coast. The Pacific oyster's shape may be highly variable and greatly influenced by environmental conditions. The upper, flat right valve is smaller than the left, and the inner surface of the valves is white with a faint purple hue over the muscle scar. The Kumamoto oyster is smaller, but is prized for its deeper cup (Figure 21-5). It spawns in the fall in nature and grows more slowly than the Pacific oyster.

Oyster disease and shellfish pests are a major concern to the state resource agencies and the oyster industry. Because the west coast industry depends on the movement of animals across state lines, the industry is subject to regulations established through cooperative agreements between resource agencies. All oyster seed and shellstock not destined for a terminal market that cross state lines are examined for the presence of disease and exotic "hitchhikers" (pests) which could be harmful to the natural resources and commercial interests. Seed and shellstock that do not pass certification are destroyed through cooperative agreements with the State and the industry. The various state natural resource agencies have a cooperative program which regulates the interstate movement of shellfish seed and seedstock.

Oyster diseases on the west coast occur both in hatcheries and during grow out in the natural environment. Hatcheries are artificial environments which can stress oysters and render them susceptible to an array of infections. When disease outbreaks occur in hatcheries, the stocks are destroyed and systems disinfected. This is a protective measure for the natural resource and considered the most economically practical approach by the industry.

Natural environment associated oyster diseases on the west coast are not as widespread and devastating as those of Atlantic oysters on the east and gulf coasts, but they do occur. The most significant, in terms of reduced production, is the SMS of Pacific oysters. Summer mortality of Pacific oysters was first reported in California in the 1960s with mortality levels as high as 65 percent of adult Pacific oysters. Similar conditions occur in Pacific oysters cultured in Korea, France and Washington state. California oyster losses attributed to SMS have fluctuated over the years, and studies have addressed the initiating agent as possible pathogens, environmental factors and impacts, and stressors such as the combination of depleted energy reserves and attempted gonadal maturation. For decades, SMS was researched without resolving the cause. In 1993 and 1994, summer mortalities of Pacific oyster seed in Tomales Bay reached 52 and 63 percent, respectively, and were associated with elevated water temperatures above 68°F (20°C) and a bloom of the dinoflagellate, *Gymnodinium sanguineum* (= splendens). The etiology of this syndrome is complex with numerous environmental factors influencing disease outbreaks, but recent studies clearly implicate the role of a herpes virus specific to oysters. Warm water events resulted in expression of the virus, followed by mortalities. Growers are attempting to circumvent the problem by not planting Pacific oyster seed during the warmer months from May to October. However, seed availability during the cooler months has been a problem. A promising approach, which is being explored currently, is the use of survivors of multiple summer mortality episodes for broodstock.

Bonamiasis of the European oyster is caused by the protozoan parasite *Bonamia ostreae*. It has been detected in European oysters cultured in at least two bays in California. The parasite infects the oyster's blood cells, destroys its immune system, and impacts other physiological processes.

During the 1980s it was discovered that the protozoan parasite *Haplosporidium nelsoni*, which causes MSX or Delaware Bay Disease in Atlantic oysters on the east coast, is present in Pacific oysters in one bay in California. It is present in low numbers and appears to have little effect on the Pacific oyster host. It is now generally accepted that *H. nelsoni* was imported to California from Japan along with Pacific oyster stock. From there, it was introduced to the east coast of the U.S. along with Pacific oyster stock imported from California. The ultimate result has been catastrophic for the eastern oyster and the east and gulf coast industries. The results of these studies demonstrate the first molecular confirmation of the introduction of an exotic marine pathogen and emphasizes the need to adhere to strict importation guidelines as established by the International Council for the Exploration of the Seas (ICES).

Shellfish and the Environment

One of the more significant challenges to aquaculture in the next decade will be the industry's ability to position itself within the environmental framework and philosophy of natural resource management. Environmental issues are a concern nationally and are paramount in California. The two sets of laws and mandated course of action can be found in the National Environmental Protection Act (NEPA) and the California Environmental Quality Act (CEQA). CEQA processes are initiated to evaluate and measure visible and potential ecological and social impacts resulting from existing and proposed human activity in the environment and to mitigate significant impacts.

