Fishery Resources

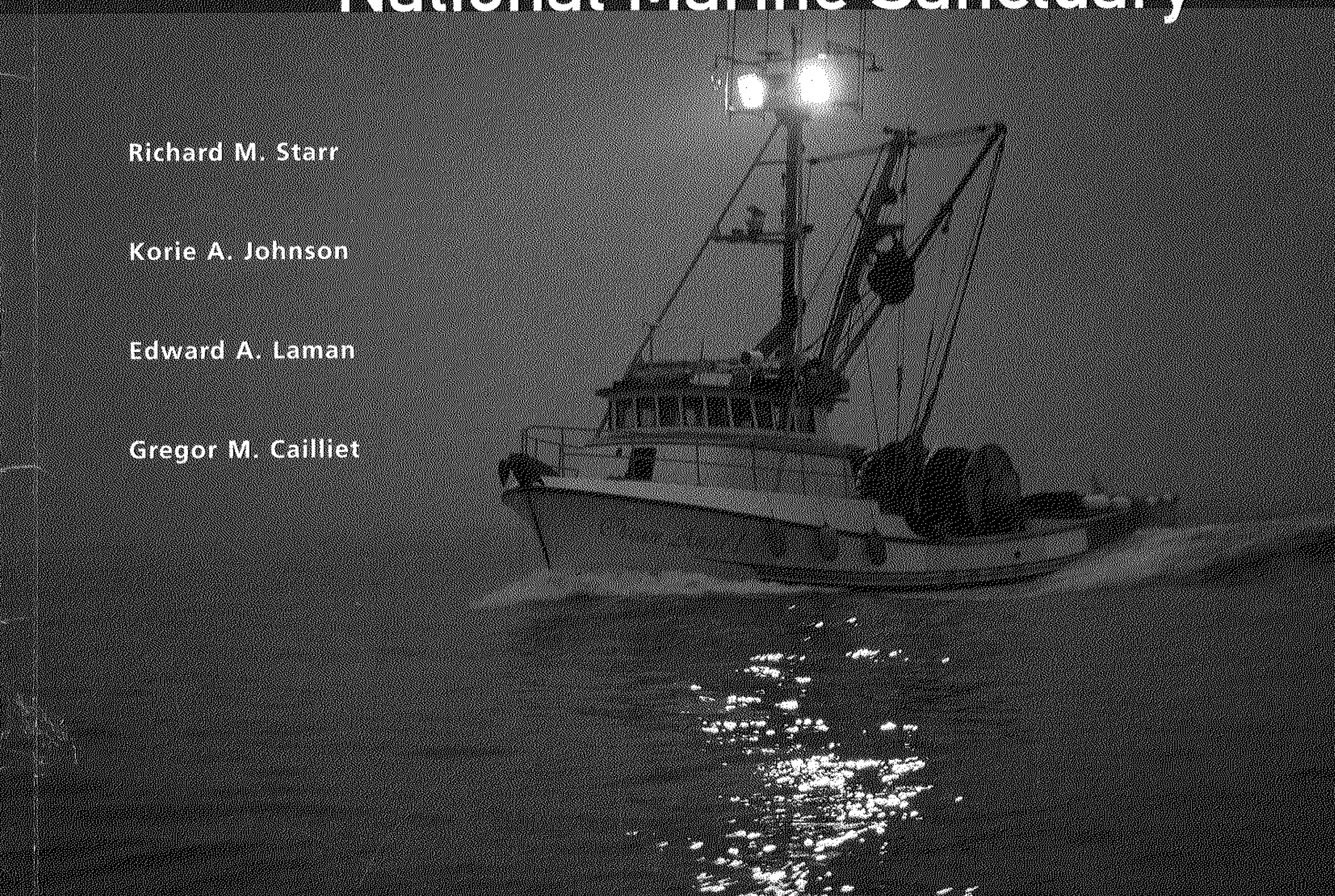
of the Monterey Bay National Marine Sanctuary

Richard M. Starr

Korie A. Johnson

Edward A. Laman

Gregor M. Cailliet



A Publication of the California Sea Grant College System

Sea Grant is a unique partnership of public and private sectors, combining research, education, and technology transfer for public service. It is a national network of universities meeting changing environmental and economic needs of people in our coastal, ocean, and Great Lakes regions.

Published by the California Sea Grant College System, University of California, La Jolla, California, 1998. Publication No. T-042. Additional copies are available for $10 (U.S.) each, prepaid (check or money order payable to "UC Regents") from: California Sea Grant College System, University of California, 9500 Gilman Drive, La Jolla, CA 92093-0232. (619) 534-4444.

This project was initiated and partially funded by the David and Lucile Packard Foundation. It was also funded in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA66RG0477, project number A/P-1, and by the Environmental License Plate Fund through the California State Resources Agency. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA, or any of its subagencies. The U.S. Government is authorized to produce and distribute reprints for governmental purposes.

Cover design: Leah Roschke, Scripps Institution of Oceanography, University of California, San Diego, based on a photo by Rick Starr.
Photo credits: pp. 7, 21, 37, 41, 91 Rick Starr; p. 1, Jens Sorenson; p. 29, DANR, University of California.

Published on recycled paper.

Fishery Resources of the Monterey Bay National Marine Sanctuary

Richard M. Starr
Marine Advisor
California Sea Grant Extension Program

Korie A. Johnson
Research Associate
California Sea Grant Extension Program
Moss Landing Marine Laboratories

Edward A. Laman
Senior Research Biologist
Tenera

Gregor M. Cailliet
Professor
Moss Landing Marine Laboratories

California Sea Grant College System
University of California
La Jolla, CA 92093-0232

Publication No. T-042
ISBN 1-888691-06-9

Acknowledgments

Fisheries and fishery management are complex topics, and many people helped to provide the information we present. We would first like to thank the fishers and scientists who regularly spend many hours at sea and on the docks collecting these data. We owe a great deal of thanks to Jeanne Sedgwick of the David and Lucile Packard Foundation for asking us to write about Monterey Bay fisheries. This project would not have been started without her help.The David and Lucile Packard Foundation, the University of California Sea Grant Extension Program, and Moss Landing Marine Laboratories all provided support for the data-compilation portion of this project. California Sea Grant provided funding for publication.

The data presented in this report came from many sources. Dawn Outram of Moss Landing Marine Laboratories helped track down some of the fishery information. Don Pearson, Larry Jacobson, Jan Mason, Mary Yoklavich, and Steve Ralston of the National Marine Fisheries Service helped immensely by providing fishery landing data and information on biological trends. Similarly, Gerry Kobylinski, Bob Leos, Bob Hardy, Paul Reilly, David VenTresca, Deb Wilson-Vandenberg, and Bob Lea of the California Department of Fish and Game provided valuable fishery and biological sampling information generated by their agency. Hans Radtke generously computed economic benefits from landing data. Lisa Ziobro from the Monterey Bay National Marine Sanctuary supplied some of the information about ports in the region.

Many people reviewed the early drafts of this report. Paul Reilly, Bob Leos, Bob Lea, and Jan Mason provided detailed comments and excellent suggestions to improve this document. Chris Dewees of the UC Sea Grant Extension Program gave us numerous suggestions, especially about ways to improve the Fisheries Management and Management Issues sections. Andrew DeVogelaere of the Monterey Bay National Marine Sanctuary, Milton Love of UC Santa Barbara, Tom McCray of the Moss Landing Fishermen's Association, Rachel Saunders of the Center for Marine Conservation, and Kon Karpov of California Department of Fish and Game also provided a helpful review of the report.

The final document is much improved as a result of the editorial guidance of Rosemary Amidei of the California Sea Grant College System and the layout and design by Joann Furse. Graphics of fishing vessels and gear were provided by Ginny Goblirsch of the Oregon State University Sea Grant Extension Program and Lynn McMasters of Moss Landing Marine Laboratories.

Executive Summary

Fisheries in central California are part of this region's rich cultural history. The original inhabitants of central California used marine species for food, tools, ornaments, and currency. In the mid- to late 1800s, immigrants from many different countries settled here and began to harvest the abundant sea life in Monterey Bay as they pursued their dreams and hopes for prosperity. Native Americans, the early settlers, and the seafaring people who followed have provided the Monterey Bay region with a rich and unique cultural identity. The region has also prospered from the important economic benefits related to the pursuit and harvest of marine species.

Recent fishery collapses in many parts of the world have led to public concern about the health of fisheries in this region. This project was initiated in an attempt to answer a very simple question, "What is the status of fisheries in the Monterey Bay region?" Unfortunately, the answer is very complex. The status of commercial and recreational fisheries and, by extension, the status or health of fish populations is influenced by numerous social, economic, environmental, and biological variables.

The world economy, international politics and trade, and demand for fish products influence the value of locally harvested species, and thus directly affect the economic viability of Monterey Bay fisheries. The amount of private and governmental funding provided to maintain the infrastructure required for fisheries is also important. The industry needs port facilities to berth and maintain fishing vessels, dredged channels to access the sea, shoreside facilities to offload, process, store, and transport fish products, and markets ready to buy seafood at a price that will support fisheries.

The ocean environment in the Monterey Bay region is very dynamic and greatly influences the sizes of resident fish populations. Often it is difficult to determine if changes in fish population sizes are the result of societal activities, such as fishing, or environmental changes. Differences in target species, the number of vessels fishing, and the types of gear used in the fishery also complicate an attempt to describe the current status of fish populations, because most of the information used to estimate the size of fish populations (stock size) is derived from fisheries. Confounding the issue is the fact that the amount of fish landed (the amount caught and sold to processors at the dock) is sometimes more a function of social or economic conditions than stock abundance. Additionally, long term data sets are usually needed to effectively model or estimate the size of fish stocks. Unfortunately, few such sets are available for fished populations in this region.

In this report, we have tried to summarize, for a general audience, the technical concepts and information that fishery scientists use to estimate the population sizes of harvested species. Although regional aquaculture ventures also contribute to local economies, we have chosen to discuss wild populations of fishes. In addition to summarizing scientific information, we have also provided a brief description of the types of fisheries operating in the region defined by the Monterey Bay National Marine Sanctuary (MBNMS), and a summary of fishery management operations.

Both local and out of area vessels fish in the Monterey Bay National Marine Sanctuary. These vessels use five primary types of fishing gear — pots and traps, trawl nets, hook-and-line gear, purse seines, and gill nets. Almost all fishes caught within the MBNMS are sold at one of five main ports: Morro Bay, Monterey, Moss Landing, Santa Cruz, and Princeton/Half Moon Bay. In recent years, more than 80% of the commercial fish landings at these five harbors were comprised of squid, rockfishes, Dover sole, anchovy, mackerel, sardine, sablefish, albacore, and salmon. Landings at Monterey and Moss Landing were higher than at the other ports in the MBNMS, because of the large volume fisheries for squid, anchovy, and sardine operating in southern Monterey Bay.

In 1994, commercial fishing in California accounted for $145 million in revenue from the dockside price paid to fishers (termed exvessel value). Ports within the MBNMS accounted for $21 million of that total. Commercial fishing activities also provided additional revenue through indirect impacts such as the purchase of goods and services related to commercial fishing. In 1994, the fishing industry provided an estimated $53 million in economic activity and approximately 2,000 jobs to local economies within the MBNMS. Although commercial fishing is economically valuable, it accounts for only a small portion of the total economy, both statewide and locally. The tourism and agriculture industries contribute much more to the local economy.

Recreational fishing in the MBNMS occurs in many forms. Anglers fish from boats, sand beaches, rocky shorelines, and piers and other artificial structures, and divers take fish underwater using pole spears and spear guns. From the 1960s through the 1980s, recreational fishing in northern and central California grew substantially, but it has remained relatively stable through the 1980s and 1990s. Salmon and rockfishes are the species most sought after by recreational fishers. Recreational fishing activities have a larger impact on California's economy than does commercial fishing. In California in 1994, recreational fishing created approximately $5 billion in personal income and over 150,000 jobs.

Regulations pertaining to the commercial and recreational harvest of species are derived from a combination of federal statutes and state law. Fisheries for species that are migratory in nature, that occur entirely in federal waters, or that have wide distributions are regulated by federal policy developed by regional fishery management councils and administered by the National Marine Fisheries Service. Fisheries for species that occur entirely within state waters are regulated by the California Fish and Game Commission and the state legislature. In cases where there is no state law or where state and federal laws overlap, federal statutes usually take precedence. In special cases, such as for some salmon species or in small ecological reserves, local or tribal regulations provide guidance for fishery managers.

Fishery managers use both fishery and scientific research data (when available) to estimate the population size of a managed species. Annual records of catch and fishing effort are used to develop models that produce indices of fish abundance. The models usually include research data collected by fishery management agencies. As with all techniques used to model the natural environment, this approach to estimating fish population abundance is not perfect. Nevertheless, the models used by fishery management agencies are remarkably good and provide information needed to manage some of the primary species harvested in central California.

Close to 200 species are caught in commercial and recreational fisheries in the MBNMS. Invertebrate species most frequently harvested commercially include spot prawn, pink shrimp, Dungeness crab, rock crab, and market squid. Harvests of spot prawn, Dungeness crab, and rock crab all increased from 1980–95. Pink shrimp populations declined throughout much of the late 1980s, then seem to have increased from 1994–95. The market squid population reached a low during the El Niño years of 1983–84, then reached record levels in 1994. Most fishery biologists believe that population sizes of the primary invertebrate species harvested are influenced more by environmental conditions than by fishing activity.

Shark and ray species are no longer harvested in large numbers in the MBNMS. Reported catches of the ten most commonly caught species showed a level trend from 1980–95. There is, however, evidence to suggest that the population sizes of some shark and ray species are lower now than they were before 1980.

Chinook salmon is the most common anadromous species caught in the MBNMS; it provides the basis for very important commercial and recreational fisheries. Reported catches of Chinook salmon have been high in the last few years. Scientific stock assessments indicate that the fall run Chinook salmon of the Sacramento River is in good shape, but that populations of Coho salmon and winter and spring run Chinook salmon are severely depressed. Fall run Chinook salmon are currently abundant because of favorable environmental conditions and improved management of the species.

Abundance of most pelagic species is greatly determined by large scale environmental phenomena. Albacore catches in the MBNMS declined from 1980–95, due to patterns of water temperature and not to population size. The population of Pacific albacore is currently thought to be stable or increasing. California landings of Pacific mackerel have declined since 1990, a result of low population abundance. Catches of Pacific mackerel fluctuated in the MBNMS from 1980–95, but the vast majority of the Pacific mackerel population occurs in southern California and Mexican waters.

Northern anchovy and Pacific sardine are the predominant nearshore pelagic fishes caught in the MBNMS. Decadal scale shifts in the environment largely determine population sizes of anchovy and sardine, although high fishing pressure can also affect the population. Anchovy spawning biomass in central California declined after 1985, but experienced a substantial increase from 1994–95. Pacific sardine populations are also increasing throughout their range after nearly disappearing from the region in the 1950s.

In the species category we term roundfish, biological and fishery data indicate that lingcod may be overfished in much of their range. Similarly, sablefish have been heavily fished in California waters, first by foreign vessels, and then by U.S. vessels. Sablefish catches in the MBNMS have been decreasing since 1980, but data from recent surveys suggest the population may be increasing. Pacific hake are very abundant seasonally in the MBNMS as they migrate from Mexican to Canadian waters. Pacific hake catches were high off central California throughout most of the 1980s. Most of the catches were delivered to San Francisco ports, however, and are not reflected in the landings for ports near the MBNMS.

Rockfishes are the most diverse group of fishes living in MBNMS waters. Rockfish, the most diverse group of fishes living in MBNMS waters, were the subject of a California Sea Grant workshop in 1986. For most of the rockfish species harvested, there is insufficient scientific information available with which to estimate abundance or population trends. Sufficient data are available to show stable or increasing trends in abundance for some rockfishes such as bank, chilipepper, shortbelly, and splitnose. Other rockfish species such as bocaccio, yellowtail, canary, and Pacific ocean perch have exhibited decreasing trends in abundance along the U.S. west coast. Most of these depleted rockfishes are deep water species that are slow growing, long lived, or have experienced high exploitation rates. Managers are concerned about the capability of some of these species to recover from high harvests.

Several species of fishes that occur in kelp forests and other nearshore habitats are under intense fishing pressure from both commercial and sport anglers. Some of these species have relatively short life spans and theoretically can withstand relatively high harvest rates. The newly established nearshore live-fish fishery, along with sustained fishing pressure from the recreational fishery, will test this theory as fishing pressure increases. There is already evidence that cabezon may be adversely affected by the new live-fish fishery.

Flatfishes are harvested commercially using a wide range of gear including trawls, hook-and-line gear, and set nets. Many flatfishes are also caught incidentally in bottom trawl fisheries for rockfishes, other roundfish, and shrimp. Landing data and stock assessments suggest that populations of most species of flatfishes are robust and could withstand increased levels of harvest.

Surfperches represent a highly abundant and diverse group of nearshore fishes in the MBNMS waters. They constitute a large proportion of the catches in the recreational fishery. Historical catch data show that surfperch populations have declined, due primarily to reductions in catches of barred and redtail surfperch. The declines in surfperch populations are attributed to a number of factors including environmental variation, lower production caused by smaller fish, habitat degradation, and increased fishing pressure.

Several management problems need to be solved to ensure that fisheries maintain an economic viability and continue to provide social and economic benefits to this region. Most fishery scientists agree that the excess of fishing capacity is the primary cause for overfishing in the world, and that fleet overcapacity is the single most important factor threatening the long-term viability of harvested fish populations. The inadvertent catch and discard of unwanted fish and invertebrates are problems in a few bottom trawl fisheries. Trawl bycatch, however, is not as large a problem here as it is in other fisheries such as the Alaska groundfish fishery and tropical shrimp fisheries.

Some people familiar with fishery management believe that the current method of allocating catch in an open access fishery is destined to create collapse in some fisheries. Three alternative strategies that have recently received a great deal of attention are the use of limited entry, individual quotas for fishers, and harvest refugia as a means to protect declining fish stocks. Fishers and fishery managers are also expressing concern at the increased loss of critical fish habitat as a result of human activities. Recent legislative changes are requiring fishery managers to more carefully consider habitat in fishery management plans.

More scientific information is needed to optimize catches from fisheries without depleting fish populations. Information is needed not only on population abundance and critical life history stages, but also on the interactions between species, the effect of harvest activities on marine habitats, and the effect of environmental change on marine fishes. Increased research is also needed to evaluate the design and effectiveness of current methodologies, and to develop new, more efficient management strategies. Although the abundance of many species has been stable for the last 15 years, some of those species had much higher abundances prior to 1980. More information is needed to determine if current fishing levels are keeping those populations depressed. In addition, the lack of information prior to the start of extensive harvest makes it difficult in some cases to determine if current populations are depleted.

The answer to the question about the status of fisheries in the Monterey Bay region is complex. Large-scale environmental changes alter the numbers of fishes in the sea on a cyclical basis. Fisheries reduce populations of marine fishes, especially relative to preharvest levels. Increased human use of the coastal zone also negatively affects fish populations by degrading spawning or rearing habitats. In the past 15 years, reported catches have increased or been stable for about 17% of the species frequently harvested in this region. Reported catches declined for about 10% of the frequently harvested species. Catches of other species are either unknown or highly variable.

The highly variable nature of the marine environment as well as historical evidence suggests that the risk of overharvest is high for numerous species. Historical evidence also suggests, however, that depleted populations are able to recover given appropriate management and protection. Commercial and recreational fisheries are also at risk because, to be economically competitive, they need community and governmental support for maintenance of port facilities. Commercial fishers need management flexibility as well; they have demonstrated an ability to survive economically by changing their operations to harvest species that are currently abundant. The challenge for our community is to maintain economically healthy fisheries by encouraging the responsible harvest of abundant species while protecting and rebuilding populations that are currently depressed.

Richard M. Starr
Korie A. Johnson
June 1997

Table of Contents

Introduction

Catch data compiled by the United Nations Food and Agriculture Organization indicate that the world catch of marine fishes increased rapidly in the 1960s and 1970s, then peaked in 1989. Subsequently, fishery declines have occurred in many of the world's most productive fishing grounds. Those areas have experienced not only diminished fish abundances, but also changes in species composition and ecological relationships. Overfishing, environmental change, habitat loss, and pollution have all been cited as reasons for the reduction in catches of fish.

The worldwide decline of fisheries and the formation of the Monterey Bay National Marine Sanctuary (MBNMS) in 1992 resulted in an increased interest in fisheries issues in this region, especially with respect to the status of local fisheries. Unfortunately, determining the status of a particular fish population is difficult, and the information needed to assess a localized fishery is often not readily available. Usually, fishery managers have little or no direct research-based information with which to assess the numbers of fish in a specific region and, therefore, rely on information derived from the fishery to estimate population sizes.

Fishery managers use data collected from commercial and recreational fisheries to infer population sizes or trends in fish abundance. They do this by developing indices and evaluating trends in those indices over time. Fishery data used for an index may include the amount of fish caught and sold at the dock (termed landed catch or landings), the rate of catch of a species (expressed as catch-per-unit-effort—for example, number of fish caught per hour), the average weight of fish landed, the average length of fish caught, or other biological information such as the sex ratio or mean length of mature fish. In addition to single indices, fishery managers develop and use population models to infer the status of fish stocks. Biological information, such as length at age by sex, is used with fishery catch data in mathematical models to estimate the number of fish caught by age category. Models are then used to develop scenarios for appropriate harvest rates for future years.

A large number of scientific documents, articles, and books have been written about the many variables that influence indices of stock abundance and population models. It is not our intention to fully describe or discuss the methods employed by fishery scientists to estimate the sizes of fish populations. Instead, we attempt to provide a summary of the population status of the primary fishery resources that are harvested in the MBNMS.

We chose to gather and display only information from the ports near the MBNMS (Fig. 1) as a construct for this overview of fisheries in the Monterey Bay region. Fish, fishers, and fishing vessels are mobile though, and fishery resources in this region cannot be fully understood without considering their distribution and harvest elsewhere as well. One of the most useful references for this purpose is *California's Living Marine Resources and Their Utilization*. Editors William Leet, Christopher Dewees, and Charles Haugen present a thorough description of marine resources in California. They describe fishery history, important biological characteristics of fishery resources, and the statewide status of many fish populations. The fishery data we display for catches prior to 1980 were obtained from their report.

We decided to follow the format and naming conventions of *California's Living Marine Resources and Their Utilization* as closely as possible, but to limit our narrative to the major species groups harvested in the MBNMS, and for which we have information regarding population status. We hope this parallel construction will help facilitate comparisons of fish populations in the MBNMS with those of the rest of California.

One of the reasons many people have problems understanding regional fisheries is that information related to the biology and fishery of the many species harvested is difficult to locate. Several different organizations and many different scientists collect the information about specific species or their fisheries. Thus, the information needed to evaluate the status of regional fisheries is located in many different places. Most of the commercial fishery information presented in this report originated from California Department of Fish and Game (CDFG) official landing records, which were graciously provided to us by the National Marine Fisheries Service (NMFS). We also obtained recreational catch information from the Pacific States Marine Fisheries Commission and from specific CDFG fishery biologists. Other biological and fishery catch information was obtained from published books, journal articles, and unpublished reports.

Some historical background is provided, but we focused on the years 1980–95. This time period contains the most comprehensive and accurate fishery information, and coincides with the time that some major fisheries around the world collapsed. Although detailed information is available for the last 15 years, population trends determined from that data set alone may be misleading. A level trend in the population estimates for a species during the period from 1980–95, for example, may mean that the population was robust and stable, or it may mean the fish stock was severely depressed before 1980. A severely depleted stock will remain at low levels if biological factors or fishing pressure prevent recovery. Also, a 15 year time period may not be long enough to adequately assess the population status of a species that is greatly affected by environmental variation. Nevertheless, the period from 1980–95 contains the most complete data set available, and provides an indication of trends or the current status of fishery resources in this region.

As resource abundance, markets for seafood, and technology have changed, so have the participants and target species of the fisheries. Although many changes have occurred, fisheries today remain a strong focus in our community. In addition to providing a summary of the status of fished populations, we briefly describe the types of commercial and recreational fisheries, and their economic values. We do not discuss the research and educational harvest of animals, or aquaculture ventures. Research and educational harvests are minimal; and although aquaculture is an important component of marine resource use, our objective was to focus on the commercial and recreational harvest of wild fishery resources.

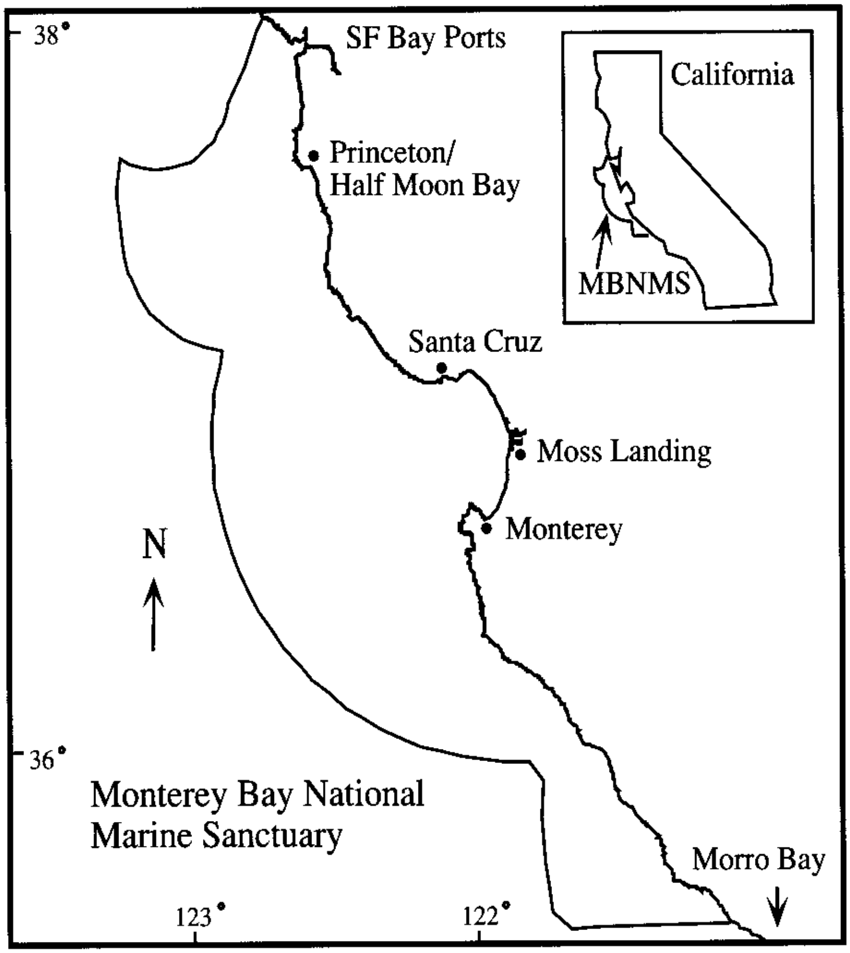


Figure 1. Location of the five major commercial fishing ports near the MBNMS.

Historical Perspective

The fishing industry has played a large role in the cultural and economic development of much of the central coast of California. In Monterey Bay, humans have been harvesting marine resources for over 7500 years. The Costanoan Indians fished year-round in Monterey Bay, both from shore and from small rafts, using seines, dipnets, weirs, harpoons, and basketry traps. From midden deposits, we know that they harvested numerous types of shellfish, nearshore fishes, and marine birds and mammals.

Beginning in the early 1800s, nonindigenous peoples visited this area to hunt for marine mammals. Russian vessels, often carrying Alaskan Aleut hunters, harvested sea otters for their fur. Intense hunting continued throughout the 1800s until the early 1900s when the otter population was nearly extirpated. The federal government gave sea otters protected status in 1911. The harvesting of whales also began in the early 1800s. Shore whaling in California was started at Monterey Bay in 1854 by Portuguese immigrants, and continued until the 1920s. Hunters targeted gray and humpback whales. Throughout this period, whaling stations were located along the entire coast of California, and several were within what is now designated as the Monterey Bay National Marine Sanctuary.

During the 1850s, local fisheries were established on the Monterey Peninsula. Chinese immigrants settled in Monterey and Pacific Grove and began harvesting large quantities of marine animals for drying and shipment back to China. Invertebrates, including abalone, urchins and mussels were harvested from intertidal and nearshore habitats. Small skiffs were used to fish for sharks and marine fishes. The Chinese settlers were also responsible for the initiation of the squid fishery. They used torches and hand-held purse seines deployed from skiffs to attract and capture squid. These early small-scale fisheries represent the beginning of a rich, post-Native American tradition of commercial fishing in the Monterey Bay area.

Historically, the majority of fish caught in what is now the MBNMS were landed in Monterey. In the early 1870s, the lighthouse at Point Piños was built, and the Monterey and Salinas Valley Railroad was completed. Subsequently, warehouses and wharfs were built and Monterey became a major commercial fishing port. The port of Moss Landing was created in 1865 when Captain Moss built a wharf to house several sailing schooners. Development of the port, however, was slowed due to the unprotected coastline and limited land transportation. Early in this century, the Santa Cruz harbor was known as a favorite summer beach resort, as well as an important commercial fishing port. Morro Bay's port didn't develop until the early 1900s, when wharfs were built and catches could be trucked to the canneries of Monterey. Princeton, formerly known as Old Landing, and now commonly called Half Moon Bay or Pillar Point Harbor, was developed not with commercial fishing in mind, but as a port for farmers to ship produce to San Francisco.

During the early 1900s, fishing gained economic importance in the area. Italian fishers came to Monterey Bay bringing their double-boat bottom seines, and later, large lampara nets. These new fishing techniques allowed for huge increases in squid landings and enabled new fisheries for northern anchovy and Pacific sardine. By 1918, the canneries that occupied the shoreline of Monterey, now referred to as Cannery Row, were producing 1.4 million cases of canned sardine per year. During the late 1930s, over 100 vessels, 19 canneries, and 20 reduction plants participating in the fishery provided hundreds of nautical and shoreside jobs. This economic boom continued until the 1940s and 1950s, when sardine and anchovy abundances began to decline. The decline is now attributed to a combination of environmental factors and excessive fishing pressure. By 1955, sardine and anchovy populations had crashed, the fishery in Monterey Bay had totally collapsed, and many of the canneries were closed.

During the 1950s and 1960s, fisheries for squid, salmon, and Dungeness crab gained in importance. Fishers who could no longer survive on sardine and anchovy catches used their lampara nets and purse seines to harvest squid. Monterey landings dominated the California squid fishery up until the early 1960s when southern California vessels entered the fishery. Salmon troll fishing, which originated in the 1880s, also grew extensively through the 1960s and 1970s. In 1980, a moratorium was placed on the issuance of permits to new participants.

Recreational fishing increased in the 1960s. Commercial Passenger Fishing Vessels (CPFVs) have taken people on chartered fishing trips since the turn of the century, but the charter fleet grew steadily during the 1960s and 1970s. About 33 charter vessels operate in the MBNMS today. Private boats also became increasingly popular during this period as small boats and motors became more affordable to the general public. Between the time periods 1958–61 and 1980–86, recreational fishing effort increased by 60%, due primarily to increases in the CPFV and private boat use.

Trawl fishing began in California in 1876 with the introduction of the paranzella, a net towed by two vessels. Throughout the early 1900s, most of the trawl fishing within the state occurred in central California. In 1946, the paranzella began to be replaced by the single vessel otter trawl, making trawling much more efficient and profitable. Increased demand for fish products during World War II initiated the widespread harvest of Dover and petrale sole, causing an expansion of the trawl fishery.

In the 1970s, trawl fisheries became a major component of local fisheries with the enactment of the Fisheries Conservation and Management Act of 1976 (FCMA or Magnuson Act). This legislation established a national fishery conservation zone (Exclusive Economic Zone or EEZ) extending from 3 to 200 nautical miles off the coast of the United States. Primary goals of the FCMA were to limit foreign catch within domestic waters, prevent overfishing by increased regulation of both U.S. and foreign fleets, and encourage the expansion of American fisheries. As a result, a system of regional committees was developed to manage domestic fisheries and foreign fishing was limited to species not otherwise utilized by American vessels.

After passage of the FCMA, the U.S. government began providing financial and technical assistance for the domestic fishing fleet, so that U.S. vessels could take advantage of all fish stocks in the U.S. EEZ. Easily acquired loans and tax deferments were made available to fishers who wished to expand or upgrade their fishing operations. These programs resulted in fishing fleets with larger and more efficient vessels that were capable of landing more fishes in a shorter amount of time. Coincidental to the passage of the FCMA, better technology enabled vessels to fish farther from port, remain at sea for longer periods, and locate and capture fishes more efficiently. Similar processes were seen in other countries as the world fishing fleet more than doubled in number between 1970 and 1990.

With this sudden expansion of fleet size and catching capability, U.S. fisheries shifted to deeper waters, thus increasing effort on groundfish species groups such as rockfishes and flatfishes. During this growth period, rockfish landings from the Pacific coast of the United States increased from 42–70% of total landings. Flatfish landings also increased, and sablefish landings doubled. Similar trends were seen in the Monterey Bay area during this time. Traditional species such as squid and salmon remained important, but increasingly larger vessels began targeting other species as well. The period after the enactment of the FCMA represents the start of the modern fishery and increased fishery regulations. Now, U.S. vessels have a high degree of fishing capability, most stocks are fully utilized, and fishery management is complex and intense.

History of Foreign Fishing

Prior to the FCMA of 1976, the only regulations on foreign vessels were those prohibiting the take of salmon, Pacific halibut, and Pacific herring. During the early 1960s, Japanese and Soviet trawlers began targeting large populations of Pacific hake and Pacific ocean perch off the west coast of the United States. Hake must be frozen and processed immediately in order to prevent the meat from degrading, so large (longer than 100 meters) ships were used to process and store the catch. These factory trawlers became numerous in U.S. waters. In 1967, more than 100 foreign vessels fished in domestic waters on the U.S. west coast, including some directly off Monterey Bay. By the 1970s, additional foreign nations were attracted to the profitable U.S. fishing grounds (including Japan, Poland, Bulgaria, West Germany, East Germany, Taiwan, and Korea). Between 1966 and 1978, annual groundfish removals by foreign countries ranged from 194 to 508 million pounds.

As a result of the FCMA, only foreign nations having a Governing International Fisheries Agreement, issued by the U.S. Congress, are now eligible to operate in American waters. Each permitted nation is provided a specific allocation of target species. Allocations are only provided for those species not otherwise utilized by U.S. fishers, and include Pacific hake, shortbelly rockfish, and jack mackerel. Pacific hake is the only species that has been consistently requested and sought by foreign countries. Further regulations restrict foreign fishing to areas north of 39° N latitude, near Pt. Arena, California, and between June 1 and October 31 of each year. Because of these restrictions, Monterey Bay has not been directly affected by foreign fishing since the early 1970s.

Historically, the foreign fishery consisted of two types of fishing operations: the trawl or directed fishery, and the joint venture fishery in which U.S. vessels caught fish and sold them at sea to foreign processors. After enforcement of the FCMA, foreign landings in the directed fishery dropped considerably, and continued to decline through 1981. Further declines occurred between 1982 and 1984 when the Soviet Union and Poland were prohibited from the fisheries for various political reasons. In 1985, sanctions were lifted and foreign landings again increased, remaining relatively stable through 1988. No allocations have been available for the directed foreign fisheries since 1988.

Joint venture fisheries began in 1978 when the FCMA reserved the Pacific hake fishery for U.S. fishers. At that time, most American vessels had neither the equipment to handle the immediate processing or storage, nor a market in which to sell hake. Joint U.S.–foreign ventures became the solution to this problem. U.S. boats caught the fish and sold it to larger foreign processors, thus providing domestic vessels with a market for their catches, and foreign vessels with fish for processing. Joint ventures grew steadily through 1989, and then declined as domestic processing became available. By 1991, foreign processing of Pacific hake by joint ventures was replaced completely by the domestic processing industry. There has been no foreign fishing in U.S. domestic waters since that time.

References

Fishery Conservation and Management Act of 1976 Fact Sheet. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Food and Agriculture Organization of the United Nations. 1992. Review of the state of world fishery resources, Part I. The marine resources. Food and Agricultural Organization of the United Nations Fisheries Circular No. 710, Rome, Italy.

Food and Agriculture Organization of the United Nations. 1993. Marine fisheries and the law of the sea: A decade of change. Food and Agriculture Organization of the United Nations, Fisheries Circular No. 853, Rome, Italy.

Gordon, B.L. 1996. Monterey Bay area: Natural history and cultural imprints. 3rd ed. Boxwood Press, Pacific Grove, CA. 375 pp.

Kemp, M.K. 1986. Cannery Row: The history of old Ocean View Avenue. The History Company, Monterey, CA. 125 pp.

King, K.A. 1985. Foreign and joint venture fishing operations off Washington, Oregon, and California, 1977–1984. National Marine Fisheries Service, North West Region Report.

King, K.A. 1990. Foreign and joint venture fishing operations off Washington, Oregon and California. National Marine Fisheries Service, North West Region Report.

Leet, W.S., C.M. Dewees, and C. W. Haugen. 1992. California's living marine resources. University of California Sea Grant, Davis. 257 pp.

Mangelsdorf, T. 1986. A history of Steinbeck's Cannery Row. Western Tanager Press, Santa Cruz, CA. 216 pp.

Pacific Fisheries Management Council. 1988. Magnuson Fishery Conservation and Management Act and fisheries management off Alaska. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Pacific Fishery Management Council. 1995. Status of the Pacific Coast groundfish fishery through 1994 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fisheries Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Swartz, S.L. and M.P. Sissenwine. 1993. Achieving long term potential from U.S. fisheries. Sea Technology, 34(8):41–46.

Vaughn, A.C. 1993. The state of groundfish resources off the northeastern United States. Fisheries 18(3):12–17.

Wall, J., R. French and R. Nelson, Jr. 1981. Foreign fisheries in the Gulf of Alaska, 1977–1978. Marine Fisheries Review 43(5):20–35.

Weber, P. Net loss: Fish, jobs, and the marine environment. 1994. Worldwatch Paper 120. Worldwatch Institute, Boston, MA.

Commercial Fisheries

Ports and Vessels

More than 1,000 commercial vessels fish within the MBNMS annually, but not all vessels fish year-round. A large number also fish in other parts of the state or nation, and enter MBNMS waters to catch and sell fish to local ports. The number of nonresident vessels fishing in MBNMS waters depends on species abundance, market price, and fish abundances in other locations. Many vessels switch gear types and target various species during different seasons or years, depending on abundance and demand for a given species. Except for a decline in the use of gill nets and an increase in the use of longlines caused by changes in regulations, the composition of gear types has remained steady for the time period from 1984–95 (Fig. 2).

Today, most fish caught within the MBNMS are landed at one of five main ports: Morro Bay, Moss Landing, Monterey Bay, Santa Cruz, and Princeton/Half Moon Bay. More than 80% of the commercial fish landings at these five harbors

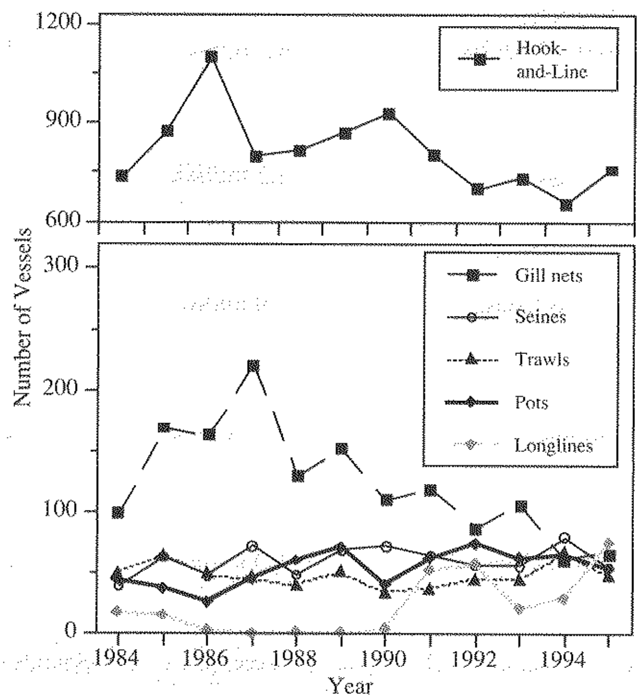


Figure 2. Number of vessels landing marine species in the MBNMS for different gear types used in the commercial fishery from 1984–95. Note that one vessel may use several gear types in a single year.

are comprised of squid, rockfishes, Dover sole, anchovy, mackerel, sardines, sablefish, albacore, and salmon. Landings at Monterey and Moss Landing are higher than at the other ports near the MBNMS, because of the large volume fisheries of squid, anchovy, and in recent years, sardine caught in southern Monterey Bay (Table 1). Princeton harbor does not receive as high a volume of fish, but has high landings of more valuable species such as Dungeness crab. At Morro Bay, fishery landings are approximately half that of Moss Landing, and include higher numbers of Dover sole and swordfish. Landings at Santa Cruz harbor, dominated by salmon, constitute a small percentage of total landings in the MBNMS. Only 5% of the main species groups caught within MBNMS waters are taken to ports outside of the area, although some vessels will land large catches in San Francisco.

Some vessels from local ports fish outside the MBNMS and then return home with their catches. This is especially common for Princeton/Half Moon Bay fishers who travel to fishing grounds north of the MBNMS boundary. Total catches from outside the MBNMS that are sold at Monterey Bay area ports equal approximately 9 million pounds. This is nearly 20% of the total landings at local ports. High value species landed at ports near the MBNMS but which are caught outside Sanctuary boundaries include salmon, sea urchin, albacore, and swordfish.

Gear Types

Commercial fisheries can be grouped according to type of gear used and species caught. There are five primary types of gear used in the

Table 1. Average Total Landings (lb), Average Economic Value, and Principal Species Landed at the Five Major Fishing Ports Near the MBNMS from 1980–95

Fishing Port	Average Total Landings (lb) 1980–1995	Average Economic Value ($) 1980–1995	Principal Species Landed
Princeton–Half Moon Bay	4.5 million	3.1 million	Market Squid Chinook Salmon Rockfishes Pacific Sanddab
Santa Cruz	1.2 million	860,000	Market Squid Chinook Salmon Northern Anchovy Rockfishes
Moss Landing	9.0 million	2.6 million	Market Squid Northern Anchovy Dover Sole Rockfishes
Monterey	16.2 million	2.8 million	Market Squid Northern Anchovy Pacific Sardine Rockfishes
Morro Bay	5.3 million	2.3 million	Dover Sole Rockfishes Sablefish

Note: Economic value equals exvessel price times pounds sold, not adjusted for inflation.

commercial fisheries that currently operate in the Monterey Bay region; each type of gear most effectively catches a specific species group. The primary gear types used include pots, trawl nets, hook-and-line gear, purse seines, and gill nets.

Pots or traps are fished in two ways. The most common method is to place a single pot at the end of a line that reaches to a surface buoy. Dungeness crab and spot prawn are captured with this method. Typical vessels in this fishery range from 10–20 meters in length, carry a crew of three people, and are rigged with a large, hydraulic winch and overhead hoist for lifting the large pots. The fishers string a baited container in a 1.5-meter-wide pot and leave it to soak for 1–3 days on soft bottoms that represent appropriate crab or prawn habitat (Fig. 3). At the end of the soak period, a vessel pulls the pot to the surface with the aid of the hydraulic winch. Legal animals are kept on board, nonlegal animals are returned to the water, and the pot is rebaited and sent back to the bottom. Vessels may fish several hundred pots at a time.

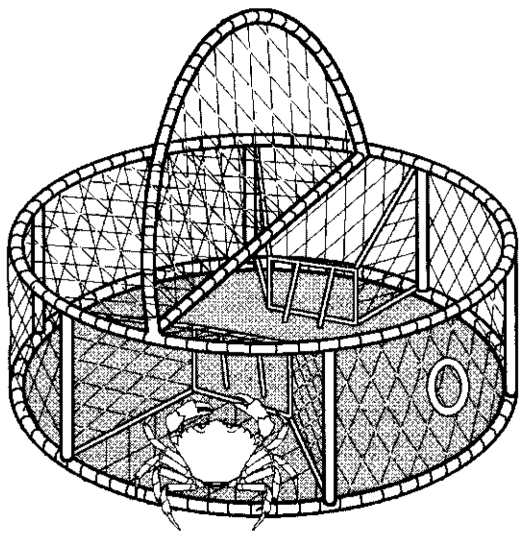


Figure 3. Commercial crab pot.

A second method of fishing pots is to attach a series of baited traps to a long ground line which is attached to a single buoy (Fig. 4). This method of fishing pots is used to catch sablefish, octopus, and hagfish. In the prevalent sablefish fishery, baited pots that are 2 meters long by 1 meter wide are either set out individually, or tied together in strings via a long ground line. They are also soaked for 1–3 days, then retrieved. In the last 12 years, an average of 53 vessels per year fished with traps from Monterey Bay ports (Fig. 2).

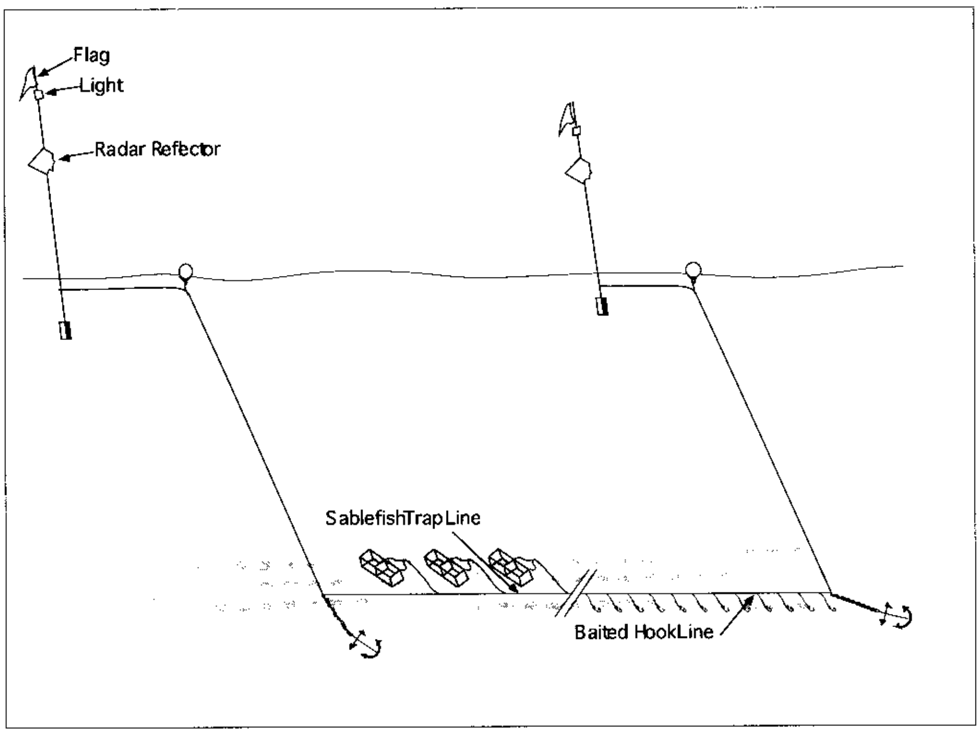


Figure 4. Longline gear used in sablefish trap and hook-and-line fishing operations.

