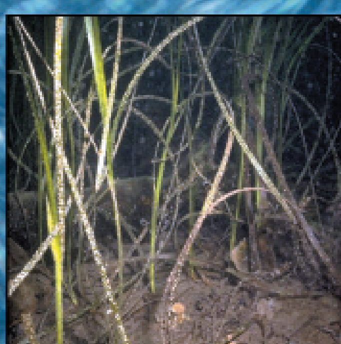
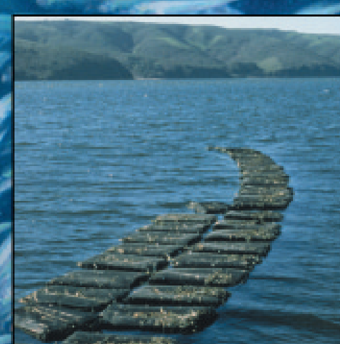
California's Living Marine Resources: A Status Report











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William S. Leet
Christopher M. Dewees
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California Department of Fish and Game
Resources Agency

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A Status Report

The Resources Agency
The California Department of Fish and Game

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The editors wish to acknowledge important contributions from many colleagues. In DFG, Joann Eres and her staff compiled a huge amount of landings data for the tables and graphs, while Nancy Wright and Chad King created the maps. Chamois Andersen and the Conservation Education staff assisted with the editing. Carrie Wilson and Paul Gregory searched out and supplied many of the photographs. Bernice Hammer and Susan Ashcraft aided in organizing and producing tables and graphs. Kristen Sortais from the California Sea Grant Program compiled the glossary and organized the photographs in the document. The ever-enthusiastic Tom Jurach of the UC Davis Repro Graphics Department was the lead person for publication design and layout.

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This publication contains a compilation of information from numerous individuals and highly regarded sources. All efforts have been made to publish the best available data and information.

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Dedication

Dr. Mia J. Tegner

California's Living Marine Resources: A Status Report is dedicated to the memory of Dr. Mia J. Tegner, a loved and respected colleague, who died in a scuba diving accident in January 2001. As a researcher at the University of California's Scripps Institution of Oceanography, Dr. Tegner was an expert in kelp forest ecology and was recognized as one of the leading scientists in the world regarding California's abalone and sea urchin resources. She cared deeply about the marine environment and became an effective spokesperson for science-based marine conservation. She firmly believed that a system of marine protected areas is critical to restoration of fisheries and the protection of biodiversity and worked with others to ensure the enactment of both the Marine Life Management Act of 1998 and the Marine Life Protection Act of 1999, and the appropriation of funds for their implementation.

Dr. Tegner's presence as a scientist and concerned citizen will be sadly missed.

Purpose and Overview

The Marine Life Management Act (MLMA), which became law on Jan. 1, 1999, opened a new era in the management and conservation of living marine resources in California. The MLMA's overriding goal is to ensure the conservation, sustainable use, and restoration of California's living marine resources, including the conservation of healthy and diverse marine ecosystems and living marine resources.

To achieve this goal, the MLMA established an innovative program for managing marine fisheries. Good fisheries managers periodically take stock of the effectiveness of their programs. With this in mind, the MLMA requires that the Department prepare an annual report on the status of sport and commercial marine fisheries managed by the state. The MLMA requires that these reports do three things: 1) identify any marine fishery that does not meet the MLMA's sustainability policies; 2) review restricted access programs; and 3) evaluate the management system and make recommendations for modifications. This first report presents the best available information for all marine and estuarine fisheries managed by the state. Under the MLMA, later annual reports will cover one-quarter of all marine and estuarine fisheries managed by the state.

The first section of *California's Living Marine Resources: A Status Report* is meant to provide lay people and specialists alike with the best available information on the oceanic, environmental, regulatory, and socioeconomic factors that affect the management affecting California's living marine resources. This discussion is divided into five chapters: *California's Variable Ocean Environment, The Status of Habitats and Water Quality in California's Coastal and Marine Environment, The Human Ecosystem Dimension, The Status of Marine Fisheries Law Enforcement* and *A Review of Restricted Access Programs*.

The second section of the report includes chapters on the three major ecosystems off California: nearshore, offshore, and bays and estuaries. Each of these chapters includes a description of the ecosystem, the major issues facing fisheries managers, and the management framework. These chapters also include evaluations of individual fisheries and species of marine wildlife, including a historical description of each fishery, the status of biological knowledge, and the status of the population. Management considerations submitted by authors for approximately half the individual fisheries are found in Appendix A.

The report concludes with chapters on *Aquaculture*, *Invasive Species*, and *Marine Birds and Mammals*.