Immediate environmental concerns relative to shellfish culture are the potential biological and physical impacts of culture technology on sensitive components of the marine ecosystem. These sensitive components include eelgrass as essential habitat for salmonids and other sensitive finfish, and the invertebrate assemblage present on and within the substrate that is essential to the food web of birds and other marine species. Also included are the impacts on the life habits of birds and marine mammals and on the physical structure of the bay. A key element of the CEQA process is the concept of significance of impact. Any activity in the bay environment has some level of impact on that environment. Correction, change, or outright abandonment of an activity is mandated if the level of impact exceeds the threshold of significance deemed sufficient to be detrimental to the biological or ecological parameter in question. It will be essential that shellfish technology not have significant adverse impact upon the health of the ecosystem on which it also depends. Shellfish culture and our living marine resources depend upon excellent water quality and a healthy environment and, therefore, these concepts are not mutually exclusive.

In response to these concerns, long term federal and state supported regional research has been initiated to study shellfish culture impacts. This research, which focuses on the industry in California, Washington and Oregon, is being conducted by university and state research agency personnel, and is monitored annually to identify areas that may need immediate alteration. In addition, federal and state funding, coupled with industry resources, is being directed toward the development of industry Best Management Practices to guide the industry in its present and future development.

Future Trends

Oyster hatchery and seed technology rapidly expanded in the 1980s and 1990s, including application of remote setting of oyster seed as an industry standard and the production and use of triploid (3 sets of chromosomes) oysters. The triploid condition prevents the onset of maturation and results in oysters characterized by year round production of high quality meat. Although triploid production was a positive technical breakthrough, oysters are sterile, resulting in a genetic “dead-end”. To overcome this, the industry now applies high pressure following fertilization to retard both polar bodies. The resultant tetraploids (4 sets of chromosomes) are then artificially crossed with diploids (2 sets of chromosomes; normal condition), thereby producing sterile triploids that are used as production oysters while maintaining a viable genetic line in the diploid broodstock. This technology, coupled with the more recent establishment of broodstock genetic programs, will be a major industry thrust. Oyster genomic research is an industry priority and a regional cooperative effort involving university and industry geneticists and oyster hatchery managers.

The establishment of a national Molluscan Broodstock Program (MBP) and the Molluscan Broodstock Center on the west coast mark the true beginning of an oyster genetics program which fosters cutting edge genetics research. Using a mix of regional and national grants, geneticists are utilizing cooperative regional research to develop genetically marked family lines that are tested and selected for high yield and survival. Scientists are exploring the alternative strategy of crossbreeding and have demonstrated at the larval and market sizes that hybrid Pacific oysters have dramatically higher yield and superior metabolic performance than their inbred parents. This striking hybrid vigor or heterosis suggests that crossbreeding, in addition to traditional selection as practiced by the MBP, could improve oyster yield dramatically and quickly. Technology is also being developed to measure and more readily define "future performance" at the larval stage, thereby avoiding costly grow out trials and stock maintenance.

Current and future trends of the oyster industry are reflected throughout the west coast and the Pacific Rim because of the industry's regional infrastructure and markets. Industry shellfish hatcheries which were once concentrated in the Pacific northwest have opened in Hawaii, thereby taking advantage of stable water quality and consistent solar radiance used in energy efficient algal culture. The primary markets for seed are west coast producers who will expand into more international markets. The industry is rapidly expanding Kumamoto oyster production because of its higher value and half shell market demand, and greater market attention will be given to value added shellfish products such as flash frozen half shell products for both domestic and international Pacific Rim markets.

The oyster industry will concentrate on developing more efficient methods of off-bottom culture techniques that are less intrusive and result in fewer environmental impacts. The greater adaptation of off-bottom culture, coupled with the higher valued half shell Kumamoto oyster, is a potential that may offset the loss of shucked product produced in bottom culture. The development and adaptation of more environmentally sound practices will remain an industry priority.

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Oyster production and value, 1950-2008.