From 1984–95, an average of 48 vessels per year fished with trawls from ports near the MBNMS. Trawl gear consists of many different styles of nets which fall into two general categories: bottom trawls and midwater trawls. Each targets a different group within the complex of groundfishes. The most common trawl net used in the Monterey Bay groundfish fishery is a bottom trawl net, also termed an otter trawl. Vessels in the bottom trawl fishery typically range from 20–30 meters in length, have a crew of 3–5 people, and tow trawls as large as 20 meters across at the opening. These nets are towed by a thick wire cable that is stored on large hydraulic winches on the back of the boat (Fig. 5). A bridle and set of wood or steel panels (termed doors) are placed at the terminus of the towing cable to force the mouth of the net open. The mouth of the net is bounded on the bottom by a heavy metal cable or weighted line (leadline) and on the top by a line with floats. As the net is dragged along the bottom, fish in its path are herded into the opening of the net and pushed to the back of the net (the codend of the net). Within this broad category of bottom trawls, different setups are used depending on the species being targeted and the preference of the vessel's skipper. For example, when targeting rockfishes over low relief rocky areas, rollers are added along the leadline to facilitate movement over rough terrain. Rollers may be several inches to several feet in diameter. Bottom trawls targeting flatfishes, such as sanddab and sole that typically lay on level sand or mud substrates, are often modified with a "tickler or sweep" chain. This chain drags along the soft sediments, chasing fish up off the bottom and into the net.

Midwater trawls are similar to bottom trawls, but are designed to fish within the water column and target such schooling fishes as widow rockfish and Pacific hake. Many of the midwater target species are fast swimmers that react quickly to disturbances. Thus, midwater nets are often much longer than bottom trawl nets, with a more tapered design, allowing them to be towed at higher speeds while producing low turbulence and drag. Midwater trawls also typically have a much larger mouth opening, both horizontally and vertically. This increases both the stability during operation and the area capable of trapping fish. Midwater trawl vessels are typically larger than bottom trawl vessels in order to handle the larger nets and higher towing speeds. They range from 25–35 meters in length.

Hook-and-line gear varies a great deal but generally consists of a series of baited hooks or lures that are either set and recovered at a later time or actively fished. An average of 837 vessels per year fished with hook-and-line gear from ports near the MBNMS from 1984–95 (Fig. 2). These vessels range in size from 7–20 meters in length, and have crews of 1–3 people. Smaller boats fish only on day trips, while the

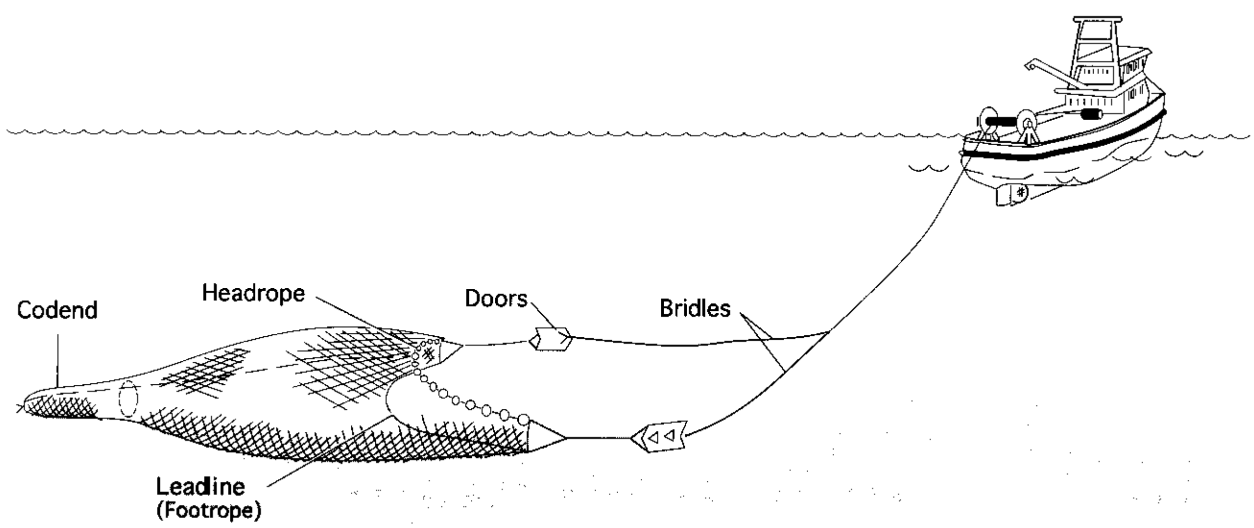


Figure 5. Example of trawl net configuration.

larger vessels can stay out for days at a time. Four major types of hook-and-line gear are in use in the Monterey Bay. The first of these is the long-line or set-line gear that is placed on the bottom. This gear consists of a line anchored at two ends with one end attached to a buoy at the surface (Fig. 4). A line with baited hooks or lures lays along the bottom between the anchors. Sablefish, rockfishes, and halibut are often caught with longline gear. A new type of set-line fishing has begun in the nearshore areas for the live fish market. In this fishery, termed tree or pipe fishing, a small boat is used to set numerous 2-meter-long plastic pipes along the bottom in shallow water. Each pipe is outfitted with 4–5 baited hooks.

A second type of longline gear is the vertical set or drift line, sometimes termed dinglebar or Portuguese longline fishing. This gear type consists of a fishing line weighted at one end with the other end attached either to the vessel or to a buoy. Baited hooks are arranged vertically in the water column. This gear is often not anchored to the bottom and is used in a drift or slow cruising mode. Often, this gear is used to fish for rockfishes that may be distributed vertically around pinnacles or over irregular rocky bottoms.

A third type of hook-and-line fishing, trolling, is designed to catch fast-swimming fishes such as albacore and salmon. Usually, flashy lures and bait are used in this type of fishery and are trolled behind the moving vessel on heavily weighted fishing lines. The lines are mounted on outrigger poles to ensure separation, and are controlled by small electric or hydraulic winches or gurdies (Fig. 6). Trolling vessels fish at various speeds and depths depending on target species.

A fourth type of hook-and-line gear, the traditional setup of a rod, reel, line, and hook or lure is used by small commercial fishing vessels in nearshore waters. Although commercial fishers will catch nearshore rockfishes with hook-and-line gear, it is far more prevalent in the sport fishery.

An average of 60 vessels per year fished with encircling nets such as purse seines and lampara nets from ports near the MBNMS between 1984 and 1995. The typical seine vessel averages 15–25 meters in length and has a hold capacity of 40,000–80,000 pounds. Crew sizes for these boats may be 5–7 people or more. Purse seines are the most commonly used encircling nets in this region. They are used in highly targeted fisheries such as those for anchovy, sardine, mackerel, and market squid. When a school of fish or squid is located, one end of the net is drawn away from the vessel by a skiff, while the main vessel steams in a wide circle. The size of the circle is dependent upon the size of the seine net, which is typically 200–400 meters long and less than 50 meters deep (Fig. 7). Once the end of the net is back on the main vessel, the

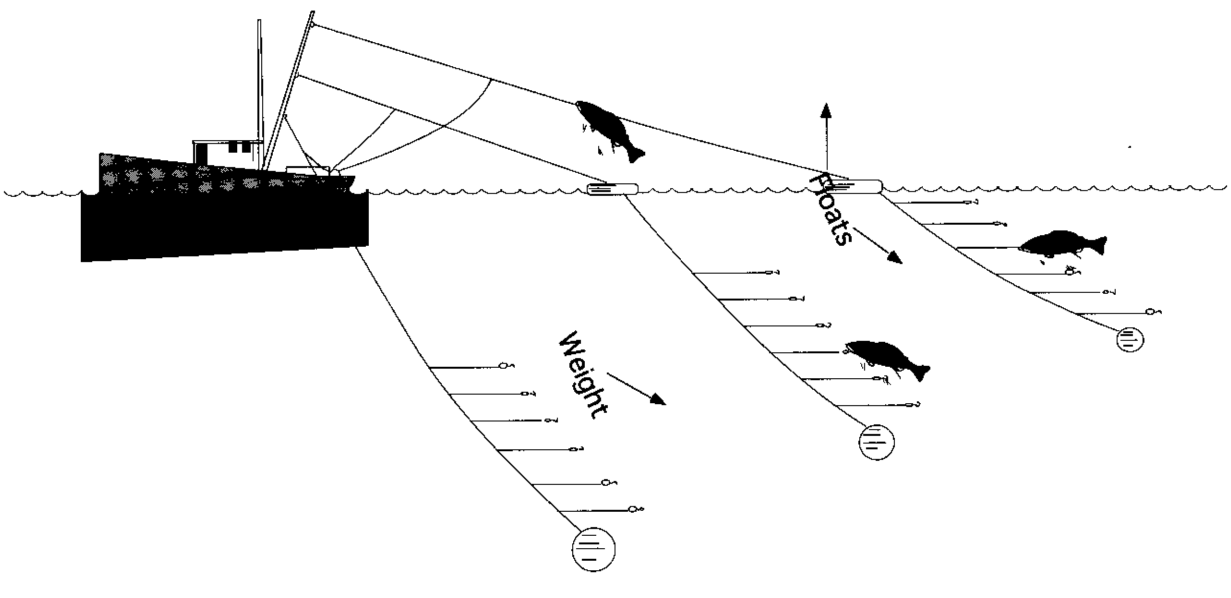


Figure 6. Example of troll fishing gear configuration.

weighted bottom edge of the seine is pulled (pursed) underneath the schooling fish, and most of the net is hauled aboard. The portion of the net known as the bag is strapped next to the boat and emptied using hydraulic pumps or large dip nets, called brails. In the squid fishery, the vessel deploying the purse seine is typically assisted by a second vessel that uses high intensity lights to attract the animals to the surface at night.

Gill nets consist of a single wall of webbing, usually made of monofilament line, bound at the top by a float line and at the bottom by a weighted line, and used for entangling fish by their gills. Gillnets can range up to 450 meters long and are deployed from smaller vessels (7–15 meters in length) using either bow or stern-mounted rollers (Fig. 8). Various sizes of net webbing are used for different target species. The primary species caught with gill nets and landed into ports near the MBNMS include deepwater rockfishes and swordfish. With the passage of California Proposition 132 in 1990, gill nets were restricted to federal waters, farther than three miles off the mainland and one mile from offshore islands. From 1984–90, an average of 155 vessels per year fished with gill nets from Monterey Bay ports. Since 1990, the average number of vessels fishing with gill nets has steadily declined.

Target Species and Landings

Close to 200 species of invertebrates and fishes were recorded in the commercial and recreational catches in this region from 1980–95 (Appendix 1). The species list provided in Appendix 1 was derived from a combination of the reported commercial landings, species composition analyses of commercial landings, and reported catches from recreational angler interviews. Appendix 1 thus may include some species which were landed, but not caught, in regional waters. It also includes only the larger invertebrate species which are commonly harvested in the recreational fishery. Undoubtedly, many more intertidal invertebrates are harvested in small numbers.

Commercial landing information is available for those species that were routinely caught and sold in this region from 1980–95 (Appendix 2). These data are derived primarily from records provided to CDFG by fish buyers. Thus, more than one species may be included in the poundage reported for a group. This lumping of landed catch into broad groups or market categories can pose a problem for the evaluation of trends in species abundance. State and federal fishery biologists resolve the problem by routinely collecting biological information on the species sold at the docks. Biologists obtain estimates of species composition of the landed catch by market categories. They then apply the ratios of species composition in the sampled market categories to the reported commercial landings to obtain estimates of the number and weight of individual species caught. Appendix 3 is an example of the results of this procedure; it provides estimates of commercial landings of individual rockfish species from 1980–95. Note that estimates of total rockfish landings from Appendix 3 do not match the totals from Appendix 2

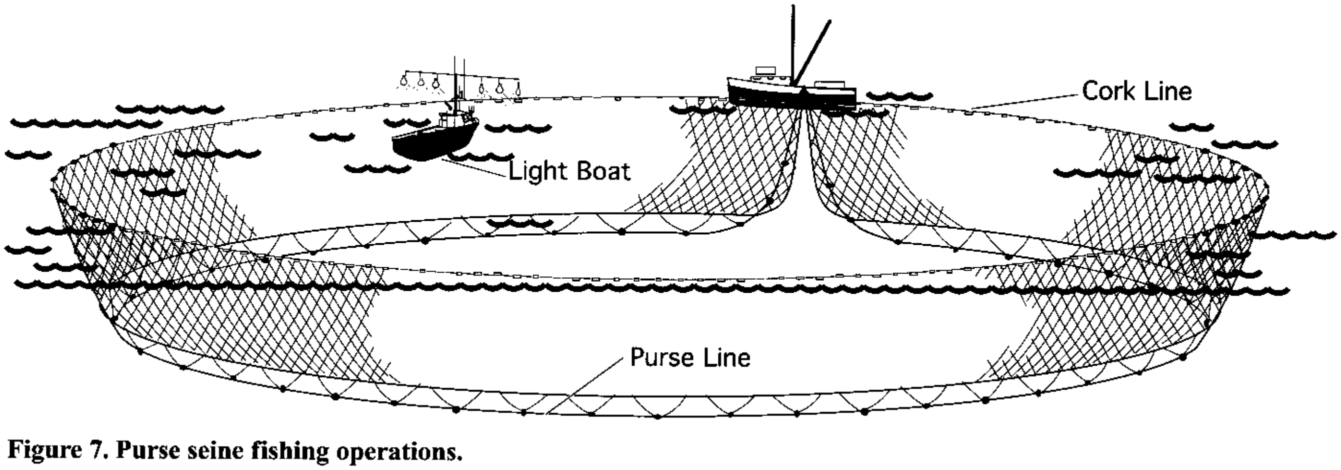


Figure 7. Purse seine fishing operations.

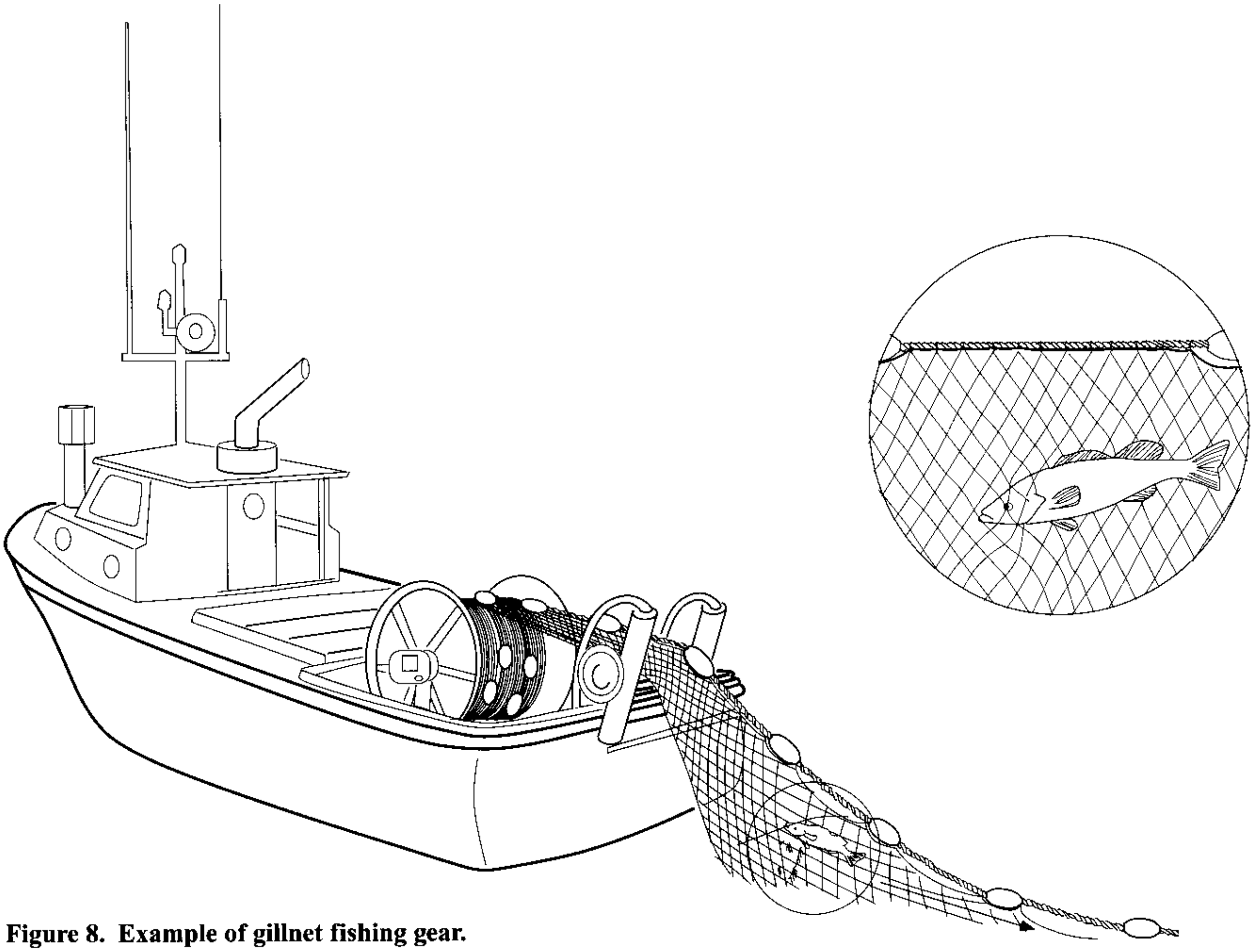


Figure 8. Example of gillnet fishing gear.

because the expansion procedures used by NMFS include rockfish landed and sampled in San Francisco as well as in other ports near the MBNMS.

More than 100 species are frequently caught (more than 1000 pounds/year or more than 1000 fish/year) in fisheries occurring in the MBNMS. For regional ports as a whole, 17 species or species groups exhibited significantly increasing trends in reported catch from 1980–95 (Table 2). Of these species, sardine and Dungeness crab landings are thought to be increasing because of improved environmental conditions, and catches of some of the races of Chinook salmon are increasing because of favorable environmental conditions and improved management activities. Sanddab, rex sole, and rock crab landings are increasing due primarily to increased market demand for those species. Thornyhead, aurora, greenspotted, cowcod, starry and rosy rockfish catches are probably increasing because of expanded fishing in deep water for rockfishes. Thornyhead catches are also increasing because of expanded fishing in deep water for rockfishes and because of increasing market demand. Catches of some nearshore rockfishes, such as kelp and vermilion are probably increasing due to increased fishing effort in the live-fish fishery.

Reported catches of 10 species or species groups exhibited significantly decreasing trends from 1980–95 when evaluated using linear regression techniques (Table 2). Landings of sablefish declined because of real declines in stock abundance, thought to be caused by over-fishing. Similarly, landings of bocaccio are declining because of high fishing pressure and poor annual survival of juveniles. Declines in landings of albacore are due to high catches

Table 2. Species for Which Landings in the MBNMS Increased, Decreased, or Were Highly Variable from 1980 to 1995

Species	Avg. Landing 1980–95	CV (% mean)	Regression Significance
Catches Increased 1980–95			
Pacific Sardine	1,831,668	189	**
Longspine Thornyhead	579,928	117	**
Rock Crab	202,923	60	**
Aurora Rockfish	87,630	100	**
Greenspotted Rockfish	81,285	76	**
Cowcod Rockfish	38,006	56	**
Starry Rockfish	21,964	119	**
Bluefin Tuna	6,542	165	**
Chinook Salmon	1,673,835	60	*
Dungeness Crab	401,031	72	*
Rex Sole	393,392	37	*
Vermilion Rockfish	158,765	63	*
Pacific Sanddab	19,987	303	*
Grass Rockfish	10,949	215	*
Turbot	6,850	64	*
Rosy Rockfish	6,453	168	*
Kelp Rockfish	3,887	177	*
Catches Decreased 1980–95			
Bocaccio	3,400,022	58	**
Sablefish	1,741,730	27	**
Albacore	1,741,351	108	**
White Croaker	434,182	54	**
Pacific Herring	177,250	92	**
Soupfin Shark	25,596	37	**
Smelt	9,076	93	**
Pacific Ocean Shrimp	381,069	101	*
Sand Sole	47,047	49	*
Pacific Butterfish	13,500	88	*
Catches Highly Variable 1980–95			
Cow Shark	1,431	384	—
Hagfish	68,728	321	—
Grenadiers	36,658	318	—
Tiger Rockfish	1,154	316	—
Silvergray Rockfish	1,292	312	—
Quillback Rockfish	2,312	286	—
Pacific Bonito	41,962	274	—
Thornyheads	154,515	269	—
Fantail Sole	2,023	259	—
Yellowfin Tuna	6,358	256	—
Spiny Dogfish Shark	1,361	248	—
Yellowtail	5,168	244	—
Ghost Shrimp	1,061	241	—
Butter Sole	3,195	228	—
Jack Mackerel	1,404,589	222	—
Shovelnose Guitarfish	1,033	219	—
Skipjack Tuna	1,423	203	—

* Regression Significant ($p<0.05$)

** Regression Highly Significant ($p<0.01$)

Note: Linear regression analysis was used to place species into significantly increasing or decreasing catch categories, and a coefficient of variation greater than 200% of the mean was used to determine if landings of a species were highly variable. Data were derived from CDFG landing records.

during El Niño years followed by lower catches in years with cooler water, not to changes in population size. The population size of Pacific albacore is currently thought to be stable or increasing. Catches of Pacific ocean shrimp are decreasing in the MBNMS for unknown reasons; environmental factors may possibly be to blame. Coastwide, populations of Pacific ocean shrimp have been strong in the past few years.

The remaining species or species groups demonstrated no significant trends in reported catch. Landings for some of these species from 1980–95 had coefficients of variation in excess of 200% of the mean, an indication that landings fluctuated greatly (Table 2). For species such as grenadiers and hagfish, the high variation in catch is caused by the newness of the fishery for those species. For species such as Pacific bonito and yellowtail, the variation results from El Niño environmental conditions, which resulted in some fishes moving northward into the MBNMS from their usual habitats further south.

Economic Value

Commercial fishing contributes to both the local and statewide economies. In 1994, commercial fishing in California accounted for $145 million in revenue from the dockside price paid to fishers (termed exvessel value). Ports within the MBNMS accounted for $17 million of that total (Fig. 9). Commercial fishing activities also provide additional revenue through indirect impacts. Indirect impacts include personal income and the purchase of goods and services related to commercial fishing. For example, fishers spend money for equipment, gasoline, gear maintenance, and crew members. These expenditures benefit a number of additional businesses including boat repair shops, marine supply stores, marinas, and the fuel industry.

Dr. Hans Radtke, an economic consultant to the Pacific Fishery Management Council, generated total impact estimates for 1994 for the primary species harvested within the MBNMS using his Fishery Economic Assessment Model. The species he used for analysis comprised about 90% of the catches sold to processors. Economic impacts were derived from input/output models and include direct, indirect, and induced income generated in the local economy by the fishing industry. Discussions of the methods for calculating impacts are included in the Pacific Fishery Management Council's annual salmon reviews. Readers unfamiliar with these methods are encouraged to refer to those documents.

Based on Dr. Radtke's calculations, the fishing industry in 1994 provided at least $53

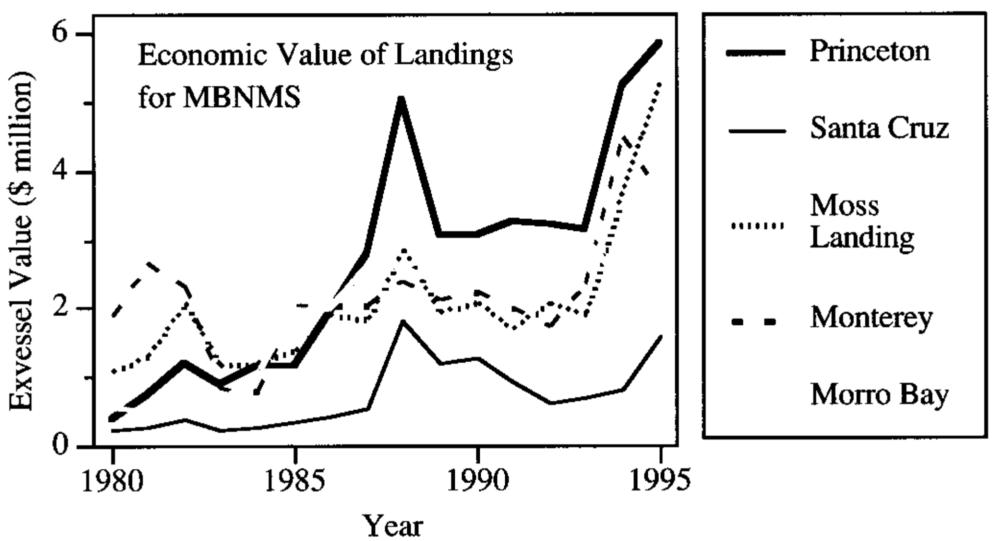


Figure 9. Economic value (exvessel price times pounds landed) generated for each of the major ports near the MBNMS from 1980–95. Economic values are adjusted for inflation to 1995 dollar value. Data provided by CDFG.

million and more than 2,000 jobs to local economies within the MBNMS. Monterey was the highest contributing port, with a total economic impact of at least $23 million, followed by Moss Landing and Princeton at $12.5 and $11.7 million, respectively. Morro Bay and Santa Cruz had much smaller economic impacts from commercial fishing. At least $4.7 million were generated at Santa Cruz, and $1.3 million were generated from Morro Bay.

By species, squid landings had the largest economic impact in 1994, providing more than $30 million to the local economy. Most of this income was generated from landings at Monterey and Moss Landing. Salmon was the next highest contributor, accounting for approximately $6.5 million in local income. The majority of annual salmon landings occur at Moss Landing and Princeton. Other economically important species include anchovy, rockfishes, sardine, Dover sole, Dungeness crab, and spot prawn.

Commercial fishing also benefits local economies by contributing to the success of other industries in the area. For example, commercial fishing provides a large benefit to exporting businesses. In 1995, seafood was ranked fifth in value of leading exports from California. Commercial fishing also creates cultural and economic benefits by creating a venue to which vacationers are attracted. The nautical atmosphere around harbors and marinas adds to local tourism, as do fish markets and restaurants featuring fresh, locally caught seafood.

Although commercial fishing is economically valuable, it accounts for only a small portion of the total economy, both statewide and locally. Much larger contributors include the tourism and agriculture industries. Agriculture, primarily in the Salinas and Pajaro valleys, is one of the largest industries in the Monterey Bay area, providing over 29,000 jobs. In 1994, agriculture was worth over $2 billion to Monterey County, and $246 million to Santa Cruz County. These values represent wholesale prices alone, and can be expanded by a factor of 3–5 times when indirect expenses and personal income are incorporated.

Tourism is another big industry along the central coast. In Monterey County alone, tourism accounted for almost $2 billion in combined direct and indirect impacts in 1994. This value includes 23,937 jobs and $422 million in personal income. In Santa Cruz County, tourism provided over 5,300 jobs, and $527 million in visitor spending and personal income. When combined, agriculture and tourism in 1994 provided over 35 times the economic value of commercial fishing to the Monterey Bay area. Included in the values for tourism, however, are the expenditures made by people who visit the area to fish recreationally, tour the harbors to see fishing boats, eat at seafood restaurants, or otherwise enjoy the cultural heritage provided by the fishing industry.

References

Amos, D. 1980. Single vessel midwater trawling: A basic guide to the theory, selection and operation of single vessel midwater trawls. University of Rhode Island, Marine Bulletin 43.

McWilliams, B. and G. Goldman. 1994. Commercial and recreational fishing in California: Their impact on the state economy. University of California, Division of Agriculture and Natural Resources, Publication CNR001.

Monterey County Crop Report. 1995. Monterey County Agricultural Commissioners Office, 1428 Abbott St., Salinas, CA.

Pacific Fishery Management Council. 1995. Economic status of the Washington, Oregon and California groundfish fisheries. Appendix F. *In:* Status of the Pacific Coast groundfish fishery through 1995 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201.

Santa Cruz County Committee for Economic Vitality. 1996. Office of Economic Development Program, report and program projection, June 1996. Report prepared for Santa Cruz County Board of Supervisors. County Administrative Office for Economic Development, Santa Cruz, CA.

Scofield, W.L. 1947. Drift and set line fishing gear in California. California Department of Fish and Game, Fish Bulletin 66. 41 pp.

Recreational Fisheries

Recreational fishing can be classified into six major groups: commercial passenger fishing vessel (CPFV), private/rental boat (skiff), beach and bank, jetty and breakwater, pier and dock, and spear fishing (Table 3). From the 1960–80s, recreational fishing in northern and central California grew substantially, with annual average catch increasing from 3.9 million fish in 1958–61 to 6.5 million fish in 1981–86, and annual fishing effort increasing by 65%. Although total catches have fluctuated, total fishing effort for all recreational fishing modes combined has remained relatively stable through the 1980–90s.

The Pacific States Marine Fisheries Commission (PSMFC) conducts annual surveys to collect data on recreational fishing catch, effort, and economic information through the Marine Recreational Fisheries Statistics Survey (Appendix 4). Anglers are interviewed directly at fishing sites for catch and fishing mode information. In addition, a telephone survey is conducted within coastal counties to interview fishers at home. These data have been collected since 1979, with the exception of 1990–92. Results from some years, however, are highly variable and less reliable. In addition, salmon catches, which are extremely important in the Monterey Bay area in some years, are not included in the information.

Results from the Marine Recreational Fisheries Statistics Survey suggest that shore fishing is the most common form of sportfishing in northern and central California. This is to be expected, as fishing from shore is the most easily accessible and least expensive form of fishing. The three modes of shore fishing, beach/bank, jetty/breakwater, and pier/dock, when combined, accounted for about half of the annual catch and fishing effort from 1981–96 (Table 3). The beach/bank method comprised over one-half of the annual shore catch and fishing effort. Numerous species are caught in the shore fishery, but target groups of species usually include surfperches, rockfishes, and flatfishes.

Private/rental boat fishing accounted for the highest average annual catch and effort for a single fishing mode from 1981–96 (Table 3). An estimated 40,000–50,000 boats/yr are launched from boat ramps at the five ports near the MBNMS. Many of these vessels are used in the recreational fishery. This fishing mode

Table 3. Average Annual Total Catch, Effort, and Primary Species Caught in Northern California for Each of the Major Sportfishing Modes From 1981–96

Fishing Mode	Avg. Catch (No. Fish) 1981–96	Avg. Effort (No. Trips) 1981–96	Primary Species Caught
Commercial Passenger Fishing Vessels (CPFV)	1.8 million	287,000	Rockfishes, Lingcod
Private/Rental Boat (PRB)	2.6 million	972,000	Rockfishes, Lingcod
All Shore Fishing (Beach/Bank, Jetty/Breakwater, Pier/Dock)	3.4 million	1.3 million	Surfperches, Smelts, Flatfishes, White Croaker, Kelp Greenling, Herring
Spearfishing	?	?	Lingcod, Rockfishes, Cabezon

Note: No data were available for 1990–92. Salmon fishing effort and catches are not included. Data provided by the PSMFC.

targets the same species as CPFVs, including salmon, rockfishes, halibut, and lingcod, but the private/rental boat average annual fishing effort is more than three times greater than that for the CPFV fishery. The average annual catch, however, is less than twice as high, most likely a result of CPFV skippers being more knowledgeable and adept at finding good fishing grounds.

CPFVs constitute the most economically important category of recreational fishing, accounting for a multimillion dollar business and well over 1 million angler trips per year off the west coast of the United States. Landings from CPFVs have been sampled by the California Department of Fish and Game since the 1950s. Popular target species in northern and central California are salmon, rockfishes, lingcod, and halibut. Albacore are also targeted in some years.

Primary Target Species

Generally, recreational fishers will catch what they can, but often attempt to catch highly prized species such as salmon, lingcod, and large rockfishes. Rockfishes are the most abundant fishes in recreational catches and are targeted most frequently. During the appropriate times of year, however, a large amount of recreational fishing effort is aimed towards salmon, one of the most popular sportfishing fisheries in central California.

Recreational fishing for salmon has been an important component of marine sport fisheries since the late 1800s. In the Monterey Bay region, almost all salmon caught are Chinook salmon, many of which originated from the Sacramento River basin. Between 1986 and 1994, an average of 26,500 Chinook salmon were caught annually in the recreational fishery. During 1995 alone, however, over 183,000 angler trips, accounting for a total catch of over 198,000 fish, were recorded in the Monterey Bay area ocean recreational salmon fishery. This was the largest recorded catch and effort in 30 years. The recreational salmon fishery is open during spring and summer months, typically between March and November. During these months CPFV and private boats leave harbors daily to target salmon. The most common and successful method of fishing for salmon is trolling.

Rockfishes are fished year round and comprise over 50% of the recreational catch in central California. The PSMFC estimates total sportfishing catch for rockfishes, in 1995 alone, at over 1.1 million fishes in northern and central California. Average rockfish catch is 10 fish per angler trip for fishers aboard CPFVs and 5–6 fish per angler trip for fishers aboard private/rental boats. Rockfishes are also caught from shore, but catch rates are considerably lower.

Economic Value

Although fewer fish are caught in the recreational fishery, it has a larger impact on California's economy than does commercial fishing. Indirect activities related to recreational fishing such as the purchase of fishing equipment, use and storage of boats, food, lodging, and transportation are responsible for the difference in revenues provided by recreational and commercial fishing. In 1985 alone, resident and visiting recreational fishers spent $2.2 million on indirect costs related to fishing in California. These indirect activities also created thousands of jobs and billions of dollars in personal income, which greatly surpass the economic benefits from commercial fishing. In California, recreational fishing annually provides communities with approximately $5 billion in personal income and more than 150,000 jobs.

References

Amos, D. 1985. Trawl fisherman's gear technology manual. University of Alaska Sea Grant Report 85–10. 80 pp.

California State Lands Commission. 1994. California comprehensive offshore resource study. Vol I.

Feinberg, L. and T. Morgan. 1980. California's salmon resource: Its biology, use and management. Sea Grant Report Series No. 3. California Sea Grant College Program No. 72.

Hollowed, A.B. and W.S. Wooster. 1992. Variability of winter ocean conditions and strong year-classes of Northeast Pacific groundfish. International Consortium for the Exploration of the Sea, Marine Science Symposia 195:433–444.

Karpov, K.A., D.P. Albin, and W.H. Van Buskirk. 1995. The marine recreational fishery in northern and central California. California Department of Fish and Game Fish Bulletin 176. 192 pp.

Kope, R.G. and L.W. Botsford. 1990. Determination of factors affecting recruitment of Chinook salmon *Oncorhynchus tshawytscha* in central California. U.S. Fisheries Bulletin 88:257–269.

Mason, J.E. 1995. Species trends in sport fisheries, Monterey, CA, 1959–86. Marine Fisheries Review 57(1):1–16.

McWilliams, B. and G. Goldman. 1994. Commercial and recreational fishing in California: Their impact on the state economy. University of California, Division of Agriculture and Natural Resources, Publication CNR001.

Pacific State Marine Fisheries Commission. 1997. Commercial and recreational fisheries statistics published on world wide web at www.psmfc.org. PSMFC, Portland, OR.

Reilly, P.N., D. Wilson-Vandenberg, D.L. Watters, J.E. Hardwick, and D. Short. 1993. On board sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, May 1987 to December 1991. California Department of Fish and Game Administrative Report 93–4.

Sullivan, C.M. 1995. Grouping of fishing locations using similarities in species composition for the Monterey Bay area commercial passenger fishing vessel fishery, 1987–1992. California Department of Fish and Game Tech Report 59.

Wilson, C.E., LA. Halko, D. Wilson-Vandenberg, and P.N. Reilly. 1996. On board sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California. California Department of Fish and Game Administrative Report 96–2.

Wilson-Vandenberg, D., P.N. Reilly, and L. Halko. 1995. On board sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1993. California Department of Fish and Game Administrative Report 95–2.

Fisheries Management

Concepts

The goal of fisheries management is to maintain healthy fish populations while providing social and economic benefits from fisheries. Management strategies are thus based upon a complex array of social, economic, and ecological concerns which must be addressed when decisions affecting a fishery are made.

An implicit assumption of management is that fishes represent renewable resources which can maintain population levels when subjected to limited harvesting on a continual basis. This assumption relies on the concept that fish populations have a surplus production which is available to be harvested. In theory, in an unfished population, the biomass (total weight) of fish in a habitat will approach a theoretical carrying capacity for that habitat. Older fish will dominate the habitat and their presence prevents all but a small percentage of the young fish produced each year from surviving to reproduce. Following this logic, if some larger, older fish are removed from the habitat, there will be room for a greater number of younger, faster growing fish to take their places. These new fish thus represent a harvestable portion of the stock because they represent a spawning biomass above and beyond that needed to maintain stock levels (Fig. 10). Although this theory is logical, the processes affecting adult mortality, adult growth and reproductive output, and juvenile survival are highly variable and make equilibrium population size a concept, not a static number.

Stock Assessments

Fishery scientists determine the health of fish populations by conducting stock assessments. Stock assessments combine available biological data with information about fishing activities to assess trends in fish abundance. There are several approaches to gathering information for stock assessments. One of the primary methods involves examining annual records of catch and fishing effort. Fishery biologists divide the amount of fish caught and sold at the dock (landings) by the amount of fishing time expended in the fishing process. The resulting number is termed catch-per-unit-effort (CPUE) and is often used as an index of abundance.

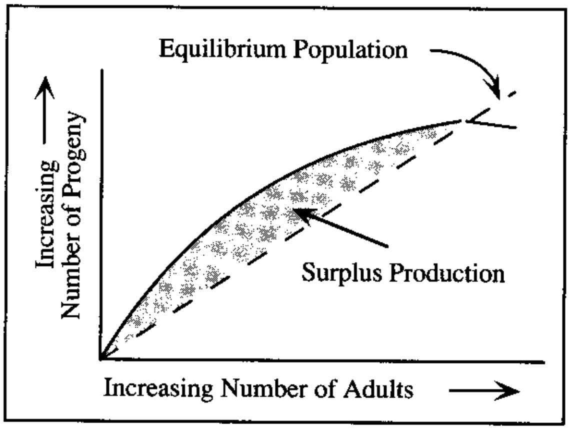


Figure 10. Theoretical relationship between numbers of adults in a fished population and the number of progeny produced. Dashed line represents number of adults needed to maintain the current population size. Hatched area represents number of fish that are considered to be surplus, and thus can be harvested without depleting the population.

As with all methods for assessing the status of a stock, reviewing catch records is not a perfect approach. A primary drawback to this approach is that it relies on indirect evidence of population size and is not a direct measurement of fish abundance. Catch records alone are insufficient to define the health of a stock because catches can fluctuate for a variety of social and economic reasons that are independent of fish abundance. A less obvious problem of using catch records is the difficulty and expense of gathering reliable data on fishing effort.

Fishery scientists also use biological information in stock assessments. The age structure of a stock provides a historical as well as contemporary view of the stock. It shows information about the current status of the stock and gives clues to events in the past that have led to the changes in that status. The shape of the age frequency distribution can also provide evidence that a stock has been overfished. Some other pieces of information that can be obtained from catch curves are: age at first entry into the fishery (recruitment), estimates of longevity, year-class strength, and estimates of total mortality. Obtaining an estimate of total mortality from catch curves is a critical component of many fishery stock assessments. Total mortality is the combination of mortality due to natural causes and mortality caused by fishing efforts.

The age at first reproduction and the size and age structure of a population are two important biological indicators of the health of fish stocks. For example, if the average length of a given age of fish decreases over time, managers assume that growth overfishing is evident. Growth overfishing occurs when fisheries catch most of the older fish or larger, faster growing fish at a given age. The result is that younger and slower growing fish are left to reproduce. After several generations, only younger and slower growing fish remain in the population. The result is a lowered mean length and weight per given age of fish, and a reduced value of the fishery.

Recruitment overfishing is of greater concern to fishery managers. For example, if most of the fish in a stock spawn for the first time when they are 10 years old, and many of the fish caught are less than 10 years old, then the potential exists to catch a large proportion of the stock before a majority of animals can spawn. This is a form of recruitment overfishing, which means more fish are removed from the stock than can replace themselves. When this type of recruitment overfishing is evident, managers often move to protect the smaller fish by imposing minimum size limits or mesh-size restrictions in an effort to conserve the spawning stock. Unfortunately, protecting small fish does not necessarily prevent another type of recruitment overfishing. Recruitment overfishing also occurs when the fishery harvests too many large, old fish. This reduces the production of larval fish because smaller fish produce fewer eggs than larger fish.

Once the status of a stock is known, fishery managers employ a variety of techniques to maintain the health of the stock. These include use of one or more of the following management strategies:

1. Fishing gear restrictions or prohibitions,
2. Fleetwide quotas on total fish taken per season,
3. Seasons and/or area closures (e.g., refuges),
4. Individual quotas on total fish taken (e.g., commercial: IFQs, recreational: bag limits),
5. Size, species, or sex limits, or
6. Restricting or limiting access to a fishery.

Once these strategies have been enacted in the form of regulations and are enforced in the respective fisheries, fishery scientists have a variety of tools at their disposal to assess whether a fishery has met or exceeded allowable biological catch or is presently underutilized. Models are also available to evaluate the performance of a fishery relative to some estimate of optimum economic yield. Most of these methods and models involve some fairly sophisticated mathematical derivations based on mortality rates and age structure of the population. Unfortunately, even with the array of tools used by fisheries managers, many species are being overfished. There are many reasons for this, some of which are:

1. Difficulties in obtaining accurate information about species that are landed. Most species sold at the dock are recorded as belonging to a market category. For instance, the "red" rockfish category recorded by fish buyers can contain species such as vermilion rockfish, starry rockfish, or canary rockfish, which have different life histories and stock sizes;

2. Difficulties in obtaining adequate biological data, and accurate catch data from fishers, especially for new or emerging fisheries;

3. Absence of long-term data sets needed to effectively model or estimate the size of fish stocks. Unfortunately, few long-term data sets are available for fished populations. Much of what is known or suspected about Monterey Bay species is derived from relatively short-term data sets. In addition, many of those short-term data sets reside in a variety of locations and are not easily collected for analysis;

4. Difficulties in managing mixed fisheries, or fisheries in which more than one species is caught at the same time. In these cases, management options are more limited if the stock of one of the species caught is healthy while the other is depleted;

5. Spatial and temporal variation in fish abundance, leading to localized depletions;

6. Environmental changes that affect survival of year-classes;

7. Difficulties in estimating bycatch and discard of animals inadvertently caught while fishing for the target species;

8. Societal desire to maximize short-term economic gain to coastal communities; or

9. Overcapitalization of the fleet (too much fishing power), causing the total allowable catch to be exceeded before managers can close the fishery.

Regulatory Process

In the United States, most fish stocks are a common property resource, meaning there is open access for utilization of the resource. Often in the case of common property resources, many harvesters tend to maximize their short term benefits, without regard to long term costs. When this occurs, each participant in the fishery has little incentive to conserve the resource. If they do not harvest their share or more, the resource will simply be harvested by another fisher. Historically, common property resources have thus been subject to inadvertent overexploitation, a phenomenon that has been called the "tragedy of the commons."

This situation, combined with the substantial social, economic, and ecological impact of fisheries, provides the rationale for fisheries management. Regulations pertaining to the commercial harvest of species are derived from a combination of federal statutes and state law. Fisheries for species that are migratory in nature, occur entirely in federal waters, or that have wide distributions are regulated by federal laws administered by the National Marine Fisheries Service. Fisheries for the species that occur entirely within state waters are regulated by the California Fish and Game Commission and the state legislature.

In cases where there is no state law or where state and federal laws overlap, federal statutes usually take precedence. In special cases, such as for some salmon species and for specific ecological reserves, local or tribal regulations provide guidance for fishery managers. An additional special regulatory process occurs when a stock of fish is harvested by more than one nation. In these cases, international fishery management councils may be established. Often, when just two countries are involved, fishery management will be determined through a treaty process. In some cases, the two nations do not agree on stock estimates or management strategies and the fishery is regulated by both (or neither) country.

Pacific Fishery Management Council

The Pacific Fishery Management Council (PFMC) was one of eight regional councils created by the Magnuson Fishery Conservation and Management Act of 1976 (FCMA). The PFMC has responsibility for federal fisheries management on the U.S. West Coast. It advises NMFS on fisheries management issues for California, Oregon, Washington, and Idaho. The voting members of the council include a representative from each state fishery management agency on the West Coast (including Idaho), a mandatory appointee from each state, at-large appointees from the states in the region, and the regional director of NMFS. The councils produce fishery management plans with public input, which describe the nature and problems of a fishery along with regulatory recommendations to conserve it. After approval by the Secretary of Commerce, regulations that implement management measures in the plans become federal law and are enforced by NMFS and state agencies (Fig. 11).

The Magnuson Act sets standards with which all fishery management plans must comply. Management plans must include conservation

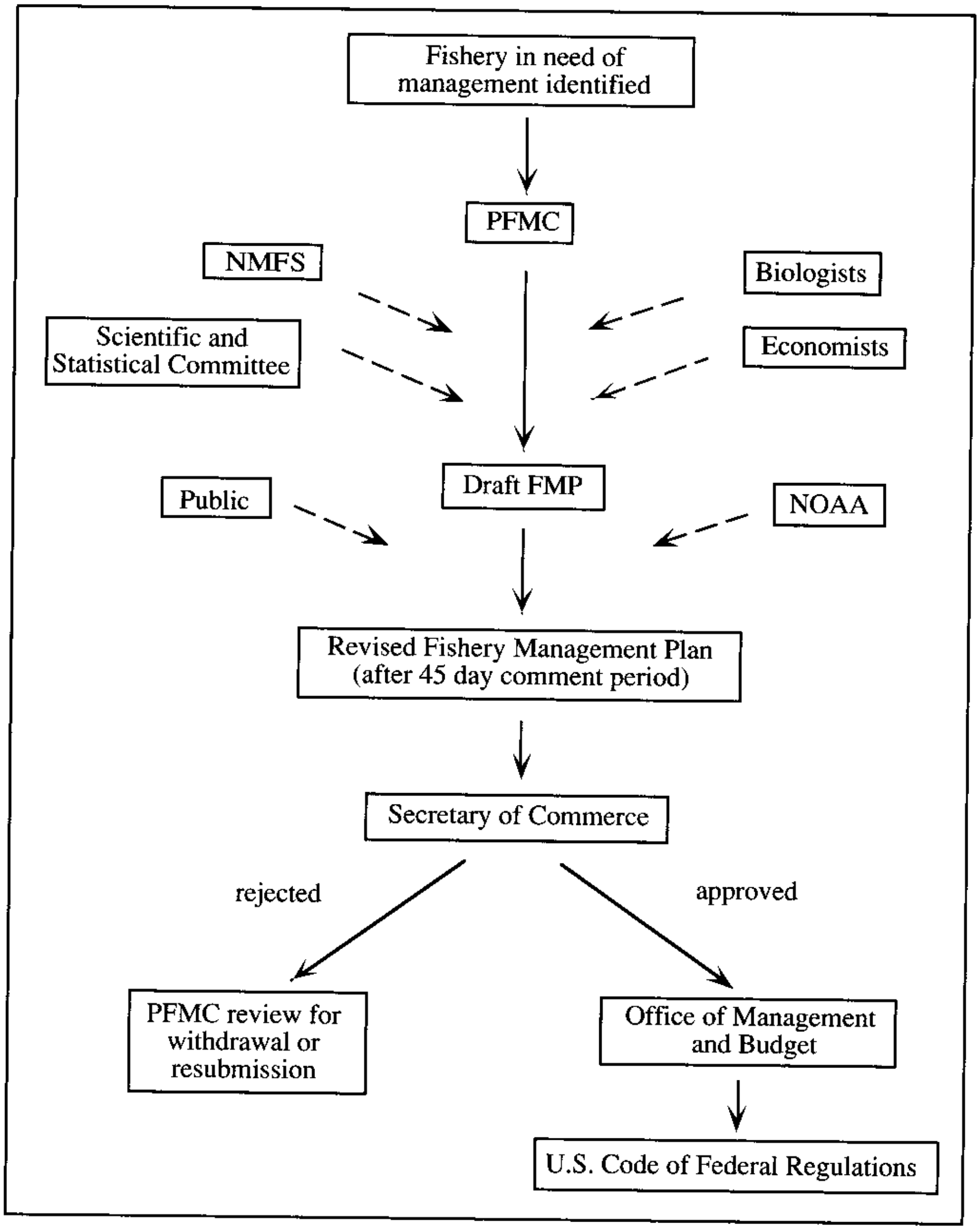


Figure 11. Fishery management process for a federally managed species.

and management measures that prevent overfishing while maintaining optimum yield from the fishery. Optimum yield can be defined as the sustainable amount of fish harvested from a fishery which will provide the greatest overall benefit in terms of food production and recreational opportunities as modified by any relevant economic, social, or ecological factors. The Magnuson Act also requires that all fishery management plans be based on the best scientific information available.