Year	Shucked pounds	Value	Year	Shucked pounds	Value	Year	Shucked pounds	Value
1950	38,600	$6,716	**1970**	1,119,484	$1,041,695	**1990**	2,040,015	$5,832,404
1951	43,300	$7,534	**1971**	978,826	$880,251	**1991**	2,002,257	$4,430,003
1952	45,100	$7,847	**1972**	885,001	$788,639	**1992**	1,910,328	$4,194,444
1953	37,600	$6,542	**1973**	726,875	$831,604	**1993**	2,224,526	$4,112,746
1954	73,500	$12,789	**1974**	799,742	$1,124,646	**1994**	2,310,286	$4,884,678
1955	218,300	$37,984	**1975**	799,885	$1,105,468	**1995**	2,166,037	$5,040,488
1956	755,600	$131,474	**1976**	716,356	$1,019,209	**1996**	1,235,351	$4,373,748
1957	1,359,200	$236,501	**1977**	929,544	$994,137	**1997**	1,107,357	$3,874,488
1958	1,158,600	$201,596	**1978**	1,025,127	$1,174,996	**1998**	1,085,185	$3,719,820
1959	1,659,699	$288,788	**1979**	1,144,623	$1,921,872	**1999**	805,976	$2,862,814
1960	1,656,689	$288,765	**1980**	939,455	$1,352,968	**2000**	835,986	$2,907,294
1961	1,568,894	$296,614	**1981**	1,061,983	$1,593,076	**2001**	1,040,893	$7,681,312
1962	1,722,139	$306,418	**1982**	999,865	$1,499,684	**2002**	1,116,932	$8,046,357

Oyster production and value, 1950-2008.								
Year	**Shucked pounds**	**Value**	**Year**	**Shucked pounds**	**Value**	**Year**	**Shucked pounds**	**Value**
1963	1,269,017	$230,719	**1983**	1,047,075	$1,719,544	**2003**	1,125,777	$8,227,316
1964	1,354,294	$253,163	**1984**	1,252,680	$2,920,799	**2004**	1,074,007	$8,406,471
1965	1,062,792	$263,440	**1985**	1,209,091	$3,064,296	**2005**	927,234	$7,675,168
1966	800,427	$221,710	**1986**	1,130,540	$2,862,643	**2006**	1,156,907	$8,705,567
1967	742,141	$207,274	**1987**	1,138,237	$2,983,353	**2007**	1,060,000	$8,775,887
1968	661,254	$197,911	**1988**	1,172,024	$3,129,851	**2008**	950,000	$7,866,000
1969	713,045	$212,099	**1989**	1,457,781	$4,259,097			

Data Source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database.

22 Culture of Marine Finfish

White seabass, *Atractscion nobilis*, in net pen. Photo credit: Hubbs-SeaWorld Research Institute.

Introduction

The impetus to develop marine aquaculture globally is strong and development is occurring in many regions. Wild fishery landings peaked in the 1980s, and current statistics of the United Nation's Food and Agriculture Organization (FAO) indicate that 80 percent of world fisheries are fully or over exploited. World population continues to increase as does the per capita consumption of seafood. Within the U.S., marine aquaculture has not advanced but the need to do so is clear. The U.S. currently imports 80 percent of its seafood of which 50 percent is farmed. The economic imbalance caused by these imports contributes $9 billion each year to the U.S. trade deficit, which is second only to oil. Recent concerns regarding food safety have also placed focus on the value of expanding a domestic supply. This notion has been further bolstered by the economic and environmental considerations related to "food miles" as seafood products are transported over great distances for packaging and final marketing.

Marine finfish farming in California and the U.S. is in its infancy. Although progress has been made in developing hatchery technologies for several species over the last 10 years, regulatory issues have stymied investment in outlets for growing these fish out in sea cages. In the U.S., commercial scale fingerling production has been demonstrated for cobia, red drum, and striped bass in the southeast; Atlantic cod and summer flounder in the northeast; and Pacific threadfin and Almaco jack in Hawaii. Offshore rearing trials have been conducted on some level for all these species, but the only commercial U.S. production of market size fish are the species being grown in Hawaii.

In California, commercial scale fingerling production of striped bass and white seabass (*Atractoscion nobilis*) has been demonstrated. The hatchery technologies for both species were developed for stock enhancement; however, white seabass enhancement has continued through the Ocean Resources Enhancement and Hatchery Program (OREHP) while striped bass has been curtailed. Growout to market has not been commercialized for either species, but two federally funded research projects have been conducted to evaluate the commercial potential for both. In addition to these two species, extensive research has been conducted in recent years on spawning and rearing of California halibut (*Paralichthys californicus*), yellowtail (*Seriola lalandi*), California sheephead (*Semicossyphus pulcher*) and cabezon (*Scorpaenichthys marmoratus*). Most of this research has been conducted by Hubbs-SeaWorld Research Institute (HSWRI) in San Diego, where spawning populations of all of these species have been maintained. In addition, several commercial abalone farms seeking opportunities to diversify have been evaluating the feasibility of raising California halibut and cabezon as a secondary species. Southern California is considered an ideal region for rearing marine fish in the U.S. because of its mild climate and ocean conditions, and high value species that are native or established. This list of species above does not represent all of the California species with aquaculture potential. Other species of interest would include tunas, lingcod and sablefish, to name a few.

A description of the rearing methods and typical results for each of these species is beyond the scope of this chapter. General methods are provided below that work well for a variety of marine species. These methods and results are based almost exclusively on the work at HSWRI; however, operational and regional differences can be expected. Specific examples are given for white seabass, California halibut, yellowtail and cabezon because most of the current interest lies with those species. California sheephead were found to grow far too slowly to be considered economical for food fish production, although production of juvenile sheephead for stock enhancement or the ornamental trade are possibilities. There is also great interest in the commercial potential for striped bass grown in sea cages. Striped bass are covered cursorily in this chapter because the culture methods for striped bass are very well documented.

History of the Ocean Resources Enhancement and Hatchery Program (OREHP)

The OREHP began in 1982 as a result of legislation (Assembly Bill 1414) authored by California Assemblyman Larry Stirling. The legislation was adopted to fund research into the artificial propagation of marine finfish species whose populations had become depleted. The ultimate goal of the legislation is to enhance populations of marine finfish species important to California for their recreational and commercial fishing value. Initially, research was focused on California halibut and white seabass; however, white seabass were eventually chosen as the primary species to focus on because of the depressed condition of the stock and its higher value to recreational and commercial fishers.

The California Department of Fish and Game (Department) manages the OREHP with the assistance of an advisory panel that consists of academic and management agency scientists, representatives of both commercial and recreational fishing groups, and the aquaculture industry. Members of the panel provide policy direction, review research proposals and recommend allocation of funds for the

OREHP. The program is funded through the sale of recreational and commercial marine enhancement stamps for all saltwater anglers south of Point Arguello.

Since 1995, the OREHP has supported the operation of the Leon Raymond Hubbard, Jr. Marine Fish Hatchery in Carlsbad, California. HSWRI operates this hatchery, which raises white seabass. As part of their OREHP contract, HSWRI has developed the culture protocols required for the program and the assessment techniques that will help evaluate the impact of the hatchery reared fish on the population. A Department Fish Pathologist works in conjunction with HSWRI staff to investigate and manage disease issues. In addition, HSWRI and the Department have obtained research grants to support collaborative projects in fish health, physiology, systems design, post release acoustic tracking, environmental monitoring and genetics.

Species Descriptions

The species described in this chapter are native to California and have historically represented important fisheries to the region. Detailed descriptions of the natural history and fisheries for each are provided in previously published Status of the Fisheries Reports.

Culture Facilities and Systems

In California, land based facilities are used for broodstock holding, maturation and larval rearing of marine finfish. Juvenile ongrowing has been conducted on a limited scale for some species in ocean cages but primarily in land based pools and raceways. Seawater is pumped into land based facilities from nearshore areas where water quality is often naturally variable with respect to parameters such as temperature and salinity. In heavily populated areas, water quality is often impaired by anthropogenic sources, which can be exacerbated by runoff during the rainy seasons.

Broodstock maturation systems are typically recirculated for biosecurity purposes and to control water temperature to induce spawning. Pool volumes range widely from 5000 to 42,000 gallons (19 to 160 kiloliters) depending on the species and number of fish used in the breeding population. Minimum tank size for spawning fish is not typically evaluated because maximum egg production is always desirable. Egg hatching and early larval rearing systems require fine control over water quality parameters because most of these species have pelagic ocean larvae that are physiologically adapted to stable ocean conditions. Low flow requirements make flow through systems practical, but recirculating systems are generally preferred for maximum control and biosecurity. Pool volumes for egg hatching and early larval rearing typically range from 80 to 450 gallons (0.3 to 1.7 kiloliters), although larger 1320 gallon (5.0 kiloliters) pools are currently being evaluated for large pelagic species. Juvenile grow out has been conducted in flow through systems (pools and raceways) up to 8000 gallons (30 kiloliters) in volume and nearshore cages up to 790,000 gallons (3000 kiloliters).

Reproduction

Spawning of marine finfish is typically allowed to occur naturally or is induced seminaturally using photo-thermal manipulation, where seasonal cycles are either natural (ambient water temperature and photoperiod) or controlled to promote spawning out of season. Hormone-induced spawning has not been investigated thoroughly for most species in California because it has not been deemed necessary. Multi-generational selective breeding programs have not been developed for any of these species.