Fishery management plans must clearly define overfishing and outline actions to prevent it, or when it already exists, must propose actions to rebuild the stocks in a definite period of time. Overfishing can be defined in several ways but must be measurable. Some measurable indicators of overfishing are: exceeding predetermined catch limits, a reduction of spawning biomass, a decline in fishery catch rates, or a shift in population age structure away from a stable age distribution.

In 1996, the U.S. Congress reauthorized the FCMA with specific amendments addressing current fishery concerns. Modifications were made in the limited access and individual quota programs, including the use of fees and the development of a central administration. The reauthorized FCMA also enforces stricter limits on acceptable catches and further limits bycatch and discards. The council addressed the issue of overfishing and authorized a fishing capacity reduction program, if developed under specified provisions. In addition, the new FCMA now requires a publication list of all fisheries under each council and all gear used in such fishing. The new law also addresses environmental and habitat concerns. NMFS is now mandated to amend all fishery management plans to include identification of essential fish habitat, to identify existing and potential adverse impacts on that habitat, and to ensure the conservation and enhancement of essential fish habitat.

National Marine Fisheries Service

The National Marine Fisheries Service is part of the National Oceanographic and Atmospheric Administration, an agency in the U.S. Department of Commerce. It is the federal agency with primary responsibility for implementing fisheries management strategies in the U.S. Exclusive Economic Zone from 3 to 200 miles from shore. NMFS has a broad array of duties relating to marine resource management. A primary responsibility is to provide scientific information for use in fishery management plans. NMFS researchers conduct field surveys to gather basic biological data, publish scientific articles, and learn about the variables that influence survival at critical stages in the life history of a species. They collect information about critical habitats for a species as well. Additionally, NMFS scientists model population dynamics of species, using data from research cruises and fishery landings. The models are then used to develop stock assessments, which are delivered to the NMFS staff that supports the PFMC regulatory process. Once fishery management plans are enacted, and regulations promulgated, NMFS fishery enforcement officers work with the U.S. Coast Guard and coastal states to enforce regulations.

California Department of Fish and Game

The California Department of Fish and Game has primary management responsibility for species that occur entirely within the state's three mile territorial sea, and also those that are not managed by the federal government. CDFG has several important functions in the process of fishery management within the state. One of their primary duties is to regulate fishing activity through licensing of fishing vessels and fishers. CDFG is responsible for the enforcement of existing statutes and regulations regarding fisheries within the state. CDFG also collects a great deal of fishery data by monitoring regional fisheries, both aboard vessels and dockside. The data collected from these monitoring programs are used to make recommendations to the PFMC and State Fish and Game Commission, publish scientific articles, maintain long-running databases of catch statistics for all regions, and produce annual commercial and recreational fishing reports.

Following preparation of a fishery management plan by PFMC and subsequent approval by the U.S. Secretary of Commerce, the director of the Fish and Game Commission for the state of California has several options to conform state law or regulations to the fishery management plan. These options center on the ability of the director to either suspend existing laws and regulations that conflict with the fishery management plan, modify existing laws and regulations to conform with the fishery management plan, or enact new laws for a limited period (up to one year) to comply with the fishery management plan. In rare cases, the state will choose to enact regulations which do not comply with fishery management plans.

Pacific States Marine Fisheries Commission

Authorized by Congress in 1947, the Pacific States Marine Fisheries Commission (PSMFC) is one of three interstate commissions dedicated to resolving fishery issues. Representing California, Oregon, Washington, Idaho, and Alaska, the PSMFC does not have regulatory or management authority; rather it serves as a forum for discussion, and works for coastwide consensus on management strategies. PSMFC also addresses issues that fall outside state or regional management council jurisdiction. The goal of PSMFC is to promote and support policies and actions directed at the conservation, development, and management of fishery resources of mutual concern to member states through a coordinated regional approach to research, monitoring, and utilization. It plays an important role on the West Coast by being the primary agency responsible for collecting, storing, and providing fishery data from each state for coastwide analysis.

Fishing Organizations

Fishing organizations play an important role in fishery management. In addition to information generated from fishery logbooks, many fishers work closely with researchers and fishery managers to design studies and collect information necessary to craft effective fishery regulations. Often, fishing organizations help by encouraging their members to collect and provide additional information for managers.

In addition to numerical data, fishers provide information on the practical aspects of fisheries. Often, state and federal fishery plans and regulations can have several different designs that meet similar management objectives. Individual fishers and fishing organizations provide resource managers with ideas for regulations to maximize economic returns or to improve the flexibility of fishing options. In this manner, input from fishers often helps make management actions more practical and enforceable.

Public Involvement

Recommendations on plans affecting federally managed species are made to PFMC by the state legislature, CDFG, NMFS, environmental organizations, and the general public. Public hearings are required by law to be held in the area of the fishery under consideration after recommendation of a fishery management plan by PFMC to the Secretary of Commerce. It is the responsibility of the director of the Fish and Game Commission to arrange times and places for the public hearings as well as provide adequate notice to the public and appropriate policy committees in the state legislature.

Special Management Areas

In addition to state and federal fishery management, there are a few areas within the MBNMS that are managed by other governmental organizations. A total of 18 marine protected areas exist in the area bounded by the MBNMS (Table 4). The majority of these protected areas are small and adjacent to shore. They were established by local jurisdictions for a specific management purpose, such as providing protection for species associated with a heavily used intertidal area. Regulations governing these areas are predominately established by city or county governments. In most cases, the harvest of selected species or species groups is prohibited. Where harvest is allowed, regulations usually follow state fishing regulations.

The largest reserve designed for fisheries management in this region is the Big Creek Ecological Reserve along the Big Sur coast. It

Table 4. Marine Protected Areas Within or Adjacent to the MBNMS

Año Nuevo Area of Special Biological Significance
Big Creek Marine Resources Protection Area Ecological Reserve
California Sea Otter Game Refuge
Carmel Bay Area of Special Biological Significance
Carmel Bay Ecological Reserve
Elkhorn Slough National Estuarine Research Reserve
Golden Gate National Recreation Area
Hopkins Marine Life Refuge
James V. Fitzgerald Marine Reserve Extension Area of Special Biological Significance
James V. Fitzgerald Marine Reserve (Marine Life Refuge)
Julia Pfeiffer Burns Area of Special Biological Significance
Julia Pfeiffer Burns State Park
Ocean Area Surrounding the Mouth of Salmon Creek Area of Special Biological Significance
Pacific Grove Marine Gardens Fish Refuge and Hopkins Marine Life Refuge Area of Special Biological Significance
Pacific Grove Marine Gardens Fish Refuge
Point Lobos Ecological Reserve Area of Special Biological Significance
Point Lobos Ecological Reserve
Point Lobos State Reserve

Note: Terrestrial state parks are not included in this list. Data provided by D.A. McArdle, California Sea Grant Extension Program.

was established in January 1994 for the purpose of scientific fisheries research, and prohibits all sport or commercial fishing. A common misconception is that the largest marine protected area in this region, the Monterey Bay National Marine Sanctuary, has regulatory authority with respect to fisheries. This is not the case. MBNMS rules specifically state that traditional commercial and recreational fisheries are allowable uses in the MBNMS, and that the MBNMS has no authority to manage fisheries. The MBNMS does have an indirect role in fishery management by protecting habitat and encouraging research.

References

California Department of Fish and Game. 1996. California sport fishing regulations. Fish and Game Commission, P.O. Box 944209, Sacramento, CA 94244-2090.

California Department of Fish and Game. 1996. Digest of California commercial fish laws and licensing requirements. Fish and Game Commission, P.O. Box 944209, Sacramento, CA 94244-2090.

Dewees, C.M. and E. Ueber. 1990. Effects of different fishery management schemes on bycatch, joint catch, and discards. Summary of a national workshop sponsored by the California Sea Grant College System and National Marine Fisheries Service. Sea Grant College Report T-CSGCP-019.

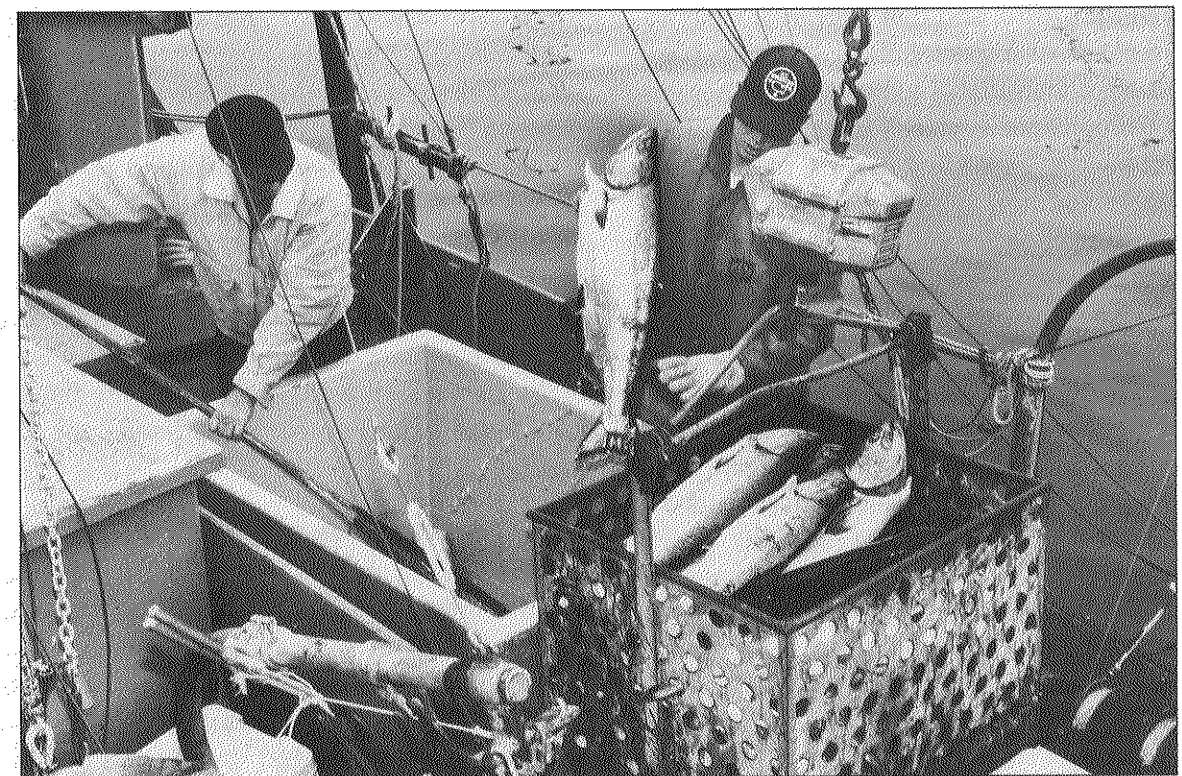
McArdle, D.A. 1997. California Marine Protected Areas. California Sea Grant College System, La Jolla, CA 92093.

Pacific Fishery Management Council. 1990. Form and function. Pacific Fisheries Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201.

Sanctuary and Reserves Division, National Oceanic and Atmospheric Administration. 1992. Monterey Bay National Marine Sanctuary final environmental impact statement/management plan. National Oceanic and Atmospheric Administration, Washington, D.C.

Wallace, R.K., Hosking, W. and S.T. Szedlmayer. 1994. Fisheries management for fishermen: A manual for helping fishermen understand the federal management process. Auburn University Marine Extension & Research Center, 4170 Commanders Dr., Mobile, Alabama 36615.

Current Management Issues



Maintenance of Viable Fisheries

Commercial and recreational fisheries have provided economic benefits and an important cultural heritage to the Monterey Bay region. A current concern is the need to ensure that fisheries maintain economic viability so they can continue to provide social and economic benefits to this region. Fishery products are now shipped all over the globe. In some cases, fishery products purchased from a distant country cost less than comparable products from this region. Many local fishers now receive the same price per pound of fish that they did 15 years ago. When adjusted for inflation, the price received for many fishery products has steadily decreased. This reduction in value has caused some fishers to move or go out of business, and all fishers are attempting to harvest what they can to offset reductions in the value of their catch. Additionally, the fishing industry has seen a decline in subsidies, such as federal funding for dredging of ports, funding for weather buoys at sea, or low-interest loans for vessel construction and maintenance.

One way to help maintain the economic viability of fisheries is for coastal communities to recognize the special needs of fishery and fish processing businesses. Future land use and fishery management decisions should account for the need for local fishers and processors to become more efficient so they can compete in world markets. Increased harvest of underutilized species is another way that fisheries may adapt and maintain economic viability. Fishers can also increase or add value to existing target species through strategies such as export marketing, or selling live fish to local fish markets and restaurants.

Overcapitalization

In the last 30 years, the rapid increase in electronic fish finding and catching technology, combined with an increased number and size of fishing vessels, has led to greater harvesting capability than fish populations are capable of supporting. The increase in global trading of fishery resources has exacerbated this problem.

Most fishery scientists agree that the excess of fishing capacity is the primary cause for overfishing in the world, and that fleet overcapacity is the single most important factor threatening the long-term viability of harvested fish populations. Fishing capacity needs to be brought into line with harvest capability in most marine fisheries. In addition to biological problems, excess fishing capacity can pose social problems as well, such as conflicts for fishing space. The Monterey squid fishery is an example of social conflicts caused by a large number of boats fishing in a small area with no set catch quota.

On a global scale, fishery managers have been addressing the problem of overcapitalization by using a variety of management tools such as limited entry programs, harvest rotations, gear limitations, vessel buy-back strategies, and individual quota systems. The global experience to date indicates that one technique alone (e.g., limited entry) is not sufficient to limit overcapitalization.

Catch Allocation

When the harvest of a stock is restricted, fishers often find themselves competing for fish. In these cases, fishery managers attempt to protect fishery resources while equitably allocating the allowable catch. To do so, fishery biologists first determine the total allowable catch for a stock based on the best available scientific information. Resource managers then allocate harvest to different sectors of the fishing industry in an attempt to maximize economic benefit to local communities while reducing the risk of overfishing. In an attempt to be fair, catch allocations are often partitioned on the basis of historical catch records. Ideally, the entire allocation for a fishery will not exceed the scientific estimate of total allowable catch. Unfortunately, this is not always the case because of political, social, and economic considerations.

One of the new innovations regarding allocation which has achieved some success around the world is the implementation of individual fishery quotas (IFQs). IFQs are similar to the ancient practice of "catch rights" in which a fisher is entitled to a certain proportion of the total allowable catch. Some countries have found that the IFQ system improves economic performance, while reducing social conflicts and the potential for excess harvest associated with overcapitalized fisheries. Catch IFQs are usually implemented along with a limited entry system that places a cap on the number of vessels allowed in a fishery. After the initial allocation set up by the IFQ system, market demand guides actual fishing effort and economic return of participating fishers. Although IFQs have proven to be effective in some situations, they have received limited acceptance in the United States because many fishers believe IFQs concentrate fishing (and thus market) power in the hands of a few people.

Multispecies Fisheries

Many fishes and invertebrates occur together in time and space, and thus are often harvested together. In many multispecies fisheries, vessels harvest both abundant and depleted populations of fishes. In the groundfish fishery, for example, rockfishes, flatfishes, and roundfishes (e.g., lingcod, sablefish, or Pacific hake) are often caught together in a single trawl tow. Species in these groups each have different life history strategies and population abundances. Some of the species caught in multispecies trawl fisheries are long-lived, have low reproduction rates, and currently have low population sizes. Others are fast growing, highly productive, and are currently abundant. Managing trawl fisheries on a species specific basis can thus result in excessive waste of abundant fishes or overharvest of depleted species.

The issue resource managers face is how to maximize catches of abundant species while minimizing catches of species complexes with low population sizes. In response to this issue, PFMC managers have enacted limited entry programs and set trip limits on species complexes, or co-occurring species groups. Many rockfish species, for example, are managed as part of the Sebastes complex with catches regulated by limited entry, trip limits, and cumulative catch limits by month. A problem with this management strategy is that it limits catches of abundant species; it also sets restrictive limits on fishers' flexibility. Many fishers have the capability to change gear type or target species in order to increase landings of species with high abundances or values, often reducing fishing pressure on low abundance species. With the limited entry system, a fisher may be prohibited from changing gear type to participate in a fishery for which an entry license is unavailable. Thus, fishers are sometimes forced to remain within a given fishery, even if fish abundances and landings are low.

Bycatch of Nontarget Species

The inadvertent catch (bycatch) of unwanted fish, shellfish, or other organisms that are captured together with target species is a problem in some fisheries, especially those using bottom trawl gear. This potential waste or inefficient use of marine species may have large economic and ecological consequences. For example, removal of an important food item (prey species) through bycatch may adversely affect another species which eats that prey. In addition to the unknown ecological consequences of harvesting nontarget species, bycatch can be a problem when undersized commercial or sport fish species are collected. These small fishes may be the species that the fisher is targeting, but have no economic value, or may be below the minimum size limit imposed by management agencies and therefore be illegal to catch. The bycatch of undersized species may increase fishing mortality estimates and thus decrease the amount of larger fish available for harvest.

Bycatch occurs in almost all fisheries. Recent estimates of bycatch rates for trawl fisheries in Oregon and Washington suggest that bycatch is 5–30% of the landed catch in west coast trawl fisheries. To minimize mortality caused by bycatch, managers implement tools such as minimum mesh size restrictions, season or area restrictions, and other management methods. Some insightful fishers are also experimenting with new net configurations, inserts, or designs to reduce bycatch in trawl fisheries.

Discard

In almost all fisheries, some fish are discarded at sea. The numbers, types, and sizes of species that are discarded are influenced by management regulations and market conditions. For example, some fishers discard undersized or lower-valued fish to meet size regulations, remain within quotas, or make space for economically more valuable species. This occurs in all fisheries, but is prevalent in the Dungeness crab fishery, sablefish fishery, and in some rockfish fisheries. Another source of discard is caused by the bycatch of prohibited species. When unreported, these discards make fishing mortality more difficult to estimate and thus make stock assessments more uncertain.

Many management techniques are used to lessen the problem of discard. One of the most common methods of lowering discards is the use of selective gear, such as nets with larger mesh size. This method works best, however, with stationary nets. As nets are pulled through the water, the net fills and effective mesh size decreases, thus lowering the selectivity of the net. Area or seasonal closures are successfully used for some species, but may simply redirect the mortality to different areas or fishes. In a few cases, managers have crafted regulations to favor fisheries that are more selective and result in less discard.

A more drastic measure is the total prohibition of discards, or enforcement of full utilization of catch. This technique is not currently in use because it would also greatly reduce profitability of fisheries. If fishers were prohibited from discarding any of their catch, then the value of the catch would be reduced, trip lengths would be shortened, and additional equipment and production costs would be required to process the additional sizes and species that are not offset by the added value of the products. One of the most successful techniques for reducing fish discard is employed by experienced fishers who reduce discard by knowing when, where, and how to fish for target species. A new approach being considered by managers is an individual bycatch quota. Placing a limit on the bycatch of each vessel encourages skippers to fish in areas in which their catch is "cleaner."

Enforcement

Fishery management agencies have several ways to monitor fishing practices, quotas, and regulation compliance. One of the principal methods is the use of fishery logbooks, which are voluntary in some fisheries, and required in others. In fisheries with mandatory logbook programs, fishers are required to keep a log with information on when and where they fished, how long they fished, the gear they used, and the estimated catch by species during a given fishing trip. These data are then collected and used with landing data to evaluate trends in catch. Occasionally, management agencies institute observer programs to collect additional information at sea on abundance, size, and species composition of catches and discards.

All fish buyers are required to provide CDFG with records of the type and amount of product they purchase from fishers. These records are termed "pink tickets"; they are collected and summarized by CDFG, then collated on a coastwide basis by the Pacific States Marine Fisheries Commission. This record keeping system is the primary method by which management agencies determine if catch quotas are met or exceeded. This method is obviously contingent on fishers' and buyers' providing accurate information. State and federal Fish and Game wardens and auditors visit docks and processing plant offices to monitor catches and watch for violations of regulations. Fishery biologists also get some feeling for compliance as they collect biological information at the dock.

CDFG, NMFS, and U.S. Coast Guard enforcement officers work together to patrol fishing grounds, board fishing vessels, and check for violations at sea. These efforts are often underfunded, however, resulting in an irregular and infrequent enforcement schedule at sea. Some resource managers have discussed ways to increase the efficiency of at-sea fishery monitoring by requiring fishing vessels to install electronic transmitters. These transmitters would enable enforcement officers to use satellite technology to track fishing vessel traffic in closed areas or during closed seasons.

Given the complexity of fishery regulations and the amount of funding for enforcement, the effectiveness of fisheries management policy is currently determined as much by the level of voluntary compliance as by enforcement activities. Compliance is influenced by a number of factors such as whether fishers or their peers agree with regulations, think they or others can violate rules without being caught, or believe the magnitude of the punishment (e.g., fine) is small compared to potential economic gains. Probably the most effective method of enforcement is getting fishers to agree that management rules are necessary and good, so they voluntarily choose to comply.

Need for More Scientific Information

More scientific information is needed for fisheries to maximize catches without depleting fish populations. Information is not only needed on population abundance and critical life history stages, but also on the interactions between species, the effect of harvest activities on marine habitats, and the effect of environmental change on marine fishes.

The development of more accurate stock assessments is difficult and is hampered by complicated ecological relationships between fishes, and a lack of research and reliable fishery data. Fishers, fishery researchers, and fishery managers often heatedly debate the variables and assumptions used in the fishery population models that form the basis of stock assessments. Often a small change in one variable such as incidental or unreported fishing mortality may greatly affect the predicted abundance of a species.

Accuracy of stock assessments has improved with an improving information base regarding marine fisheries. Nevertheless, fishers and managing agencies agree that more research cruises and fishery information are needed to improve stock assessments. Attempts to increase funding and to obtain more reliable and accurate data from research cruises and from the fishers are ongoing. In the last few years, managers and fishers have been working more closely to expand upon and improve the use of fishery data in stock assessments.

Cost Recovery

Government moneys from taxes and fees are used to support fisheries research and management programs, and there is a growing concern about the amount of money spent relative to economic gain. As fish populations decline, the total value of the landings usually shows a corresponding decline, and the cost of research and management increases relative to economic benefits. In extreme cases in which harvest of a depleted species is prohibited, the cost of research and management exceeds the exvessel value of the fishery. Although public funds for endangered species are available, securing public funds for industries with low cost/benefit ratios can be difficult. The economic cost/benefit of fisheries management is impossible to address without considering the full range of social benefits provided by fisheries. Sustained availability of high protein food resources, the creation of jobs, and the retention of cultural identity associated with fishing communities all increase the benefits of fisheries above that of strictly exvessel value.

The question of who should pay for research and management programs becomes more complicated for limited access fisheries. Limited entry and IFQ management techniques restrict access to fish resources to a set number of people. By limiting access, managers hope to improve resource conservation and increase economic viability of a fishery. Certainly, permitted fishers have a greater incentive to conserve and manage the resource for their future use, and may have a better chance of reaping a profit. But should general fees and taxes be used to manage a fishery that is no longer a common property resource? Fishers without access submit that their tax money is being used to manage fisheries from which they are restricted. Funding for limited access fisheries in the future may thus be based on fees generated by those with vested interests; the revised FCMA allows for increased use of fees in the limited access and IFQ programs.

Alternative Management Strategies

Some people believe that the current method of allocating catch in an open access fishery is destined to create fishery collapse. This argument is based on the assumption that people setting management strategies will always err on the side of maximizing catches (food) for people. When catches are always maximized, the risk or potential for population instability increases, and environmental change can make fish stocks crash. Proponents of this argument suggest that alternative management strategies are needed to protect fish stocks.

Fishery managers are beginning to consider a variety of alternative resource management strategies. For example, area management, and rotating open and closed fishing zones have proven to be successful techniques for some shellfish fisheries. Those management tools work well for sedentary animals that are highly productive, with short life spans. IFQs, individual fishing effort quotas, and gear certificates which limit the amount and type of gear used have worked in some parts of the world. Occasionally, the effort or catch allocations are sold in a bidding process. Community quotas, in which the allowable catch is distributed by a local political group to a community, is being tried in parts of the world as a new implementation of an old concept.

One alternative strategy that has recently received a great deal of interest is the use of harvest refugia as a means to protect declining fish stocks. There is some evidence to suggest that excluding fisheries and other extractive activities from reserves may be an effective method to replenish depleted stocks. There is clear evidence that refugia show increased numbers of animals and increased diversity relative to surrounding exploited areas. But proof that these newly regenerated and highly localized populations will significantly increase abundances in the exploited areas is still forthcoming. Several small harvest refugia are located along the shoreline in the MBNMS. Although they may be beneficial for some nearshore invertebrates and fishes, they are neither sufficiently large nor sufficiently diverse to protect deep-water species that are commercially fished.

Emerging Fisheries

Historically, the development of new fisheries occurs in the absence of information. Several years of fishery data are needed before a management agency can adequately regulate harvest. In some cases, fisheries have started, then failed because of a lack of a suitable market, or problems with product quality. In other cases, however, new fisheries have decimated populations before managers have been able to enact reasonable management strategies. An example of a rapidly increasing fishery is the nearshore live-fish fishery. In this fishery, small skiffs are used to set baited hooks in water less than 30 meters deep. The captured fish are held in aerated containers and transported live to seafood markets and restaurants. By marketing in this way, these creative fishers receive a higher price per pound for the fish, thus increasing the value of their catch.

Information regarding this fishery is limited as a result of the need for fishers to quickly transport their catch to live tanks in markets. Catch data provided by CDFG indicate that approximately 990,000 pounds of fishes were caught in the nearshore live-fish fishery in California in 1995, an increase of almost twenty-fold between 1989 and 1995. One of the concerns regarding this new fishery is that it targets smaller fish. These generally represent very young animals that have not had the chance to spawn. Large scale harvest of immature fish could severely affect population sizes of nearshore fishes if exploitation rates were to increase. Already, some biologists and commercial fishers have observed decreasing trends in catch rates and mean lengths, indicating stressed populations of some nearshore species, possibly caused by the nearshore live-fish fishery.

Over the years, the Monterey Bay region has experienced several short lived fisheries. Often the new fisheries exhibited patterns of boom and bust, with an initial period of rapid expansion followed by a rapid decline in landings. In some cases, the boom-and-bust cycle was caused by marketing limitations or by problems with product quality. A large hagfish fishery, for example, was established in San Francisco and Monterey areas in 1988. This fishery increased steadily through 1990, but declined in 1991 and 1992 because of a decrease in market price.

Often, however, new fisheries collapsed because harvest exceeded the biological capability of the population. Sharks, for example, take a long time to reach maturity and have a relatively low reproductive output, making them susceptible to overfishing. Sixgill and sevengill sharks are early examples of short-lived fisheries. These sharks were the most common species taken in the shark fisheries in the 1930s and 1940s, until the populations collapsed in the early 1950s. The highly migratory basking shark was the target of small localized harpoon fisheries off California for more than 80 years. Basking shark landings peaked in the 1940s and 1950s due to high demand for the oil-rich liver. This fishery quickly collapsed because of declines in stocks and the availability of alternate sources of oil. A commercial fishery for thresher shark was established in 1977, but lasted only 10 years until overfishing necessitated strict regulations. Short-lived fisheries have also existed for species other than sharks. Recently, market squid have attracted an extreme level of fishing effort as a result of high exvessel price and market demand. This is an example of a highly variable resource that could disappear quickly, leading to a rapid decline of the fishery. Because little biological and distributional information is available for this species, the outcome of the fishery is still unknown. More examples of important commercial fisheries that have grown, then quickly declined, can be found in *California's Living Marine Resources and Their Utilization*.

Protected Species

The federal and state governments have enacted legislation to provide specific protection for all marine mammals and some fish species. In most cases, the resulting regulations have successfully conserved or enhanced the population of protected species. These regulations, however, have also affected fishery operations for those species for which there is a direct competition between humans and the protected species. Two obvious instances of competition for fishery resources in the MBNMS involve sea lions/salmon fishers and sea otters/abalone fishers. Many sea lions have learned to follow vessels fishing for salmon and attack the hooked salmon before they can be brought aboard the fishing vessel. As sea lion populations have grown, conflicts with fishers have increased. In some years, fishers relate that sea lions take a large proportion of the salmon they have hooked. The result is an increased mortality of salmon and a decreased yield to the fishery. Similarly, there is direct competition between sea otters and abalone fishers. In some locations, the combined harvest by sea otters and humans has severely depleted abalone populations.

Habitat Loss

Fishers and fishery managers are expressing concern at the increased loss of fish habitat resulting from human activities. Of primary importance is the loss of critical fish habitat that species require for certain life history stages such as spawning or rearing. In order for fish stocks to remain healthy, they must have adequate spawning, rearing, and feeding habitat. Prey species also need adequate habitats and resources in which to complete their life cycles.

Habitats most threatened by human activities include estuaries and coastal wetlands, eelgrass and kelp beds, and rocky banks. Coastal wetlands and estuarine waters are among the most sensitive, most accessible, and therefore most altered of coastal habitats. They also contain valuable nursery areas for early life stages of several marine species. These important habitats are easily degraded by urban and agricultural development. Efforts are underway at many levels to reduce the amount of destruction and to restore valuable habitat resources off our coast and thereby enhance our fisheries.

Fishing activities such as bottom trawling change habitat that is important to some species for the completion of their life cycles. Since the advent of roller gear in the late 1970s, fishers have been able to drag nets over rougher terrain than before. Trawl nets towed over rocky bottoms alter both species composition and the physical structure of habitats. Scientists are currently attempting to quantify the effects of changes caused by trawling. Some scientists believe that trawling on soft bottom habitats increases the productivity of the bottom for fishes, whereas others believe that trawling degrades the bottom by changing the diversity, age structure, and relative abundance of benthic invertebrates.

Recent changes in the Magnuson Fishery Conservation and Management Act mandate that habitat be considered in fishery management plans. The NMFS is currently developing strategies to identify and protect essential fish habitats. Essential fish habitats include those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity, at levels required to support a sustainable fishery and healthy ecosystem. These strategies are expected to be implemented by fishery management councils as soon as possible.

References

Boyd, R.O. and C.M. Dewees. 1992. Putting theory into practice: Individual transferable quotas in New Zealand's fisheries. Society of Natural Resources 5:179–198.

California Department of Fish and Game. 1997. California sport fishing regulations. Department of Fish and Game, P.O. Box 944209, Sacramento, CA 94244-2090.

Dewees, C.M. and E. Ueber. 1990. Effects of different fishery management schemes on bycatch, joint catch, and discards: Summary of a national workshop sponsored by the California Sea Grant College and the National Marine Fisheries Service. California Sea Grant Report T-CSGCP-019.

Food and Agriculture Organization of the United Nations, Marine Resources Service, Fishery Resources Division. 1995. Review of the state of the world fishery resources: Marine fisheries. Food and Agriculture Organization of the United Nations Fisheries Circular No. 884. Food and Agriculture Organization of the United Nations, Rome, Italy. 105 pp.

Fowle, S. 1993. Fish for the future: A citizen's guide to federal marine fisheries management. Center for Marine Conservation, Washington D.C. 142 pp.

Fox, D.S. and R.M. Starr. 1996. Comparison of research and fishery catch data. Canadian Journal of Fisheries and Aquatic Sciences 53(12):2681–2694

Gulland, J.A., ed. 1988. Fish population dynamics: Implications for management. John Wiley and Sons, New York, NY. 218 pp.

Hall, M.A. 1996. On bycatches. Reviews in Fish Biology and Fisheries 6(3): 319–352.

Hancock, D.A. and J.P. Beumer. 1996. Proceedings:

Second world fisheries congress, Brisbane, Australia.
Hightower, J.E. 1990. Multispecies harvesting policies for Washington–Oregon–California rockfish trawl fisheries. U.S. Fishery Bulletin 88(4):645–656.
Lea, R.N., R.D. McAllister, and D.A. VenTrensca. 1995. Biological aspects of nearshore rockfishes of the genus *Sebastes* with notes on ecologically related sportfishes off central California. California Dept. of Fish and Game, Fish Bulletin 177.
Martin, L. and G.D. Zorzi. 1993. Status and review of the California skate fishery. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report 115. pp 39–52.
Murawski, S.A. 1991. Can we manage our multispecies fisheries? Fisheries 16(5):5–13.
Pacific Fishery Management Council. 1979. The Fishery Conservation Management Act. Pacific Fishery Management Council 1977–1978 Progress Report, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201.
Pacific Fishery Management Council. 1995. Status of the Pacific Coast groundfish fishery through 1995 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201.
Pikitch, E.K., D.L. Erickson, and J.R. Wallace. 1988. An evaluation of the effectiveness of trip limits as a management tool. National Marine Fisheries Service Northwest and Alaska Fisheries Science Center processed report 88–27. Seattle, WA. 33 pp.
Richards, L.J. and A.J. Cass. 1987. The British Columbia inshore rockfish fishery: Stock assessment and fleet dynamics of an unrestricted fishery. *In*: Melteff, B.R., ed., Proceedings of the international rockfish symposium. Alaska Sea Grant Report no. 87–2. pp. 299–308.
Rogers, J.B. and E.K. Pikitch. 1992. Numerical definition of groundfish assemblages caught off the coasts of Oregon and Washington using commercial fishing strategies. Canadian Journal of Fisheries and Aquatic Sciences 49:2648–2656.
Rose, C. 1994. Observation of fish behavior in trawls: Finding ways to reduce bycatch. National Marine Fisheries Service, Alaska Fisheries Science Center, Quarterly Report, April–May–June 1994.
Wallace, R.K., W. Hosking, and S.T. Szedlmayer. 1994. Fisheries management for fishers: A manual for helping fishers understand the federal management process. Auburn University, NOAA Award NA37FD0079. 56 pp.

Environmental Factors Affecting Fish Populations

From both a biological and economic viewpoint, a current description of local fisheries is only a snapshot in time of a larger temporal picture. The physical environment in the Monterey Bay region is very dynamic and greatly influences the population size of resident fish populations. Recent studies have shown that the dominant oceanographic feature in this area, the California Current, has fluctuated in strength and productivity every 10 years or so for the last 100 years. Zooplankton abundance in the California Current, for example, declined by more than 70% from 1950–91. Paleontological records suggest that larger scale environmental fluctuations have occurred every 80–100 years. As the environment has fluctuated, the dominant species inhabiting marine waters off Monterey and the resulting ecological relationships have also changed. Correspondingly, in the last 100 years, the primary species or species groups harvested by commercial fisheries have changed several times, as have the composition and character of the vessels used, and people participating in commercial fisheries.

Fish populations have fluctuated for centuries, long before fishing became a factor in stock abundance. For several marine species, population trends in the last 200 years are highly correlated with environmental factors. Pelagic larval stages are particularly vulnerable to ocean conditions, with mortality levels determining recruitment levels and year-class strength of subsequent adult populations. Further relationships clearly exist between environmental conditions and the survival of later juvenile and adult stages. The causes for these relationships, however, are extremely complicated.

Physical ocean characteristics play an important role in determining species composition and fish abundance. The MBNMS occurs in a transition zone between the warmer southern California Bight and the colder California Current waters. As the global environment changes, the dominance of either the colder or warmer water systems within this transition zone changes. During warmer years, for example, fish species common to southern California and Mexico may be more prevalent in the Monterey Bay area, whereas they may be almost nonexistent in colder years.

These long term shifts in local oceanographic conditions can span from a single year to decades. The results of decadal, or longer, scale shifts are evident in fish populations beyond the time of actual environmental change, producing long-term cycles of highs and lows in abundance. One such regime shift in the North Pacific is determined by the mean position and intensity of a seasonal low pressure area known as the Aleutian Low. In the North Pacific, water masses are driven by a clockwise-flowing central Pacific gyre and a counterclockwise-flowing Alaskan gyre. The boundary between these two circulation systems is called the Subarctic Current (or West Wind Drift) and is located at 45–50° N latitude. The Subarctic Current divides into two branches as it nears the coast of North America. One branch, the California Current, flows south, the other, the Alaska Current, flows north.

During years that the Aleutian Low intensifies, the location of the boundary between the central Pacific gyre and the Alaskan gyre moves southward. In those years, the cooler, productive subarctic waters travel shoreward and northward with the Alaska Current. High primary production in the Alaska Current leads to increased zooplankton abundance, and consequently, increased fish production off Alaska and British Columbia. One such event began in the late 1970s and persisted into the late 1980s. During this time Alaska salmon catches were close to historic highs, and strong year-classes of walleye pollock, Pacific cod, Pacific halibut, sablefish, Pacific hake, atka mackerel, and chub mackerel were evident. During that time, California Current waters were less productive than in previous years.

Conversely, during years that the Aleutian Low weakens, the productive subarctic waters travel south into the California Current system. When this happens, fish stocks off Oregon and California benefit. In both scenarios, once these strong year-classes have passed through the fisheries, declines in fish production and landings are evident. This natural decline in fish abundance and biomass is difficult to separate from effects of fishing.

On a shorter time scale, a global environmental condition termed El Niño has been known to affect many important fisheries. In California waters, an El Niño is expressed as increased water temperature, decreased salinity, onshore and poleward advection of water masses, and delayed annual phytoplankton blooms. For many species, onshore advection of water traps larvae and pelagic juveniles in nearshore waters, where predation is increased, resulting in poor year-class success. This causes an additional decrease in stock biomass when the failed year-classes are unable to replace losses in the population due to natural and fishing mortality. El Niño conditions have resulted in dramatically reduced squid populations in California, and have had secondary effects on the many species of fish, birds, and mammals that feed on squid. Rockfish recruitment is also documented to be poor during El Niño conditions. Increased water temperatures and delayed production result in poor adult condition and a drop in larval survival. For some species, such as squid and California halibut, El Niño years result in low catches, but the populations rebound to higher levels in following years.

A physical oceanographic condition that acts on a seasonal basis is upwelling. Upwelling occurs off the west coast of the United States during the spring and summer months, when northerly winds drive surface waters offshore. These surface waters are replaced by deep, nutrient rich waters, resulting in high levels of primary and secondary production in nearshore waters. The timing and magnitude of upwelling can have a pronounced effect on survival of many important fish stocks. Excessive upwelling can result in eggs and larvae being dispersed too far offshore, preventing fishes from reaching essential nursery grounds. Too little upwelling leads to a loss of spring and summer plankton blooms, thus lowering abundance and quality of food available to fishes. Minimum upwelling also results in a lack of offshore transport, causing eggs and larvae, many of which are adapted for offshore waters, to remain in coastal waters where predation is high. Thus, a number of important fish species are affected, both positively and negatively, by the effects of seasonal upwelling.

References

Beamish, R.J. 1993. Climate and exceptional fish production off the west coast of North America. Canadian Journal of Fisheries and Aquatic Sciences 50:2270–2291.

Hayward, T.L., D.R. Cayan, P.J.S. Franks, P.E. Smith, R.J. Lynn, F.B Schwing, A.W. Mantyla, J.A. McGowan and E.L. Venrick. 1995. The state of the California Current in 1994–1995: A period of transition. California Cooperative Oceanic and Fisheries Investigations, Report 36:19–39.

Hollowed, A.B., K.M. Bailey, and W.S. Wooster. 1987. Patterns in recruitment of marine fishes in the Northeast Pacific Ocean. Biological Oceanography 5:99–131.

Lenarz, W.H., D.A.VenTresca, W.M. Graham, F.B. Schwing, and F. Chavez. 1995. Explorations of El Niño events and associated biological population dynamics off central California. California Cooperative Oceanography and Fisheries Investigations, Report 36:106–119.

MacCall, A.D. and M.H. Prager. 1988. Historical changes in abundance of six fish species off southern California, based on CalCOFI egg and larvae samples. California Cooperative Oceanography and Fisheries Investigations, Report 29:91–101.

McGowan, J.A., D.B. Chelton, and A. Conversi. 1996. Plankton patterns, climate, and change in the California Current. California Cooperative Oceanography and Fisheries Investigations, Report 37:45–67.

Mysak, L.A. 1986. El Niño, Interannual variability and fisheries in the Northeast Pacific Ocean. Canadian Journal of Fisheries and Aquatic Science 43:464–497.

Parrish, R.H., C.S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biological Oceanography 1(2):175–203.

Roemmich, D. and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267(5202):1324–1326.

Sakuma, K.M. and S. Ralston. 1995. Distributional patterns of late larval groundfish off central California in relation to hydrographic features during 1992 and 1993. California Cooperative Oceanography and Fisheries Investigations, Report 36:179–192.

Shepherd, J.G., J.G. Pope, and R.D. Cousens. 1984. Variations in fish stocks and hypotheses concerning their links with climate. Rapports et Proces Conseil Permanent International Pour L'Exploration de la Mer. 185:255–267.

Tegner, M.J and P.K. Dayton. 1987. El Niño effects on southern California kelp forest communities. Advances in Ecological Research 17:243–279.

Ware, D.M. and R.E. Thomson. 1991. Link between long-term variability in upwelling and fish production in the Northeast Pacific Ocean. Canadian Journal of Fisheries and Aquatic Science 48:2296–2306.

Woodbury, D. and S. Ralston. 1991. Interannual variation in growth rates and back-calculated birthdate distributions of pelagic juvenile rockfishes (*Sebastes spp.*) off the central California coast. Fisheries Bulletin 89(3):523–533.

Invertebrates

A wide variety of invertebrates are harvested in commercial and recreational fisheries off the coast of California. Most species are harvested in small quantities, or are collected incidentally to trawl fishing operations, and are discarded at sea. A few invertebrate species are harvested and sold in large quantities.

In the Monterey Bay National Marine Sanctuary, the primary species which are harvested and sold commercially are the market squid, spot prawn, and Dungeness crab. Nearshore subtidal species such as abalone and sea urchin, and small numbers of intertidal animals such as mussels and clams are commercially harvested as well. Recreational harvests consist of a small number of abalone and intertidal animals. In addition to commercial and recreational fisheries, small numbers of invertebrates are harvested for research and educational purposes. Although the commercial and recreational harvest of intertidal animals has severely depleted populations in a few locations, it is poorly documented. For that reason, we do not cover intertidal animals in this document. Also, the cause for the decline of localized invertebrate populations cannot always be attributed to current levels of human harvest. In some cases, such as for abalone, populations were probably overfished in the early 1900s and have never fully recovered because of environmental change and otter predation. Pismo clams and sea urchins also were once plentiful around the bay, but may have declined because of a combination of predation by humans and sea otters and environmental change.

Red Abalone (*Haliotis rufescens*)

Distribution: Red abalone are found from Turtle Bay, Baja California to Sunset Bay, Oregon. Highest abundances occur in northern California, in Sonoma and Mendocino counties. Red abalone inhabit rocky shores in areas of high wave action and water currents. In northern California, they are found intertidally in water depths from near the high tide mark out to at least 165 m.

Life History: Red abalone spawn during spring and summer months throughout

California. In southern California, they may spawn twice annually. Fecundity ranges from only a few thousand eggs for first-time spawners, to as many as 6 million eggs for older females. During spawning, eggs and sperm are released into the water column where fertilization takes place. Fertilized eggs develop into free-swimming larvae. After a period of about two weeks, a shell begins to form, and the young abalone begin to gradually sink to the bottom. Once settled, they adhere to rocks in cracks and crevices where they graze on algae. During the first year of life, individuals typically grow to about 2.5 cm shell length. By 4–5 yr of age, most individuals are 7–10 cm in length.

Fishery History and Trends: Commercial diving for red abalone began in California in the late 1800s. During the 1940s, the coastline between Monterey and Point Conception produced commercial landings of about 720,000 red abalone annually. Historically, these Monterey area landings were the majority of the California commercial catch. In the 1950s, divers became more efficient at harvesting abalone with the advent of the "hookah" system. This system provides air to the diver through 90–150 m of hose connected to a full face mask, and allows for longer dive times and a more thorough inspection of crevices. A large recreational fishery for abalone also developed throughout California in the 1950s. Between 1965 and 1985, the number of recreational divers, shorepickers, and free divers targeting abalone increased four-fold.

After 1970, commercial landings of abalone declined drastically (Fig. 12), largely as a result of reduced population caused by increased fishing pressure and an expansion of sea otter populations. With the decline of red abalone populations, fishers began targeting other abalone species, such as pink, black, green, and white. By the early 1980s, catches of these other species from southern California waters comprised over three-fourths of the California abalone catch. Catches in the MBNMS averaged 83,000 lb/yr from 1980–95, with no evidence of increasing or decreasing trends (Fig. 13).

Current red abalone stocks throughout central and southern California remain overutilized because of a combination of increased harvest

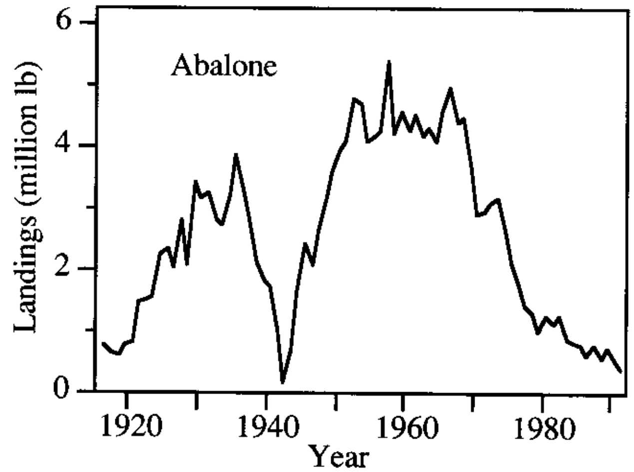


Figure 12. Reported commercial landings of all abalone species in California from 1920–91.

efficiency and market demand in the commercial fishery, and continued fishing effort by the recreational fishery. Predation by sea otters places additional pressure on red abalone stocks in central California.