White seabass, California halibut and yellowtail are all “batch” spawners that release pelagic eggs. Egg sizes average approximately 0.0488, 0.0323, and 0.0531 inches (1.24, 0.82, and 1.35 millimeters) in diameter for each species, respectfully. In group spawning situations, females will release hundreds of thousands of eggs to several million eggs per batch. White seabass and yellowtail are spring and early summer spawners. California halibut have an extended spawning period from late winter to late fall.

Unlike the other species mentioned, female cabezon produce an adhesive egg mass that attaches to hard substrate. A captive broodstock at HSWRI has yielded egg clusters estimated (gravimetrically) to contain tens of thousands to several hundred thousand eggs. Cabezon spawn in the winter and spring.

Age and Growth

Growth of each of these species is highly dependent on water temperature. The growth of marine fish reared in recirculating systems benefits from temperature control that can be maintained year round. Not only is growth faster when temperature is optimized, but it is stable and predictable. Rearing fish in flow through systems, including cages, is done at the mercy of ambient water temperatures and growth fluctuates accordingly. Optimum rearing temperatures for the different culture species and life stages described here have not been empirically defined. Life history patterns are often used to help guide culture methods, but even then information may be lacking. Ocean surface temperatures in southern California typically range from 53 to 72°F (12 to 22°C), which will support culture of all the species described herein. However, growth and performance of most species is maximized when water temperatures are on the upper end of this range-64 to 72°F (18 to 22°C). This is especially true for striped bass and California halibut. Yellowtail and white seabass are expected to benefit from warmer temperatures of 72 to 77°F (22 to 25°C) that would be more typical off Mexico. Cabezon are coastal groundfish that perform best in cooler waters of 53 to 58°F (12 to 14°C). It is important to note that white seabass, California halibut, and striped bass are found in brackish water as juveniles and, therefore, are generally tolerant of changing temperature and salinity. Yellowtail and cabezon are coastal species that are expected to be less tolerant, although this has not been empirically demonstrated.

Growth to market size for these species has been evaluated on a limited basis. A typical market size for farm raised fish is approximately 2 pounds (1 kilogram) for fresh or live product. The species described here can be expected to reach market size in 1 to 3 years. When ranked from fastest to slowest growing based on preliminary research, the following order results: yellowtail, striped bass, and white seabass, with California halibut and cabezon roughly tied for last.

Food and Feeding

The larvae of the pelagic species described in this chapter begin feeding several days after they hatch. Egg hatching occurs in just a couple of days for all species except cabezon eggs, which hatch in a couple of weeks. With the exception of white seabass, which are large enough to consume newly hatched brine shrimp (*Artemia spp.*) as a first feed, the other species require smaller prey items such as rotifers for the first week of feeding before transitioning to brine shrimp nauplii. Beginning at approximately 3 weeks of age, dry feed is offered to the fish in addition to the brine shrimp in a "weaning" process. The amount of brine shrimp nauplii is slowly reduced as fish begin feeding on the dry feed. Once on dry feed, the feed size is increased as the fish grow. The feed type, characterized by the protein and fat content, may also be adjusted to reduce costs and improve fillet quality.

Parasites and Disease

The disease organisms observed among cultured species described here are listed in Table 22-1. This list includes only those diseases observed among fish cultured at HSWRI, and a review of the literature would likely include additional pathogens. The number of disease organisms can be related directly to the culture history for each species, as well as the scale of production. This is balanced against the relative hardiness of each. Species cultured over a longer time period and on a larger scale tend to be associated with a greater number of disease organisms. Striped bass is an exception because it is extremely hardy and very well suited to the culture environment.