Management: North of Yankee Point (near Carmel), no commercial harvest of abalone is allowed, with the exception of the Farallon Islands and the coastline of San Mateo County, and sportfishing is restricted to shorepicking and free diving. For the sportfishery, the catch limit is set at four red abalone per day. All harvest of black abalone is prohibited. The size limit for red abalone, measured by greatest shell diameter, is set at 7 in. All legal-sized abalone detached from the rocks must be retained, and fishers must stop detaching abalone when the bag limit is reached. Abalone may only be taken during the months of

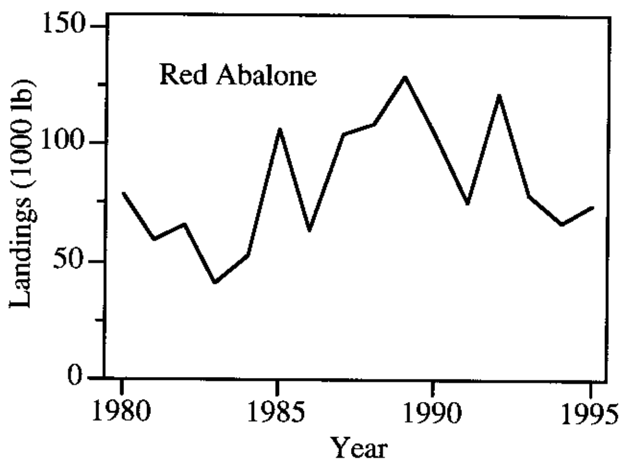


Figure 13. Reported commercial landings of red abalone at the five major ports near the MBNMS from 1980–95.

April, May, June, August, September, October, and November. Gear provisions and set fishing hours also apply. In the fall of 1997, state legislation closed all sport and commercial fisheries for abalone south of San Francisco. The fisheries will remain closed until CDFG can show that populations have sufficiently recovered to support fisheries.

References

Ault, J.S. 1985. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Black, green and red abalones. Biological Report, U.S. Fish and Wildlife Service. 19 pp.

Cox, K.W. 1960. Review of the abalone of California. California Department of Fish and Game 46:381–406.

Dewees, C.M. and L.T. Davies. 1992. Sea urchins, abalone and kelp: Their biology, enhancement and management. California Sea Grant College Program, Summary of an international conference. 55 pp.

Mottet, M.G. 1978. A review of the fishery biology of abalones. State of Washington Department of Fisheries, Technical Report 37. 81 pp.

Shepherd, S.A., M.J. Tegner, and S.A. Guzmán del Próo, eds. 1992. Abalone of the world: Biology, fisheries and culture. *In*: Proceedings of the first international symposium on abalone. Fishing New Books, Oxford.

Red Sea Urchin (*Strongylocentrotus franciscanus*)

Distribution: Red sea urchin are found on the west coast of North America from the tip of Baja California, northward to Sitka and Kodiak, Alaska. Off California, dense concentrations occur patchily throughout the state. Red sea urchin usually occupy shallow waters, from intertidal zones to depths greater than 50 m, but have been found as deep as 125 m. They prefer rocky substrates and are common in and around kelp beds.

Life History: The spawning season of red sea urchin varies with locality and from year to year. In central California, spawning occurs in late spring and early summer. During spawning season, adult urchin release eggs and sperm into the water column. Larval urchin then develop through a series of free-living stages. Juveniles settle out of the water column in 6–8 wk. Urchins typically grow 13–25 mm/yr, reaching harvestable size (79–84 mm) in 4–5 yr. Growth above this size range slows considerably. The red sea urchin is one of the largest species of sea urchin in the world, growing to a test diameter of about 18 cm.

Fishery History and Trends: Sea urchins are harvested for their roe, or gonads. Hookah gear, similar to that used in the abalone fishery, is used. The red sea urchin is the main urchin species currently harvested off the west coast of North America. The fishery was developed in the early 1970s for export to Japan. Fishery managers also encouraged the fishery as a way to reduce fishing pressure on abalones and to reduce grazing by urchins on valuable kelp beds.

The sea urchin fishery grew steadily through the 1970s with landings reaching 40 million lb in 1987. By 1996, the sea urchin fishery was the most valuable fishery in California. Originally, the bulk of the landings came from the northern Channel Islands and off the southern California coast. Continued high fishing pressure, as well as El Niño conditions between 1982 and 1984, led to lowered catches in the southern half of the state. Total California landings were maintained during this time by the expansion of the sea urchin fishery into northern California. From 1985 to 1988, northern California landings increased from 1.9–30.4 million lb. Although the sea urchin fishery has remained productive and lucrative since the late 1980s, total landings and catch per unit effort have declined, especially in northern California. Urchin landings at ports near the MBNMS averaged 117,000 lb/yr from 1980–95 (Fig. 14).

In addition to fishing pressure, larval survival has a large impact on the status of sea urchin populations. Annual recruitment is greatly dependent on the fate of larvae as they are carried by ocean currents either offshore or into suitable nearshore habitats for settlement. Ocean conditions in the Southern California Bight appear to be especially favorable for relatively consistent recruitment. Recruitment in northern California, however, is less predictable, and urchin populations tend to exhibit

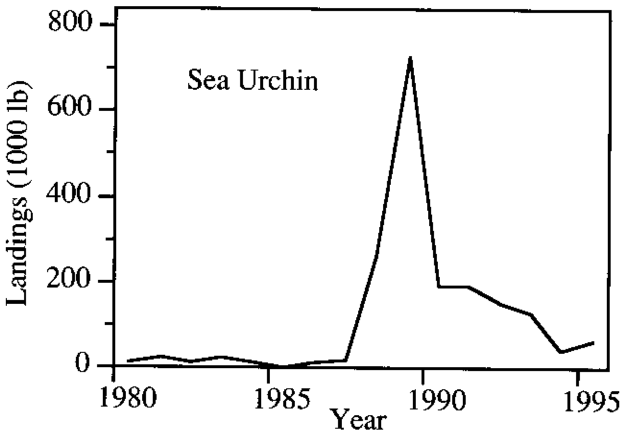


Figure 14. Reported commercial landings of sea urchin at the five major ports near the MBNMS from 1980–95.

cyclical patterns of rapid increases followed by rapid declines. Surveys by the California Department of Fish and Game (CDFG) indicate that in northern California, red sea urchin are currently about one-third as abundant as they were prior to the onset of the commercial fishery.

Management: The sea urchin fishery is managed by the CDFG through use of a limited entry system, seasonal closures, and size limits. The urchin fishing season extends through most of the year, with certain days of the week closed during specific months. Urchin harvested in southern and northern California must have shell diameters larger than 3.25 and 3.5 in, respectively.

References

Botsford, L.W. and J.F. Quinn. 1996. Spatial management of the northern California red sea urchin fishery. California Sea Grant Biennial Report of Completed Projects 1992–94. pp 103–110.

Botsford, L.W., S.R. Wing and J.G. Brittanacher. 1993. Rotating spatial harvest of a benthic invertebrate, the red sea urchin, *Strongylocentrotus franciscanus*. Alaska Sea Grant College Program. International symposium on the management of exploited fish. pp. 409–428.

Dewees, C.M. and L.T. Davies. 1992. Sea urchins, abalone and kelp: Their biology, enhancement and management. California Sea Grant College Program. Summary of an international conference. 55 pp.

Kato, S. and S.C. Schroeter. 1985. Biology of the red sea urchin, *Strongylocentrotus franciscanus*, and its fishery in California. Marine Fisheries Review 47(3):1–20.

Phu, C.H. 1990. The U.S. sea urchin industry and its market in Tokyo. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Region, Technical Memorandum 25. 36 pp.

Tegner, M.J. 1989. The feasibility of enhancing red sea urchin, *Strongylocentrotus franciscanus*, stocks in California: An analysis of the options. Marine Fisheries Review 51(2):1–22.

Pacific Ocean Shrimp (*Pandalus jordani*)

Distribution: Pacific ocean shrimp, also known as pink shrimp, are found from Unalaska Island, Alaska to San Diego, California, but are most abundant from southern Vancouver Island, British Columbia to northern California. Adults occur over mud or sand bottoms at depths between 36 and 357 m, but may migrate to surface waters at night. Pink shrimp also migrate seasonally, moving to greater depths in fall to spawn, and returning to shallower waters in spring.

Life History: Pink shrimp are protandric hermaphrodites, meaning they are born male and then become female between 2 and 3 yr of age. Individuals mate once as males and once or twice as females during their lives. Fertilization occurs externally, and eggs are carried on the abdomen of the females. Females produce between 800 and 3,900 eggs, with fecundity varying with region and adult size. Eggs develop into pelagic larvae that appear between February and May. Demersal juveniles first appear between June and August within the shallower areas of the adult depth range. Pink shrimp reach a maximum age of 5 yr in the northern part of their range, and 3 yr in the southern part of their range. Maximum recorded carapace length is 30 mm.

Fishery History and Trends: The pink shrimp fishery constitutes the majority of shrimp harvest along the Pacific coast of the United States. Pink shrimp are harvested within discontinuous areas between British Columbia and central California, but the majority of the catches occur between Washington and northern California. The pink shrimp fishery began in the 1950s after the discovery of populations large enough for commercial harvest. Between 1952 and 1974, pink shrimp were harvested by commercial vessels towing a single bottom trawl. Beginning in 1974, vessels began towing nets from each side of the boat, and catches substantially increased. Annual landings were high through the 1970s, averaging 5.7 million lb in California alone (Fig. 15).

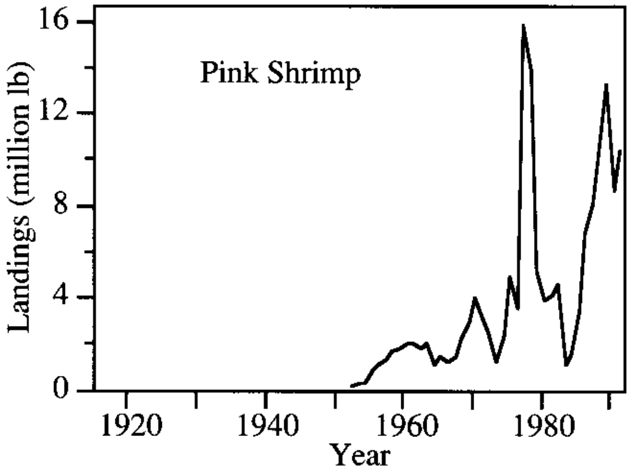


Figure 15. Reported commercial landings of pink shrimp in California from 1952–91.

During 1983, El Niño conditions caused landings to drop considerably, and many vessels left the fishery. Pink shrimp populations quickly recovered, however, and California landings through the rest of the 1980s remained high, averaging 5.9 million lb annually. California landings of pink shrimp increased considerably during the early 1990s, peaking at 18.7 million lb in 1992.

In central California, the majority of pink shrimp catches occur in the Morro Bay area. From 1980–95, landings exhibited large fluctuations, reaching a high of 1.2 million lb in 1980 and a low of 34 lb in 1991 (Fig. 16). Only a small portion of this variability is attributable to fishing effort. More influential factors are variations in juvenile survival and recruitment due to environmental conditions during larval stages.

Management: Pink shrimp are regulated by the CDFG. Pink shrimp may be harvested only between April 15 and October 31, and in water depths of 90 m or greater. In order to protect 0 and 1 yr old shrimp, net mesh size must be at least 1 3/8 in, and shrimp count per pound must be 170 or less. In addition, fishing is only allowed when catch rates are above 350 lb/hr, to protect shrimp when population levels are low.

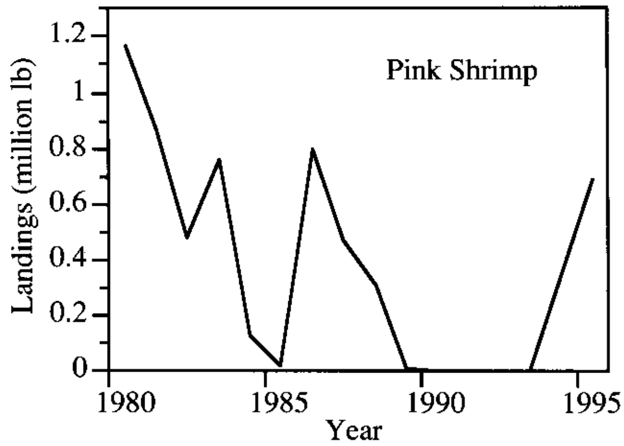


Figure 16. Reported commercial landings of pink shrimp at the five major ports near the MBNMS from 1980–95.

References:

Dahlstrom, W.A. 1970. Synopsis of biological data on the ocean shrimp *Pandalus jordani* Rathbun, 1902. Food and Agriculture Organization of the United Nations, Fisheries Report, 57(4):1377–1416.

Hannah, R.W. 1993. Influence of environmental variation and spawning stock levels on recruitment of ocean shrimp (*Pandalus jordani*). Canadian Journal of Fisheries and Aquatic Sciences 50(3):612–622.

Wolotira, R.J. Jr., M.J. Allen, T.M. Sample, R.L. Henry, C.R. Iten, and S.F. Noel. 1990. Life history and harvest summaries for selected invertebrate species occurring off the west coast of North America. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Center, Technical Memorandum 183. 191 pp.

Spot Prawn (*Pandalus platyceros*)

Distribution: Spot prawns range from Alaska to San Diego, California. The highest concentrations in the Monterey Bay area occur near canyon heads at depths of 45–220 m, although they are fished out to 400 m.

Life History: Spot prawns spend their early years as males. They first spawn as males, then transform into females after approximately 3 yr. By age 4, all males have transformed to females and will live for a maximum of two additional spawning seasons. Peak spawning occurs in September at depths of 150–220 m. Fecundity increases with size; smaller females may extrude

1400 eggs, whereas larger females may produce as many as 5000 eggs. Larvae hatch in late winter and then undergo an 83 day pelagic larval phase. At lengths of 20–134 mm, they begin to settle as juveniles to nearshore kelp areas. Adults migrate from kelp habitats to offshore areas.

Fishery History and Trends: Spot prawns have been harvested by trawlers and shrimp trappers since 1921. In the early years, California landings were less than 2000 lb/yr. Landings rose considerably in the 1970s, when fishers in Santa Barbara initiated a trawl fishery that specifically targeted spot prawn (Fig. 17). Total California landings reached a peak of 371,000 lb in 1981, of which more than 58,000 lb, worth $161,000, were harvested from MBNMS waters. In 1982, catches dropped considerably, and by 1984 the CDFG ordered a temporary closure of the spot prawn trawl fishery. A similar year-long closure of the trawl fishery for prawns in 1986 prompted an increased interest in the trap fishery, and created a new sales market. Fishers were able to sell live prawns to restaurants for $5.00–$6.50/lb, an increase over the $3.50/lb they received for trawl caught prawns. With this increase in exvessel price and demand for live prawns, trawl fishers began fitting their boats with live wells.

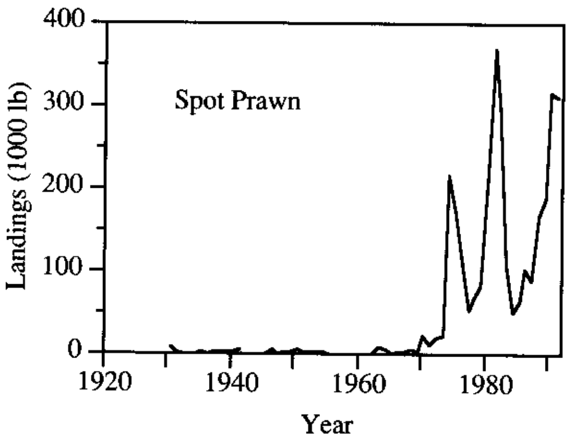


Figure 17. Reported commercial landings of spot prawn in California from 1920–91.

Although 75% of the prawn landings in California were from traps in the early 1990s, almost all the catch of spot prawn from the MBNMS are now taken by trawls. Trawl vessels accounted for 82% of the 1996 landings. In 1995, landings within the MBNMS totaled 199,000 lb and were worth $1.3 million (Fig. 18).

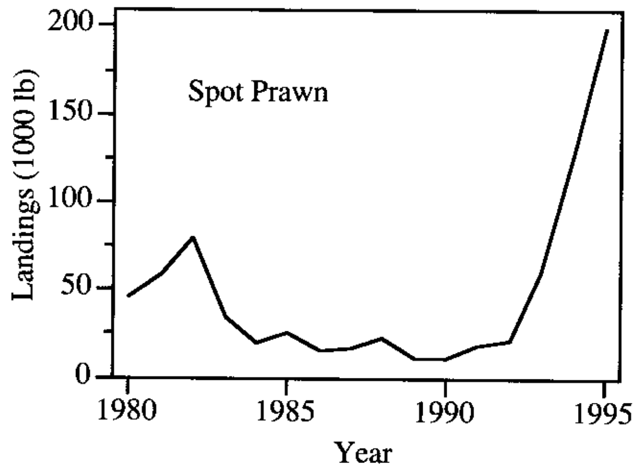


Figure 18. Reported commercial landings of spot prawn at the five major ports near the MBNMS from 1980–95.

Future trends in prawn populations are difficult to predict because of the lack of a documented stock-recruitment relationship. Current concerns about the fishery relate more to the use of trawl gear and the incidental catch of other species than to the harvest rates of prawns.

Management: The spot prawn fishery is managed by a limited entry program with non-transferable permits. Additional regulations for trawlers include seasonal closures, minimum mesh size, and incidental catch limits. Traps are required to be less than 6 ft around with openings of less than 5 in and must have a destructive device to prevent them from capturing animals if lost from the buoy.

References:

Frady, T., ed. 1981. Proceedings of the international pandalid shrimp symposium. University of Alaska Sea Grant Report 81-3. 35 pp.

Marliave, J. B. and M. Roth. 1995. Agarum kelp beds as nursery habitat of spot prawns, *Pandalus platyceros* Brandt, 1851 (Decapoda, Caridea). Crustacea, 68(1):27–37.

Sunada, J.S. 1984. Spot prawn (*Pandalus platyceros*) and ridgeback prawn (*Sicyonia ingentis*) fisheries in the Santa Barbara Channel. California Cooperative Oceanic and Fisheries Investigations, Report 25:100–104.

Sunada, J.S. 1986. Growth and reproduction of spot prawns in the Santa Barbara Channel. California Department of Fish and Game, 72:83–93.

Dungeness Crab (*Cancer magister*)

Distribution: Dungeness crab range from the eastern Aleutian Islands, Alaska to Santa Barbara, California, with the highest concentrations occurring off northern California, Oregon and Washington. They occupy all substrates from the intertidal zone to depths of 230 m, but occur most commonly in sand or sand/mud bottoms in waters less than 90 m deep.

Life History: Dungeness crab males reach sexual maturity at 3 yr of age and a carapace width of 140 mm, whereas females mature at 2 yr of age and a width of 100 mm. Mating occurs from March to July, when females molt. Females carry eggs under their abdominal flap for 7–10 months before hatching. Fecundity increases with increasing adult size, ranging from 500,000–2 million eggs per female. Larvae hatch in winter and subsequently undergo a series of planktonic stages. Benthic settlement occurs after approximately 3–4 months. The distribution of larvae is dependent on many environmental parameters, such as temperature, salinity, and currents. Males are larger than females, reaching a maximum width of 23 cm and weight of 3.8 lb in their lifetime (6 yr).

Fishery History and Trends: A small Dungeness crab fishery was established in 1848 off San Francisco. Sailboats and steam-powered engines, first used in 1885, allowed the fishery to expand beyond the shoreline. Coupled with the increase in boat power was a transition in gear to baited hoop nets and ring nets. In the early 1900s, a fishery using trammel nets was established in Monterey. The use of trammel nets was prohibited in 1915. In 1938, crab traps were introduced, but they were quickly banned. From 1939–43, harvest was legal only using hoop nets. Crab traps became legal again in 1943. Thereafter, landings increased considerably (Fig. 19).

The Dungeness crab fishery within the MBNMS now comprises only a small portion of total California landings. From 1980–87, reported catch ranged from 138,000 to 428,000 lb (Fig. 20). From 1987–88, landings at ports near the MBNMS rose to nearly 1 million lb, with additional landings from MBNMS waters occurring in San Francisco. From 1989–93, landings dropped again, averaging 478,000 lb and $955,000. Catches from 1994–95, however, totaled 826,000 lb and 988,000 lb, respectively. This compares with a total California catch in 1994 of 13.5 million lb worth $18.5 million.

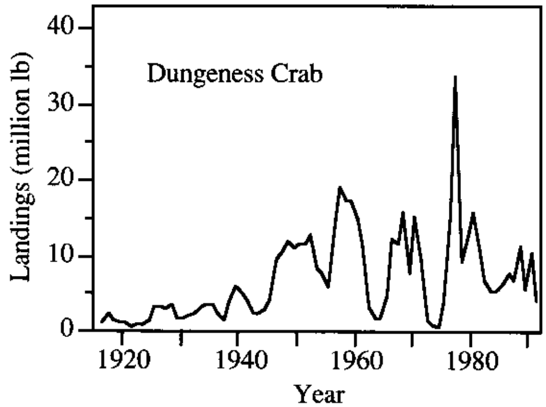


Figure 19. Reported commercial landings of Dungeness crab in California from 1916–91.

A number of factors are thought to influence the Dungeness crab fishery. These include: overfishing, ocean climate change, nemertean worm infestation of eggs, and chemical pollution of juvenile habitat. Some fishers are also concerned that trawling during the molting season is causing a decline in the fishery. Total crab landings for the coast, however, exhibit large cyclical fluctuations, rather than a steadily decreasing trend, despite the fact that commercial fishers are thought to harvest over 80% of legal-sized male crabs each year. This leads most fishery biologists to believe that coastwide, the Dungeness crab population abundance is more a function of environmental variables than fishing pressure. Dungeness crab research conducted in Washington supports this hypothesis.

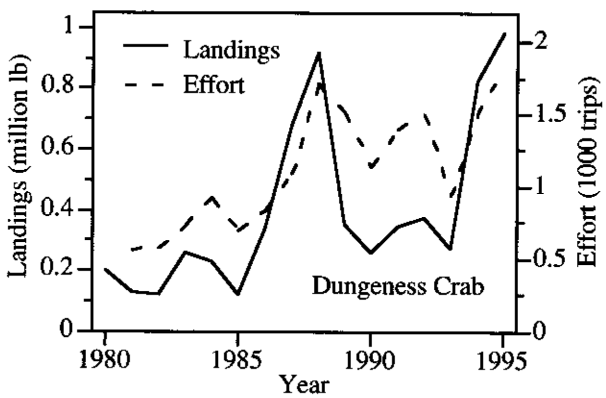


Figure 20. Reported commercial landings and fishing effort for Dungeness crab at the five major ports near the MBNMS from 1980–95.

Management: Historically, the Dungeness crab fishery has been heavily regulated. It is now a limited entry fishery. In the Monterey Bay area, Dungeness crab can be taken from November 15 through June 30. All traps are required to have a destruct device (e.g., twine that rots after a set amount of time) to prevent ghost fishing should the trap be lost. Traps must be emptied within 96 hr of deployment, and crabs must be harvested in prime condition. Each trap buoy must display an identification and permit number. No crab less than 6.25 in is allowed to be taken and only 1% of the total catch can be between 5.75 and 6.25 in. Trawlers and draggers are allowed no more than 500 lb/ boat as incidental catch. The recreational season is open from the Saturday preceding the second Tuesday in November until June 30, and there is a catch limit of ten crabs per person.

Females are not legally harvested in the fishery. Some researchers have suggested that an all male fishery could have detrimental effects on the population. More than 87% of all legal sized males are taken by the fishery each year; this lowers the ratio of males to females to less than one. As female crab will only mate with a male large enough to adequately embrace her, the male must be larger than the female at time of mating. Few males greater than 140 mm in carapace width are available during the mating season. Thus the larger, more fecund females may be prevented from successfully mating.

References

Armstrong, D.A. 1990. Shells and warmth: The advantage of estuarine recruitment to the juvenile Dungeness crab and implications for the fishery. Bulletin of Marine Science 46(1):244–251.

Botsford, L.W. and R.C. Hobbs. 1995. Recent advances in the understanding of cyclic behavior of Dungeness crab (*Cancer magister*) populations. Proceedings of a symposium of shellfish life histories and shellfishery models, 25–29 June, 1990, Moncton, New Brunswick. International consortium for the exploration of the sea, marine science symposium 199.

Caddy, J.F. (ed). 1989. Marine invertebrate fisheries: Their assessment and management. John Wiley and Sons, Inc, New York, NY. 752 pp.

Pauly, G.B., D.A. Armstrong, and T.W. Heun. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates — Dungeness crab. Biological Report, U.S. Fish and Wildlife Service. 20 pp.

Rounsefell, G.A. 1975. Ecology, utilization, and management of marine fisheries. C.V. Mosby Co., St. Louis, MO. 516 pp.

Smith, B.D. and G.S. Jamieson. 1991. Possible consequences of intensive fishing for males on the mating opportunities of Dungeness crabs. Transactions of the American Fisheries Society 120:650–653.

Wild, P.W. and R.N. Tasto, eds. 1993. Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the Central California Fishery Resource. California Department of Fish and Game, Fish Bulletin 172. 352 pp.

Rock Crab (*Cancer productus, C. antennarius, and C. anthonyi*)

Distribution: Red rock crab (*C. productus*) range from Kodiak Island, Alaska to San Diego, California, brown rock crab (*C. antennarius*) range from Sequim, Washington to Baja California, and yellow rock crab (*C. anthonyi*) range from Humboldt Bay, California to Baja California. Although these species are found throughout much of the Pacific Southwest, red rock crab are most abundant north of Point Conception, while brown rock crab are most abundant south of San Francisco, and yellow rock crab are most abundant south of Pt. Conception. All three species are found from the low intertidal zone to depths of at least 91 m. Rock crab occupy a wide range of habitats including bays and estuaries, gravel and rocky substrates, subtidal reefs, and nearshore areas with sand and mud bottoms.

Life History: Female rock crab mate during the soft-shelled condition that occurs after molting. Mating is most common in spring and fall, but occurs year round. During mating, males deposit spermatophores inside the female. Spermatophores contain sperm that is viable for a year or longer, and may last for multiple spawnings. Eggs are fertilized internally, extruded about 11 weeks after mating, and carried underneath the abdominal flap by the female. Female red rock crab produce between about 0.4

million and 4 million eggs per egg mass. Eggs develop into planktonic larvae that are abundant over the continental shelf. Larval rock crab grow through several developmental stages before recruiting to nearshore habitats in spring. Growth in adult rock crab progresses through a series of molts. Red rock crab are the largest of the three species with a maximum carapace width of 190 mm in males and 168 mm for females. In brown rock crab, the maximum carapace width is at least 155 mm in males and no more than 145 mm in females. In yellow rock crab, the maximum carapace width is 165 mm for males and 148 mm for females.

Fishery History and Trends: Three species of rock crab (yellow, brown, and red) are harvested off California. These species are not separated in landing statistics, so specific catches of individual rock crab species are difficult to distinguish. Rock crab are harvested using traps, and either landed alive for retail sale by fresh fish markets, or landed as crab claws. The most common traps used in the rock crab fishery are rectangular with 2 × 2 in welded wire mesh. Traps are set and buoyed in 25–75 m of water in both open sandy areas and near rocky habitats. Traps are usually retrieved 2–4 days after being set.

Rock crab landings have been reported since 1930, but landings were low until 1950. The rock crab fishery grew steadily through the 1960s, 1970s, and 1980s, with California landings peaking in 1986 at over 2.1 million lb. Historically, the majority of landings in the rock crab fishery have come from southern California. Beginning in the 1980s, the fishery expanded into areas north of Point Conception. Today, however, southern California catches still account for more than 90% of the total landings. Low rock crab catches north of Morro Bay result from the combination of lower fishing effort and preferential harvest of Dungeness crab, rather than low availability of the species. Rock crab landings from ports near the MBNMS increased from 1980–95 and averaged 203,000 lb/yr (Fig. 21).

Little information is available on the population status of rock crab. Catch rates are known to have decreased, however, in areas with extended fishing pressure. Rock crab populations are also affected by variable larval survival and recruitment resulting from environmental factors.

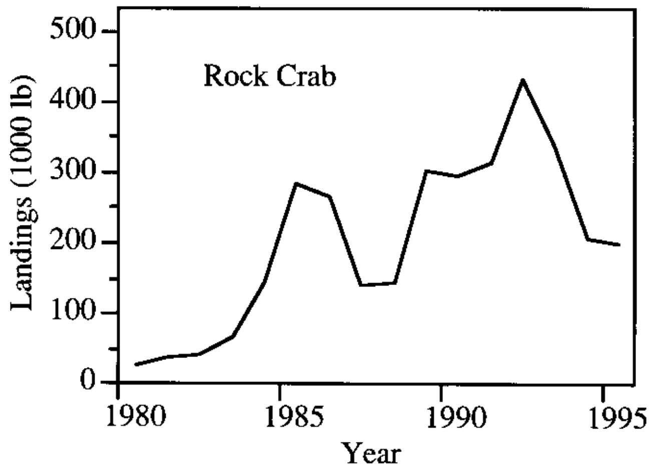


Figure 21. Reported commercial landings of rock crab at the five major ports near the MBNMS from 1980–95. Note that these data do not include landings of only crab claws.

Management: The commercial rock crab fishery is managed by the CDFG. A minimum harvest size for rock crab is set at a carapace width of 4.25 in to account for sizes of all three rock crab species. The recreational fishery is regulated by a minimum size limit of 4.0 in and a bag limit of 35 per day. Rock crab traps are also required to have open rings with a diameter of 3.5 in to allow for the escape of smaller individuals.

References

Carroll, J.C. and R.N. Winn. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) — Brown rock crab, red rock crab and yellow crab. U.S. Fish and Wildlife Service, Biological Report 82(11.117). 16 pp.

Carroll, J.C. 1982. Seasonal abundance, size composition, and growth of rock crab, *Cancer antennarius* Stimpson, off central California. Journal of Crustacean Biology 2(4):549–561.

Winn, R.N. 1985. Comparative ecology of three cancrid crab species (*Cancer anthonyi*, *C. antennarius* and *C. productus*) in marine subtidal habitats in southern California. Ph.D. dissertation. University of Southern California, Los Angeles. 235 pp.

Market Squid (*Loligo opalescens*)

Distribution: Market squid range from southeast Alaska to Baja, California. Highest population concentrations are south of San Francisco. Adults are dispersed over the continental shelf, then form large spawning aggregations in shallow water.

Life History: Larval market squid hatch at 2.7 mm mantle length and grow rapidly. They stay schooled for about 4–8 wk, then disperse over the continental shelf as they grow. Males and females show no initial size differences but growth rates diverge with age. Maximum obtainable mantle length is 190 mm for males and 180 mm for females.

Market squid aggregate in deeper water, then move inshore to spawn. They are terminal spawners; these squid live 1–2 yr, then spawn and die. Spawning occurs year-round in nearshore waters from San Francisco to Baja. In southern California, peak spawning occurs from October–February. In central California, peak spawning occurs from June–September. During spawning, adults migrate to semi-protected nearshore bays with sandy bottoms and rocky outcrops. Females produce 20–30 gelatinous capsules (180–300 eggs/capsule) which are anchored to the seafloor with thin stalks. Embryonic development ranges from 15–90 days, depending on water temperature.

Fishery History and Trends: Historically, the market squid fishery has been important throughout California. In 1863, Chinese settlers on the Monterey Peninsula established a small fishery using multiple skiffs with torches and hand-held seines to capture squid. The lampara net, a much more effective capture method, was introduced by Italian immigrants in 1905, increasing catches to 40,000 lb/haul. In 1946, landings increased to 38 million lb because of increased demand in both the local and foreign markets (Fig. 22). Monterey catches dominated California landings prior to 1961 when landings in southern California began to increase. Squid are marketed for human consumption (fresh, frozen, or canned) or sold as bait. Currently, most of the catch is exported.

Purse seining within Monterey Bay was outlawed in 1953 due its possible disruption of egg clusters. In 1959, the use of lights to concentrate squid schools also became illegal, effectively excluding the brail and pump systems. Fishers themselves actually requested this ban to keep processors from directly luring squid to docks for harvest by dip nets. Thus, fishers had to rely on scouts and the use of lampara nets to catch the squid. In 1987, lights were again legalized and a modified purse seine with no bottom chain was first used in the bay. By 1989, this modified purse seine was used throughout the bay, and by 1990 all lampara use ceased.

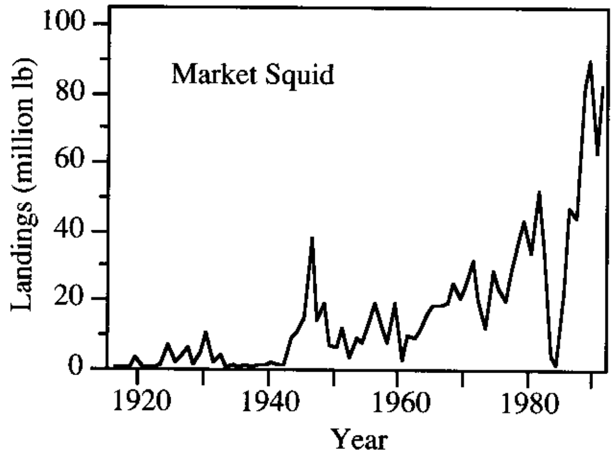


Figure 22. Reported commercial landings of market squid in California from 1916–91.

From 1981–83, squid catches within the MBNMS were relatively high, with annual landings totaling more than 20 million lb (Fig. 23), but landings decreased drastically to a low of 1 million lb in the El Niño years of 1983–84. From 1985–88, annual landings stabilized at approximately 10 million lb, then began to increase again. In 1994, landings reached the highest level since 1946. The fishery for market squid was the largest and most profitable fishery in the Monterey Bay area in 1994. A total of 35.8 million lb of squid worth over $5.2 million was landed at the ports near the MBNMS during 1994. Moss Landing and Monterey accounted for 30% and 57% of this catch, respectively.

The commercial squid fishery is thought to annually harvest a large portion of adult spawning aggregates in small areas such as Cannery Row. In more recent years, the squid fishery has expanded from traditional fishing grounds off Cannery Row to other areas along the central California coast. Total squid landings have

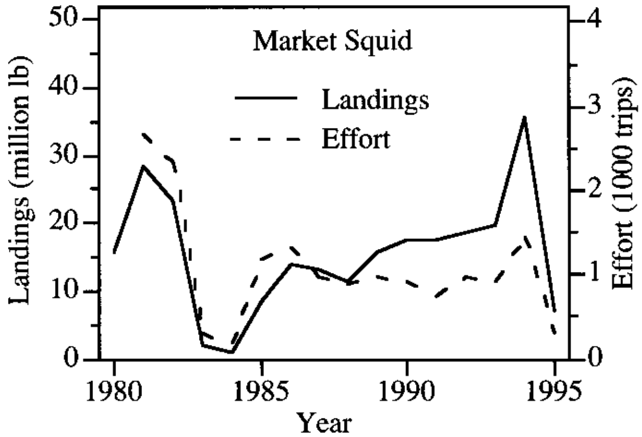


Figure 23. Reported commercial landings and fishing effort for market squid at the five major ports near the MBNMS from 1980–95.

historically exhibited large fluctuations, rather than decreasing trends, despite this intense fishing pressure (Fig. 22). This fluctuation, and the occurrence of squid spawning in unfished areas along the open coast, has led many fishery biologists to believe that the market squid population size is more a function of environmental variables than fishing pressure. The record harvests of the past few years, however, combined with the importance of squid as prey items for many species, have caused some biologists to suggest a more precautionary approach to squid fishery management.

Management: Regulations pertaining to the harvest of squid are minimal and have historically been related more to fishery conflicts and social concerns than to resource protection. There is no limit on the amount of squid that can be commercially harvested. The large harvests of the past few years have prompted some concerned fishers to request new legislation to restrict the number of boats in the fishery. Their rationale is that a limited entry fishery will reduce the risk of overfishing, maintain economic viability of the fishery, and limit negative effects of fishing gear on squid eggs.

References

Dewees, C.M. and R.J. Price. 1982. Overview of the squid fishery on the Pacific coast of the United States. *In:* Proceedings of the international squid symposium, Aug 9–12, 1981, Boston, Massachusetts. pp 197–212.

Kato, S. and J.E. Hardwick. 1975. The California squid fishery. Food and Agricultural Organization of the United Nations, Fisheries Report 170 (Suppl.). 150 pp.

Pleschner, D.B. 1988. Vince Aliotti: Seining squid in Monterey Bay. Pacific Fishing, October. pp. 38–43.

Recksiek, C.W. and H. W. Frey. 1978. Biological, oceanographic, and acoustic aspects of the Market Squid, *Loligo opalescens* Berry. California Department of Fish and Game, Fish Bulletin 169. 185 pp.

Spratt, J.D. and B. Leos (eds.). 1993. Monterey Bay commercial fisheries report #4. California Department of Fish and Game. 6 pp.

Spratt, J.D. and L.A. Ferry. 1993. A profile of the Monterey squid fleet in 1992. California Department of Fish and Game, Marine Resource Division, Administrative Report No. 93–2.

Wilimovsky, N.J., L.S. Incze, and S.J. Wetrheim (eds). 1988. Species synopses: Life histories of selected fish and shellfish of the Northeast Pacific and Bering Sea. Washington Sea Grant Program and Fisheries Research Institute, University of Washington, Seattle. 111 pp.

Sharks and Rays

Sharks and rays are cartilaginous fishes (i.e., elasmobranchs) whose populations often are affected by fishing far more than most bony fishes. They are highly susceptible to overfishing because they are less abundant, reach maturity at much later ages, and have fewer offspring than bony fishes. This leads to reduced ability to sustain continuous fishing pressure and maintain a viable population.

Shark fisheries, including those targeting sixgill, sevengill and basking shark, first boomed in the 1930–40s during World War II because of the high demand for liver oil. Populations quickly declined in the early 1950s and the fisheries collapsed. In the early 1980s, processors began carefully dressing and marketing shark products, resulting in an increased demand for shark meat as a food item. This led to the demise of the short-lived Pacific angel shark fishery in 1989. Similar occurrences were recorded for fisheries on common thresher shark, and to a lesser extent, leopard shark. The gill net ban in the early 1990s also lowered fishing effort on many shark species in California. Presently, there are no directed commercial fishing operations in Monterey Bay for any shark or ray species. Commercial operations in other areas of California are also very small. Almost all current landings of sharks occur as incidental catches from other fisheries.

Leopard Shark (*Triakis semifasciata*)

Distribution: Leopard shark range from Mazatlan, Mexico, into the northern Sea of Cortez, and north to Oregon. They are most common in shallow waters and migrate seasonally into estuaries and protected bays for spawning.

Life History: Leopard shark are live bearers and produce from 7 to 36 offspring (pups) in an annual reproductive cycle. Pupping occurs in the spring from March through July. In Monterey Bay, leopard shark use Elkhorn Slough as a nursery ground. Males mature at 7 yr of age and females at age 10 when they are between 102 and 107 cm in length. These sharks reach a maximum size of about 140 cm and a presumed maximum age about 30 yr. The oldest aged male was 24 yr and 135 cm long, and the oldest aged female was 20 yr and 130 cm long.

Fishery History and Trends: Commercial landings of leopard shark have decreased in northern California and increased in southern California since the 1980s. The banning of gill netting in San Francisco Bay and in nearshore areas probably contributed to the decline in leopard shark landings in central California after 1986. At this time abundances of leopard sharks in the San Francisco and Monterey Bay areas seem to be relatively stable. However, populations could decrease if fishing intensity were to increase or fishers started to effectively target smaller, younger sharks. Leopard shark landings at ports near the MBNMS averaged 8,700 lb/yr from 1980–95 (Fig. 24).

Management: Leopard shark are a popular game fish in San Francisco Bay and Elkhorn Slough and are landed by recreational anglers throughout California. Gear types used to catch leopard shark include hook-and-line, spearfishing, bow and arrow, and some commercial longline gear. Estimates of the catch of leopard shark are confounded by the unknown quantity which are landed under the market category shark/unspecified. Presently, the sport catch is regulated by a daily bag and possession limit of three and a minimum size of 36 in.

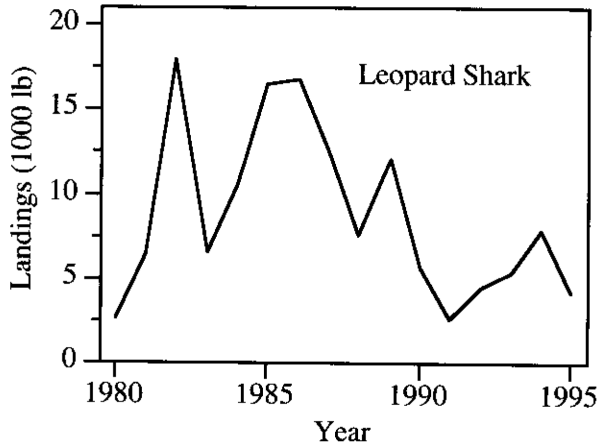


Figure 24. Reported commercial landings of leopard shark at the five major ports near the MBNMS from 1980–95.

References

Cailliet, G.M. 1992. Demography of the central California population of the leopard shark (*Triakis semifasciata*). Australia Journal of Marine and Freshwater Resources 43:183–193.

Cailliet, G.M., D.B. Holts, and D. Bedford. 1991. A review of the commercial fisheries for sharks on the west coast of the United States. *In*: Proceedings of an international workshop on the conservation of elasmobranchs. Sydney, Austr. pp. 13–29.

Ferguson, A. and G.M. Cailliet. 1990. Sharks and rays of the Pacific coast. Monterey Bay Aquarium Foundation, Monterey, California. 64 pp.

Kusher, D.I., S.E. Smith, and G.M. Cailliet. 1992. Validated age and growth of the leopard shark, *Triakis semifasciatus*, from central California. Environmental Biology of Fishes 35(2):187–203.

Roedel, P.M. and W.E. Ripley. 1950. California sharks and rays. California Department of Fish and Game, Fish Bulletin 75.

Smith, S.E. and N. Abramson. 1990. Leopard shark *Triakis semifasciata* distribution, mortality rate, yield, and stock replenishment estimates based on a tagging study in San Francisco Bay. U.S. Fishery Bulletin 88(2):371–381.

Common Thresher Shark (*Alopias vulpinus*)

Distribution: Common thresher shark are found worldwide in temperate and subtropical seas. In the eastern Pacific they are caught from Chile to Vancouver Island, British Columbia, excluding equatorial waters. Both adults and subadults congregate nearshore in spring and summer. Although most often caught in surface waters, thresher shark have been taken from depths of 70 m. They also appear to be highly migratory.

Life History: Common thresher shark are live bearers with a typical litter size of 4 pups. Pupping generally occurs from March to June. Off California, females reach maturity at sizes greater than 4.25 m. Males mature at approximately 3.25 m. The estimated maximum age for thresher shark is 30 yr. Maximum lengths for males and females are 6 m and 5 m, respectively.

Fishery History and Trends: Common thresher sharks were the target of an important commercial fishery for 10 yr starting in 1977. The fishery originated in southern California, but expanded to Morro Bay, Monterey, and San Francisco after 1982. Commercial thresher shark landings for all of California peaked in 1982, had declined substantially by 1986, and crashed soon after as a result of overfishing. Today, thresher shark are still fished between San Diego and Morro Bay, but constitute a very small fishery. In general, thresher shark populations are thought to be depleted. Common thresher shark landings at ports near the MBNMS averaged 112,000 lb/yr from 1980–95 (Fig. 25).

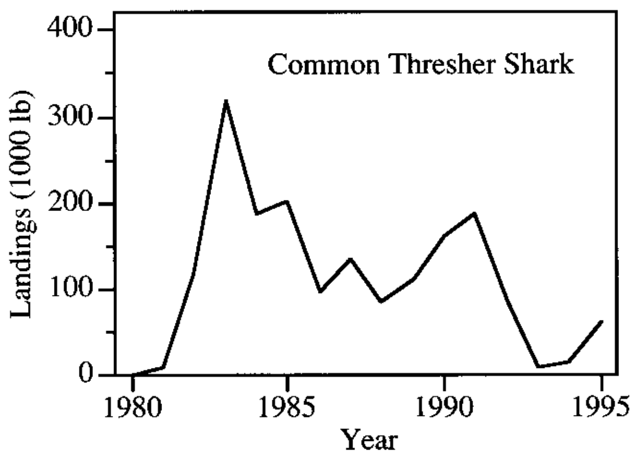


Figure 25. Reported commercial landings of common thresher shark at the five major ports near the MBNMS from 1980–95.

Management: Worldwide, thresher shark are a commercially sought species, and off the coast of North America, they are primarily caught in drift gill nets. However, there are no directed commercial fisheries for thresher shark in Monterey Bay. Thresher shark is also a highly prized sport fish, especially in southern California. The common thresher shark is not a federally regulated species. Take of thresher shark by commercial and sport fishers is regulated under the general provisions of the California Fish and Game Code.

References

Cailliet, G.M. and D.W. Bedford. 1983. The biology of three pelagic sharks from California waters, and their emerging fisheries: A review. California Cooperative Oceanic and Fisheries Investigations, Report 24:57–69.

Cailliet, G.M., D.B. Holts, and D. Bedford. 1991. A review of the commercial fisheries for sharks on the west coast of the United States. *In*: Proceedings of an international workshop on the conservation of elasmobranchs. Sydney, Australia. pp. 13–29.

Cailliet, G.M., L.K. Martin, J.T. Harvey, D. Kusher, and B.A. Welden. 1983. Preliminary studies on the age and growth of Blue, *Prionace glauca*, Common Thresher, *Alopias vulpinus*, and Shortfin Mako, *Isurus oxyrinchus*, sharks from California waters. *In:* Proceedings of an international workshop on age determination of oceanic pelagic fishes: Tunas, billfishes, sharks. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Tech. Rept. 8:179–188.

Strasburg, D.W. 1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. U.S. Fishery Bulletin 138(58):335–361.

Anadromous Fishes

Salmonids are an extremely important species group on the Pacific coast. They have been the attention of many researchers, and so much has been written about them that we can only briefly summarize their fisheries in this report.

Salmon are anadromous fishes, spending different stages of their life in freshwater and marine environments. Fluctuations in environmental conditions of both habitats can thus trigger large variations in population abundance. Salmon populations are also extremely vulnerable to human-induced degradation of aquatic environments.

Large-scale human influences on salmon populations began as early as the 1850s with the advent of the gold rush in California. During early settlement, hydraulic dredging methods used by gold miners released soil and debris into streams and rivers which clogged waterways, covered spawning gravel, and smothered eggs and juvenile fish. As agriculture developed, farmers began draining wetlands and diverting rivers, resulting in a redistribution of waters needed by salmon for reproduction and survival. With urban development came the construction of dams and aqueducts to provide controlled flow, domestic water, and hydroelectric power. All of these human activities have caused many salmon populations to decline over the last hundred years.

In the last 20 years, efforts have increased to protect salmon as a food and economic resource. Laws have been enacted to more carefully regulate harvest and human activities near salmon habitats. State and federal agencies and nongovernmental organizations are conducting both habitat and stock enhancement projects. Salmon hatcheries are run by federal and state governments and used to generate large releases of young from small spawning runs. Improved ocean conditions and these efforts by government agencies and community organizations have increased the size of salmon stocks, and we have seen an expansion in the population of some stocks over the last decade. In the Monterey Bay recreational fishery alone, the average total catch for Chinook salmon increased from 4800 fish/yr in the period from 1976–86 to 26,600 fish/yr from 1986–94 (Fig. 26). Salmon catches in 1995 were seven-fold larger than before, with almost 200,000 fish caught in the recreational fishery. Commercial catches of Chinook salmon also increased during the same time period.

Although Chinook salmon dominate the commercial and sport catch off California, small numbers of coho and pink salmon are also occasionally harvested. In addition to the salmon species off our coast, steelhead are an important anadromous fish caught by sport fishers in California. There are no directed commercial fisheries for steelhead in California and possession of steelhead aboard commercial trollers is prohibited.

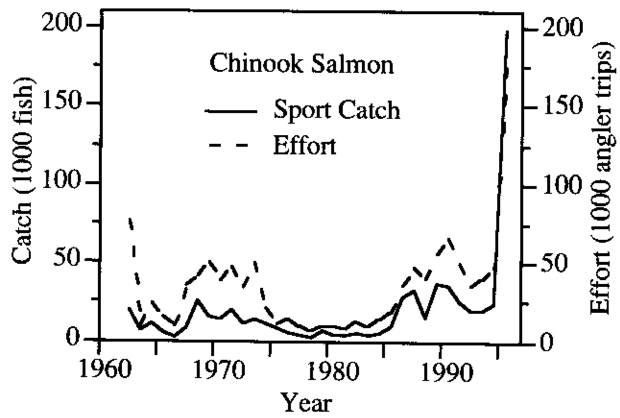


Figure 26. Reported sport catch and effort for Chinook salmon in Monterey Bay from 1962–95. Data provided by CDFG, Inland Fisheries Division.

Most of the Chinook salmon caught in the Monterey Bay region originated in the Sacramento River or its tributaries. In the Sacramento River system, there are four distinct runs of Chinook salmon that are named after the time they enter fresh water: fall, late-fall, winter, and spring. Sacramento River fall and late-fall Chinook populations are relatively healthy at the moment. Winter run Chinook salmon abundance dropped from more than 100,000 fish in 1979 to a historic low of 191 fish in 1991, and received federal protection under the Endangered Species Act. The spring run Chinook salmon was once the most abundant salmon in California, with up to 1 million fish returning to spawn in each of the Central Valley and Klamath/Trinity watersheds. Today, the number of spring run Chinook returning to these river systems has declined to fewer than 10,000 fish annually. It is these weaker salmon runs that greatly affect fishery management and water policy throughout the state of California.

Coho salmon are smaller than Chinook salmon and use many of the coastal streams and rivers that Chinook do not. There is only one race or run of coho salmon in California in contrast to the many Chinook runs. The abundance of coho salmon between the Oregon border and Monterey Bay was once estimated at over 500,000 fish. Today, this population has declined to less than 15,000 wild fish. Because of this drastic decline, southern Oregon and northern and central California coho salmon stocks have been listed as "threatened" under the Endangered Species Act.

Steelhead (anadromous rainbow trout) have two races or runs in California: summer or spring run, and winter run. Many of the larger streams entering the MBNMS have small runs of steelhead. Steelhead once ranged from Alaskan waters to San Diego, California. Fishery managers are concerned that there are currently no viable populations south of San Luis Obispo county. A few river systems in California have runs that are listed on the federal endangered species list.

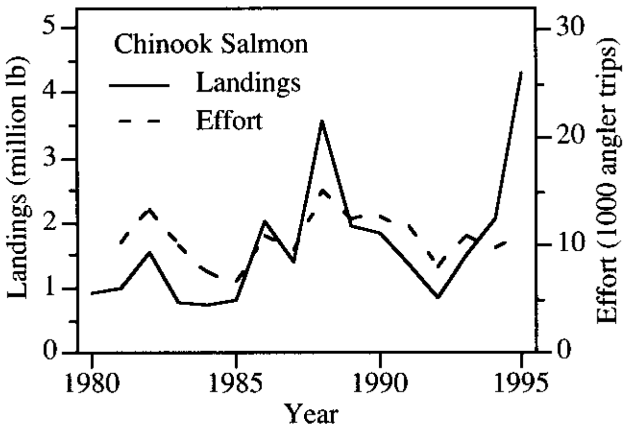


Figure 27. Reported commercial landings and fishing effort for Chinook salmon at the five major ports near the MBNMS from 1980–95.

Chinook Salmon (*Oncorhynchus tshawytscha*)

Distribution: Chinook salmon range from Japan to the Bering Sea and southward to San Diego, California. Chinook spawn year-round in suitable river systems from the Sacramento–San Joaquin rivers and northward. Chinook are the largest of the salmon species with a maximum recorded length of 147 cm and weight of 58 kg.

Life History: Juvenile salmon emigrate downriver and out to sea where they reach adulthood. Adults mature at 3 yr of age and most animals migrate back upstream at age 3–5 to spawn in their stream of origin. Females create large depressions in gravel habitats and deposit 270–20,000 eggs. Nearly all die 2 to 4 wk after spawning.

Fishery History and Trends: The ocean troll fishery for salmon started in the 1880s in Monterey Bay. Originally, sailboats were used to fish for salmon, but by 1910 almost all trollers were using powered boats. In the 1960s and 1970s, the salmon fishing fleet grew extensively as fishers who had other jobs during the rest of the year joined the summer fishery. In 1980, a moratorium was placed on the issuance of permits to new participants in the ocean commercial salmon fishery in order to increase individual profits and reduce overall fishery impacts. A limited-entry program was implemented in 1983. Chinook salmon populations and catches have been increasing since 1985. In 1995, more than 4.3 million lb of salmon were landed at ports near the MBNMS (Fig. 27).

Management: Chinook salmon are a federally managed species. Regulations are set regarding gear types for commercial and sport fisheries as well as bag limits, size limits, and seasons for sport fishers. The 1997 commercial regulations for central California Chinook salmon were the most restrictive ever. Commercial fisheries south of San Francisco were closed from June 1–22 and July 19–August 31. The minimum size limit is 26 in. Those races of Chinook salmon which can be legally harvested are caught using trolling gear with specific regulations on the type of hooks and amount of weight allowed per line. The recreational fishery in 1997 was open May 24–30, June 17–July 6, and August 12–September 14. The minimum size limit for the recreational fishery is 24 in, with a limit of two fish per day.

References

Allen, M.A. and T.J. Hassler. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) — Chinook salmon. Biological Report, U.S. Fish and Wildlife Service. 26 pp.

Healy, M.C. 1994. Variation in the life history characteristics of Chinook salmon and its relevance to conservation of the Sacramento winter run of Chinook salmon. Conservation Biology 8(3):876–877.

Hedrick, P.W., D. Hedgecock, and Hamelberg. 1995. Effective population size of winter-run Chinook salmon. Conservation Biology 9(3):615–624.

Mason, J.E. 1965. Chinook salmon in offshore waters. International North Pacific Fisheries

Commission Bulletin 16:41–74.
Pearcy, W.G. 1992. Ocean ecology of north Pacific salmonids. Washington Sea Grant Program. University of Washington Press, Seattle. 179 pp.
Vogel, D. 1992. Sacramento winter Chinook: Problem and recovery. Northwest Scientist 66(2). 141 pp.

Coho Salmon (*Oncorhynchus kisutch*)

Distribution: Coho salmon range from Korea and Japan to the Bering Sea and southward to northeast Baja California. Coho salmon spawn in river systems from Monterey Bay northward, but rarely enter the Sacramento–San Joaquin system. Coho salmon reach lengths up to 98 cm and have a maximum life span of 5 yr.

Life History: Most juveniles spend one year in fresh water before migrating to the ocean, although some spend two. Nearly all are mature at age 3 and return upriver to spawn. Spawning occurs from September to March and peaks from November to January. Females release 1,000–7,600 eggs which they deposit in depressions made in flat gravel. Eggs are immediately covered with gravel and guarded for up to 2 wk. Almost all coho die after spawning. Late larval stages, known as fry, emerge from the gravel from March to May.

Fishery History and Trends: There have been declines in California's salmon populations since the 1950s and 1960s. Coho salmon abundance has declined by 99%, and the race is now listed as endangered by California agencies and as threatened by the U.S. government. These declines are due primarily to habitat destruction and water diversion. Landings reflect the current severe fishery restrictions. Excluding the anomalously high catches in 1991, coho landings at ports near the MBNMS averaged less than 13,000 lb/yr from 1980–95 (Fig. 28).

Management: The retention of Coho salmon in the commercial fishery has been prohibited since 1994, but coho salmon are still an important sport fish in California. Coho fisheries are regulated under general provisions of the California Fish and Game Code. Although Chinook are usually the majority of the catch, coho can make up as much as half of the total sport catch in some years.

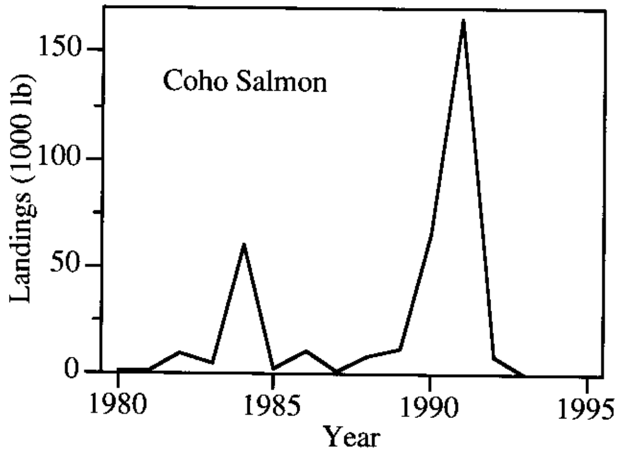


Figure 28. Reported commercial landings of Coho salmon at the five major ports near the MBNMS from 1980–95.

References

Godfrey, H. 1965. Coho salmon in offshore waters. International North Pacific Fisheries Commission Bulletin 16:1–39.
Hassler, T.J. 1987. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) — Coho salmon. Biological Report, U.S. Fish and Wildlife Service. 19 pp.
Laufle, J.C., G.B. Pauley, and M.F. Shepard. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) — Coho salmon. Biological Report, U.S. Fish and Wildlife Service. 28 pp.
Pearcy, W.G. 1992. Ocean ecology of north Pacific salmonids. Washington Sea Grant Program. University of Washington Press, Seattle. 179 pp.

Pelagic Fishes

Pelagic fishes dwell within the water column, away from the protection and shelter of bottom habitats. Pelagic fishes can be categorized into two types: nearshore and oceanic fishes. The oceanic forms, such as tunas, swordfishes, and some sharks, spend much of their life cycle in the open ocean. These fishes are known to make extensive migrations across the open ocean, occasionally coming close to the continents. Nearshore pelagic fishes include herring, sardine, and anchovy. These fishes live most of their life cycle in waters close to the continents, taking advantage of the high productivity of coastal waters.

Population abundances of most pelagic species are greatly determined by large-scale environmental phenomena. Decadal-scale shifts in the environment determine population sizes by affecting the success of spawning and recruitment. High fishing pressure at a time of changing environmental conditions can also influence population sizes, however. Many of the pelagic species are sought after by large fishing fleets with high fishing capability. The high fishing capacity of large vessels and fleets can quickly reduce populations of schooling fishes, because the catchability of the fish does not diminish at the same rate as does population size. Schooling fishes will remain in groups that are relatively easy to catch with large nets until population abundance becomes very small. This makes fishery management of schooling pelagic species more difficult. The movements of many of the pelagic fishes across international boundaries also makes fishery management more difficult than for more residential species.

Albacore (*Thunnus alalunga*)

Distribution: Albacore are found worldwide in temperate seas. In the Pacific they range from Alaska to Revillagigedo Island, Mexico. They are a pelagic species living in open seas. Albacore tend to aggregate in the vicinity of ocean fronts. During the day, they swim near the bottom of the mixed layer and make excursions to surface waters at night.

Life History: Spawning takes place from January to June between Hawaii and Japan, near the western part of the subtropical convergence. Young albacore grow at a rate of 4 cm/mo. Later growth slows to 7–13 cm/yr. Adults grow to a length of more than 150 cm and can weigh up to 93 lb. Albacore migrate across the North Pacific Ocean in the course of one year. Migration is eastward from spawning grounds, across the North Pacific. Albacore first appear off Baja and southern California in mid-June and early July, then continue to move north and into coastal waters in response to warming surface waters.

Fishery History and Trends: Because of their migration pattern, albacore are exposed to fisheries of several nations. The California fishing season extends from June to January. Albacore were first reported in the sport fishery off Santa Catalina Island at the turn of the century. As the size, speed, and technology of boats has increased, so have albacore landings. The gear, however, has changed very little. Because albacore travel in loose knit schools, commercial harvesting is most effectively accomplished by trolling with baited hook-and-line. In the Monterey Bay area, commercial vessels only fish albacore seasonally and switch gears or target species to participate in other fisheries, such as the salmon fishery. In the commercial albacore fishery, 6.9 million lb were landed in California in 1994. Again, only 5% came from the Monterey Bay area. At ports near the MBNMS, there has been a decline in total landings and fishing effort since the mid-1980s (Fig. 29). Albacore fishing is now also popular in the recreational CPFV fishery. In 1995, 1,296 albacore were landed in the California recreational CPFV fishery. A total of 1,161 of those were reported in southern California and only 82 were landed in the MBNMS.

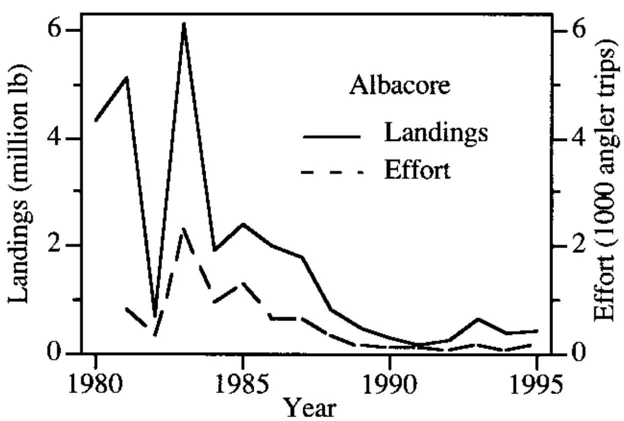


Figure 29. Reported commercial landings and fishing effort for albacore at the five major ports near the MBNMS from 1980–95.

Historically, there has been a tremendous fluctuation in albacore landings due to changes in nearshore distribution and surface availability (Fig. 30) . This variability is caused by environmental factors such as winds, location of cool sea surface temperatures, and intense storms that displace albacore offshore. During El Niño years, albacore may appear off Oregon and Washington and be very near shore in California waters. Albacore catch is greatest when surface temperatures are 18.3–19.7° C.

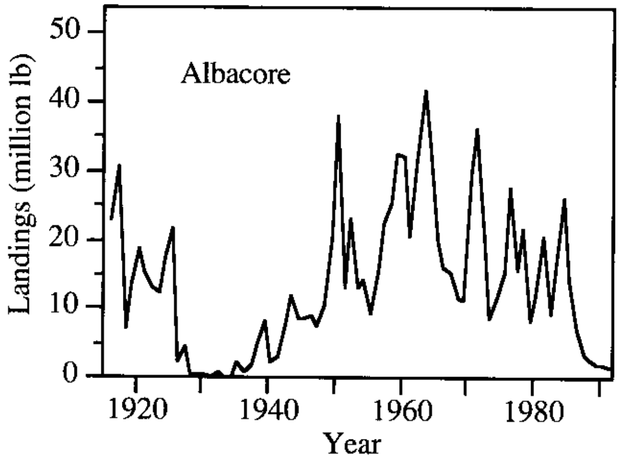


Figure 30. Reported commercial landings of albacore in California from 1916–91.

Management: Albacore exhibit substantial yearly fluctuations in year class strength. This fact, coupled with the highly migratory lifestyle of the species, makes albacore stock status difficult to determine. Stock assessments based on catch rates from fisheries showed a slight decreasing trend in abundance between 1980 and 1990. In more recent years, however, abundance estimates have increased, possibly due to the strong year-class of 1989 and cessation of high seas drift gill net fishery by foreign vessels.

References

Holts, D. 1985. Recreational albacore, *Thunnus alalunga*, fishery by U.S. West Coast commercial passenger fishing vessels. Marine Fisheries Review 47(3):48–53.

Laurs, R.M. and R.J. Lynn. 1977. Seasonal migration of North Pacific albacore, *Thunnus alalunga*, into North American coastal waters: Distribution, relative abundance, and association with transition zone waters. U.S. Fishery Bulletin 75(4):795–822.

Lui, Hsi-Chiang and N. Bartoo. 1995. Report of the fourteenth North Pacific albacore workshop. Taipei, Taiwan, Republic of China. 39 pp.

Parrish, R.H, N.W. Bartoo, S.F. Herrick Jr., P.M. Kleiber, R.M. Laurs and J.A. Wetherall. 1989. Albacore Management Information Document. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Center, Technical Memorandum 126. 56 pp.

Pacific Mackerel (*Scomber japonicus*)

Distribution: Pacific mackerel are found worldwide in temperate and subtropical waters. In the North Pacific they range from Alaska to Mexico, but are most abundant south of Point Conception. They are a pelagic schooling fish that occur in inshore waters, but are found as far offshore as 400 km.

Life History: Spawning occurs off California from late April to July. Pacific mackerel are batch spawners, spawning up to 8 times per yr and releasing approximately 70,000 eggs per batch. Eggs hatch three days after fertilization. Some mackerel mature in their second year and about half reach maturity at 33 cm. Pacific mackerel may reach a length of 64 cm and weigh up to 6.4 lb, but are usually no longer than 41–46 cm nor weigh more than 1.5–2.5 lb. They may live 9–11 yr.

Fishery History and Trends: Prior to 1928–29, Pacific mackerel were sold primarily as a fresh fish item and market demand was low. In the late 1920s, processors began canning Pacific mackerel. With this increased market demand, sardine fishers started using seine nets to target mackerel. Off season albacore fishers also began targeting mackerel by herding them into a concentrated frenzy and using large dip nets to scoop the mackerel out of the water. Currently, seine nets account for nearly all the commercial fishing effort for Pacific mackerel. Pacific mackerel also are commonly caught as bycatch in trawl fisheries.

The California fishery peaked in 1935 at 146 million lb, followed by several decades of fluctuating decline (Fig. 31). In 1953–54, the fishery seemed exhausted, but was rejuvenated for several subsequent years after a good recruitment year. After a series of poor recruitment years in the 1960s, a moratorium was placed on mackerel fishing in 1970. The populations recovered and fishing began again in 1976 with California-based seine vessels accounting for nearly all of the commercial fishing effort for Pacific mackerel in U.S. waters. California landings have been on a downward trend since 1988, with 1995 landings at the lowest level since the fishery reopened in 1976. At ports near

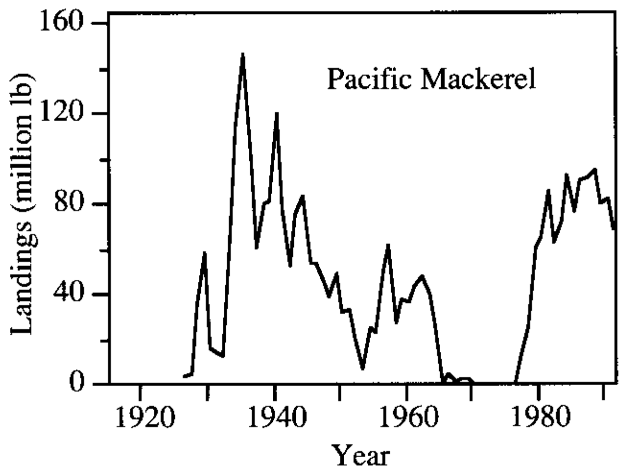


Figure 31. Reported commercial landings of Pacific mackerel in California from 1926–91.

the MBNMS, annual landings fluctuated greatly between 1980–95. In 1983, 1984, and 1990 landings exceeded 5 million lb (Fig. 32).

California landings of Pacific mackerel have declined since 1990. The decline in landings is thought to be a result of low population size caused by poor recruitment, which has been below average since 1989. Stock biomass is believed to be considerably lower than in the 1970s and 1980s. Decreased landings are also the result in part of decreased effort by seine fishers who have shown increased participation in the more lucrative winter squid and summer tuna fisheries. Less than 5% of the California catch of Pacific mackerel is taken from MBNMS waters.

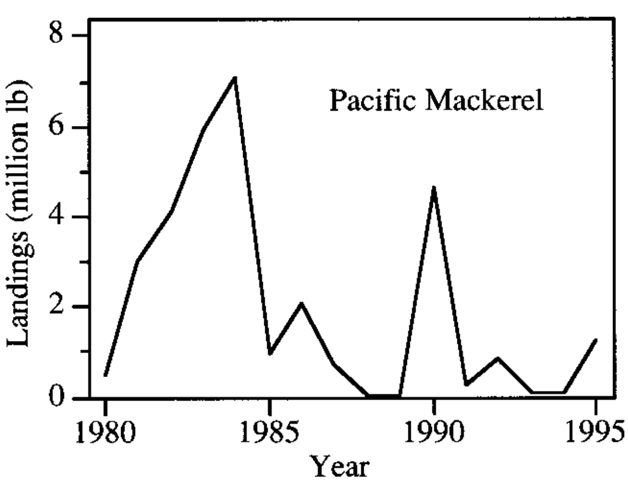


Figure 32. Reported commercial landings of Pacific mackerel at the five major ports near the MBNMS from 1980–95.

Management: Pacific mackerel are caught in large quantities in both the United States and Mexico. The United States accounts for about 64% of total landings. The U.S. fishing season for Pacific mackerel is defined as a 12 month period from July 1 to June 30. Mackerel can be fished every month until the harvest quota is met. If stock biomass falls below 40 million lb, a moratorium is implemented on all directed catch. A fishing quota of 30% of the stock biomass is set, when biomass is between 40 million and 300 million lb. If stock biomass is above 300 million lb, there is no limitation on total catch.

CDFG set the 1995–96 Pacific mackerel commercial fishing quota at 21.6 million lb, 33% lower than the previous season. California landings during the 1995–96 season remained below the quota, totaling 15.9 million lb. The biomass of Pacific mackerel at the beginning of the 1996–97 fishing season was estimated at 104 million lb. Because the estimate is above the minimum needed for a fishery, but below 300 million lb, a coastwide quota was set for the 1996–97 fishing season at 19.2 million lb. This is the lowest estimate of biomass and most restrictive quota since the late 1970s.

References

Barnes, J.T. and D.H. Hanan. 1995. Status of the Pacific mackerel resource and fishery, 1994 and 1995. California Department of Fish and Game, Marine Resources Division, Admin. Report 95–4. 20 pp.

Barnes, J.T, M. Yaremko, and T. Bishop. 1996. Status of the Pacific mackerel resource during 1996 and management recommendations for the fishery. California Department of Fish and Game, Marine Resources Division, unpublished report. 32 pp.

Jacobson, L.D., E.S. Konno and J.P Pertierra. 1994. Status of Pacific mackerel and trends in biomass, 1978–1993. California Cooperative Oceanic and Fisheries Investigations, Report 35:36–39.

Parrish, R.H. and A.D. MacCall. 1978. Climatic variation and exploitation in the Pacific mackerel fishery. California Department of Fish and Game, Fish Bulletin 167.

Northern Anchovy (*Engraulis mordax*)

Distribution: Northern anchovy are small, short-lived schooling fish ranging from Queen Charlotte Island, British Columbia to Baja California. Three genetically distinct sub-populations of northern anchovy are recognized within their range: a northern sub-population extends from British Columbia to northern California. A central sub-population extends from San Francisco, California to northern Baja California, and a southern sub-population extends from northern Baja California to Magdalena Bay, Mexico. Northern anchovy are found from the surf zone to depths of over 300 m. They are occasionally seen in schools hundreds of kilometers offshore.

Life History: Anchovies spawn year-round, thus exposing larvae to a number of environmental conditions. A peak in larval abundance occurs from February–April. Pinnipeds, cetaceans, and other fish prey upon anchovy, but 32% of anchovy egg mortality is due to cannibalism. Larval anchovy require dense concentrations of plankton to feed effectively. Both winter storms and strong spring upwelling disturb ocean water masses and decrease feeding effectiveness. Year-class strength is highest in years when wind duration and strength is minimal at the onset of larval feeding. Larval anchovy are known to compete with larval sardine for food. In years when sardine biomass is high, anchovy are smaller in length than normal. Anchovy rarely exceed 4 yr of age, but 7 yr old fish have been documented. They reach a maximum length of 23 cm, but most fish are much smaller.

Fishery History and Trends: Northern anchovy are harvested using lampara nets and purse seines, and sold fresh frozen or as bait. Northern anchovy are harvested as part of the "wetfish" fishery which also targets Pacific mackerel, jack mackerel, Pacific bonito, market squid, sardine, and tunas. Anchovy are often targeted when large catches of these other, more lucrative species are not available. The anchovy fishery was small until the collapse of the Pacific sardine fishery in 1952. After a brief period of high catches, low anchovy marketability caused landings to decline in 1954. California catches remained at low levels through 1964. Landings of anchovy have fluctuated greatly since that time (Fig. 33).

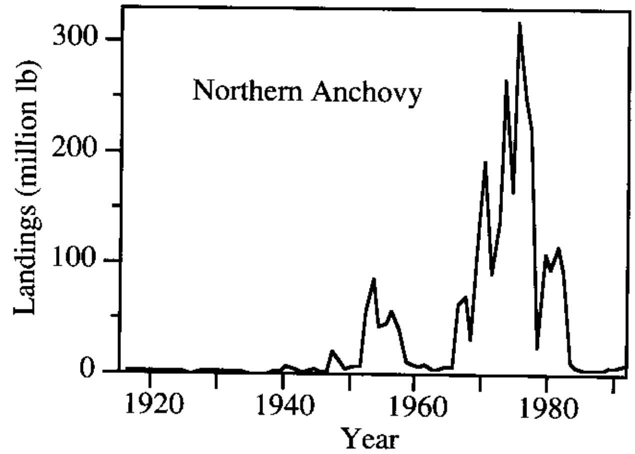


Figure 33. Reported commercial landings of northern anchovy in California from 1916–91.

Anchovy harvest in the MBNMS peaked in 1981 with landings of 10 million lb, then declined to a low of 1.4 million lb in 1983 (Fig. 34). Between 1985–89, landings averaged 1.9 million lb/yr. Landings rose to about 5 million lb/yr in 1990–91, but have subsequently returned to about 2.3 million lb/yr. In 1994, Moss Landing and Monterey fishers harvested 2.2 million lb of anchovy, worth $300,000 (54% of the total value for the California anchovy fishery). The high exvessel price for anchovy in 1994 was due to a 7 cent increase in the price per pound. The price had dropped by 1995, as Moss Landing and Monterey landings accounted for 2.4 million lb, valued at $92,000.

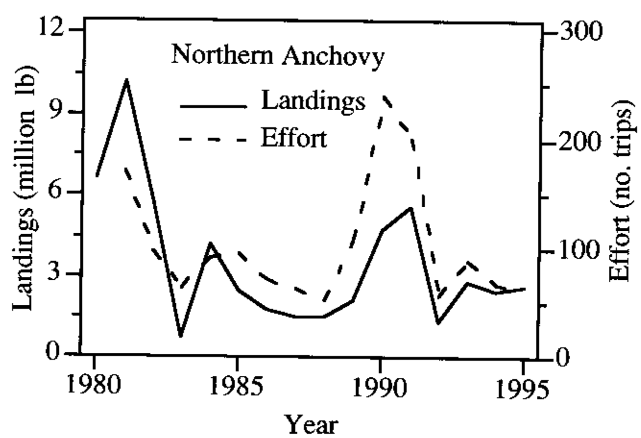


Figure 34. Reported commercial landings and fishing effort for northern anchovy at the five major ports near the MBNMS from 1980–95.

The northern anchovy has long been considered a boom-and-bust species. Anchovy abundances were probably higher in the 19th and early 20th centuries than they are presently, and may have peaked 1,600 years ago. Sediment cores taken off Santa Barbara indicate that fluctuations in population size have occurred every 30–60 years as far back as 200 AD. Population trends derived from sediment records agree with fishery-derived estimates when direct comparisons can be made. This fluctuation in population size suggests that species interactions and environmental factors play a large role in the patterns seen in the fishery.

Short-term fluctuations in northern anchovy biomass related to environmental factors are also evident. Spawning biomass within the central sub-population, as estimated from fish spotter data and egg production indices, declined after 1985 due to low recruitment. High recruitment in 1993, however, resulted in subsequent increases in population biomass for 1994–95. Current biomass is considered to be stable, but low relative to historical levels. The estimated spawning biomass in 1995 for the central sub-population was 856 million lb.

Management: Northern anchovy stocks cross the United States–Mexico border, and at one time this fishery was managed jointly between the United States and Mexico. There is currently, however, no agreement between the United States and Mexico to manage this species as a unit. The Pacific Fisheries Management Council (PFMC) and the state of California are discussing options for anchovy management. Until a working Fishery Management Plan is adopted, CDFG will allow 22 million lb to be harvested annually.

References

Baumgartner, T.R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. California Cooperative Oceanic and Fisheries Investigations, Report 33:24–40.

Kucas, S.T., Jr. and J. Parsons. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) — Northern anchovy. U.S. Fish and Wildlife Service, Biological Report 82(11.50). 13 pp.

Lasker, R. and A. MacCall. 1983. New ideas in the fluctuations of clupeoid stocks off California. *In*: Proceedings of the joint oceanographic assembly 1982—General symposia, Ottawa. 189 pp.

Soutar, A. and J. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. California Cooperative Oceanic and Fisheries Investigations, Report 13:63–70.

Soutar, A. and J. Isaacs. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediment off California. U.S. Fishery Bulletin 72:257–273.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. Alaska Fisheries Science Center, NMFS/NOAA, 7600 Sand Point Way NE, Seattle, Washington 98115.

Pacific Sardine (*Sardinops sagax*)

Distribution: Pacific sardine are small pelagic fish ranging from Guaymas, Mexico to Alaska. Pacific sardine are found in nearshore waters out to 50 km. In the past there were thought to be three separate sardine stocks. In more recent years, however, the three stocks are believed to actually be part of one single stock that migrates northward with increasing age and in response to changing temperatures. The temperature tolerance for Pacific sardine is 55–63°F.

Life History: Pacific sardine are multiple spawners, maturing by age 2. Age of maturity may increase as spawning biomass increases. Spawning occurs year-round, with peaks in larval abundance varying spatially. Larval density peaks in August in the southern portion of their range and in January–April in the northern portion of their range. Some sardine recruit to the fishery at age 2, but most are not exploited until age 3. They attain a maximum age of 13 yr, and a maximum length of 40 cm.

Fishery History and Trends: Sardine fisheries have been important within California since the turn of the century (Fig. 35). During the peak harvest periods in the 1930s and 1940s, sardine were used for fish meal, soap oil, paint mixer, vitamins, glycerin, and shortening. The decline

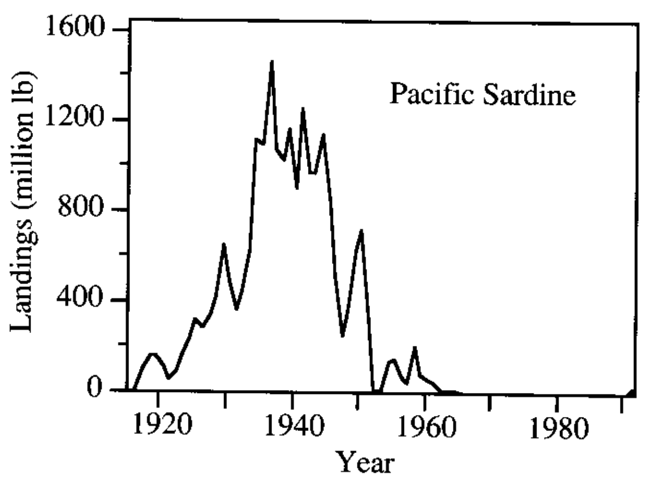


Figure 35. Reported commercial landings of Pacific sardine in California from 1916–91.

in stock biomass caused many of the canneries to close by the 1960s. In 1974, a moratorium limited the take to incidental catch totaling no more than 110,000 lb/yr. These regulations remained in place through 1981 in the hope that this would allow the population to recover. Catches between 1975–86 remained less than 5000 lb/yr. In 1986, CDFG allowed the first targeted sardine fishery since the 1974 closure, and landings at ports near the MBNMS began to increase. In 1992, reported catches totaled 6.8 million lb, the highest in 20 yr (Fig. 36). Much of this catch was trucked to southern California and processed for use in pet foods. In 1993, catches declined because of poor market demand for canned sardine. A new canning line developed in 1994 that allowed fishers to target smaller sardine, and catches rose again that year. In 1995, landings peaked again at 12.5 million lb, nearly twice that of the 1992 landings, and were worth over $500,000. In 1996, sardine landings totaled over 17.6 million lb and were worth over $880,000. Exvessel price remained consistent at $70–80 per ton, despite an increase in the inquiries for purchasing sardine by both foreign and domestic companies.

The Pacific sardine has long been considered a boom-and-bust species. Fluctuations in population size are apparent as far back as 200 AD. Twelve main occurrences, separated by 20–200 yr, have been documented, with the highest population existing 1,000 yr ago. This fluctuation in population size suggests that species interactions and environmental factors play a large role in the pattern seen in the fishery. In 1996, CDFG estimated the coastwide sardine biomass to be more than 1 billion lb. It is believed that sardine populations are generally increasing in abundance.

Management: Prior to 1967, Pacific sardine were managed by seasonal closures and catch limits of whole fish for reduction. From 1967–85, the fishery was limited to incidental catch. Small, directed fisheries have been allowed since 1986 with specific catch quotas. At this time, a joint research effort exists with the United States and Mexico to assess spawning biomass. Current studies show that the sardine population is expanding at a rate of approximately 25% per year. Until a joint United States–Mexico plan is adopted, the fishery will continue to be regulated by the state of California. Based on the CDFG biomass estimate, the 1997 harvest quota was set at 119 million lb for the California fishery, an increase of 41% over the 1996 harvest quota. This annual sardine harvest quota is divided so that two-thirds are allocated to the southern California fishery south of San Luis Obispo, and one-third is allocated to the northern California fishery.

References

Barnes, J.T., A.D. MacCall, L.D. Jacobson, and P. Wolf. 1992. Recent population trends and estimates for the Pacific sardine (*Sardinops sagax*). California Cooperative Oceanic Fisheries Investigations, Report 33:60–75.

Baumgartner, T.R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of

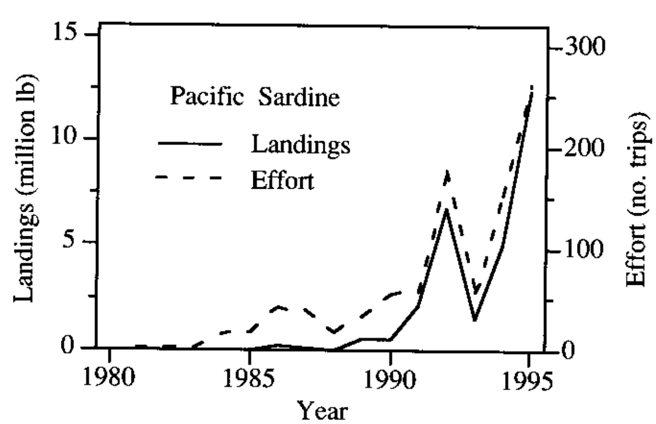


Figure 36. Reported commercial landings and fishing effort for Pacific sardine at the five major ports near the MBNMS from 1980–95.

Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. California Cooperative Oceanic Fisheries Investigations, Report 33:24–40.

Lluch-Belda, D., S. Hernandez-Vazquez, D.B. Lluch-Cota, C.A. Salinas-Zavala and R.A. Schwartzlose. 1992. California Cooperative Oceanic Fisheries Investigations, Report 33:50–59.

Smith, P.E. 1990. Monitoring interannual changes in spawning area of Pacific sardine (*Sardinops sagax*). California Cooperative Oceanic Fisheries Investigations, Report 31:145–151.

Soutar, A. and J. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. California Cooperative Oceanic Fisheries Investigations, Report 13:63–70.

Soutar, A. and J. Isaacs. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediment off California. U.S. Fishery Bulletin 72:257–273.

Wolf, P. 1992. Recovery of the Pacific sardine and the California sardine fishery. California Cooperative Oceanic Fisheries Investigations, Report 33:76–86.

Roundfish

The roundfish category is more of a commercial than ecological grouping. This group contains such fishes as lingcod, sablefish, and Pacific Hake. These species are ecologically very different, but all are important components of California fisheries. Several additional roundfish species are commercially harvested along the west coast of America, including Pacific cod and jack mackerel, but are not specifically targeted along the central coast of California. We have tried to provide several references for further information on such species.

Lingcod (*Ophiodon elongatus*)

Distribution: Lingcod are only found off the west coast of North America and range from Point San Carlos, Baja California to the Shumagin Islands along the Alaska Peninsula. Postlarvae to 8 cm in length are pelagic. Juveniles occur in shallow bays on sand and mud bottoms from nearshore to depths to 33 m. Adults range from the surface to 467 m deep. The center of lingcod abundance is off British Columbia.

Life History: Lingcod migrate inshore to spawn in rocky habitats. Spawning occurs off California from November through March and peaks in December and January. Egg masses are deposited and guarded by the male until the eggs hatch. Fecundity ranges from 50,000 eggs produced by a 61 cm long female to 170,000 eggs produced by a 91 cm long fish. In California, some females mature at a length of 51 cm, half are mature at 58 cm, and all are mature at 71 cm. Fifty percent of males are mature at a length of 41 cm. Maximum recorded length for a lingcod is 150 cm and maximum weight is 32 kg. Maximum age is 20 yr.

Fishery History and Trends: Lingcod comprise a substantial portion of the recreational landings and are an important commercial species as well. Between 1980–95, an average of 180,000 lingcod were caught annually in the recreational fishery. During the 1980s, two-thirds of the commercial catch of lingcod was derived from the trawl fishery. Landings at ports near the MBNMS averaged 482,000 lb/yr from 1980–95, but the commercial catch has fluctuated greatly in the last 15 yr, presumably due to the influx of periodic strong year-classes into the fishery (Fig. 37). This cyclical trend has also been evident coastwide since the onset of the fishery in the early 1900s (Fig. 38). Another indication of episodic recruitment is that mean lengths of both males and females decreased by approximately 10 cm between 1978–83 and 1992–93.

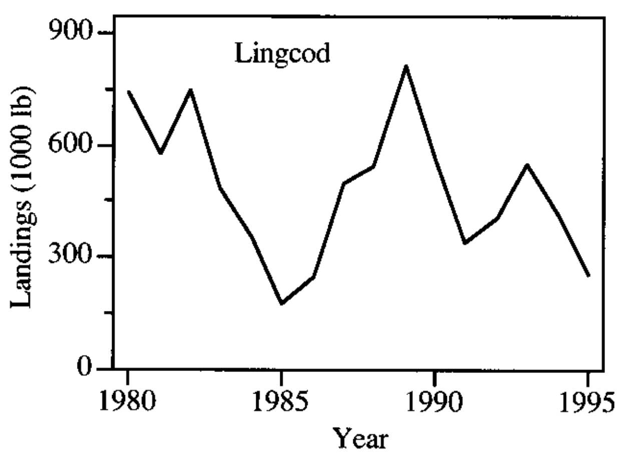


Figure 37. Reported commercial landings of lingcod at the five major ports near the MBNMS from 1980–95.

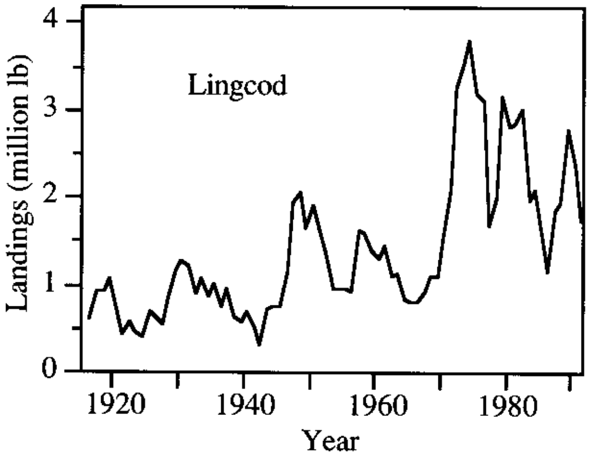


Figure 38. Reported commercial landings of lingcod in California from 1916–91.

Lingcod stocks along the West Coast have been heavily utilized. NMFS models suggest that from northern Oregon to southern British Columbia, lingcod catches have been just below the overfishing level. In southern Oregon and California, the commercial catch is dominated by 2–4 yr old fish and 50% of the females are immature, leading to concerns about overharvest in this area as well.

Management: Lingcod fisheries are regulated in California by both state and federal regulation. The 1996 acceptable biological catch (ABC) for combined commercial and recreational catch set by the PFMC for the Monterey management area was 1.5 million lb, or 63% of the area's commercial and recreational catches of the late 1980s to early 1990s. Sport take of lingcod in California is limited to a daily bag and possession limit of 5 fish and a minimum length of 22 in.

References

Bargmann, G.G. 1982. The biology and fisheries for lingcod (*Ophiodon elongatus*) in Puget Sound. Washington Department of Fish, Technical Report 66. 69 pp.

Cass, A.J., R.J. Beamish and G.A. McFarlane. 1990. Lingcod (*Ophiodon elongatus*). Canadian Special Publ. Fisheries and Aquatic Sciences 109. 35 pp.

Miller, D.J. and J. Geibel. 1973. Summary of blue rockfish and lingcod life histories: A reef ecology study; and Giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. California Department of Fish and Game, Fish Bulletin 158. 137 pp.

Phillips, J.B. 1959. A review of the lingcod, *Ophiodon elongatus*. California Department of Fish and Game 45(1):19–27.

Shaw, W.N. and T.J. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) — Lingcod. Biological Report, U.S. Fish and Wildlife Service. 10 pp.

VenTresca, D.A., J.L. Houk, M.J. Paddack, M.L. Gingras, N.L. Crane, and S.D. Short. 1996. Early life-history studies of nearshore rockfishes and lingcod off central California, 1987–92. California Department of Fish and Game, Marine Resources Division Administrative Report 96–4. 77 pp.

Wilson-Vandenberg, D., P.N. Reilly, and C. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. California Department of Fish and Game, Marine Resources Division Administrative Report 96–6. 96 pp.

Sablefish (*Anoplopoma fimbria*)

Distribution: Sablefish range from Baja to the Bering Sea, with the majority of the population in the Gulf of Alaska. They are most abundant in depths greater than 370 m over clay and hard mud bottoms. In Monterey Bay they are most abundant between 900–1200 m along the edges of the Monterey Bay submarine canyon.

Life History: Sablefish have a maximum age of approximately 20 yr, but most of the fish caught are 3–8 yr old. Spawning occurs during winter in water depths between 230 and 1,100 m. For males and females respectively, 50% maturity is reached by age 5 and age 7. Females each release 100,000–1 million eggs. Larvae live in surface waters, whereas juveniles are associated with the ocean floor in waters less than 150 m deep. Adults reach 102 cm in length and 125 lb in weight, but are usually less than 76 cm long and 24 lb in weight. Sablefish are first caught in the fishery at the end of their second year when they are approximately 43 cm long. Sablefish have several market names including black cod, butterfish, and Alaskan cod. The meat is very oily with 14% fat content, making it ideal for smoking, but difficult to freeze.

Fishery History and Trends: Sablefish are taken in the trap fishery, in the longline fishery, and by bottom trawlers as part of the groundfish fishery. The U.S. commercial fishery began as early as 1905 as incidental catch by halibut fishers. During World War II, demand increased greatly with the need for sablefish livers to manufacture vitamin A. In 1958, Pacific coast landings had increased to 21 million lb, and all harvesting was by Canadian and U.S. fishers. In the 1960s, however, Russian and Japanese factory vessels began fishing for sablefish. Sablefish removals from California waters peaked in 1972 with 144.2 million lb caught, primarily by Japanese vessels. Only about 20% of the catch was landed into California ports (Fig. 39). In 1976, the FCMA returned the California sablefish fishery back to domestic fishers, and California became the dominant Pacific coast state for sablefish landings. Monterey is one of the main ports for sablefish landings in California.

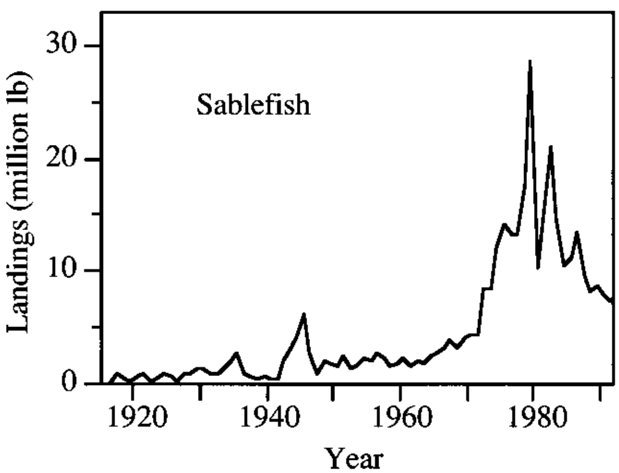


Figure 39. Reported commercial landings of sablefish in California from 1916–91.

Landings for ports near the MBNMS have been decreasing since 1980, although fishing effort has increased (Fig. 40). Since 1990, annual reported catch has been below 2 million lb. The decline in catch has been attributed to reduced populations caused by fishing and limited recruitment. Because market demand of sablefish is high, the value of sablefish in the marketplace has not dropped as quickly as the catch. In 1995, landings in this region increased slightly to 1.9 million lb, but the value increased to more than $2 million.

The sablefish stock along the Pacific coast was assessed in 1994 using both traps and trawl

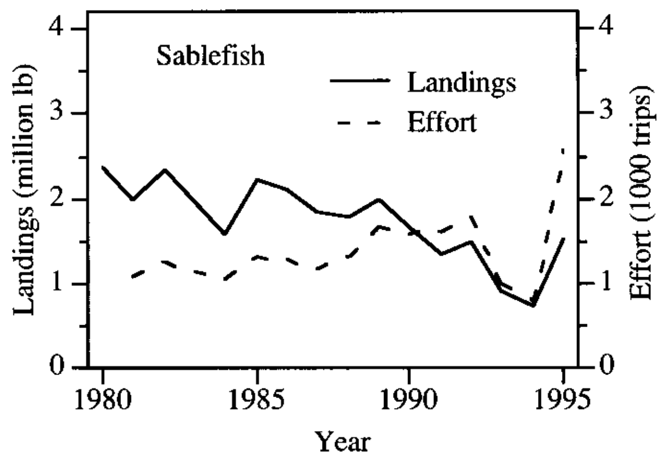


Figure 40. Reported commercial landings and fishing effort for sablefish at the five major ports near the MBNMS from 1980–95.

surveys. Surveys indicated a substantial decline in sablefish from 1990–93, especially for larger females. A record high catch of young sablefish was recorded in 1992. This may lead to strong recruitment levels in upcoming years.

Management: Until the 1970s, little direct management was enacted for sablefish. The sablefish fishery is now one of the few fisheries which allocates available harvest between different gear types. Trip limits are used to regulate this fishery. The 1996 and 1997 coastwide ABC were set at 20.1 million lb, which includes an estimated 2 million lb of fishery discard.

References

Cailliet, G.M., E.K. Osada, and M. Moser. 1988. Ecological studies of sablefish in Monterey Bay. California Department of Fish and Game 74(3):132–153.

Hunter, J.R., B.J. Macewitcz, and C.A. Kimbrell. 1989. Fecundity and other aspects of the reproduction of sablefish, *Anoplopoma fimbria*, in central California waters. California Cooperative Oceanic and Fisheries Investigations, Report 30:61–72.

Melteff, B.R., ed. 1983. Proceedings of the international sablefish symposium. 1983. University of Alaska Sea Grant Report 83–8. Alaska Sea Grant Program, University of Alaska, Fairbanks.