Table 22-1. List of observed disease organisms among several cultured species.				
	Protozoans	**Bacterial**	**Invertebrate Parasites**	**Others (Fungal, Virus, Etc)**
White Seabass	*Uronema* *Myxosporidean* *Trichodina* *Ichthyobodo* *Cryptobia* *Hexamita* Sporozoan	*Flexibacter* *Vibrio spp*. Epitheliocystis Spirochete *Piscirickettsia salmonis* Mycobacterium	Monogenean trematodes (*Anchoromicrotyle guayamensis* (gill fluke) and *Gyrodactylus* (skin fluke) Copepods (*Caligus* and *Lepeophtheirus*)	Fungus (unidentified) Herpesvirus Viral Nervous Necrosis Virus
California Halibut	*Trichodina* *Ichthyobodo* (formally *Costia*)	Epitheliocystis *Flexibacter*	Monogenean trematodes	Fungal pseudoneoplasm
Yellowtail	Myxosporidian *Trichodina*	*Flexibacter* Epitheliocystis	*Anisakis* Monogenean trematodes (*Zeuxapta seriolae* (gill fluke) and *Benedenia seriolae* (skin fluke)	
Striped Bass	*Trichodina*	*Vibrio spp.*		
Cabezon	*Uronema* *Ichthyobodo*		Monogenean trematode (*Gyrodactylus*) (skin fluke)	

Among the noninfectious diseases, gas bubble disease is often severe among white seabass cultured in shallow water systems that are not adequately degassed, including floating raceways in natural water bodies. Nutritional deficiencies are also likely prevalent among cultured marine fish, although the cause and effects are not well understood.

Predators and Competitors

Cannibalism can be a significant problem among younger life stages of marine fish before size grading is practical. Cannibalism can be reduced by optimizing feeding and nutrition and by grading the fish. In outdoor rearing pools, birds such as herons are known to prey on cultured fish. Bird predators can effectively be excluded using inexpensive netting. In cages, marine mammals such as California sea lions and harbor seals can be a problem for cage operators if given the opportunity. Birds, both diving and non-diving, can also prey on caged fish. To prevent predation on caged fish, extra netting is typically employed over the cage and below the water line around the fish containment net. Removing dead or dying fish from the cages promptly will reduce the attraction to predators.

Aquaculture Potential

The aquaculture potential for these species has yet to be demonstrated on a commercial basis but is considered to be very good because there are known markets for fresh and live products. Because the current regional supply of these species is from the wild, the availability is often inconsistent and limited by natural abundance and fishing regulation. In other regions, species similar to all but cabezon are being successfully cultured commercially. Among the croaker species, red drum and seatrout are being cultured in the U.S., while totoaba, corvina and maigre are being evaluated for culture in Mexico, Argentina and the Mediterranean.

A number of flatfish species are also being cultured. On the U.S. east coast, the summer flounder and southern flounder are being evaluated for culture. In Japan, flounders have been cultured on a commercial scale for many years. The speckled flounder and fine flounder are also being cultured in South America. The commercial culture of several species of jacks is also well established worldwide with increasing interest in expansion. The four most highly valued jack species are the yellowtail "hamachi", the kingfish yellowtail, goldstriped amberjack or yellowtail, and the greater amberjack. Commercial culture of one or more of these species has been taking place in Japan, Australia and New Zealand for many years, while new operations are currently being established in Europe and South America. Striped bass and its hybrids are cultured in many parts of the world on commercial basis.

Conclusions

Aquaculture of marine finfish is in its infancy in the U.S. and California has done little to improve this condition. With 1100 miles (1800 kilometers) of coastline in California, opportunities to farm the ocean should be readily available. Unlike the agriculture industry in California, which consistently ranks number one in the nation (about $33.8 billion in 2007), mariculture opportunities in California are impeded by competing uses for coastal resources and a restrictive regulatory environment. Recent legislation (California Sustainable Oceans Act of 2006) was passed that should provide greater definition to the regulatory requirements involved in permitting coastal sites for farming marine finfish.

One of the top priorities for the National Oceanic and Atmospheric Administration's aquaculture program is to produce a sound and effective regulatory framework for marine aquaculture in the U.S., including federal waters. The focus is on sustainable aquaculture (finfish and shellfish) on land and in the ocean to meet the growing demand for seafood.

There is a clear need for aquaculture development worldwide. California has access to the coastal resources and high value marine species necessary to compete in the world seafood market; however, until recently regulations effectively deterred development of marine finfish culture. The new regulations should provide the framework to develop sustainable finfish culture in California.

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23 Culture of Salmon

Salmon sorting at Mokelumne River hatchery. Photo credit: Department.

History

Different methods are used for aquaculture production of salmon. The three major techniques are salmon ranching, land based tank operations and net pen rearing. At salmon ranch hatcheries, adult fish are spawned, the eggs are hatched and the young are reared in tanks to increase their size and chances of survival in the wild. The salmon smolts are then released and grow to market size while at liberty in the ocean. After maturing at sea the salmon return to the hatchery where they are harvested. If at least three to five percent of the released salmon return to be harvested, a private salmon ranch may be profitable. However, it is not uncommon for 98 to 99 percent of the salmon to be lost to natural and fishing mortality before they can return to the hatchery so private operations often do not have enough fish return to be cost effective.