Parks, N.B. and F.R. Shaw. 1989. Relative abundance and size composition of sablefish (*Anoplopoma fimbria*) in the coastal waters of California and southern Oregon, 1984–88. National Oceanic and Atmospheric Administration, National Marine

Fisheries Service, Northwest Center, Technical Memorandum 167.
Sonu, Sunee C. The Japanese Sablefish Market. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Region, Technical Memorandum 31.
Dewees, C.M. 1980. University of California Sea Grant, Marine Advisory Program. Leaflet 21155.

Pacific Hake (*Merluccius productus*)

Distribution: Pacific hake, also referred to as Pacific whiting, are silver, cod-shaped fish. They range from the Gulf of Alaska to the Gulf of California and are most abundant within the California Current. Hake are midwater schooling fishes which occur at depths between 10 and 900 m. Highest densities are found at depths between 50 and 550 m.

Life History: Adults may reach 90 cm in length and at least 23 yr of age. Hake mature at age 3–4 and 34–40 cm in length. During spring and summer they are found in the northern part of their range at feeding grounds as far north as central Vancouver. In autumn, adults migrate south to southern and Baja California to spawning grounds. Spawning takes place in winter over the continental slope. Large concentrations of pelagic eggs and larvae float upwards and remain at the base of the mixed layer. Juveniles 1–3 yr old are found primarily off central and southern California. Most 0–1 yr old fish occur farther inshore than older juveniles.

Fishery History and Trends: Historically, foreign vessels have dominated the Pacific hake fishery off the west coast of the United States. The fishery was started in 1966 by Soviet trawlers, which caught more than 302 million lb. By 1976, more than 523 million lb were harvested by vessels from several foreign nations. After 1976, the Fisheries Conservation and Management Act limited the ability of foreign vessels to fish in U.S. waters. Because Pacific hake meat deteriorates and softens quickly after the fish is caught, however, most domestic vessels were not equipped to properly handle or process hake. This instigated several joint venture efforts in which domestic fishers would catch the fish and transfer them at sea to foreign processing vessels. Joint venture fisheries disappeared as improved processing techniques for hake were developed for U.S.-based processors.

In recent years, catches of Pacific hake have been largely influenced by annual recruitment. Higher catches occur 3–4 yr following strong recruitment years. Very large year-classes of Pacific hake were produced in 1980 and 1984, leading to high catches in central California throughout most of the 1980s. Most of the landings were delivered into San Francisco ports, however, and are not reflected in the landings for ports near the MBNMS (Fig. 41). Coastwide recruitment was average or low between 1987 and 92, but a strong 1994 year-class is indicated from high bycatch of juveniles in recent years.

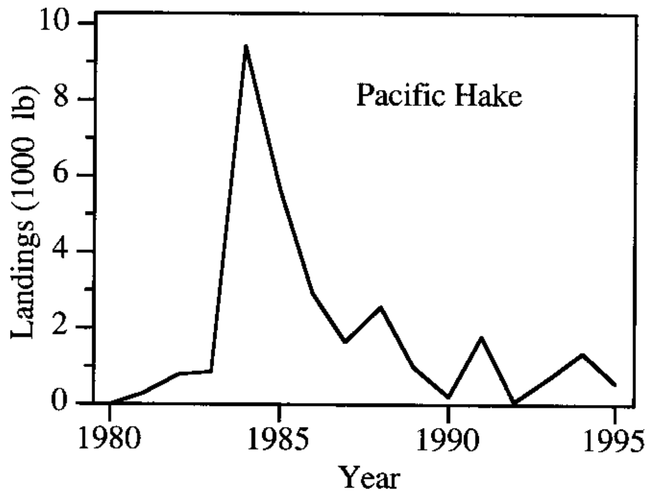


Figure 41. Reported commercial landings of Pacific hake at the five major ports near the MBNMS from 1980–95.

Management: The Pacific hake fishery is managed using quotas, geographic and seasonal restrictions, mesh size, and incidental catch levels. The 1996 stock assessment projected a total ABC of 583 million lb. The ABC for 1997 was 639 million lb. The effectiveness of current management plans has been limited because there is currently no agreement between the United States and Canada on how to divide the predicted ABC between the two countries. In the absence of an agreement, each country has set quotas that sum to 114–128% of the ABC. In 1997, the PFMC set a U.S. harvest guideline of 512 million lb, or 80% of the predicted ABC for the stock. Since the end of joint venture fishing in 1989, the total U.S. and Canadian reported catch has met or exceeded the ABC by 10–15% each year.

References

Bailey, K.M., R.C. Rancis, and P.R. Stevens. 1982. The life history and fishery of Pacific whiting, *Merluccius productus*. California Cooperative Oceanic and Fishery Investigations, Report 23:81–98.

Dark, T.A. (ed.). 1985. Pacific whiting: the resource, industry, and management history. Marine Fisheries Review 47(2):1–98.

Dorn, M. Status of the coastal Pacific whiting resource in 1996. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115-0070.

Mason, J.C. 1986. Fecundity of the Pacific hake, *Merluccius productus*, spawning in Canadian waters. U.S. Fishery Bulletin 84(1):209–217.

Rexstad, E.A. and E.K. Pikitch. 1986. Stomach contents and food consumption estimates of Pacific hake, *Merluccius productus*. U.S. Fishery Bulletin 84(4):947–956.

Rockfishes

Rockfishes belong to the family Scorpaenidae and the genus *Sebastes*, which contains the largest number of California marine fish species, comprising 62 described species from California waters. Commercial landings of rockfishes have also included fish in the genus *Sebastolobus*, represented by two species: the short spine thornyhead (*Sebastolobus alascanus*) and long spine thornyhead (*Sebastolobus altivellis*). Until the mid-1980s, most *Sebastes* and *Sebastolobus* landings were lumped into a single category of rockfish. It has only been within recent years that landings of the two genera have been reported separately. For this report, rockfishes and thornyheads will be discussed as a single group.

Rockfishes are important ecologically and economically; approximately 85% of the known rockfish species are utilized in California commercial and sport fisheries. They are an extremely diverse group of animals that occupy depths ranging from the intertidal zone to 800 m deep, and habitats ranging from the middle of the water column to sand, mud, and rock bottoms. In addition to occupying different habitats, rockfishes exhibit many different life histories.

Reproductive capacity of rockfishes is directly related to size, with larger females carrying significantly more eggs than smaller females. Fertilization and development of embryos is internal. Females release hundreds to millions of relatively undeveloped, free-swimming larvae into the water column. These larvae remain in the plankton from one month up to a year in some species before settling out to become juveniles, often in association with the bottom. This extended planktonic period makes environmental variation an important determinant of the population abundance of many rockfish species. Once on the bottom, individuals of many species migrate into deeper water as they mature.

Rockfishes have been harvested in commercial fisheries throughout their range since the mid-1800s. California landings greatly increased in the 1970s as more American vessels entered the groundfish trawl fishery after passage of the FCMA (Fig. 42). Between 1980 and 1993 trawling effort declined while the use of gill nets to catch rockfishes increased. Because of these changes in gear type, commercial fishing effort for rockfishes as a group has remained relatively stable, but total rockfish catch for the MBNMS has declined (Fig. 43).

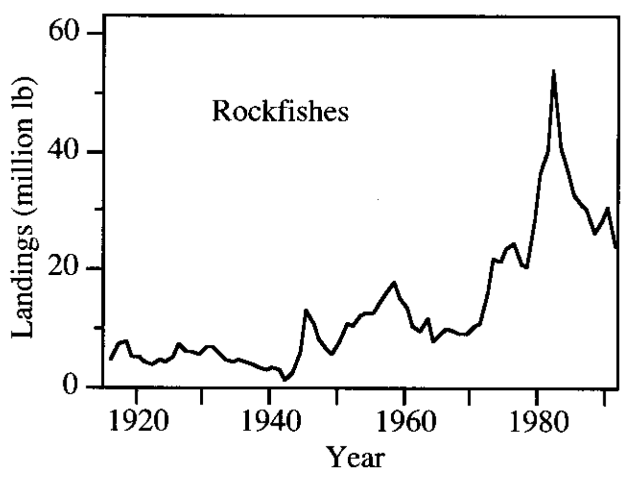


Figure 42. Reported commercial landings for all rockfishes in California from 1916–91.

Historically, rockfishes have been marketed under a variety of names such as rockcod, snapper, or red snapper. The grouping of species into market categories makes trends in abundance

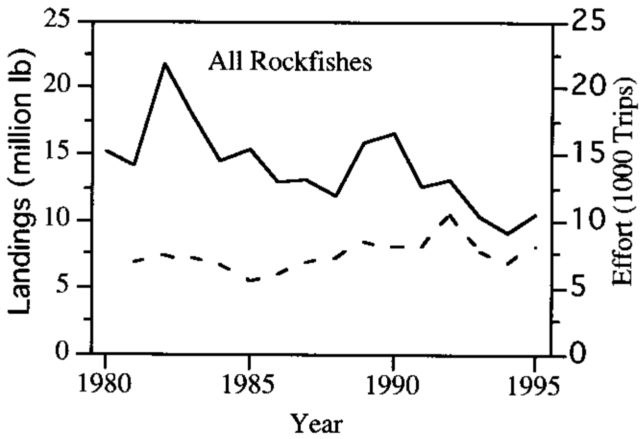


Figure 43. Reported commercial fishing effort for all rockfishes in the MBNMS from 1980–95.

difficult to delineate from catch data. To provide some idea of population trends, fishery scientists record the species composition of samples of fish that are sold at the docks by market category, and then attempt to evaluate indices of abundance by partitioning catches by species, depth, and life history.

Of the species for which stock assessments are available, several are considered to be exhibiting stable or increasing trends in abundance. Stock assessments published by NMFS for bank rockfish, chilipepper, shortbelly rockfish, widow rockfish, and splitnose rockfish show stable or increasing trends in abundance. The widow rockfish population, however, is currently stable at a low level of abundance. The stock in 1994 was estimated to be about one-third its size in 1980.

Stock assessments published by NMFS for bocaccio, yellowtail rockfish, canary rockfish, and Pacific ocean perch show decreasing trends in abundance on the U.S. West Coast. Most of these rockfishes are deep water species that are slow growing, long-lived, and have experienced high exploitation rates. Managers are concerned about the capability of some of these species to recover from high harvest rates. Pacific ocean perch, for example, were overfished in the 1960s and the population has not yet recovered. Bocaccio is considered to be at a population level that is 15%–20% of what it was in 1970. Similarly, off parts of the West Coast, the canary rockfish population is 50% of what it was thought to be in 1977. In addition to reduced numbers of canary rockfish, managers are concerned that the age structure of canary rockfish has shifted so that few older fish remain in the population. Survey estimates of abundance for yellowtail rockfish have been highly variable, but the most recent stock assessment indicates a downward trend. Data used in stock assessments for black and darkblotched rockfishes, and thornyheads are not conclusive enough to make statements concerning the status of these stocks in California. More information is needed to adequately estimate stock size for management purposes.

Recreational fishing for rockfishes has existed in Monterey Bay since 1875. Early fisheries focused exclusively on the nearshore, shallow water rockfishes. Increased fishing pressure through the 1960s caused catches of shallow water rockfishes to drop in some locations. To compensate for decline in catch rates, sport fishers began traveling farther from port to fishing grounds near Año Nuevo, or Point Sur. By 1977, advanced echosounder technology allowed vessels to also fish for deeper species at the edge of the Monterey submarine canyon. This shift to deeper water provided catches of larger fishes at locations much closer to port. Catches of deep water species in the Commercial Passenger Fishing Vessel fishery increased from 2% of the total catch between 1959 and 1972 to 21% of the total catch between 1986 and 1994.

Although catches have fluctuated in the past 30 yr, catch rates remained relatively stable (Fig. 44), partly due to the shift from shallow to deep water and from near-to-far fishing locations. As catches declined in one location, skippers simply moved to another where catch rates were higher, enabling fishers to continue to catch comparable numbers of fish. Because shifts in location can maintain catch rates, landings alone are not good indicators of stock status. Instead, stocks need to be evaluated by specific areas. Since 1987, CDFG has recorded catch and effort for shallow, deep, and mixed depth rockfish groups separately, for both near and distant fishing grounds in northern and central California (Table 5). For these data, catch rates remained relatively stable for most species. Exceptions include chilipepper and bocaccio, which experienced declining catch per angler hour.

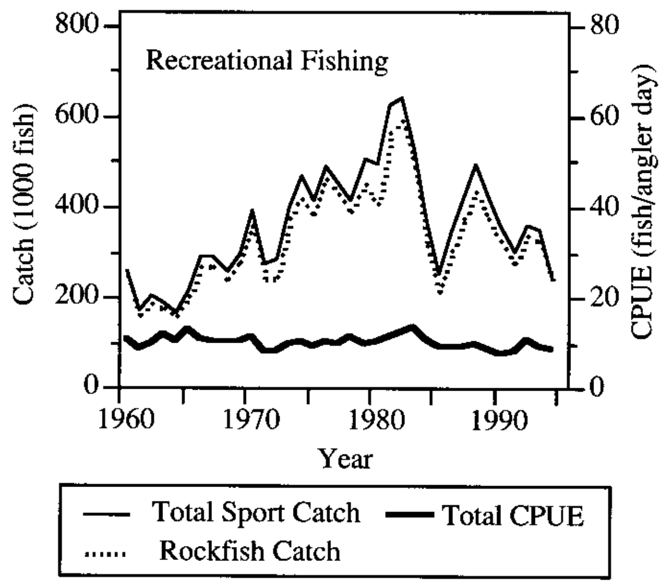


Figure 44. Total sport catch, total rockfish sport catch, and total recreational catch per unit effort for Monterey Bay ports from 1960–95. Data provided by Jan Mason, National Marine Fisheries Service.

Catch statistics alone, however, are not always a good indicator of population status. Length data, when available, can sometimes provide further information on stock size, recruitment success, and fishing pressure. Rockfish length data were collected from the recreational fishery intermittently by CDFG from 1959–73, and nearly continuously from 1977–94. For eight of the ten species with sufficient information to evaluate, the recent data (1987–94) exhibit no decreasing or increasing trends in mean length. This would indicate that fishing has not adversely affected nearshore rockfish populations. Eight years is too short a time period in which to evaluate a length index, however. When the longer 18 yr data set (1977–94) is examined, mean lengths for eight of the ten rockfishes show a statistically significant decline (Table 6). CDFG has reported that some of the decreases in mean length evident in these data may be the result of successful recruitment of smaller fishes in recent years. As large numbers of small fish become available to the fishery, the overall mean size of rockfish caught would thus decrease. CDFG biologists base this conclusion on increasing catch rates coincident with declining mean lengths.

Although the data collected prior to 1977 are not as comprehensive as the later data, they do provide a longer term view of trends in mean length. When the 1959–94 data are evaluated, six of the ten species reviewed exhibited decreases in mean lengths (Table 6). Lengths recorded for bocaccio and chilipepper, and greenstriped, olive, widow, and yellowtail rockfishes all declined significantly from 1959–94, presumably due to fishing pressure. This suggests that for blue and rosy rockfishes, the decrease in mean size apparent from 1977–94 may have been due to successful recruitment and a corresponding increase in the numbers of small fish available to anglers.

In the following species discussions, we have chosen to discuss the top ten most commonly caught rockfishes within the MBNMS. Additional descriptions of shortbelly and blue rockfish are provided because shortbelly rockfish are very abundant and blue rockfish are an important component of the recreational fishery.

Bank Rockfish (*Sebastes rufus*)

Distribution: Bank rockfish are found from Guadalupe Island, Baja California to Newport,

Table 5. Species Groupings Used by CDFG for Analysis of Fishing Trends in the Nearshore Recreational Fishery in the Monterey Bay Area

Group	Members
Shallow (<60 m) Rockfishes	Blue Olive Black Gopher
Mixed Depth Rockfishes	Canary Rosy Starry Copper Vermilion
Deep (>100 m) Rockfishes	Chilipepper Bocaccio Greenspotted Greenstriped
Other	Lingcod Sablefish Pacific Hake Pacific Sanddab Pacific Mackerel

Note: Groupings were provided by Paul Reilly, CDFG.

Table 6. Rockfish Species Exhibiting Significant Declines in Mean Length, for Three Tme Periods from 1959–94

	Decreasing Mean Length		
Species	1959–1994	1977–1994	1987–1994
Chilipepper	**	**	
Olive	**	**	
Bocaccio	*	*	
Greenstriped	*	*	
Yellowtail	*	*	
Widow	*		
Blue		**	
Rosy		**	
Greenspotted		**	*
Canary			**

* Regression Significant ($p < 0.05$)

** Regression Highly Significant ($p < 0.01$)

Note: Data were provided by Jan Mason, NMFS.

Oregon in water depths from 33–270 m. Their center of distribution ranges from Fort Bragg, California into northern Baja California. They seem to be very mobile and live in both hard bottom and midwater habitats on the edges of rocky banks.

Life History: Bank rockfish spawning occurs from December to May, with a peak in February off central California. Fifty percent of this species is mature at 36 cm in length, and all are reproductively mature at 38 cm. Females produce between 65,000 and 610,000 eggs per season. Bank rockfish reach a maximum length of 51 cm and a maximum age of 50 yr.

Fishery History and Trends: Bank rockfish are commercially caught using gill nets or otter trawls equipped with roller gear; a small amount are harvested with hook-and-line gear. In 1987, Monterey gill net landings of bank rockfish doubled when California regulations forced gill net fishing operations deeper than the 100 fathom isobath. The commercial landings of bank rockfish in the MBNMS averaged over 1.1 million lb/yr from 1980–95. Catches steadily declined between 1988–94 (Fig. 45). Catches in 1994 were estimated to be only about 317,000 lb (Appendix 3). Some of this decline in landings may have resulted from gill net fishers changing over to longline gear to enable them to fish within state waters. Catches increased again in 1995, totaling over 571,000 lb.

NMFS population surveys conducted every 3 yr between 1977 and 1995 indicate that more than 90% of the bank rockfish population occurs off central and northern California. A bank rockfish stock assessment prepared in 1994 indicated that stocks had remained relatively stable since 1986. There was, however, a significant decline in mean length of bank rockfish landed in central and northern California from 1978–88.

Management: Bank rockfish have a long life span and a slow growth rate so they are not able to sustain a high rate of harvest. Females have just reached the length of 100% sexual maturity when they are of a size that is caught in the fishery. The PFMC currently does not specifically limit the catch of bank rockfish; they are managed as a part of the Sebastes complex.

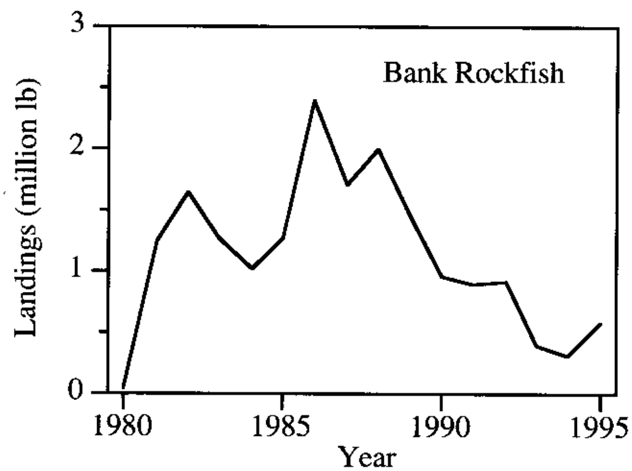


Figure 45. Estimated commercial landings of bank rockfish at the five major ports near the MBNMS from 1980–95.

Within the 21.3 million lb ABC set for the Sebastes complex in California and southern Oregon in 1997, the PFMC is estimating that 179,000 lb of bank rockfish will be harvested.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for

1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.
Pearson, D.E. and S. Ralston. 1990. Trends in landings, species composition, length-frequency distributions, and sex ratios of 11 rockfish species (genus *Sebastes*) from central and northern California ports (1978–88). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA Technical Memorandum NMFS no. NOAA-TM-NMFS-SWFC-145. 65 pp.
Watters, D.L. 1993. Age determination and confirmation from otoliths of the bank rockfish, *Sebastes rufus* (Scorpaenidae). MS Thesis, San Jose State University. 59 pp.
Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Blackgill Rockfish (*Sebastes melanostomus*)

Distribution: Blackgill rockfish range from central Baja California to Washington. Young fish are caught in waters as shallow as 200 m, but adults normally are located in water depths ranging from 230–820 m. Although they have been caught on soft bottom habitats, they normally occupy deep rocky habitats.

Life History: Blackgill rockfish spawning occurs from January through June with a peak off central California in February. Fifty percent of this species is mature at 36 cm in length (age 7–8), and all are reproductively mature at a length of 38 cm. Females produce as many as 770,000 eggs per season. Blackgill rockfish reach a maximum length of 61 cm.

Fishery History and Trends: Blackgill rockfish were targeted with hook-and-line fisheries in the 1970s and also fished with gill nets in the 1980s. Currently, blackgill rockfish are caught primarily by trawlers along with bank and splitnose rockfishes. Within the MBNMS recorded catches of blackgill rockfish fluctuated greatly from 1980–95 (Fig. 46). Much of this fluctuation could be due to changes in fishing location or in gear used, rather than fluctuations in actual catch or population sizes.

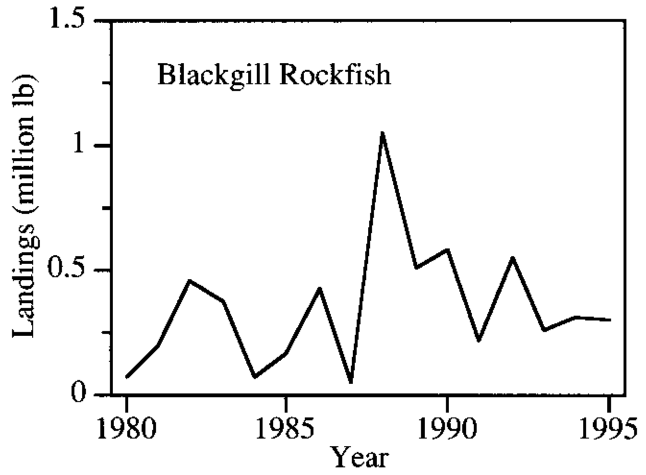


Figure 46. Estimated commercial landings of blackgill rockfish at the five major ports near the MBNMS from 1980–95.

Management: The PFMC currently does not specifically limit the catch of blackgill rockfish; it is managed as a part of the Sebastes complex. Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Moser, H.G. and E.H. Ahlstrom. 1978. Larvae and pelagic juveniles of blackgill rockfish, *Sebastes melanostomus*, taken in midwater trawls off southern California and Baja California. Journal of Fisheries Research Board of Canada 35(7):981–996.

Blue Rockfish (*Sebastes mystinus*)

Distribution: Blue rockfish range from Punta Santo Tomas in Baja California to the Bering Sea. They form schools in kelp forests and over rocky bottoms from the surface to 100 m deep. They are very abundant throughout much of their range.

Life History: Mating generally occurs during late fall. Eggs mature in December or January at which time the eggs are fertilized with the stored sperm. Eyed larvae are released into the water column from January to May, with juveniles appearing in the kelp canopy about April or May. Age of initial spawning is protracted in both sexes; approximately 10% spawn for the first time at 3 yr of age. By age 5 (26 cm in length), half of all males have spawned. By age 6 (28 cm in length), half of all females have spawned. Blue rockfish reach a maximum length of 53 cm and a maximum age of about 23 yr.

Fishery History and Trends: Blue rockfish are primarily harvested in Monterey Bay in the CPFV fishery and by skiff fishers and divers. They comprise a large proportion of the total sport catch, but are not important in the commercial fishery. Although yearly catches and landings fluctuate, the population size of blue rockfish in the MBNMS seems to be relatively stable. Commercial landings declined in the early 1980s then increased, presumably as a result of improved recruitment (Fig. 47). Sport landings of blue rockfish followed a similar pattern, dropping sharply during the mid–1980s and then increasing in the 1990s from new recruitment. The sharp increase in blue rockfish landings in 1985 was caused by an unusually large series of landings from gill net fishers.

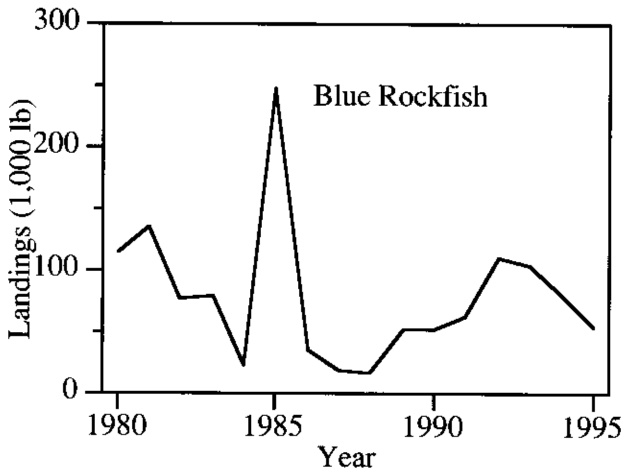


Figure 47. Estimated commercial landings of blue rockfish at the five major ports near the MBNMS from 1980–95.

Management: This species is not currently under management by PFMC. Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Klingbeil, R.A. 1976. Southern range extensions of the blue rockfish, *Sebastes mystinus*, the flag rockfish, *S. rubrivinctus*, and the shortbelly rockfish, *S. jordani*. California Department of Fish and Game Fish Bulletin 62:160.

Miller, D.J. and J. Geibel. 1973. Summary of blue rockfish and lingcod life histories: A reef ecology study; and Giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. California Department of Fish and Game Fish Bulletin No. 158. 137 pp.

VenTresca, D.A., J.L. Houk, M.J. Paddack, M.L. Gingras, N.L. Crane, and S.D. Short. 1996. Early life-history studies of nearshore rockfishes and lingcod off central California, 1987–92. California Department of Fish and Game, Marine Resources Division Administrative Report 96–4. 77 pp.

Wilson-Vandenberg, D., P.N. Reilly, and C. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. California Department of Fish and Game, Marine Resources Division Administrative Report 96–6. 96 pp.

Bocaccio (*Sebastes paucispinis*)

Distribution: Bocaccio form schools above the bottom and are found individually in rocky crevices. They range from Baja California to Kodiak Island, Alaska, and occur in water depths from 20–517 m. They occupy midwater habitats as well as a wide variety of benthic habitats ranging from kelp forests to both high and low relief rocky outcrops. They are common from northern Baja California to the Washington–British Columbia border.

Life History: Eyed larvae are extruded from January through May off central and northern California. Young-of-the-year can be as long as 18 cm at the end of the first year of growth. Fifty percent of bocaccio are mature when they are 42 cm in length and 4 yr old. Males mature at slightly smaller sizes than females. Fecundity increases from 20,000 eggs in a 38 cm long fish to 2.3 million in a 77 cm long fish. Bocaccio reach a maximum length of 91 cm and can weigh as much as 15 lb. Maximum age is about 50 yr.

Fishery History and Trends: Bocaccio are important in the commercial trawl and hook-and-line fisheries in Monterey Bay. They usually are marketed as red snapper or rockcod. They are also important in the sport catch as well. Commercial landings at ports near the MBNMS averaged 2.9 million lb/yr from 1980–95, however, catches consistently declined each year during that time (Fig. 48).

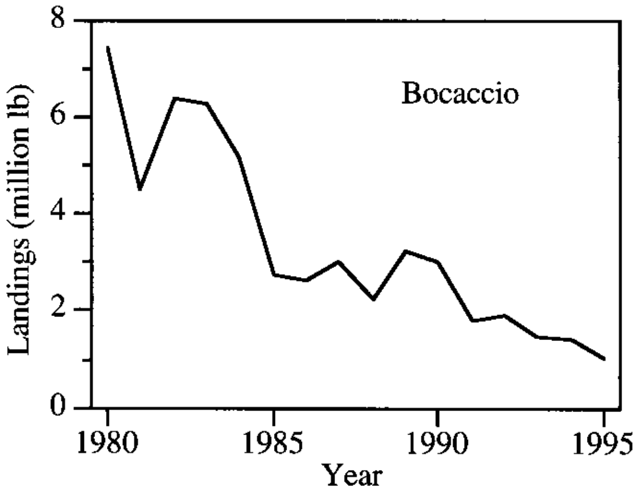


Figure 48. Estimated commercial landings of bocaccio at the five major ports near the MBNMS from 1980–95.

Stock assessment models show that bocaccio spawning stocks are severely depleted. Recruitment levels for bocaccio are highly variable, but have generally dropped as spawning stocks have declined. Stock assessments suggest that bocaccio abundance is 15–20% that of 1970, which is thought to have been an anomalously high abundance year for bocaccio. There have been no strong recruitment episodes since that provided by the 1984 year-class.

Management: This species is managed by PFMC. From 1983–90 bocaccio were managed in combination with other rockfish in the Sebastes complex. The PFMC uses trip and frequency limits to constrain total complex landings. After 1990, specific bocaccio trip limits were established to keep catch within the harvest guidelines. The 1997 ABC for bocaccio in California and southern Oregon was 584,000 lb. This quota applies to all gear types and includes the recreational fishery. The 1997 harvest guideline, however, was set at 853,000 lb to account for fish discarded at sea. Some fishery managers believe that the stock size will continue to decline with harvest provided by the current ABC unless recruitment greatly improves.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Love, M.S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the southern California Bight. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report No. 87. 38 pp.

Moser, H.G. 1967. Reproduction and development of *Sebastodes paucispinis* and comparison with other rockfishes off southern California. Copeia 1967:773–797.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearson, D.E. and S. Ralston. 1990. Trends in landings, species composition, length–frequency distributions, and sex ratios of 11 rockfish species (genus *Sebastes*) from central and northern California ports (1978–88). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA Technical Memorandum NMFS no. NOAA-TM-NMFS-SWFC-145. 65 pp.

Ralston, S., J.N. Ianelli, R.A. Miller, D.E. Pearson, D. Thomas, and M.E. Wilkins. 1996. Status of bocaccio in the Conception/Monterey/Eureka INPFC areas in 1996 and recommendations for management in 1997. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 3150 Paradise Drive, Tiburon, California 94920.

Wilkins, M.E. 1980. Size composition, age composition, and growth of chilipepper, *Sebastes goodei*, and bocaccio, *S. paucispinis*, from the 1977 rockfish survey. Marine Fisheries Review 42:48–58.

Chilipepper (*Sebastes goodei*)

Distribution: Chilipepper range from Magdalena Bay, Baja California to Queen Charlotte Sound, British Columbia from the surface to 467 m depth. Adults are found in large schools over deep rocky reefs as well as sand and mud bottoms.

Life History: Spawning occurs from September to April with a peak during December and

January. Females reach 50% maturity at a length of 28 cm and an age of about 4 yr . Males mature at about 20 cm and 2 yr of age. The maximum length attained by chilipepper is about 56 cm and they reach approximately 20 yr of age.

Fishery History and Trends: Chilipepper are a very important component of commercial trawl and sport fisheries in central California. Commercial landings at ports near the MBNMS were stable from 1980–95, averaging 3.0 million lb/yr (Fig. 49). NMFS biomass estimates of chilipepper in California also remained relatively constant from 1977–95. Abundance estimates from catch data, age composition data, and length data all indicate that the stock size of chilipepper is increasing. CDFG data collected from the CPFV fishery show declining catch rates in some locations, however, suggesting there may be localized depletions.

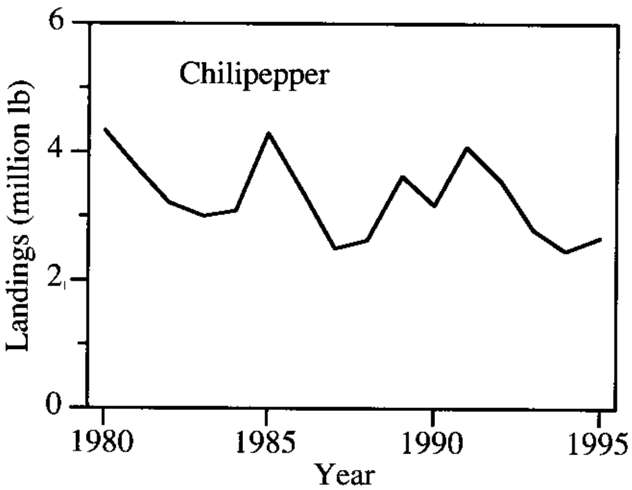


Figure 49. Estimated commercial landings of chilipepper at the five major ports near the MBNMS from 1980–95.

Management: This species is under management by the PFMC. Quotas and gear regulations, such as mesh size, are some of the measures used to regulate this fishery. The 1996 and 1997 coast-wide ABC for chilipepper was 8.8 million lb.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Love, M.S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the Southern California Bight. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report No. 87. 38 pp.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearson, D.E. and S. Ralston. 1990. Trends in landings, species composition, length-frequency distributions, and sex ratios of 11 rockfish species (Genus *Sebastes*) from central and northern California ports (1978–88). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA Technical Memorandum NMFS no. NOAA-TM-NMFS-SWFC-145. 65 pp.

Wilkins, M.E. 1980. Size composition, age composition, and growth of chilipepper, *Sebastes goodei*, and bocaccio, *S. paucispinis*, from the 1977 rockfish survey. Marine Fisheries Review 42:48–58.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Darkblotched Rockfish (*Sebastes crameri*)

Distribution: Darkblotched rockfish range from Santa Catalina Island in southern California to the Bering Sea. They have been observed in water depths ranging from 6–975 m deep, but usually occupy soft bottom habitats in water depths from 50–450 m.

Life History: Spawning occurs from November to March, with smaller animals spawning later in that time period. Females reach 50% maturity between ages 4–8 at lengths of 27–39 cm. Males mature at lengths of about 27–36 cm and 4–5 yr of age. The maximum length attained by darkblotched rockfish is about 57 cm and they reach approximately 66 yr of age.

Fishery History and Trends: Darkblotched rockfish are caught primarily in deep water by trawlers. Recorded catches of darkblotched rockfish in the MBNMS averaged about 109,000 lb/yr from 1980–95, although catches fluctuated greatly (Fig. 50). Much of this fluctuation could be due to changes in fishing location or changes in gear used, rather than fluctuations in actual catch or population sizes. There is currently insufficient data about dark-blotched rockfish to enable fishery scientists to produce a stock assessment. The life history traits of old age and slow growth suggest that harvest rates should only be 4–6% of the stock. Declining trends in mean size suggest that current harvest rates are in the range of 7–11% of the stock.

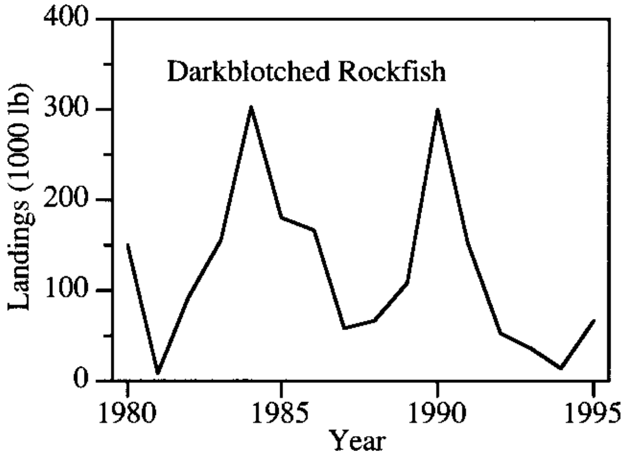


Figure 50. Estimated commercial landings of dark-blotched rockfish at the five major ports near the MBNMS from 1980–95.

Management: The PFMC currently does not specifically limit the catch of darkblotched rockfish; it is managed as a part of the Sebastes complex. Within the 21.3 million lb ABC set for the Sebastes complex in California and southern Oregon in 1997, PFMC is estimating that 104,000 lb of darkblotched rockfish will be harvested.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearson, D.E. and S. Ralston. 1990. Trends in landings, species composition, length-frequency distributions, and sex ratios of 11 rockfish species (genus *Sebastes*) from central and northern California ports (1978–88). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA Technical Memorandum NMFS no. NOAA-TM-NMFS-SWFC-145. 65 pp.

Shortbelly Rockfish (*Sebastes jordani*)

Distribution: Shortbelly rockfish are found from southern Baja California to British Columbia from the surf line (young-of-the-year) to 310 m deep (adults). Peak abundances are centered between the Farallon Islands and Santa Cruz and off the Channel Islands, California. Adult shortbelly rockfish form large schools in the middle of the water column or over smooth bottom habitats near the shelf break.

Life History: Spawning occurs from January through April. Approximately 50% of females are mature by age 3, and nearly all are mature by age 4. Fecundity ranges from 6,200 eggs for a 17 cm long fish to 50,000 eggs for a 30 cm long fish. Maximum recorded age for shortbelly rockfish is 22 yr, but fish older than 10 yr are uncommon. Most are less than 29 cm long, with a maximum recorded length of 30 cm.

Fishery History and Trends: The shortbelly rockfish is thought to be the most abundant rockfish off the coast of California, but it has been fished very little. NMFS trawl surveys estimate a population size of over 145 million fish, equaling approximately 33 million lb in biomass, with over 80% of the population off central California. If this fishery is developed in the future, there is a major concern regarding mesh size for nets designed to target this species. Because these fish are relatively small, the mesh sizes required to catch them in profitable numbers would also capture large quantities of other economically important fishes that are undersized.

Management: The 1997 coastwide ABC for shortbelly rockfish is 52 million lb. General provisions of the take of finfish for commercial and sport fisheries in the California Fish and Game code govern the take of this species.

Biologists have recommended against bottom trawling for this species because of the hazard to young fish of other commercially important species.

References

Klingbeil, R.A. 1976. Southern range extensions of the blue rockfish, *Sebastes mystinus*, the flag rockfish, *S. rubrivinctus*, and the shortbelly rockfish, *S. jordani*. California Department of Fish and Game Fish Bulletin 62:160.

Lenarz, W.H. 1980. Shortbelly rockfish, *Sebastes jordani*: A large unfished resource in waters off California. Marine Fisheries Review (March–April): 34–40.

Love, M.S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the southern California Bight. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report No. 87. 38 pp.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearson, D.E., J.E. Hightower, and J.T.H. Chan. 1991. Age, growth, and potential yield for shortbelly rockfish (*Sebastes jordani*). Fisheries Bulletin 89:403–409.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Splitnose Rockfish (*Sebastes diploproa*)

Distribution: Splitnose rockfish range from central Baja California to southeast Alaska. Juveniles have been observed in shallow water and around floating mats of kelp. Adults occupy soft bottom habitats in water depths ranging from 91–579 m.

Life History: Spawning occurs from January to September with peak spawning in July. Females reach 50% maturity between ages 6 and 9 at lengths of 18–23 cm. Males mature at lengths of about 20–29 cm and 7–10 yr of age. The maximum length attained by splitnose rockfish is about 46 cm and they reach approximately 84 yr of age. Growth is faster in the northern portion of their range.

Fishery History and Trends: Splitnose rockfish are caught primarily with trawl nets equipped with roller gear in the deepwater rockfish fishery. Recorded catches of splitnose rockfish in the MBNMS averaged about 518,000 lb/yr from 1980–95 (Fig. 51). Linear regression analysis conducted on the landings data indicates that catches in the MBNMS have been declining since 1983. However, a preliminary stock evaluation for splitnose rockfish conducted in 1994, using four different types of surveys, showed no coastwide evidence of a declining population. Also, there was no evidence of a decline in mean lengths of splitnose rockfish from 1978–88.

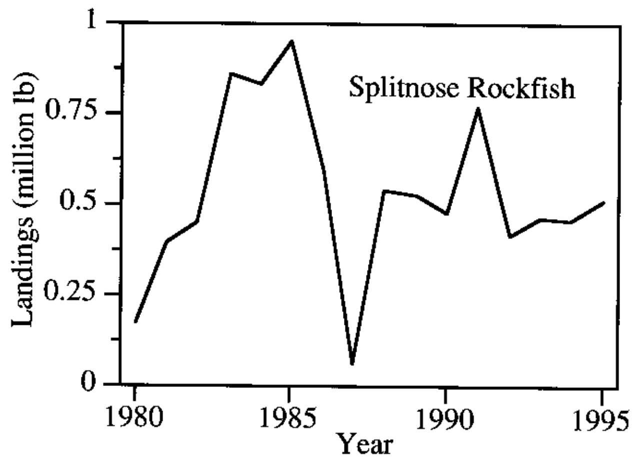


Figure 51. Estimated commercial landings of splitnose rockfish at the five major ports near the MBNMS from 1980–95.

Management: Splitnose rockfish have low fecundity and low growth rates, so they are not able to sustain a high rate of harvest. Most splitnose rockfish caught in the commercial fishery are larger than the size of 50% maturity, however, so this species may be less vulnerable to overfishing than other rockfishes. The PFMC currently does not specifically limit the catch of splitnose rockfish; it is managed as a part of the Sebastes complex. Within the 21.3 million lb ABC set for the Sebastes complex in California and southern Oregon in 1997, PFMC is estimating that 1.9 million lb of splitnose rockfish will be harvested.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearson, D.E. and S. Ralston. 1990. Trends in landings, species composition, length-frequency distributions, and sex ratios of 11 rockfish species (Genus *Sebastes*) from central and northern California ports (1978–88). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA Technical Memorandum NMFS no. NOAA-TM-NMFS-SWFC-145. 65 pp.

Rogers, J.B. 1994. Preliminary status of the splitnose rockfish stock in 1994. Appendix H in Appendix Volume 2, Status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Vermilion Rockfish (*Sebastes miniatus*)

Distribution: Vermilion rockfish range from central Baja California to the Prince William Sound, Alaska. They range in depth from shallow subtidal waters to 472 m deep. Adults are usually found near the bottom on rocky habitats, but juveniles are often seen in kelp beds.

Life History: Spawning occurs from September through November. Vermilion rockfish reach 50% maturity at an age of 5 yr and a length of 37 cm. The maximum length attained by vermilion rockfish is about 76 cm and they have a life span of about 43 yr. Females 32 cm long will carry 63,000 eggs, whereas a 55 cm long fish will produce about 1.6 million eggs.

Fishery History and Trends: Vermilion rockfish are caught primarily in the commercial hook-and-line fishery and in the recreational fishery. The relatively long life and slow growth of this species, along with fishery monitoring information suggests that vermilion rockfish may be easily overfished in nearshore areas with high fishing pressure. Although recorded catches of vermilion rockfish in the MBNMS have fluctuated greatly from 1980–95, there is an upward trend in yearly landings with average landings of about 149,000 lb/yr (Fig. 52). This is thought to be a result of a strong year class in 1985 that has provided a boost to the fishery since 1988.

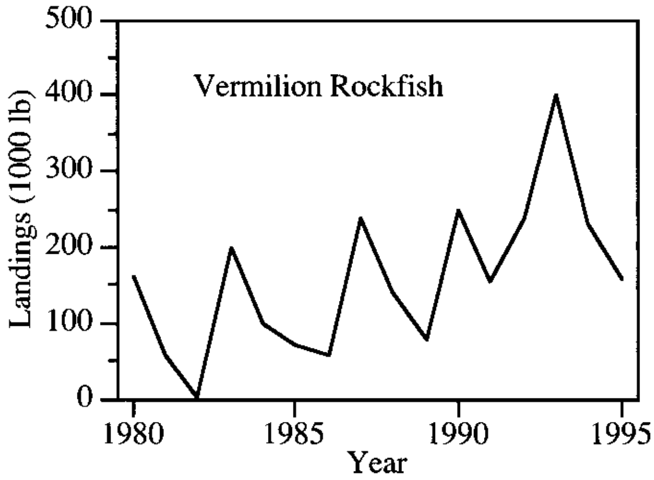


Figure 52. Estimated commercial landings of vermilion rockfish at the five major ports near the MBNMS from 1980–95.

Management: The PFMC currently does not specifically limit the catch of vermilion rockfish, which is managed as a part of the Sebastes complex. Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

VenTresca, D.A., J.L. Houk, M.J. Paddack, M.L. Gingras, N.L. Crane, and S.D. Short. 1996. Early life-history studies of nearshore rockfishes and lingcod off central California, 1987–92. California Department of Fish and Game, Marine Resources Division Administrative Report 96–4. 77 pp.

Wilson-Vandenberg, D., P.N. Reilly, and C. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. California Department of Fish and Game, Marine Resources Division Administrative Report 96–6. 96 pp.

Widow Rockfish (*Sebastes entomelas*)

Distribution: Widow rockfish range from Todos Santos Bay, Baja California to Kodiak Island, Alaska. They form large schools in the water column from the surface to 400 m deep.

Life History: Fifty percent of widow rockfish are reproductively mature at an age of 5 yr, and nearly all are mature by age 8 at an average length of 42 cm. Fecundity ranges from 55,600 eggs in a 33 cm long female to 915,200 eggs in a 48 cm long female. Larvae are extruded off California in February. Juveniles are observed in shallow water habitats by April. Adults are found in large schools, often with other rockfish species, both in the middle of the water column and also over rocky bottoms. Widow rockfish reach a maximum length of 61 cm and a maximum age of 59 yr.

Fishery History and Trends: Widow rockfish landings rank in the top three for commercial fisheries in California behind chilipeppers and thornyheads. They are also a component of the sport landings. Commercial landings at ports near the MBNMS averaged 1.5 million lb/yr from 1980–95 (Fig. 53). Widow rockfish landings peaked in 1982 at 7.3 million lb/yr when the trawl fishery began targeting the species. Landings have been much lower since that time because of decreased population sizes and increased regulations. The coastwide widow rockfish stock in 1994 was estimated to be at 167 million lb, about one-third the biomass in 1980. This stock abundance is near the level expected at the current rate of harvest, and is expected to remain stable if recruitment also remains stable.

Management: This species is under management by PFMC. Quotas and gear regulations such as mesh size are some of the measures used to regulate this fishery. The coastwide ABC for 1997 was set at 17 million lb.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

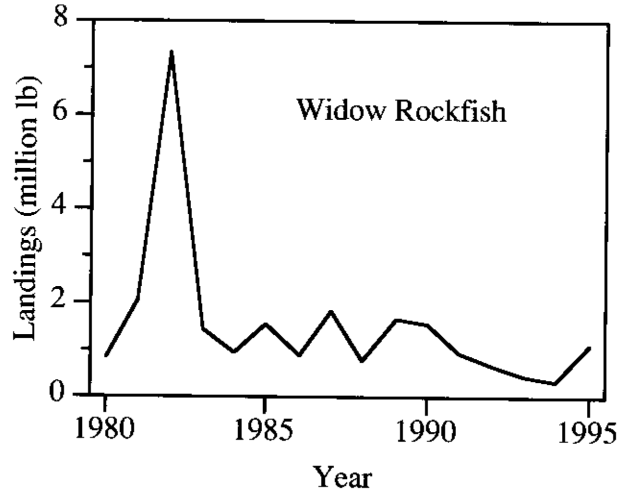


Figure 53. Estimated commercial landings of widow rockfish at the five major ports near the MBNMS from 1980–95.

References

Boehlert, G.W., W.H. Barss, and P.B. Lamberson. 1982. Fecundity of the widow rockfish, *Sebastes entomelas*, off the coast of Oregon. U.S. Fishery Bulletin 80:881–884.

Gunderson, D.R. 1984. The great widow rockfish hunt of 1980–82. North American Journal of Fisheries Management 4:465–468.

Lenarz, W.H. and D.R. Gunderson (editors). 1987. Widow rockfish: Proceedings of a workshop, Tiburon, California, December 10–11, 1980. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report 48.

Love, M.S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the Southern California Bight. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report No. 87. 38 pp.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearson, D.E. and S. Ralston. 1990. Trends in landings, species composition, length-frequency distributions, and sex ratios of 11 rockfish species (Genus *Sebastes*) from central and northern California ports (1978–88). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA Technical Memorandum NMFS no. NOAA-TM-NMFS-SWFC-145. 65 pp.

Yellowtail Rockfish (*Sebastes flavidus*)

Distribution: Yellowtail rockfish range from San Diego, California to Kodiak Island, Alaska.

The center of abundance is from Oregon to British Columbia. They are found from the surface to 549 m deep, but are rare at depths greater than 329 m. Yellowtail rockfish form large single-species and multispecies schools.

Life History: Juvenile yellowtail rockfish are often found in shallow water habitats such as kelp beds. As they grow, they then migrate into deeper water, where they occur as adults. Tagging studies have shown that some individuals make only short movements, whereas others may move up to 1,000 km. Spawning occurs in winter, with a peak in February. Juveniles begin to appear in kelp beds by April. Females mature between lengths of 37 and 45 cm and from 6–10 yr of age. Males mature at a slightly smaller length (30 cm) and younger age (4 yr) than females. Yellowtail rockfish reach a maximum length of 66 cm. The oldest aged yellowtail rockfish was a 64 yr old male.

Fishery History and Trends: Yellowtail rockfish are landed commercially in both the trawl and hook-and-line fisheries. They also make up a considerable component of the sport landings. Coastwide yellowtail rockfish landings increased from 2.6 million lb in 1967 to 21.2 million lb in 1983, then declined after trip limits were implemented in 1985. From 1991–95, coastwide landings averaged 10.8 million lb/yr. Landings of yellowtail rockfish in the MBNMS are a very small portion of the total California landings. Commercial landings at ports near the MBNMS averaged 662,000 lb/yr from 1980–95, but have been less than 310,000 lb/yr since 1992 (Fig. 54).

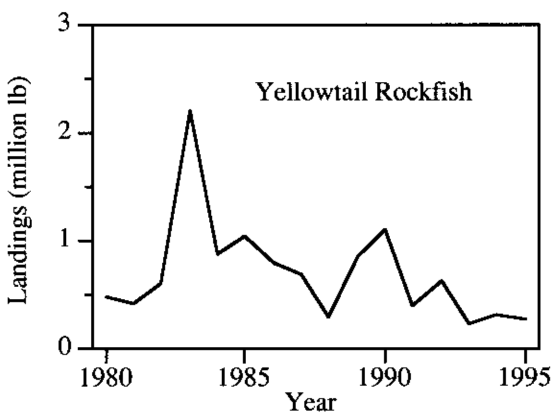


Figure 54. Estimated commercial landings of yellowtail rockfish at the five major ports near the MBNMS from 1980–95.

Population estimates for yellowtail rockfish are highly variable, making conclusions concerning trends difficult. Despite this high variability, the coastwide trend in abundance appears downward. Some recent stock assessments indicate that this species has been overfished in much of its range.

Management: The yellowtail rockfish fishery is managed by the PFMC as two stocks separated by a boundary at Cape Lookout, Oregon. The PFMC currently does not specifically limit the yellowtail rockfish catch in this region; they are managed as a part of the Sebastes complex. Within the 3.2 million lb ABC set for the Sebastes complex, PFMC is estimating that 571,000 lb of yellowtail rockfish will be harvested in California and southern Oregon in 1997.

Sport catch of rockfish is regulated by a bag limit of 15 fish per day of any combination of species.

References

Love, M.S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the Southern California Bight. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report No. 87. 38 pp.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pearcy, W.G. 1992. Movements of acoustically-tagged yellowtail rockfish *Sebastes flavidus* on Heceta Bank, Oregon. U.S. Fishery Bulletin 90:726–735.

Ralston, S. and D.F. Howard. 1995. On the development of year-class strength and cohort variability in two northern California rockfishes. U.S. Fishery Bulletin 93(4):710–720.

Stanley, R.D., B.M. Leaman, L. Haldorson, and V.M. O'Connell. 1994. Movements of tagged adult yellowtail rockfish, *Sebastes flavidus*, off the west coast of North America. U.S. Fishery Bulletin 92:655–663.

Tagart, J.V. and F.R. Wallace. 1996. Status of yellowtail rockfish resource in 1996. Draft manuscript. Washington Department of Fish and Wildlife, 600 Capitol Way N, Olympia, WA 98501.

Thornyheads (*Sebastolobus altivelis* and *S. alascanus*)

Distribution: Both species in the genus *Sebastolobus* range from northern Baja California to Alaska. The shortspine thornyhead is the more shallowly distributed of the two species, ranging from 28 m to 1,667 m deep, whereas the longspine thornyhead ranges from 363 m to 1,667 m deep. These two species are distributed over mud bottoms at the same depths and regions as sablefish and Dover sole, and make up a portion of the mixed fishery termed the deep water complex, or Dover sole, thornyhead, sablefish (DTS) complex. Thornyhead landings have been recorded separately since the 1970s. Until only recently, however, most of the thornyhead landings were reported in the "red rockfish" category.

Life History: The two species in this genus are noted for spawning gelatinous egg masses. Spawning occurs for both species in late winter and early spring. Approximately 50% of female shortspine thornyhead are mature at a length of 21 cm (estimated age 13 yr). Each female may release as many as 400,000 eggs annually. Larvae and young juveniles are pelagic for 14 to 15 months and settle to the bottom during January to June of the year following hatch. Longspine thornyhead females reach 50% maturity at a length of about 19 cm (estimated age 14 yr). A female can produce up to 100,000 eggs per spawning event and may spawn two to four times annually. Young juveniles are pelagic for as long as 20 months and begin settling to the bottom when they are about 5 cm long. Shortspine thornyheads reach a maximum length of 75 cm and a maximum estimated age of over 100 yr. Longspine thornyheads reach a maximum length of 38 cm and an estimated maximum age of at least 45 yr.

Fishery History and Trends: Thornyheads are important trawl caught species in the Monterey Bay groundfish fishery. Commercial landings of thornyheads have increased since the 1980s with increased trawling effort in deep waters and increased market demand. Landings for both species caught in the MBNMS from 1980–95 averaged 1.8 million lb/yr, with shortspine thornyheads accounting for about 66% of the landings (Fig. 55). There is a large amount of uncertainty in recent stock assessments because of uncertainty in natural mortality, fishing mortality, growth rates, survey results, and resulting biomass estimates.

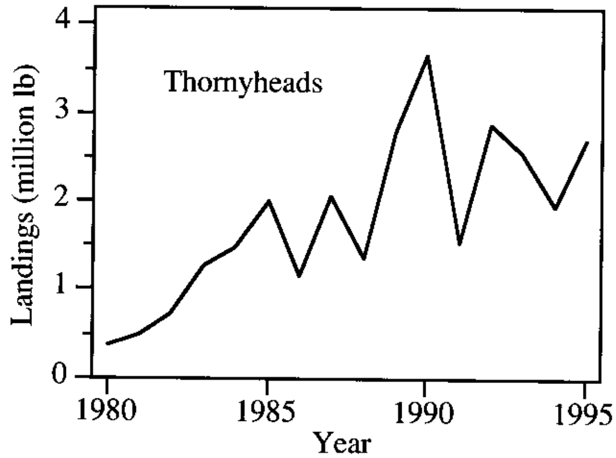


Figure 55. Estimated commercial landings of thornyheads at the five major ports near the MBNMS from 1980–95.

Management: These species are managed by PFMC. Quotas and gear regulations such as mesh size are some of the measures used to regulate this fishery. In 1997, the coastwide ABC for shortspine thornyhead was set at 2.2 million lb, and for longspine thornyhead at 15.4 million lb. The harvest guideline for the shortspine thornyhead, however, was set at a higher level because of the uncertainty in the stock assessment.

References

Ianelli, J.N., R. Lauth, and L.D. Jacobson. 1994. Status of the thornyhead (*Sebastolobus* sp.) resource in 1994. National Marine Fisheries Service, Alaska Fisheries Science Center. 58 pp.

Kline, D.E. 1996. Radiochemical age verification for two species of deep-sea rockfish (*Sebastolobus altivelis* and *S. alascanus*). M.S. Thesis, San Jose State University. 127 pp.

Love, M.S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the Southern California Bight. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report No. 87. 38 pp.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for

1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.
Pearcy, W.G. 1962. Egg masses and early developmental stages of the scorpaenid fish, *Sebastolobus*. Journal of the Fisheries Research Board of Canada 19:1169–1173.

Other Nearshore Rockfishes

Several species of rockfishes that occur in kelp forests and other nearshore habitats are under increasing fishing pressure from both commercial and sport anglers. Recently, markets for live, small rockfishes have added previously seldom caught fishes to the commercial landings. Species such as black-and-yellow, copper, grass, gopher, kelp, china, brown, and olive rockfishes that inhabit kelp beds are frequently caught in the recreational and commercial live fish fisheries. Many of these species have relatively short life spans compared to other rockfishes and can withstand relatively high harvest rates. Peak spawning is often from February to March. Other than olive rockfish, these species do not generally form schools, and are thought to move only short distances during their lifetimes. Most of these fishes are caught using hook-and-line gear or by divers. Harvest is regulated by the general provisions of the California Fish and Game Code for commercial and sport take.

References

Hallacher, L.E. and D.A. Roberts. 1985. Differential utilization of space and food by the inshore rockfishes (Scorpaenidae: *Sebastes*) of Carmel Bay, California. Environmental Biology of Fishes 12(2):91–110.
Karpov, K.A., D.P. Albin, and W.H. Van Buskirk. 1995. The marine recreational fishery in northern and central California, a historical comparison (1958–86), status of stocks (1980–86), and effects of changes in the California current. California Department of Fish and Game, Fish Bulletin No. 176. 192 pp.
O'Connell, V.M., D.A. Gordon, A. Hoffman, and K. Hepler. 1992. Northern range extension of the vermilion rockfish (*Sebastes miniatus*). California Department of Fish and Game Fish Bulletin 78(4):173.
VenTresca, D.A., J.L. Houk, M.J. Paddack, M.L. Gingras, N.L. Crane, and S.D. Short. 1996. Early life-history studies of nearshore rockfishes and lingcod off central California, 1987–92. California Department of Fish and Game, Marine Resources Division Administrative Report 96–4. 77 pp.
Wilson-Vandenberg, D., P.N. Reilly, and C. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. California Department of Fish and Game, Marine Resources Division Administrative Report 96–6. 96 pp.
Wylie Echeverria, T. 1987. Thirty-four species of California rockfishes: Maturity and seasonality of reproduction. U.S. Fishery Bulletin 85:229–250.

Flatfishes

Flatfishes are found nearly worldwide. Three families, including the left-eyed flounders (Bothidae), right-eyed flounders (Pleuronectidae), and tonguefishes (Cynoglossidae) are present along the Pacific coast of North America. Many of these species are harvested commercially using a wide range of gear including trawls, hook-and-line gear, and set nets. Many flatfishes are also caught incidentally in bottom trawl fisheries for roundfishes, rockfishes, and shrimp. Landing data and stock assessments suggest that populations of most species of flatfishes are robust and could withstand increased levels of harvest.

Flatfish are unique in that they undergo extreme metamorphosis between larval and juvenile stages. Larval flatfish are most often pelagic with a symmetrical body and an eye on each side of its head. After a certain length of time, specific to each species, dramatic changes in morphology take place; one eye migrates to the other side of the body and the skull twists correspondingly. During this transition, the fish begins swimming with a sideways tilt to compensate for the anatomical changes. By the time the migration of the eye is complete, the fish settles to the bottom with its eyed, pigmented side up and swims with undulating body movements.

California Halibut (*Paralichthys californicus*)

Distribution: California halibut range from northern Washington to southern Baja California. Their habitat is variable, but they are found mostly over sandy bottoms. Halibut occur in estuaries and in shallow coastal waters out to 183 m deep.

Life History: California halibut may reach 152 cm in length and 33 yr of age. Halibut are broadcast spawners. The spawning season extends from February to August, peaking in May. Eggs and larvae are pelagic and most abundant in the water column close to shore. Transformed larvae settle to bays, estuaries, and shallow coastal zones. Juveniles are most abundant in bays where they remain for at least two years before shifting to open coastal regions. Males mature at 2–3 yr of age, and females mature at age 4–5 yr. Adults move inshore to spawn during spring and summer and offshore during winter.

Fishery History and Trends: Catches of halibut are highest during the spring and summer in central California. Halibut are an important species in both the commercial and recreational fisheries in California. They are currently fished commercially using trawl, gill net, and hook-and-line gear. Fishers began using set nets to catch halibut in the 1880s. Trawls have been used since 1930, and accounted for the largest catches of halibut prior to 1969. In 1970, new regulations established area and season closures making trawling too costly and shifting effort towards set nets. In 1990, the California Marine Resources Protection Act restricted gill netting to outside of three miles. The measure had a dramatic effect on halibut landings, reflected by a 32% drop in catches in southern California between 1993 and 1994. In 1994, trawls were the most productive method of catching California halibut, followed by hook-and-line and gill net gear.

Total commercial catch of halibut in central California remained stable from 1980 to 1995 (Fig. 56), but there is evidence of a shift in halibut populations to the north. San Francisco ports alone accounted for over 49% of the California catch in 1994. The value of halibut landed has been increasing since 1980, reaching as high as $989,000 in 1992.

California halibut are caught recreationally from CPFVs, private boats, and from shore. Private boats exert the most pressure on the

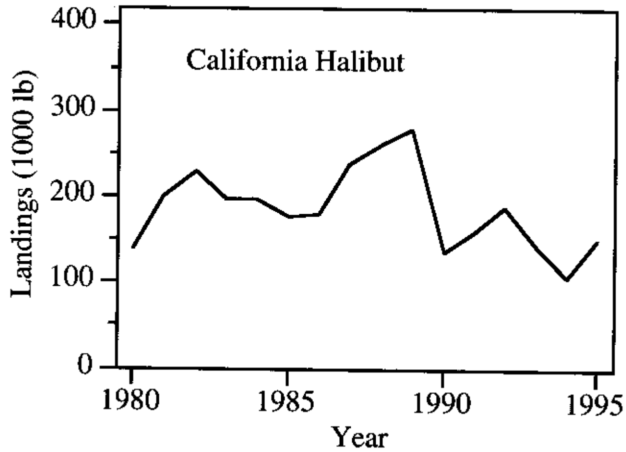


Figure 56. Reported commercial landings of California halibut at the five major ports near the MBNMS from 1980–95.

halibut population, accounting for 75% of the recreational halibut fishing effort from 1980–87. Halibut catch from private boats is difficult to monitor, however, so trends from the private recreational fishery are not well documented.

Recreational halibut catches in the CPFV fishery in California fluctuated greatly between 1936 and 1995. The highest catch of 143,500 fish occurred in 1948 following World War II. Starting in 1949, annual catches declined sharply through 1957 until a limit of two fish with a 22 in minimum length was placed on fishers. Catches and regulations continued to fluctuate until the fishery declined drastically in 1971 when a five fish, 22 in size limit was established. Between 1991–95, the number of halibut caught annually by CPFVs in the Monterey Bay area decreased from 114 to 15 fish. At the same time, however, catches reported for CPFVs in the San Francisco area increased from 559 to more than 13,000 fish. This is most likely a combined result of a northern shift in the halibut population, as well as increased fishing effort for halibut due to the decline in the striped bass fishery.

Management: The commercial halibut fishery is regulated using a number of methods. Gill and trammel nets are subject to depth, area, and season closures throughout the state. A minimum codend mesh size of 7.5 in is enforced for trawls to allow escapement of undersized fishes. A minimum size limit for the commercial fishery is set at 22 in. Possession of halibut as incidental catch by gill net, trammel net, or trawl net is limited to 4 fish. The recreational fishery is regulated with a 22 in size limit and a catch limit of five fish south of Point Sur and 3 fish north of Point Sur.

References

Haugen, C.W., ed. 1990. The California halibut, *Paralichthys californicus*, resource and fisheries. California Department of Fish and Game Fish Bulletin 174.

Kramer, S.H. 1990. Habitat specificity and ontogenetic movements of juvenile California halibut, *Paralichthys californicus*, and other flatfishes in shallow waters of southern California. Ph.D. thesis, University of California San Diego. 266 pp.

Reed, R.J. 1988. Changing the size limit: How it could affect California halibut fisheries. California Cooperative Oceanic Fisheries Investigations, Report 29:158–166.

Dover Sole (*Microstomus pacificus*)

Distribution: Dover sole are right-eyed flatfish that range from the Bering Sea to central Baja California. They are found over mud and sand bottoms between 18 and 914 m deep. Juvenile Dover sole settle in shallow water and migrate into deeper water as they age.

Life History: Adults reach 76 cm in length and as old as 53 yr. Dover sole spawn in deep water during winter months. Females reach maturity at about 7 yr of age and 33 cm in length. A 42.5 cm long female will release as many as 52,000 planktonic eggs. At a length of 57.5 cm, the number of eggs can increase to 266,000. Dover sole have a prolonged metamorphosis from larval to juvenile stages requiring a period of up to a year. This long planktonic stage indicates that environmental conditions greatly influence year-class strength. Eggs are most abundant beyond the 200 m isobath where current flow is 10–15 cm/s, resulting in southward transport.

Fishery History and Trends: Dover sole are one of the dominant fishes of the California commercial groundfish fishery. They are harvested by bottom trawlers and marketed as filets. Because many flatfish are caught together in the trawl fishery, effort data for individual species are not available. Commercial fishing effort for all trawl-caught flatfishes, however, remained constant from 1980–95 (Fig. 57). Dover sole

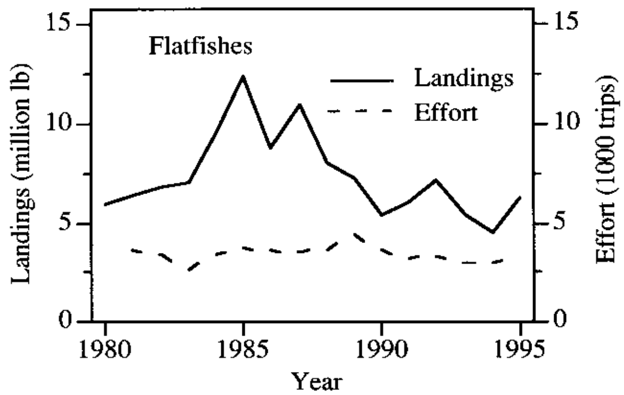


Figure 57. Reported commercial landings and fishing effort for all flatfishes (except California halibut) at the five major ports near the MBNMS from 1980–95.

landings at ports near the MBNMS greatly increased in the early 1980s, reaching a high of 8 million lb in 1985 (Fig. 58). Catches in the 1990s have declined due to increased regulation, lower recruitment, and reduced market demand. This has caused trawlers to redirect their efforts towards the more marketable thornyheads and sablefish.

Stock assessments suggest that Dover sole populations are depressed along most of the Pacific coast. Off Oregon and Washington in the late 1970s, harvest rates were appropriate for the Dover sole abundance. Since that time, abundance has declined as catches increased. Current population models suggest that harvest rates of the last 6 yr will result in overfishing the Dover sole population off Oregon and Washington. From Cape Mendocino to southern Oregon, stock assessments indicate that biomass is low as a result of reduced recruitment. Female spawning biomass is estimated to be only 18% of its unfished level.

Recent stock assessments for the Monterey management area indicate that Dover sole biomass in this region may be above the management target level. Dover sole landings on the West Coast for the last 5 yr have been below the recommended ABC, and NMFS survey biomass estimates have been stable since 1980.

Management: Dover sole are managed as part of the Dover–Thornyhead–Sablefish complex. Cumulative landing limits and trip limits are used to regulate catches of this fishery. The PFMC has implemented license limitations of the complex, creating two fishing fleets: the

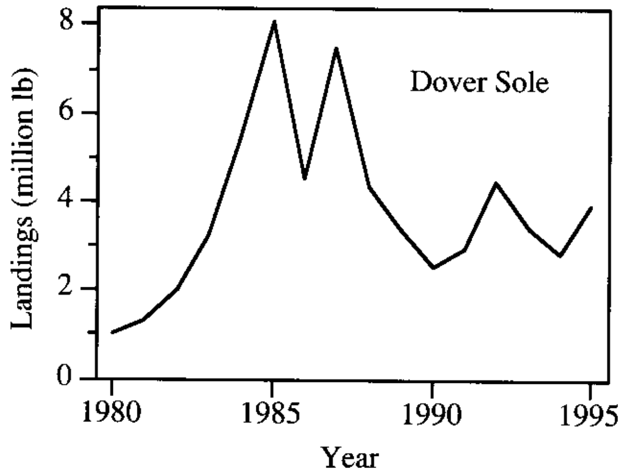


Figure 58. Reported commercial landings of Dover sole at the five major ports near the MBNMS from 1980–95.

permitted limited entry fleet and the nonpermitted open access fleet, which has more restricted harvest guidelines. The 1997 ABC for the Monterey management unit was set as a range of 7–9.7 million lb. The lower limit of the range was determined by the 1990–94 average landing level, the upper limit was derived from the 1995 stock assessment.

References

Hagerman, F.B. 1952. The biology of the Dover sole. California Department of Fish and Game, Fish Bulletin 85. 48 pp.

Horton, H.F. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Dover and rock sole. Biological Report, U.S. Fish and Wild-life Service. 17 pp.

Markle, D.F., P.M. Harris, and C.L. Toole. 1992. Metamorphosis and an overview of early-life-history stages in Dover sole *Microstomus pacificus*. U.S. Fishery Bulletin 90:285–301.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

English Sole (*Pleuronectes vetulus*)

Distribution: English sole are right-eyed flatfish. They can be distinguished from other flatfishes because their heads are particularly pointy and their right eye can be seen from the blind side of their body. English sole range from Baja California to Northwest Alaska between depths of 20–330 m, with yearly shifts towards shallower water in spring and deeper water in winter.

Life History: Adults can reach lengths of 57 cm and have been aged to 17 yr. Spawning occurs between January and March. All females are mature at a length of 36 cm and 3–5 yr in age. A female will release an average of 150,000 eggs at a length of 30 cm and 1.9 million eggs at a length of 44 cm. Eggs are pelagic but sink several hours before hatching. Young are pelagic for 6–10 wk before settling out to shallow areas such as estuaries and nearshore sandy habitats. As the fish grow they gradually shift to deeper waters. Reproductive success for English sole is highly variable from year to year. This in turn affects the amount and sizes of fish caught in the fishery. Juvenile survival is thought to be primarily influenced by water temperature and transport processes occurring between spawning grounds and nursery grounds.

Fishery History and Trends: English sole have been harvested commercially since the 1880s as part of the California commercial groundfish fishery. Over the last 10 yr, annual landings of English sole in California have remained stable at just below 3 million lb; most fish were caught between San Francisco and Eureka. Annual English sole landings at ports near the MBNMS fluctuated between 300,000 and 1 million lb from 1980–95 (Fig. 59). A slightly decreasing trend in both MBNMS and total California landings is evident since 1992. This is due to decreased market demand and a switch in effort towards thornyheads and sablefish.

NMFS surveys suggest that the English sole population off Oregon and Washington greatly increased from 1977–92. The increase resulted from a high recruitment during that time. High recruitment levels, combined with early age at maturity, suggest that English sole could safely withstand higher catch rates in the short term.

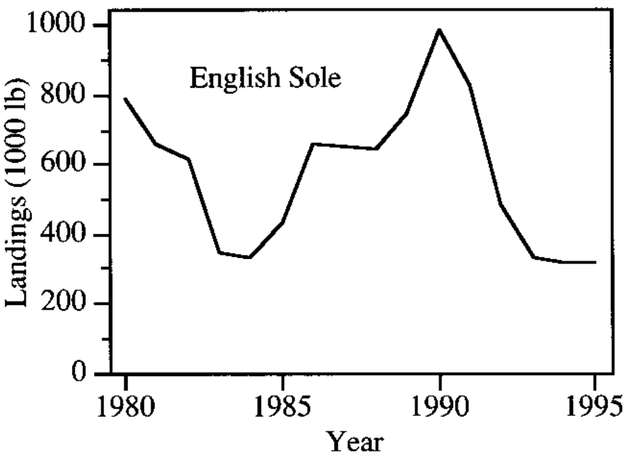


Figure 59. Reported commercial landings of English sole at the five major ports near the MBNMS from 1980–95.

There is no recent stock assessment for English sole in the Monterey management area, but NMFS survey indices suggest that population abundance in this region was level from 1983–95.

Management: Currently, English sole are managed through gear regulations including trawl net mesh size. The 1997 ABC for California and southern Oregon was set at 2.4 million lb. This is about equal to the 1983–91 average catch for that area.

References

Krygier, E.E. and W.G. Pearcy. 1986. The role of estuarine and offshore nursery areas for young English sole, *Parophrys vetulus* Girard, off Oregon. U.S. Fisheries Bulletin 84:119–132.

Lassuy, D.R. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) — English sole. U.S. Fish and Wildlife Service, Biological Report 82(11.101).

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Pacific Sanddab (*Citharichthys sordidus*)

Distribution: Pacific sanddab are left-eyed flatfish which occur over sand and mud habitats. They are found from the Bering Sea to southern Baja, but are most abundant between southern California and the Gulf of Alaska. They range from intertidal waters to depths greater than 550 m. Younger sanddab are found in shallower waters with the bulk of the population occurring between depths of 5 and 150 m.

Life History: Adults reach lengths of 41 cm and ages of at least 11 yr. Fifty percent of female Pacific sanddab are mature by a length of 19 cm and 3 yr of age. Spawning takes place between July and September. Females may spawn twice in a season. Larvae and early juveniles are pelagic before settling into shallow, sandy coastal areas.

Fishery History and Trends: Pacific sanddab are an important species in the commercial trawl and longline fisheries. Commercial landings within the MBNMS have increased since 1980 (Fig. 60). Adult populations are currently in good condition and are not in danger of being overfished. This is a very stable and most likely underutilized resource throughout its range. Pacific sanddab are sold fresh and whole in markets and restaurants. Sanddab are also often taken by anglers aboard CPFV and private vessels both for consumption and as bait fish.

Management: There is no limit, either in number or size, for the commercial or recreational take of Pacific sanddab.

References

Arora, H.L. 1951. An investigation of the California sanddab, *Citharichthys sordidus* (Girard). California Department of Fish and Game, Fish Bulletin 37:3–42.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Petrale Sole (*Eopsetta jordani*)

Distribution: Petrale sole are right-eyed flatfish found over sandy bottoms. They range

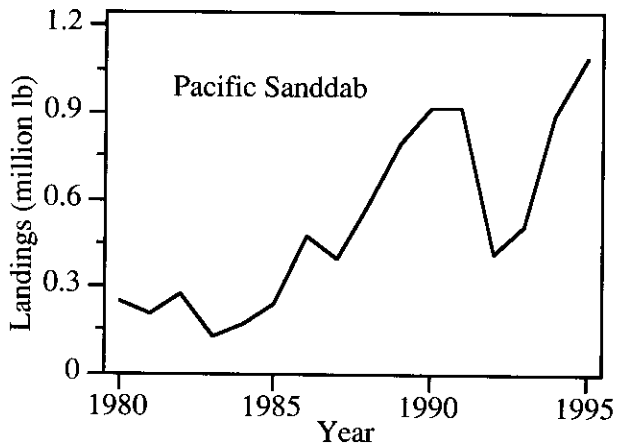


Figure 60. Reported commercial landings of Pacific sanddab at the five major ports near the MBNMS from 1980–95.

from the Bering Sea to northern Baja California. Petrale sole have been caught from intertidal areas to depths of more than 550 m, but are most abundant in waters from 90–275 m deep. Adult fishes make extensive migrations both inshore-offshore and along the coast.

Life History: Petrale sole reach 75 cm in length and have been aged to 25 yr. All males are mature by a length of 41 cm and all females are mature by a length of 46 cm. Spawning occurs from January to April off British Columbia, and from November to March off Oregon. Females produce from 400,000–1.2 million pelagic eggs.

Fishery History and Trends: Petrale sole are a popular recreational fish, occasionally caught by anglers during deepwater rockfish trips. They are also a large part of the flatfish trawl fishery from California to the Gulf of Alaska. Petrale sole are the most highly prized food fish of the small flatfishes. Coastwide, the population has undergone substantial fluctuations. For the management areas off Oregon and Washington, NMFS and Oregon Department of Fish and Wildlife trawl surveys indicated a two-fold decline in biomass from the mid-1970s to mid-1980s, followed by a general increase in biomass through 1992. Recent catch analyses suggest that off Oregon and Washington, the petrale sole population is near the expected long term average level of abundance. Stock assessments indicate that the petrale sole population could currently withstand higher catch rates.

Small scale fluctuations in petrale sole abundance have also been evident from an evaluation of catches in the Monterey Bay area. At ports near the MBNMS, annual petrale sole landings fluctuated between 200,000 and 800,000 lb from 1980–95 (Fig. 61).

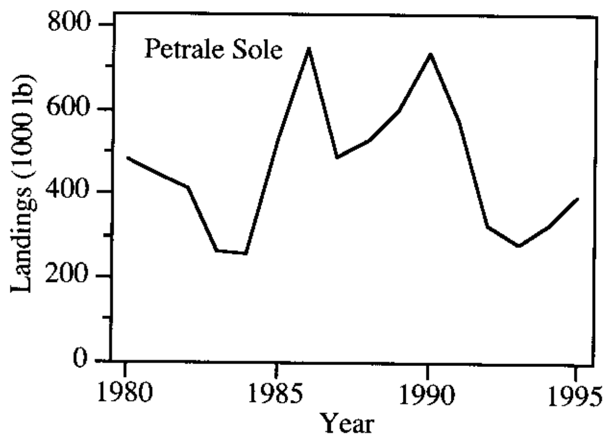


Figure 61. Reported commercial landings of Petrale sole at the five major ports near the MBNMS from 1980–95.

Management: Petrale sole are managed through gear regulations including trawl net mesh size. A 1993 stock assessment reported populations equal to expected long-term average abundances. The 1997 ABC was set at 1.8 million lb. for the Monterey management area.

References

Forrester, C.R. 1969. Life history information on some groundfish species. Fisheries Board of Canada, Technical Report 105:1–17.

Hart, J.L. 1973. Pacific Fishes of Canada. Fisheries Research Board of Canada, Bulletin 180. 740 pp.

Ketchen, K.S. and C.R. Forrester. 1966. Population dynamics of the Petrale sole, *Eopsetta jordani*, in waters off western Canada. Fisheries Research Board of Canada, Bulletin 153:1–195.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Rex Sole (*Errex zachirus*)

Distribution: Rex sole are small-mouthed, right-eyed flatfish, with a long pectoral fin on the eyed side. They range from the Bering Sea to Baja California, and are found from the intertidal zone to depths of more than 870 m. Rex sole are most abundant over mud and mud-boulder habitats.

Life History: Adults can reach lengths of 60 cm and have been aged to 24 yr. Females grow faster and larger, and live longer than males. All females are mature at a length of 30 cm and an age of 9 yr, while all males are mature at a length of 22 cm and an age of 5 yr. Spawning time is extremely variable. Females produce 3,900–238,000 eggs. Larvae take about 1 yr to metamorphose into bottom-dwelling adults.

Fishery History and Trends: Rex sole are rarely taken by recreational fishers, but are a large part of the flatfish trawl fishery from California to the Bering Sea. Commercial landings within the MBNMS are variable, but have shown some increase since 1985 (Fig. 62).

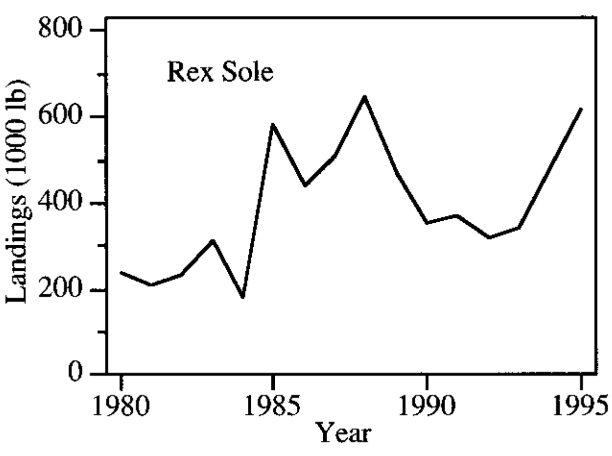


Figure 62. Reported commercial landings of Rex sole at the five major ports near the MBNMS from 1980–95.

The coastwide biomass of rex sole was estimated to be 6.6–8.8 million lb in the late 1970s to early 1980s. Biomass estimates in the mid-1980s to mid-1990s then increased almost four-fold to 24.3–30.9 million lb. The biomass estimates of the rex sole population in the Monterey management area followed a similar trend. Biomass in this region was estimated at approximately 1.9 million lb during the 1970s and early 1980s, with biomass peaking at approximately 4.7 million lb in 1983. The increase in commercial landings since 1985 is a reflection of the current high abundance of rex sole.

Management: Rex sole are managed through gear regulations including trawl net mesh size. In PFMC stock assessments, rex sole are lumped into an "other flatfish" category. The 1997 ABC for the Monterey management area for the "other flatfish" category was set at 4 million lb.

References

Hosie, M.J. 1976. The rex sole. Oregon Department of Fish and Wildlife, Information Report 76–2:1–5.

Hosie, M.J. and H.F. Horton. 1977. Biology of the rex sole, *Glyptocephalus zachirus*, in waters off Oregon. U.S. Fisheries Bulletin 75:51–60.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended acceptable biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Wilkins, M.E. 1996. Long term trends in abundance: Results of triennial bottom trawl surveys of west coast groundfish resources between 1977 and 1995. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Other Nearshore Species

Nearshore rocky bottoms and kelp beds are areas of high productivity. They also contain a diversity of microhabitats where fishes can forage and find shelter. As a result, nearshore areas are inhabited by a very diverse assemblage of fishes, including shallow water rockfishes, lingcod, cabezon, surfperches, croakers, greenlings, and sculpins. Population assessments for most of these nearshore species are not available. A discussion of the catch trends for all of these fishes is thus beyond the scope of this report. We describe only three of these nearshore, nonrockfish groups, but include a number of excellent references that contain further information on nearshore fishes. See Appendices 2 and 3 for commercial landing records and Appendix 4 for recreational catch estimates of these species or species groups.

Surfperches (Embiotocidae)

Surfperches represent a highly abundant and diverse group of fishes in the temperate waters of the northeast Pacific Ocean. Nineteen species of surfperch are found off California; they occur in a wide range of habitats including nearshore sandy bottoms, intertidal and subtidal rocky substrates, and kelp beds. They are also highly abundant near artificial structures such as jetties and piers. We have chosen to address surfperch as a single group and not to describe life history and fishery trends for individual species. Further information on this group of fishes can be found in the references provided.

Fishery History and Trends: Because surfperch are easily caught by both boat and shore-based anglers, they constitute a significant portion of the recreational fishery. Surfperch are also frequently caught by divers with pole spears and spear guns. In 1995, over 540,000 surfperch were caught by recreational fishers in northern and central California. The majority of these catches occurred in shorebased fisheries. Important species in the sportfish catches include barred, striped, redtail, walleye, rubberlip, pile, and shiner surfperch (Table 7). Historical catch data show that between 1958–61 and 1981–86, surfperch average weight per fish declined. Catches also declined from 1.2 million to 760,000 fish/yr. The declines are attributed primarily to reductions in catches of barred and redtail surfperch. For the time periods from 1987–89 and 1994–96, average catch further decreased to approximately 490,000 fish/yr. Steady declines in surfperch populations are attributed to a number of factors including environmental variation, lower larval production caused by smaller fish, habitat degradation, and increased fishing pressure.

Table 7. Surfperch Species Harvested in the Recreational Fishery Between 1980 and 1996, Listed in Order of Average Annual Catch

Species	Average Catch (× 1000 fish) 1980–96
Barred	157.3
Striped	98.5
Redtail	98.2
Walleye	95.7
Shiner	74.4
Silver	53.1
White	48.4
Pile	46.5
Black	26.8
Rubberlip	22.9
Calico	14.8
Rainbow	12.4
Sharpnose	1.6
Spotfin	1.3
Kelp	0.4
Dwarf	0.1
Reef	<0.1
All species	759.5

Note: No data available for 1990–92.
Data provided by the PSMFC.

The commercial fishery for surfperch is much smaller than the recreational fishery. Larger aggregating species, such as barred and redtail surfperch, typically provide the bulk of the commercial surfperch landings in northern and central California. In 1995, 26,000 lb of surfperches, worth $50,000 in exvessel price, were landed at ports near the MBNMS. Commercial landings averaged 27,000 lb/yr from 1980–95 (Appendix 2). Over 97% of these landings were barred surfperch landed at Morro Bay.

References

Fritzsche, R.A. and T.J. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Pile perch, striped seaperch, and rubberlip seaperch. U.S. Fish and Wildlife Service, Biological Report 82(11.103). 15 pp.

Hart, J.L. 1973. Pacific Fishes of Canada. Fisheries Research Board of Canada, Bulletin 180. 740 pp.

Cabezon (*Scorpaenichthys marmoratus*)

Distribution: Cabezon range from Punta Abreojos, Baja California to Sitka, Alaska and are found on hard bottoms intertidally to a depth of 83 m.

Life History: Spawning occurs from late October to March and peaks in January. Females deposit egg masses in a nest site which is guarded by the male until the eggs hatch. Males begin maturing at 2 yr of age and at a length of approximately 20 cm. All are mature by age 3 yr. Females begin to mature during their third year and between a length of 25–48 cm. All females are mature by their fifth year. Fecundity can range up to 152,000 eggs from a 76 cm long female and there is some evidence that off Washington spawning may occur more than once during a year. The largest recorded cabezon was 99 cm long and weighed 24 lb.

Fishery History and Trends: Cabezon are highly sought after by divers and recreational anglers. They do not make up a large portion of CPFV catches but are generally one of the larger fishes caught by anglers, with an average weight of about 4.4 lb. Cabezon are harvested in the commercial fishery primarily by hook-and-line fishers. Commercial landings of cabezon in this region averaged 15,000 lb/yr from 1980–93. Commercial landings increased substantially in 1994–95 (Fig. 63), due primarily to an increase in the nearshore live fish fishery.

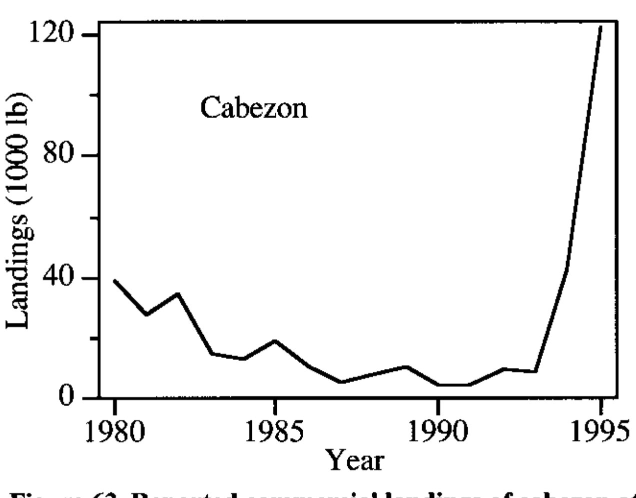


Figure 63. Reported commercial landings of cabezon at the five major ports near the MBNMS from 1980–95.

Management: Cabezon are not a federally regulated species by PFMC. Sport catch of cabezon is regulated under the general finfish provisions of the California Fish and Game Code. There is no size limit for cabezon, but a bag limit is set at 10 fish per day. Some concerns exist about the potential for overharvest of small cabezon in the nearshore live fish fishery. Recent data collected by CDFG biologists indicate that a majority of cabezon caught in the live fish fishery are below the length of 50% maturity. An excessive harvest of small fish could present problems for this species.

References

Hart, J.L. 1973. Pacific Fishes of Canada. Fisheries Research Board of Canada Bulletin No. 180.

Moyle, P.B. and J.J. Cech, Jr. 1988. Fishes: An Introduction to Ichthyology. New York: Prentice-Hall. 559 pp.

O'Connell, C.P. 1953. The life history of the cabezon *Scorpaenichthys marmoratus* (Ayres). California Department of Fish and Game, Fish Bulletin 93. 76 pp.

Review of some California fisheries for 1994–95. California Cooperative Oceanic Fisheries Investigations, Report No. 36:7–18.

White Croaker (*Genyonemus lineatus*)

Distribution: White croaker range from Magdalena Bay, Baja California to Vancouver Island, British Columbia. They live near the bottom over sandy substrates from the surf zone to a depth of 200 m.

Life History: White croaker spawn year round in central California. Females can spawn multiple times within a season, and fecundity ranges from an estimated 800 eggs in a 15 cm long female to 37,200 eggs in a 25 cm long female. Eggs and larvae are pelagic, and larvae settle to the bottom as they develop. Juveniles are found near the bottom in 3–6 m of water, then migrate to deeper water as they mature. Fifty percent maturity is reached by both males and females after 1 yr of growth. By age 3–4 yr, all white croakers are mature. White croaker can reach a length of 41 cm and live to be 12 yr old.

Fishery History and Trends: Statewide, white croaker are frequently caught in recreational fisheries and are an important constituent of the commercial catch as well. They are not landed commercially in great numbers in Monterey Bay, however, and are often sold as bait fish. After the Vietnam War, many Vietnamese fishers immigrated to the Monterey Bay area

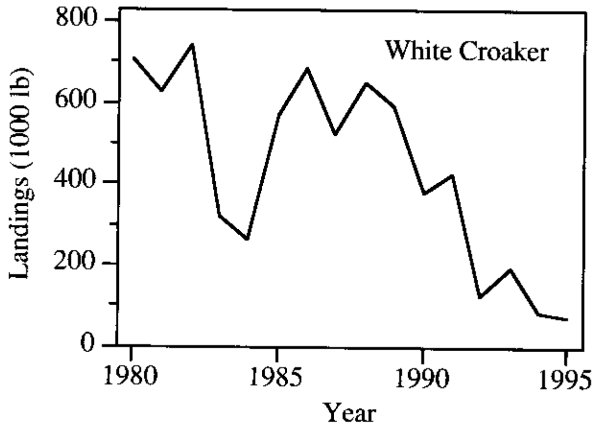


Figure 64. Reported commercial landings of white croaker at the five major ports near the MBNMS from 1980–95.

and were encouraged to fish for white croaker. These fishers have since gradually moved on to other, more profitable fisheries. In addition, the gill net ban in the early 1990s lowered fishing pressure on the white croaker. As a result, landings have dramatically declined at ports near the MBNMS in the last 15 yr, despite the increase in biomass estimated by the NMFS (Fig. 64).

Management: The commercial fishery for white croaker does not fall under the purview of the PFMC. The fishery is managed exclusively by CDFG rules and regulations. Sport catch is regulated by the general provisions for finfish in the California Fish and Game Code.

References

Love, M.S., G.E. McGowen, W. Westphal, R.J. Lavenberg, and L. Martin. 1984. Aspects of the life history and fishery of the white croaker, *Genyonemus lineatus* (Sciaenidae), off California. U.S. Fisheries Bulletin 82:179–198.

Watson, W. 1982. Development of eggs and larvae of the white croaker *Genyonemus lineatus* Ayres (Pices: Sciaenidae), off the southern California coast. U.S. Fisheries Bulletin 80:403–417.

General References

California Department of Fish and Game. 1996. California sport fishing regulations. Fish and Game Commission, P.O. Box 944209, Sacramento, California 94244-2090.

California Department of Fish and Game. 1996. Digest of California commercial fish laws and licensing requirements. Fish and Game Commission, P.O. Box 944209, Sacramento, California 94244-2090.

California Sea Grant College Program. 1986. Rockfish: A Focus for Research? R. Amidei, ed. Report T-CSGCP-015. California Sea Grant, University of California, La Jolla, CA.

Eschmeyer, W.N. and E.S. Herald. 1983. A field guide to Pacific coast fishes. Houghton Mifflin Co., Boston, MA. 336 pp.

Gotshall, D. 1987. Marine animals of Baja California: A Guide to Common Fishes and Invertebrates. Sea Challenges, Monterey, CA. 113 pp.

Karpov, K.A., D.P. Albin, and W.H. Van Buskirk. 1995. The marine recreational fishery in northern and central California, a historical comparison (1958–86), status of stocks (1980–86), and effects of changes in the California Current. California Department of Fish and Game, Fish Bulletin No. 176. 192 pp.

Lea, R.N., R.D. McAllister, and D.A. VenTresca. In press. Biological aspects of nearshore rockfishes of the genus *Sebastes* with notes on ecologically related sportfishes off central California. California Department of Fish and Game, Fish Bulletin No. 177.

Leet, W.S., Dewees, C.M., and C. W. Haugen. 1992. California's living marine resources. University of California Sea Grant, Davis, CA. 257 pp.

Love, R.M. 1991. Probably more than you ever wanted to know about the fishes of the Pacific coast. Really Big Press, Santa Barbara, CA. 215 pp.

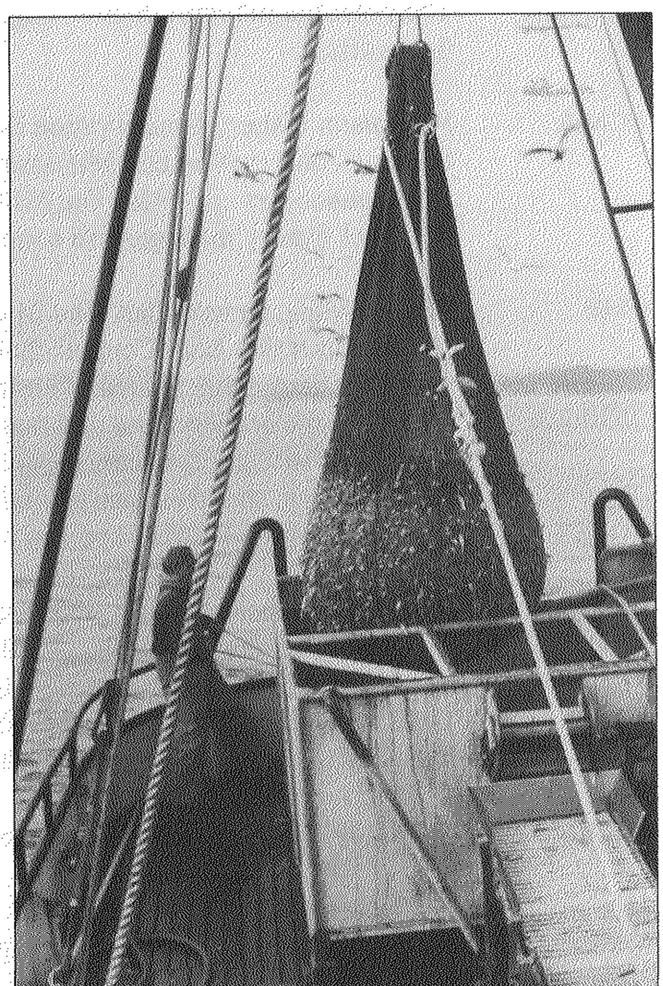
Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin No. 157.

Moyle, P.B and J.J. Cech, Jr. 1988. Fishes: An introduction to ichthyology. Prentice Hall, New York, NY. 559 pp.