In contrast, the basic concept of public mitigation hatcheries is to produce enough fish to replace those lost due to human activities which have eliminated access of fish to spawning and rearing habitat. The purpose of these hatcheries is to provide for existing fisheries and also return enough adult fish to the hatchery to produce sufficient eggs to continue the process. In essence the 'profit' for a public mitigation hatchery is the continuation of spawning runs and the maintenance of recreational and commercial fisheries.

Land based tank operations maintain all of the fish at the facility until harvest. Fish are kept in tanks made of concrete, fiberglass or other materials. Round tanks are commonly used and are often in the range of 30 to 40 feet (9 to 12 meters) in diameter. Water is pumped through the tanks to maintain good water quality, and growth comes from manufactured feed provided by the aquaculturist. Captive broodstock programs are operated in a similar manner and may be utilized to augment or reestablish depleted stocks of fish.

Net pen facilities use young fish produced in hatcheries, which are then placed into pens where they are fed until grown to market size. The pens are normally made from flexible netting material suspended from floats and are generally a few hundred square feet at the surface. Pens are often linked together to form large units of up to many acres. The net pens are usually placed in sheltered saltwater areas where protection from ocean storms is provided and good water quality is maintained by natural currents. Technologies are being developed to create large scale enclosed ocean rearing systems in order to address concerns about disease and effluent discharge and their effects on wild fish and local ocean environments.

Salmon have been produced in California by both private and public hatcheries. While the history of private trout production in California is strong and dates back to the 1800s, private commercial production of salmon in California has been intermittent and never very substantial. The beginning of recent interest in commercial salmon production was the authorization by the California Legislature in 1968 for the first (and only) private salmon ranching operation. In 1979, the legislature authorized the operation's move to a site on Davenport Landing Creek (Santa Cruz County), where the operation was active for several years.

In California, land based tank operations were tried in the 1980s and 1990s and accounted for some limited private aquaculture production of salmon. Most commercially produced salmon were from tank rearing operations located in northern California, where cold water suitable for salmon culture is more readily found. Fish were grown to market size in tanks using either fresh or salt water. Steelhead trout, *Oncorhynchus mykiss*, were produced from domestic broodstock maintained by California aquaculturists, whereas coho salmon, *O. kisutch*, and Atlantic salmon, *Salmo salar*, eggs or fingerings were imported from out of state to California farms. Salmon culture has not been a major component of the California's private aquaculture industry and never contributed more than 5 percent to the total value of the industry's production. Currently there are no commercial salmon culture operations in California.

Conversely, public salmon hatchery operations play a key role in the management of California's natural resources. Hatcheries have been built and operated to supplement natural salmon resources or to mitigate for the loss of natural production that occurs when water and power generation projects eliminate salmon spawning habitat. Thus, hatcheries help provide for the multiple beneficial use of the state's water resources. Public hatcheries produce approximately 40 million fish each year and are critical to maintaining the state's recreational and commercial salmon fisheries. Recent research suggests that hatchery produced fish provide a substantial percentage of the ocean fishery off the central California coast.

Public hatchery production of salmon in California dates back to 1872 with the establishment of Baird Hatchery on the McCloud River in the upper Sacramento River drainage. Several other salmon hatcheries and egg taking stations also began operations in the late 1800s and early 1900s. Baird originally operated as an independent hatchery, then as an egg collecting station for salmon and trout reared at Mount Shasta Hatchery (then called Sisson Hatchery). After the construction of Shasta Dam, Mount Shasta Hatchery and the upper Sacramento spawning grounds were separated from the lower Sacramento River and the Pacific Ocean. Coleman National Fish Hatchery was built in 1942 to mitigate for lost spawning habitat above Shasta Dam. It replaced many of the early hatcheries, including most of the salmon operations at Mount Shasta. Coleman Hatchery is on Battle Creek, a tributary of the Sacramento River at Anderson (south of Redding). Livingston Stone Hatchery, located north of Redding at Shasta Dam, was constructed to help in the recovery of listed winter-run Chinook salmon, *O. tshawytscha*. These two facilities are the only federally operated fish hatcheries in California. Today there are six California Department of Fish and Game (Department) operated salmon mitigation hatcheries, two of which also raise fish for recreational and commercial fishery enhancement. The Department is also involved in a multi-agency captive coho salmon rearing program at Warm Springs Hatchery to recover depleted Russian River coho stocks. All six of these state operated hatcheries have been built since 1955. The mitigation hatcheries are located on central valley and north coast rivers downstream from dams constructed for water or power development.