Pacific Fishery Management Council. 1995. Status of the Pacific coast groundfish fishery through 1995 and recommended biological catches for 1996: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pacific States Marine Fisheries Commission. 1997. Commercial and recreational fisheries statistics published on world wide web at www.psmfc.org. Pacific States Marine Fisheries Commission, Portland, OR 97201.

VenTresca, D.A., J.L. Houk, M.J. Paddack, M.L. Gingras, N.L. Crane, and S.D. Short. 1996. Early life-history studies of nearshore rockfishes and lingcod off central California, 1987–92. California Department of Fish and Game, Marine Resources Division Administrative Report 96–4. 77 pp.



Glossary

ABC	Acceptable (sometimes Allowable) Biological Catch. A seasonally determined catch or range of catches based on the best scientific estimates of current stock conditions.
Age at 50% maturity	Age at which 50% of the population is reproductively mature.
CDFG	California Department of Fish and Game
CPFV	Commercial Passenger Fishing Vessel
CPUE	Catch per Unit Effort. The total number or weight of fish harvested by a defined unit of fishing effort. Measures of "unit of effort" are variable and defined separately within each fishery (e.g., angler day, hours fished, trips, vessel days, number of hooks, etc.)
EEZ	Exclusive Economic Zone. The zone out to 200 miles in which the United States claims control over natural resources.
Fecundity	The potential net reproductive output of a female (e.g., the number of eggs present in the ovaries).
FCMA	Magnuson Fishery Conservation and Management Act, or "Magnuson Act." The Fishery Conservation and Management Act was created in 1976 and was renamed the "Magnuson Act" in 1980. The MFCMA established the 200-mile EEZ and the regional fishery management council system.
FMP	Fishery Management Plan. The Magnuson Fishery Conservation and Management Act provides that each Council shall prepare a FMP with respect to each fishery within its geographical area of authority. Among the necessary components of such FMPs are the conservation and management measures (1) applicable to foreign and domestic fishing, (2) necessary and appropriate for the conservation and management of the fishery, and (3) consistent with the seven national standards, the other provisions of the FCMA, and any other applicable law.
IFQ	Individual Fishery Quotas. IFQs are under consideration in California and are in use in a few fisheries around the world. They are certificates or licenses given to individual fishers which represent the right to catch and sell a certain share of the TAC. When these certificates are transferable between fishers they are referred to as Individual Transferable Quotas (ITQs).
MBNMS	Monterey Bay National Marine Sanctuary
Monterey Management Area	The area from 36° N latitude to 40° 30' N latitude off central California that is designated as a fishery management area by the PFMC.

MSY	Maximum Sustainable Yield. An average over a reasonable length of time of the largest catch that can be harvested continuously from a stock without reducing its long-term productive potential.
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
OY	Optimum Yield. The term "optimum," with respect to the yield from a fishery, means the amount of fish (1) that will provide the greatest overall benefit to the nation, with particular reference to food production and recreational opportunities, and (2) that is prescribed as such on the basis of the maximum sustainable yield from such fishery, as modified by any relevant economic, social, or ecological factors.
PFMC	Pacific Fishery Management Council
PSMFC	Pacific States Marine Fisheries Commission
Recruitment	The stage or time at which young individuals of a species are first harvested by a fishery.
Sebastes Complex	A rockfish management group that includes bocaccio, canary, chilipepper, yellowtail, and the remaining rockfish group. The remaining rockfish group includes all rockfishes harvested, but not individually addressed with stock assessments.
Stock	A segment of a fish population that is selected to be harvested and managed.
TAC	Total Allowable Catch. The total amount in weight of fishes that can be harvested from a particular fishery over a predetermined length of time.

Appendices

Appendix 1. Common and Scientific Names of Species Commonly Caught and Sold in Commercial (C) Fisheries and Recreational (R) Fisheries in Central California from 1980–95

Common Name	Scientific Name	C	R
Abalone, red	*Haliotis rufescens*	x	x
Anchovy, northern	*Engraulis mordax*	x	x
Barracuda, California	*Sphyraena argentea*		x
Bass, kelp	*Paralabrax clathratus*		x
Bass, striped	*Morone saxatilis*	x	x
Bonito, Pacific	*Sarda chiliensis*	x	x
Butterfish, Pacific	*Peprilus simillimus*	x	x
Cabezon	*Scorpaenichthys marmoratus*	x	x
Clam, California jackknife	*Tagelus californianus*		x
Clam, common littleneck	*Protothaca staminea*	x	x
Clam, common Washington	*Saxidomus nuttalli*	x	x
Clam, gaper	*Tresus nuttallii*	x	x
Clam, northern quahog	*Mercenaria mercenaria*		x
Clam, northern razor	*Siliqua patula*		x
Clam, Pismo	*Tivela stultorum*	x	x
Clam, purple	*Nuttallia nuttallii*		x
Clam, rosy razor	*Solen rosaceus*		x
Clam, softshell	*Mya arenaria*		x
Cod, Pacific	*Gadus microcephalus*	x	
Crab, box	Family: Lithodidae	x	
Crab, Dungeness	*Cancer magister*	x	x
Crab, rock	*Cancer spp.*	x	x
Crab, shore	*Pachygrapsus spp.*		x
Crab, shore	*Hemigrapsus spp.*		x
Croaker, white	*Genyonemus lineatus*	x	x
Flounder, arrowtooth	*Atheresthes stomias*	x	x
Flounder, starry	*Platichthys stellatus*	x	x
Fringehead, onespot	*Neoclinus uninotatus*		x
Fringehead, sarcastic	*Neoclinus blanchardi*		x
Goby, yellowfin	*Acanthogobius flavimanus*		x
Greenling, kelp	*Hexagrammos decagrammus*	x	x
Greenling, rock	*Hexagrammos lagocephalus*		x
Greenling, painted	*Oxylebius pictus*		x
Grenadier, Pacific	*Coryphaenoides acrolepis*	x	
Guitarfish, shovelnose	*Rhinobatus productus*	x	x
Hagfish, Pacific	*Eptatretus stoutii*	x	
Hagfish, black	*Eptatretus deani*	x	
Hake, Pacific	*Merluccius productus*	x	x
Halfmoon	*Medialuna californiensis*		x
Halibut, California	*Paralichthys californicus*	x	x
Halibut, Pacific	*Hippoglossus stenolepis*	x	x
Herring, Pacific	*Clupea pallasii*	x	x
Irish Lord, brown	*Hemilepidotus spinosus*		x
Irish Lord, red	*Hemilepidotus hemilepidotus*		x
Jacksmelt	*Atherinops californiensis*	x	x
Kelpfish, giant	*Heterostichus rostratus*		x
Limpet	Subclass Prosobranchia		
Limpet, owl	Lottia gigantea	x	x
Lingcod	*Ophiodon elongatus*	x	x
Lizardfish, California	*Synodus lucioceps*	x	x
Louvar	*Luvarus imperialis*	x	
Mackerel, jack	*Trachurus symmetricus*	x	x
Mackerel, Pacific	*Scomber japonicus*	x	x
Midshipman, plainfin	Porichthys notatus		x
Monkeyface-eel	*Cebidichthys violaceus*	x	x
Mussel, California	*Mytilus californianus*	x	x
Mussel, bay	*Mytilus edulis*	x	x
Octopus	*Octopus spp.*	x	x
Opah	*Lampris guttatus*	x	
Opaleye	*Girella nigricans*		x
Prawn, ridgeback	*Sicyonia ingentis*	x	
Prawn, spot	*Pandalus platyceros*	x	
Prickleback, rock	*Xiphister mucosus*		x
Queenfish	*Seriphus politus*	x	x
Ratfish	*Hydrolagus colliei*		x
Ray, bat	*Myliobatis californica*	x	x
Rockfish, aurora	*Sebastes aurora*	x	x
Rockfish, bank	*Sebastes rufus*	x	x
Rockfish, black	*Sebastes melanops*	x	x
Rockfish, black-and-yellow	*Sebastes chrysomelas*	x	x
Rockfish, blackgill	*Sebastes melanostomus*	x	x
Rockfish, blue	*Sebastes mystinus*	x	x
Rockfish, bocaccio	*Sebastes paucispinis*	x	x
Rockfish, bronzespotted	*Sebastes gilli*	x	x
Rockfish, brown	*Sebastes auriculatus*	x	x
Rockfish, calico	*Sebastes dallii*		x
Rockfish, canary	*Sebastes pinniger*	x	x
Rockfish, chameleon	*Sebastes phillipsi*	x	
Rockfish, chilipepper	*Sebastes goodei*	x	x
Rockfish, China	*Sebastes nebulosus*	x	x
Rockfish, copper	*Sebastes caurinus*	x	x
Rockfish, cowcod	*Sebastes levis*	x	x
Rockfish, darkblotched	*Sebastes crameri*	x	x
Rockfish, flag	*Sebastes rubrivinctus*	x	x
Rockfish, gopher	*Sebastes carnatus*	x	x
Rockfish, grass	*Sebastes rastrelliger*	x	x
Rockfish, greenblotched	*Sebastes rosenblatti*	x	x
Rockfish, greenspotted	*Sebastes chlorostictus*	x	x
Rockfish, greenstriped	*Sebastes elongatus*	x	x
Rockfish, halfbanded	*Sebastes semicinctus*		x
Rockfish, honeycomb	*Sebastes umbrosus*	x	x
Rockfish, kelp	*Sebastes atrovirens*	x	x
Rockfish, olive	*Sebastes serranoides*	x	x
Rockfish, Pacific ocean perch	*Sebastes alutus*	x	
Rockfish, pink	*Sebastes eos*	x	
Rockfish, quillback	*Sebastes maliger*	x	x
Rockfish, redbanded	*Sebastes babcocki*	x	x
Rockfish, rosy	*Sebastes rosaceus*	x	x
Rockfish, shortbelly	*Sebastes jordani*	x	x
Rockfish, speckled	*Sebastes ovalis*	x	x
Rockfish, splitnose	*Sebastes diploproa*	x	x
Rockfish, squarespot	*Sebastes hopkinsi*	x	x
Rockfish, starry	*Sebastes constellatus*	x	x
Rockfish, stripetail	*Sebastes saxicola*	x	x
Rockfish, swordspine	*Sebastes ensifer*	x	x
Rockfish, tiger	*Sebastes nigrocinctus*	x	x
Rockfish, treefish	*Sebastes serriceps*	x	x
Rockfish, vermilion	*Sebastes miniatus*	x	x
Rockfish, widow	*Sebastes entomelas*	x	x

(continued)

Appendix 1 (continued). Common and Scientific Names of Species Commonly Caught and Sold in Commercial (C) Fisheries and Recreational (R) Fisheries in Central California from 1980–95

Common Name	Scientific Name	C	R
Rockfish, yelloweye	*Sebastes ruberrimus*	x	x
Rockfish, yellowtail	*Sebastes flavidus*	x	x
Sablefish	*Anoplopoma fimbria*	x	x
Salmon, chinook	*Oncorhynchus tshawytscha*	x	x
Salmon, coho	*Oncorhynchus nerka*	x	x
Salmon, pink	*Oncorhynchus gorbuscha*	x	x
Sanddab, longfin	*Citharichthys xanthostigma*	x	x
Sanddab, Pacific	*Citharichthys sordidus*	x	x
Sanddab, speckled	*Citharichthys stigmeaus*	x	x
Sardine, Pacific	*Sardinops sagax*	x	x
Scallop, rock	*Hinnites multirugosus*		x
Sculpin, staghorn	*Leptocottus armatus*	x	x
Sea cucumber	*Parastichopus spp.*	x	x
Sea stars	Class: Asteriodea	x	x
Seabass, white	*Astractoscion nobilis*	x	x
Señorita	*Oxyjulis californica*		x
Shark, bigeye thresher	*Alopias superciliosus*	x	
Shark, blue	*Prionace glauca*		x
Shark, brown smoothhound	*Mustelus henlei*	x	x
Shark, common thresher	*Alopias vulpinus*	x	
Shark, gray smoothhound	*Mustelus californicus*	x	x
Shark, sevengill	*Notorynchus cepedianus*	x	x
Shark, shortfin mako	*Isurus oxyrinchus*	x	
Shark, sixgill	*Hexanchus griseus*	x	x
Shark, soupfin	*Galeorhinus galeus*	x	x
Shark, spiny dogfish	*Squalus acanthias*		x
Sheephead, California	*Semicossyphus pulcher*	x	x
Shrimp, bay	*Crangon stylirostris*	x	x
Shrimp, Pacific ocean	*Pandalus jordani*	x	
Skate, big	*Raja binoculata*	x	x
Skate, longnose	*Raja rhina*	x	x
Skate, California	*Raja inornata*	x	x
Skate, thornback	*Platyrhinoidis triseriata*	x	x
Smelt, eulachon	*Thaleichthys pacificus*		
Smelt, night	*Spirinchus starksi*	x	x
Smelt, surf	*Hypomesus pretiosus*	x	x
Snail, sea	Subclass: Prosobranchia	x	x
Sole, bigmouth	*Hippoglossina stomata*	x	x
Sole, butter	*Pleuronectes isolepis*	x	x
Sole, Dover	*Microstomus pacificus*	x	x
Sole, English	*Pleuronectes vetulus*	x	x
Sole, fantail	*Xystreurys liolepis*	x	x
Sole, petrale	*Eopsetta jordani*	x	x
Sole, rex	*Errex zachirus*	x	x
Sole, rock	*Pleuronectes bilineata*	x	x
Sole, sand	*Psettichthys melanostictus*	x	x
Squid, market	*Loligo opalescens*	x	x
Sturgeon, green	*Acipenser, medirostris*		x
Sturgeon, white	*Acipenser transmontanus*		x
Surfperch, barred	*Amphistichus argenteus*		x
Surfperch, black	*Embiotoca jacksoni*	x	x
Surfperch, calico	*Amphistichus koelzi*	x	x
Surfperch, dwarf	*Micrometrus minimus*		x
Surfperch, pile	*Rhacochilus vacca*	x	x
Surfperch, rainbow	*Hypsurus caryi*	x	x
Surfperch, rubberlip	*Rhacochilus toxotes*	x	x
Surfperch, sharpnose	*Phanerodon atripes*		x
Surfperch, shiner	*Cymatogaster aggregata*		x
Surfperch, walleye	*Hyperprosopon argenteum*	x	x
Surfperch, white	*Phanerodon furcatus*	x	x
Swordfish	*Xiphias gladius*	x	
Thornyhead, longspine	*Sebastolobus altivelis*	x	
Thornyhead, shortspine	*Sebastolobus alascanus*	x	
Tomcod, Pacific	*Microgadus proximus*		x
Topsmelt	*Atherinops affinis*	x	x
Tuna, albacore	*Thunnus alalunga*	x	x
Tuna, bigeye	*Thunnus obesus*	x	x
Tuna, bluefin	*Thunnus thynnus*	x	x
Tuna, skipjack	*Katsuwonus pelamis*	x	x
Tuna, yellowfin	*Thunnus albacares*	x	x
Turbot, C-O	*Pleuronichthys coenosus*	x	x
Turbot, curlfin	*Pleuronichthys decurrens*	x	x
Turbot, diamond	*Hypsopsetta guttulata*	x	x
Turbot, hornyhead	*Pleuronichthys verticalis*		x
Urchin, purple sea	*Strongylocentrotus purpuratus*	x	x
Urchin, red sea	*Strongylocentrotus franciscanus*	x	x
Whitefish, ocean	*Caulolatilus princeps*	x	x
Wolf-eel	*Anarichthys ocelatus*	x	x
Yellowtail	*Seriola dorsalis*	x	x

Note: This table includes a few species which are caught beyond MBNMS boundaries, but sold at local ports. It does not include those species harvested for bait or scientific or educational purposes.

Appendix 2. Reported Commercial Landings of Major Species and Species Groups at the Five Major Ports Near the MBNMS from 1980–91. Species Listed in Order of Decreasing Average Annual Landings

Species	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Market squid	15,713,265	28,269,123	23,363,078	2,068,840	932,768	8,531,907	13,828,631	13,123,184	11,454,979	15,790,899	17,649,494	17,576,788
Rockfishes	10,462,748	8,364,031	13,068,812	12,930,568	7,940,081	8,630,688	8,776,709	8,828,103	8,684,247	11,450,892	9,660,163	6,837,813
Dover sole	1,042,137	1,315,195	2,009,955	3,262,916	5,405,140	8,082,551	4,519,329	7,523,960	4,358,730	3,412,762	2,519,450	2,953,608
Northern anchovy	6,679,657	10,217,156	5,763,316	707,134	4,177,162	2,512,490	1,782,483	1,491,055	1,537,969	2,081,348	4,699,020	5,590,562
Pacific mackerel	499,561	2,989,317	4,113,087	5,928,458	7,102,472	990,830	2,086,598	708,652	51,847	31,690	4,663,101	296,725
Pacific sardine	150	5	86	35	719	4,748	186,180	104,843	6,532	524,688	547,204	2,131,519
Sablefish	2,368,287	2,002,982	2,328,241	1,949,524	1,584,432	2,214,718	2,122,592	1,859,997	1,779,125	1,991,999	1,670,491	1,335,563
Albacore	4,322,751	5,125,896	677,539	6,115,167	1,927,326	2,414,847	2,017,542	1,790,799	834,885	475,182	291,655	153,122
Chinook salmon	913,539	981,128	1,567,162	790,597	733,019	814,868	2,030,550	1,405,669	3,578,899	1,964,856	1,850,872	1,364,819
Jack mackerel	159,946	466,339	618,403	5,417,138	12,082,730	502,873	421,435	462,544	268,448	85,816	462,828	96,168
Unspecified mackerel	90,986	8,122	407,030	1,686,352	8,670,540	4,983,914	2,318,024	1,411,843	83,509	116,457	869,668	363,207
English sole	795,605	664,140	619,133	347,164	330,659	436,428	659,569	654,257	643,473	751,578	988,109	831,294
Sanddab	249,068	202,871	273,419	131,138	174,156	236,923	472,884	395,379	577,256	795,636	919,382	920,141
Lingcod	739,769	576,606	748,206	488,253	351,987	177,559	246,843	495,655	546,692	812,533	567,055	340,728
Petrale sole	480,640	446,105	413,033	263,607	256,503	535,504	748,316	488,121	526,810	598,986	733,290	576,572
Swordfish	453	694	41,841	567,067	437,576	1,115,371	751,817	763,368	779,243	587,463	584,239	462,872
White croaker	706,195	624,949	740,836	320,707	263,125	565,657	682,275	520,298	648,217	590,096	377,875	427,106
Dungeness crab	199,764	129,390	116,808	259,155	231,577	123,556	341,340	682,450	916,957	355,518	256,183	344,321
Rex sole	237,133	211,137	230,325	314,652	179,116	581,821	439,077	507,233	647,891	471,288	351,822	369,084
Pacific ocean shrimp	1,167,514	873,281	483,762	761,659	126,810	24,244	801,395	473,145	313,257	10,848	1,187	34
Rock crab	27,684	37,056	43,287	67,102	143,287	283,648	266,562	142,992	145,410	303,282	296,482	314,188
California halibut	138,381	200,104	229,043	196,999	197,359	176,228	178,488	236,748	261,048	280,039	134,829	159,282
Pacific herring	345,848	276,789	551,635	285,986	209,316	135,048	310,357	137,047	28,518	27,439	281,143	243,980
Sea urchin	11,747	22,128	12,453	22,909	9,930	1,778	10,993	16,649	261,544	729,097	192,095	193,316
Common thresher shark	2,362	10,799	117,362	319,302	188,633	203,912	97,366	134,941	85,977	113,267	160,927	187,920
Red abalone	78,487	59,179	65,741	40,675	52,226	106,432	63,843	104,102	109,108	129,427	104,426	75,102
Skate	69,526	115,318	84,333	79,642	54,134	47,723	56,081	47,280	58,491	105,703	99,985	81,801
Hagfish	0	0	0	0	0	0	0	0	224,064	3,036	869,813	0
Sand sole	41,358	52,303	70,444	63,911	75,674	68,704	91,870	50,762	31,204	24,489	16,812	31,316
Unspecified flatfish	94,437	81,558	69,686	42,700	54,576	93,583	87,528	45,731	39,696	47,223	11,308	8,249
Pacific bonito	284	1,975	16,129	146,415	10,215	5,176	3,969	451,517	2,077	443	28,685	46
Grenadiers	0	0	0	1,090	13,713	409	153	0	172	615	22,092	1,316
Spot prawn	46,253	59,399	78,992	35,002	20,110	25,165	15,036	16,986	22,108	11,279	11,006	18,747
Crab claws	0	0	0	0	0	0	47,254	111,887	105,612	99,772	61,144	11,026
Unspecified fish	31,624	20,120	17,399	54,268	22,007	18,004	52,604	128,635	92,298	13,747	2,580	277
Surfperch	24,607	18,564	35,983	27,865	13,542	12,402	24,003	43,980	37,484	31,790	30,127	26,935
Opah	0	0	1,537	50,159	58,901	57,443	23,350	18,226	12,733	42,068	27,754	19,498
Unspecified shark	81,561	48,103	36,603	34,310	41,612	56,257	27,769	18,189	19,660	10,168	6,826	2,853
Starry flounder	3,502	5,772	1,444	13,792	42,720	80,066	59,913	38,101	64,769	22,109	9,594	19,256
Soupfin shark	47,787	23,647	30,074	34,969	33,806	38,330	24,176	29,344	16,179	20,010	24,023	19,342
Cabezon	38,859	27,412	34,576	14,074	12,459	19,011	10,289	4,479	7,553	10,234	4,181	3,825
Coho salmon	2,152	2,013	9,728	4,894	60,370	2,542	11,326	1,383	9,322	12,746	66,633	166,260
Shortfin mako shark	1,037	20	6,413	40,290	18,096	18,225	13,177	35,117	16,550	33,654	55,931	41,901
Unspecified salmon	4,691	15,943	10,584	6,736	10,850	14,007	64,904	19,141	57,753	31,458	23,030	3,813

(continued)

Appendix 2 (continued). Reported Commercial Landings of Major Species and Species Groups at the Five Major Ports Near the MBNMS from 1980–95. Species Listed in Order of Decreasing Average Annual Landings

Species	1992	1993	1994	1995	Total	Mean
Market squid	18,605,308	19,753,011	35,759,316	7,070,465	249,491,056	15,593,191
Rockfishes	7,763,623	6,989,386	6,546,080	5,952,734	142,886,678	8,930,417
Dover sole	4,479,887	3,418,151	2,829,364	3,955,772	61,088,907	3,818,057
Northern anchovy	1,340,921	2,832,819	2,511,768	2,612,081	56,536,941	3,533,559
Pacific mackerel	844,835	85,468	87,399	1,258,181	31,738,221	1,983,639
Pacific sardine	6,819,313	1,489,543	5,047,560	12,443,559	29,306,684	1,831,668
Sablefish	1,492,942	910,569	739,330	1,516,889	27,867,681	1,741,730
Albacore	255,453	650,160	367,882	441,411	27,861,617	1,741,351
Chinook salmon	868,497	1,517,210	2,073,241	4,326,435	26,781,361	1,673,835
Jack mackerel	245,077	761,476	422,198	0	22,473,419	1,404,589
Unspecified mackerel	3,467	0	0	1,257,556	22,270,675	1,391,917
English sole	487,181	331,778	318,838	321,169	9,180,375	573,773
Sanddab	417,414	504,599	802,120	858,607	7,930,993	495,687
Lingcod	404,220	552,543	410,940	253,472	7,713,061	482,066
Petrale sole	326,645	278,297	323,889	396,553	7,392,871	462,054
Swordfish	416,726	374,074	240,611	394,604	7,518,019	469,876
White croaker	125,145	195,722	84,889	73,822	6,946,914	434,182
Dungeness crab	372,269	273,741	825,714	987,759	6,416,502	401,031
Rex sole	320,071	340,489	476,147	616,986	6,294,272	393,392
Pacific ocean shrimp	2,574	216	367,187	689,988	6,097,101	381,069
Rock crab	430,912	338,936	205,802	200,139	3,246,769	202,923
California halibut	189,933	140,933	107,874	151,653	2,978,941	186,184
Pacific herring	0	1,470	83	1,347	2,836,006	177,250
Sea urchin	151,375	126,335	42,036	63,641	1,868,026	116,752
Common thresher shark	84,976	10,151	16,287	63,778	1,797,960	112,373
Red abalone	122,135	79,140	67,245	73,911	1,331,179	83,199
Skate	122,196	53,491	47,720	73,556	1,196,980	74,811
Hagfish	407	459	1,104	762	1,099,645	68,728
Sand sole	52,723	44,928	16,392	19,858	752,748	47,047
Unspecified flatfish	17,269	5,786	3,232	2,000	704,562	44,035
Pacific bonito	1,882	2,086	195	293	671,387	41,962
Grenadiers	7,931	8,777	60,341	469,913	586,522	36,658
Spot prawn	22,033	61,114	129,602	198,773	771,605	48,225
Crab claws	51,788	24,504	3,696	927	517,610	32,351
Unspecified fish	1,230	3,735	323	73	458,924	28,683
Surfperch	33,891	26,416	22,624	26,468	436,681	27,293
Opah	45,478	13,381	24,489	41,514	436,531	27,283
Unspecified shark	2,819	3,461	4,210	5,566	399,967	24,998
Starry flounder	18,165	9,686	5,255	8,077	402,221	25,139
Soupfin shark	13,495	21,823	15,465	17,068	409,538	25,596
Cabezon	9,193	8,644	42,239	122,756	369,784	23,112
Coho salmon	8,275	392	21	254	358,311	22,394
Shortfin mako shark	32,749	16,878	14,786	19,151	363,975	22,748
Unspecified salmon	2,721	38,223	2,714	1,801	308,369	19,273

(continued)

Appendix 2 (continued). Reported Commercial Landings of Major Species and Species Groups at the Five Major Ports Near the MBNMS from 1980–95. Species Listed in Order of Decreasing Average Annual Landings

Species	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Pacific angel shark	9,974	18,144	14,058	12,249	23,063	20,292	17,079	33,817	23,923	24,197	11,640	6,061
Pacific butterfish	46,311	26,044	20,388	5,157	3,276	3,696	30,073	12,097	5,858	11,221	2,808	12,419
Bigeye thresher shark	0	0	0	42,757	8,982	27,685	5,527	6,733	5,972	8,647	6,902	23,178
Smelt	14,257	14,174	31,677	21,318	3,342	10,949	12,990	5,673	5,854	5,423	9,924	2,134
Leopard shark	2,583	6,421	17,913	6,516	10,554	16,461	16,814	12,546	7,543	12,081	5,680	2,650
Turbot	2,507	8,448	4,676	1,818	5,085	5,302	4,020	2,644	3,716	9,476	11,960	8,476
Yellowfin tuna	115	66,550	813	9,949	641	4,044	2,194	2,250	3,969	384	5,516	1,517
Octopus	12,439	7,151	18,158	6,051	1,471	416	413	1,605	2,102	19,888	6,661	2,838
Pacific sanddab	0	0	80	64	0	0	0	0	0	0	0	0
Bluefin tuna	80	0	0	128	644	1,167	444	706	1,369	1,503	13,193	2,777
Rock sole	810	5,495	9,606	4,752	8,866	11,810	5,834	5,036	2,830	9,199	3,846	3,497
Yellowtail	1,626	1,068	12,649	10,432	50,138	137	349	337	187	128	0	117
Louvar	0	0	0	0	9,164	12,875	4,932	4,207	8,743	1,621	3,128	3,106
Butter sole	0	0	0	200	0	575	23,321	18,820	7,863	0	67	0
Unspecified tuna	616	0	395	2,455	590	1,580	1,327	1,489	4,058	1,198	2,203	2,959
White seabass	1,423	2,365	1,405	4,389	2,493	2,185	2,860	811	1,199	1,101	6,892	877
Unspecified shrimp	2,659	2,992	496	8,305	14,926	4,614	2,625	904	1,892	365	42	0
Jacksmelt	5,132	1,234	1,585	0	816	992	1,133	391	1,651	2,159	2,237	4,293
Fantail sole	0	0	153	3	21,030	157	3,405	354	2,234	4,223	0	0
Pacific hake	0	274	774	883	9,419	5,633	2,914	1,616	2,580	994	219	1,778
Bigeye tuna	813	163	97	2,720	160	1,213	1,270	3,012	8,378	531	580	3,803
Cow shark	0	0	249	63	87	68	142	252	20	0	0	22,015
Spiny dogfish shark	3,858	1,313	613	465	13,517	470	12	299	619	156	0	7
Kelp greenling	3,116	135	543	128	8	79	559	529	2,195	3,829	227	1,594
Skipjack tuna	40	0	0	11,366	1,305	0	774	0	596	536	247	4,122
Ghost shrimp	0	1,313	1,030	10,295	1,511	2,266	480	35	51	0	0	0
Shovelnose guitarfish	0	0	48	14	0	29	84	374	5,724	7,696	605	147
Total	48,031,694	64,711,934	59,246,906	46,057,681	54,444,506	45,082,270	46,918,161	45,642,316	40,061,410	45,132,175	52,301,081	44,714,651

Taxonomic Groups	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Invertebrates	17,259,812	29,461,012	24,183,805	3,279,993	1,534,616	9,104,026	15,378,572	14,673,939	13,333,020	17,450,375	18,578,720	18,536,360
Sharks and Rays	218,688	223,765	307,618	570,563	392,484	429,423	258,143	318,518	234,934	327,883	371,914	387,728
Anadromous Fish	920,382	999,084	1,587,474	802,227	804,239	831,417	2,106,780	1,426,193	3,645,974	2,009,060	1,940,535	1,534,892
Pelagic Fish	12,149,237	19,180,118	12,224,945	20,946,118	34,742,875	12,747,452	9,943,118	7,363,992	3,638,919	3,989,716	12,482,972	9,388,519
Nearshore	7,073,876	10,523,037	6,364,203	1,155,159	4,450,826	2,661,295	2,313,411	2,196,896	1,581,141	2,645,267	5,558,860	7,978,643
Offshore	4,915,415	8,190,742	5,242,339	14,373,821	18,209,319	9,583,284	7,208,272	4,704,552	1,789,330	1,258,633	6,461,284	1,313,708
Roundfish	2,368,287	2,003,256	2,329,015	1,951,497	1,607,564	2,220,760	2,125,659	1,861,613	1,781,877	1,993,608	1,692,802	1,338,657
Rockfish	10,462,748	8,364,031	13,068,812	12,930,568	7,940,081	8,630,688	8,776,709	8,828,103	8,684,247	11,450,892	9,660,163	6,837,813
Surfperch	24,607	18,564	35,983	27,865	13,542	12,402	24,003	43,980	37,484	31,790	30,127	26,935
Flatfish	3,085,578	3,193,128	3,930,997	4,643,716	6,750,884	10,309,652	7,293,554	9,967,146	7,167,520	6,427,008	5,700,469	5,880,775

Note: Species with annual landings less than 1000 lb/yr are not included. Data were collected by CDFG and provided by NMFS.

(continued)

Appendix 2 (continued). Reported Commercial Landings of Major Species and Species Groups at the Five Major Ports Near the MBNMS from 1980–95. Species Listed in Order of Decreasing Average Annual Landings

Species	1992	1993	1994	1995	Total	Mean
Pacific angel shark	5,176	5,358	3,202	3,042	231,275	14,455
Pacific butterfish	7,034	14,807	9,958	4,857	216,004	13,500
Bigeye thresher shark	3,470	1,523	3,012	6,369	150,757	9,422
Smelt	3,272	817	1,349	2,062	145,215	9,076
Leopard shark	4,552	5,344	7,837	4,290	139,785	8,737
Turbot	16,770	13,936	6,878	3,888	109,600	6,850
Yellowfin tuna	1,433	2,126	0	220	101,721	6,358
Octopus	4,242	4,924	1,493	155	90,007	5,625
Pacific sanddab	49	1,181	86,427	231,996	319,797	19,987
Bluefin tuna	9,428	39,943	14,661	18,634	104,677	6,542
Rock sole	3,434	7,320	3,642	10,412	96,389	6,024
Yellowtail	5,340	174	5	0	82,687	5,168
Louvar	2,111	10,732	1,391	1,661	63,671	3,979
Butter sole	15	130	122	0	51,113	3,195
Unspecified tuna	11,745	14,447	3,523	1,035	49,620	3,101
White seabass	1,633	5,855	9,733	2,120	47,341	2,959
Unspecified shrimp	0	0	50	0	39,870	2,492
Jacksmelt	282	1,536	12,849	2,816	39,106	2,444
Fantail sole	25	18	455	307	32,364	2,023
Pacific hake	44	706	1,389	552	29,775	1,861
Bigeye tuna	389	64	645	0	23,838	1,490
Cow shark	0	0	0	0	22,896	1,431
Spiny dogfish shark	188	132	133	0	21,782	1,361
Kelp greenling	5,051	568	1,959	1,104	21,624	1,352
Skipjack tuna	285	441	123	2,929	22,764	1,423
Ghost shrimp	0	0	0	0	16,981	1,061
Shovelnose guitarfish	520	169	1,111	0	16,521	1,033
Total	47,103,624	42,434,245	61,242,149	47,291,766	790,384,769	49,399,048

Taxonomic Groups	1992	1993	1994	1995	Total	Mean
Invertebrates	19,762,636	20,661,921	37,402,141	9,285,758	269,886,706	16,867,919
Sharks and Rays	269,621	118,161	112,652	173,669	4,715,764	294,735
Anadromous Fish	879,493	1,555,825	2,075,976	4,328,490	27,448,041	1,715,503
Pelagic Fish	10,010,917	6,293,211	8,732,491	18,479,882	202,314,482	12,644,655
Nearshore	8,174,490	4,340,899	7,569,569	15,062,137	89,649,709	5,603,107
Offshore	1,591,350	1,190,836	740,724	3,417,745	90,191,354	5,636,960
Roundfish	1,500,917	920,052	801,060	1,987,354	28,483,978	1,780,249
Rockfish	7,763,623	6,989,386	6,546,080	5,952,734	142,886,678	8,930,417
Surfperch	33,891	26,416	22,624	26,468	436,681	27,293
Flatfish	6,329,581	5,097,232	4,980,635	6,577,278	97,335,153	6,083,447

Note: Species with annual landings less than 1000 lb/yr are not included. Data were collected by CDFG and provided by NMFS.

Appendix 3. Estimated Commercial Landings of Rockfishes at the Five Major Ports, Plus San Francisco, Near the MBNMS from 1980–95, Determined from an Expansion of Species Composition Sampling Conducted by CDFG. Species are Listed in Order of Decreasing Average Annual Landings

Rockfish Species	1980	1981	1982	1983	1984	1985	1986	1987	1988
Bocaccio	7,426,744	4,500,656	6,409,315	6,270,772	5,191,674	2,737,095	2,643,871	3,029,991	2,254,595
Chilipepper	4,315,858	3,750,835	3,195,253	2,968,613	3,074,213	4,295,938	3,372,293	2,489,449	2,606,528
Widow	824,625	2,034,589	7,330,123	1,434,804	932,848	1,522,349	846,757	1,794,812	770,280
Bank	37,966	1,242,705	1,635,111	1,265,628	1,014,704	1,267,396	2,384,034	1,712,305	1,987,809
Shortspine Thornyhead	166,634	474,992	677,362	1,225,917	1,460,985	1,982,241	817,401	255,745	1,355,963
Yellowtail	471,592	399,773	602,216	2,207,425	866,367	1,023,936	785,857	673,448	285,432
Longspine Thornyhead	53,098	9,199	46,294	42,814	8,956	13,652	120,555	123,070	769
Splitnose	171,456	395,701	452,027	861,866	833,534	945,407	592,091	56,862	542,145
Blackgill	64,300	191,240	457,080	368,243	66,950	164,249	422,029	50,644	1,044,751
Rockfishes	166,346	62,267	278,788	306,523	141,585	176,087	321,755	777,951	422,887
Vermilion	160,503	58,658	1,257	200,407	100,474	72,660	58,179	237,193	141,763
Thornyheads	149,138	4,492	3,707	1,304	465	5,821	228,780	1,683,958	12,096
Canary	89,981	77,982	39,812	60,601	107,852	365,592	1,774	12,052	32,733
Darkblotched	148,107	8,568	91,369	155,524	300,897	179,327	165,221	57,249	66,632
Aurora	5,261	0	7,557	16,754	1,432	58,094	59,373	0	185,710
Greenspotted	19,892	60,343	111,662	33,944	27,091	64,178	9,699	7,477	55,231
Blue	114,150	135,258	75,281	77,739	22,665	247,928	34,611	17,211	15,480
Brown	395,520	150,188	130,385	46,021	7,979	11,422	0	3,599	7,183
Gopher	139,911	115,748	85,030	64,929	8,873	699	247	0	12
Yelloweye	28,263	292,635	30,111	3,840	10,526	2,455	8,400	7,705	24,755
Speckled	0	30,380	28,607	195,295	17,596	45,429	81,840	9,749	16,546
Cowcod	23,614	17,567	26,977	22,482	63,947	18,765	11,773	18,705	19,831
Olve	26,022	1,660	7,010	79,195	0	1	1,573	15,486	12,739
Copper	42,849	3,857	10,213	41,165	3,859	1,235	1,993	2,065	64,599
Starry	490	268	4,930	1,050	205	9,302	448	0	14,834
China	52,671	42,459	32,532	16,420	15,064	6,537	3,701	12,642	15,835
Greenstriped	40,706	582	13,436	11,779	9,985	21,644	8,186	4,870	17,995
Back	26,537	12,414	9,582	17,790	7,767	21,801	23,749	12,684	669
Redbanded	0	2,660	7,081	2,463	116,971	44,224	7,475	45	316
Stripetail	37,600	55,619	27,640	693	1,132	11,203	4,042	653	2,281
Grass	0	133	33	0	0	0	41	3,141	0
Black-and-Yellow	0	0	0	0	0	0	0	63,768	0
Shortbelly	6,429	611	1,624	13,171	4,889	62,371	4,280	701	558
Rosy	0	0	0	5,391	0	178	100	0	217
Flag	395	0	25,153	2,694	2,428	423	6,207	2,630	1,894
Greenblotched	4,065	8,030	3,430	0	9,389	0	301	0	232
Kelp	68	25	0	2	0	204	0	11,650	0
Sharpchin	0	0	0	1,259	3,415	10,799	1,428	82	0
Quillback	0	0	0	0	0	0	0	0	0
Rosethorn	0	0	0	18	0	1,602	308	0	2,259
Silvergray	0	0	0	0	15,947	4,080	0	0	263
Rougheye	0	0	0	0	0	0	0	16,223	0
Tiger	0	14,516	0	0	0	0	0	0	0
Pacific Ocean Perch	1,018	2,389	1,586	774	2,202	785	166	127	591
Yellowmouth	0	0	0	0	0	0	0	16,223	0
Total	15,211,812	14,158,999	21,859,674	18,026,136	14,458,416	15,403,546	13,031,057	13,185,031	11,986,970

Note: Species with estimated annual landings less than 1000 lb/yr are not included. Data were analyzed and provided by NMFS.

(continued)

Appendix 3 (continued). Estimated Commercial Landings of Rockfishes at the Five Major Ports, Plus San Francisco, Near the MBNMS from 1980–95, Determined from an Expansion of Species Composition Sampling Conducted by CDFG. Species are Listed in Order of Decreasing Average Annual Landings

Rockfish Species	1989	1990	1991	1992	1993	1994	1995	Total	Mean
Bocaccio	3,259,889	3,045,340	1,823,350	1,918,492	1,456,909	1,388,203	1,043,451	46,973,603	2,935,850
Chilipepper	3,629,118	3,144,087	4,080,665	3,517,807	2,780,217	2,449,895	2,660,380	48,015,291	3,000,956
Widow	1,636,765	1,507,166	945,951	647,396	428,210	333,835	1,070,181	23,236,066	1,452,254
Bank	1,439,174	944,831	897,210	902,143	391,061	317,039	571,604	17,972,754	1,123,297
Shortspine Thornyhead	1,787,774	2,139,332	538,901	1,050,940	1,043,399	1,304,571	943,687	17,059,210	1,066,201
Yellowtail	837,565	1,091,610	391,433	620,077	227,136	308,419	265,160	10,585,854	661,616
Longspine Thornyhead	992,191	1,501,233	963,389	1,772,942	1,496,848	609,471	1,524,372	9,225,755	576,610
Splitnose	524,447	480,012	768,916	413,295	461,526	454,433	508,363	8,290,625	518,164
Blackgill	502,371	582,159	219,983	547,358	261,013	305,751	301,798	5,485,619	342,851
Rockfishes	378,176	700,325	446,640	190,507	75,312	72,659	71,883	4,423,345	276,459
Vermilion	77,139	248,443	154,414	239,747	402,144	230,487	156,766	2,379,731	148,733
Thornyheads	12,090	36,677	25,277	46,586	8,395	21,609	231,841	2,323,098	145,194
Canary	191,481	211,139	244,248	123,367	146,781	122,791	117,891	1,856,096	116,006
Darkblotched	107,282	300,252	150,797	51,380	35,316	12,027	66,601	1,748,442	109,278
Aurora	185,408	217,385	3,379	203,755	197,834	142,192	117,941	1,396,814	87,301
Greenspotted	40,637	69,918	180,038	148,070	188,057	142,694	141,629	1,280,668	80,042
Blue	50,908	50,811	61,878	109,704	103,860	79,470	53,744	1,136,548	71,034
Brown	16,822	14,718	86,390	77,545	104,079	79,361	40,739	776,431	48,527
Gopher	20	91	5	135,187	123,893	129,824	156,210	820,768	51,298
Yelloweye	15,909	58,215	121,531	62,139	71,498	67,014	26,951	803,684	50,230
Speckled	47,832	17,937	22,369	33,094	12,495	31,724	30,245	621,138	38,821
Cowcod	46,119	51,686	35,824	57,632	72,829	42,938	77,405	584,480	36,530
Olive	993	15,598	175,046	28,303	13,176	47,825	24,389	422,994	26,437
Copper	1,690	1,609	48,140	46,971	66,666	30,743	36,510	361,315	22,582
Starry	25,915	30,256	57,486	75,677	37,725	71,620	21,217	350,933	21,933
China	979	1,413	10,656	30,246	9,471	36,175	23,561	257,691	16,106
Greenstriped	39,385	6,901	21,532	14,024	8,154	23,005	16,829	218,307	13,644
Black	5,136	2,445	10,522	14,650	38,027	28,350	8,065	213,651	13,353
Redbanded	5,319	7,258	9,924	9,659	8,106	964	14,499	236,964	14,810
Stripetail	1,137	17,746	4,515	501	8,392	6,432	18,454	160,440	10,028
Grass	0	0	3,249	11,613	20,535	55,698	80,736	175,179	10,949
Black-and-Yellow	0	0	0	20,308	7,140	25,959	54,324	171,499	10,719
Shortbelly	1,279	4,975	2,791	936	1,327	1,967	18,835	120,315	7,520
Rosy	760	16,597	16,836	12,924	5,785	40,147	4,319	103,254	6,453
Flag	832	1,288	1,632	8,531	18,168	12,181	1,878	85,939	5,371
Greenblot ched	200	2,163	548	518	16,431	19,147	21,182	81,571	5,098
Kelp	0	0	40	856	15,534	17,208	16,607	62,126	3,883
Sharpchin	69	3,966	5,332	9,867	1,717	7,103	4,114	49,151	3,072
Quillback	0	0	3,820	4,184	223	26,559	2,198	36,984	2,312
Rosethorn	5,851	8,418	1,060	2,694	0	2,502	320	25,032	1,565
Silvergray	0	389	0	0	0	0	0	20,679	1,292
Rougheye	0	0	0	0	352	0	2,387	18,962	1,185
Tiger	0	3,022	0	806	0	112	0	18,456	1,154
Pacific Ocean Perch	0	72	0	6,787	131	818	934	17,362	1,085
Yellowmouth	0	0	0	0	0	0	0	16,223	1,014
Total	15,873,787	16,537,940	12,535,725	13,172,606	10,376,205	9,110,463	10,560,422	225,488,789	14,093,049

Note: Species with estimated annual landings less than 1000 lb/yr are not included. Data were analyzed and provided by NMFS.

Appendix 4. Estimated Catch of Species in Northern California Sport Fisheries. Species are Listed in Decreasing Average Annual Number of Fish Caught per Year

Species	Average Catch (Fish/yr × 1000)	Species	Average Catch (Fish/yr × 1000)
Surf smelt	2617.67	Sablefish	19.10
Blue rockfish	752.09	White surfperch	17.03
Black rockfish	364.06	Unspecified rockfish	16.83
Yellowtail rockfish	353.06	Pacific staghorn sculpin	16.00
White croaker	335.31	Calico surfperch	14.82
Pacific sanddab	328.44	Rainbow surfperch	12.80
Jack smelt	265.09	Brown smoothhound shark	12.14
Night smelt	258.74	Quillback rockfish	10.89
Canary rockfish	188.15	Rosethorn rockfish	10.46
Lingcod	180.35	Swordspine rockfish	9.18
Chilipepper rockfish	175.78	Speckled sanddab	8.94
Brown rockfish	160.67	Unspecified surfperch	8.66
Barred surfperch	159.14	Speckled rockfish	8.65
Copper rockfish	106.39	Rainbow trout	8.19
Striped surfperch	98.85	Sand sole	7.97
Redtail surfperch	98.56	Top smelt	7.79
Walleye surfperch	97.46	Scorpionfish	7.04
Pacific mackerel	97.06	Monkeyface prickleback	6.86
Bocaccio rockfish	95.96	Rougheye rockfish	6.18
Gohper rockfish	95.20	Spiny dogfish shark	5.61
Olive rockfish	93.05	Sea run trout	5.44
Kelp greenling	92.66	Coho salmon	4.71
Pacific herring	89.73	Cowcod rockfish	4.54
Shiner surfperch	77.55	Flag rockfish	4.43
Rosy rockfish	65.61	Albacore tuna	4.33
Vermilion rockfish	59.49	Pacific bonito	4.26
Cabezon	56.99	Bat ray	3.96
Northern anchovy	54.62	Longfin sanddab	3.71
Silver surfperch	53.70	Buffalo sculpin	3.70
Widow rockfish	49.84	Kelp bass	3.54
Pacific sardine	49.79	Yellowfin goby	3.53
White surfperch	49.12	Pacific tomcod	3.40
Greenspotted rockfish	48.06	Rock sole	3.31
Striped bass	47.09	Greenblotched rockfish	2.85
Pile surfperch	46.55	Pacific sand lance	2.76
Jack mackerel	41.72	Petrale sole	2.74
Chinook salmon	39.98	Shortspine thornyhead	2.61
China rockfish	37.43	Unspecified sanddab	2.46
Pacific halibut	36.49	Sea bass	1.91
Starry flounder	29.39	Sharpnose surfperch	1.61
Starry rockfish	28.79	American shad	1.59
Black surfperch	27.00	Squarespot rockfish	1.44
Black-and-yellow rockfish	24.86	Sevengill shark	1.39
Rock greenling	24.31	Cutthroat trout	1.35
Kelp rockfish	24.27	Blue shark	1.31
Yelloweye rockfish	23.51	Spotfin surfperch	1.28
Rubberlip surfperch	23.41	Lefteye flounder	1.21
Greenstriped rockfish	23.07	Gray smoothhound shark	1.21
Leopard shark	21.54	Unspecified sculpin	1.19
Grass rockfish	19.82	Unspecified salmon	1.15
Pacific hake	19.47	Dover sole	1.06
		Total	8528.00

Note: Species with estimated annual catch less than 1000 fish/yr are not included. Data were provided by PSMFC.