Hatchery Location

Iron Gate ....On the Klamath River below Copco Lake (Siskiyou County)
Trinity..............................On the Trinity River below Trinity Lake (Trinity County)
Feather River ....On the Feather River below Lake Oroville (Butte County)
Mokelumne River............On the Mokelumne River below Camanche Reservoir (San Joaquin County)
Nimbus...........................On the American River below Folsom Lake (Sacramento County)
Warm Springs ....On Dry Creek below Lake Sonoma (Sonoma County)

The Department also operates the Merced River Fish Installation below Lake McClure (Merced County) to rehabilitate fall run Chinook salmon in the Merced River and there is a non-profit salmon and steelhead enhancement hatchery on the Smith River at Rowdy Creek (Del Norte County). It operates under an individual category in the California Fish and Game Code. One hundred percent of current (2009) Rowdy Creek production is to be coded wire tagged to evaluate performance and potential impacts on wild populations.

Status

Nationally, and internationally, net pen rearing of salmon has proven to be the most successful method of private aquaculture production of salmon for the seafood market but has been criticized for its effects on wild stocks of fish due to increased nutrient loading, release of drugs and therapeutants to the environment, disease and concentration of parasites, and escape of fish which are genetically distinct from local populations. Legislation passed in 2003 prohibits, with minor exceptions, the culture of salmonids in California coastal waters and currently there is no private aquaculture of salmon being conducted in the state.

Ocean salmon acclimation and imprinting pen programs have been attempted in California with the intent of increasing local ocean harvest. In these programs fish from public hatcheries are kept for a period of time (days or weeks) deemed sufficient to acclimate the fish to local conditions with the assumption that they will remain in the general area after release. Saltwater pen operations in recent years have been located at Tiburon, Port San Luis, Monterey and Santa Cruz. The intent of these net pen programs is to enhance local ocean fisheries, but evaluation of tagged fish released in the early 1990s suggests that they may exhibit more movement than formerly thought. Current (2008) California Fish and Game Commission policy calls for the tagging of these fish and development of a monitoring plan to evaluate performance.

State and federal hatcheries produce Chinook and coho salmon using the same production techniques as other salmon ranching operations. Returning adults are artificially spawned and the offspring are reared to smolt or yearling size before they are released at the hatchery or at other freshwater or brackish/saltwater sites to migrate to the ocean where they grow to adults. Chinook salmon return to be spawned, usually three or four years after release. Coho generally spend one year in freshwater and return from the ocean to spawn as three-year olds.

A ‘Constant Fractional Marking Program’ for Central Valley fall run Chinook was instituted in 2006. The objectives of this program include evaluation of contribution rates of hatchery fish to overall salmon populations, exploitation rates of hatchery and naturally produced fish in ocean and inland fisheries, effects of water project operations on fall run Chinook salmon, and effects of hatchery produced fish on naturally produced populations. Twenty-five percent of all fall run fish released from Central Valley hatcheries will be coded wire tagged. Tags will be recovered in the ocean and inland fisheries, during carcass surveys and other monitoring operations, and from fish returning to the hatcheries.

Hatchery Genetic and Management Plans (HGMPs) are being prepared for all stocks propagated at public hatcheries in response to recent Endangered Species Act (ESA) listings of several Pacific salmon and steelhead stocks. These will be submitted for federal review by the National Marine Fisheries Service to evaluate potential interactions with listed stocks. Public hatchery production is currently based on the ‘Goals and Constraints’ guidance document for each hatchery and remains relatively constant; therefore years of low natural production result in harvests with a larger proportion of hatchery fish. Most of the public hatchery production of salmon in California is intended to mitigate for the loss of habitat caused by construction of dams for water and power development. The concept of providing mitigation for losses to fish and wildlife caused by the building of a government project was originally established by the U.S. Congress when it enacted the Fish and Wildlife Coordination Act of 1934. The need to replace the natural fishery resources eliminated by these projects continues to have high priority with the people of California.

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Further Reading

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