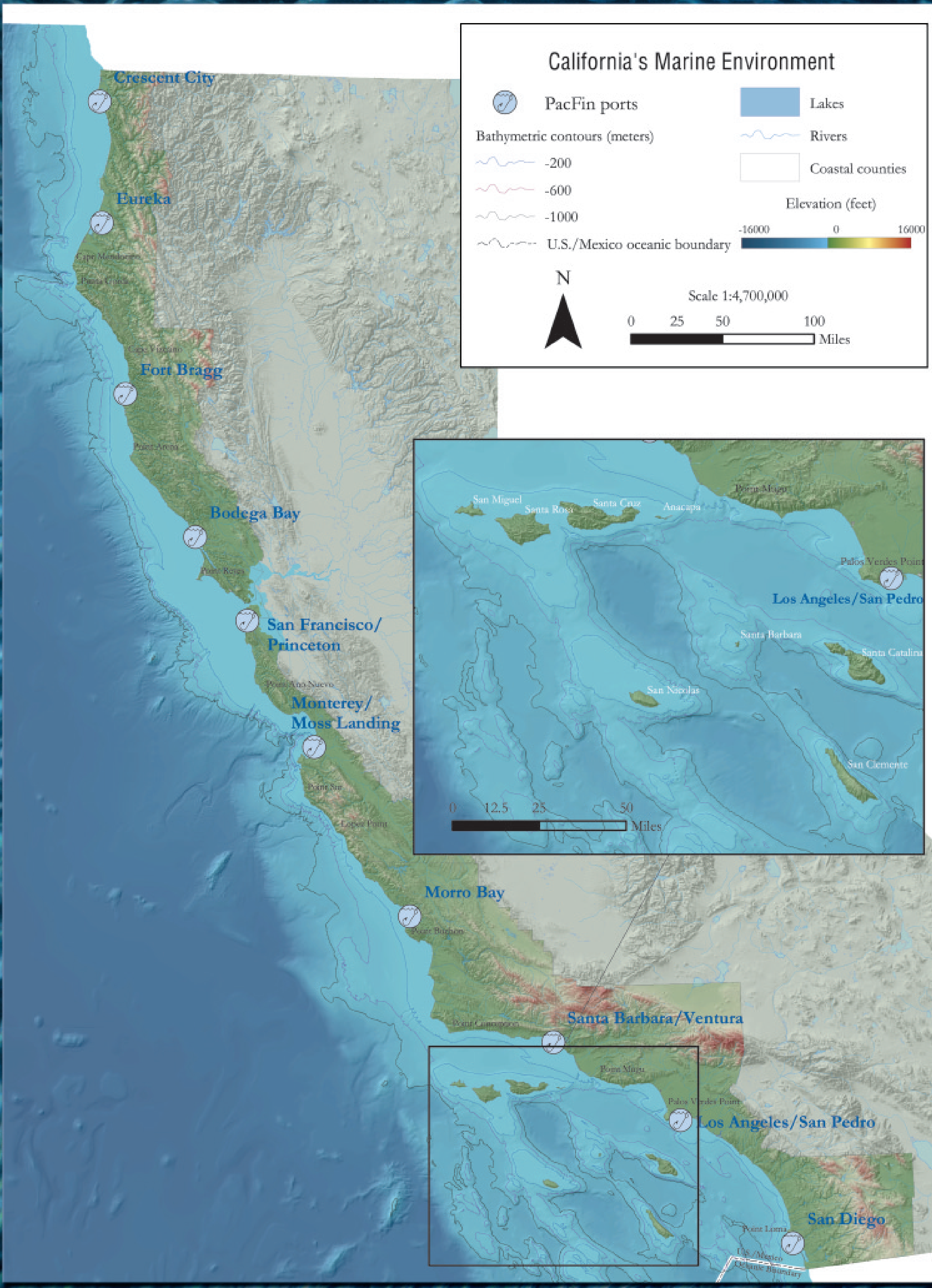
California's Marine Environment
PacFin ports
Lakes
Bathymetric contours (meters)
Rivers
-200
Coastal counties
-600
Elevation (feet)
-1000
-16000
0
16000
U.S./Mexico oceanic boundary
N
Scale 1:4,700,000
0
25
50
100
Miles
Crescent City
Eureka
Fort Bragg
Bodega Bay
San Francisco/
Princeton
Monterey/
Moss Landing
Morro Bay
Santa Barbara/Ventura
Los Angeles/San Pedro
San Diego
Point Mugu
San Miguel
Santa Rosa
Santa Cruz
Anacapa
Palos Verdes Point
Santa Barbara
Santa Catalina
San Nicolas
San Clemente
0
12.5
25
50
Miles

Table of Contents

Introduction and Historical Overview

California's Living Marine Resources: A Status Report is the fourth edition in a series of reports that address the status of California's marine and anadromous fisheries and other marine life. Since the California Department of Fish and Game published *California Ocean Fisheries Resources to the Year 1960* (1961) and *California's Living Marine Resources and Their Utilization* (1971), and the California Sea Grant Program updated and expanded *California's Living Marine Resources and Their Utilization* in 1992, the state's marine resources and their management have continued to undergo constant change. For example, by the early 1990s the sardine fishery, which was the world's largest during the first half of the 20th century and practically has been non-existent since the 1960s, reappeared under precautionary management. In 1998, the sardine resource was declared fully recovered. Tropical tunas were an extremely valuable segment of California fish landings until the tuna canning industry moved overseas during the mid-1980s. Changes in California's commercial fisheries between 1970 and 1990 included the development of specialized and valuable fisheries for sea urchins, hake, Pacific herring and widow rockfish.

Change has continued in many fisheries since the 1992 edition of this report. For example, increased international demand for squid resulted in a 500 percent increase in landings to over 300 million pounds annually during non-El Niño years. This expansion attracted many new participants from salmon purse seine fisheries in the Pacific Northwest. A squid management plan including restricted access is currently being developed. In 1994, gillnets were prohibited in most of the nearshore areas of the coast and islands of southern and central California. This happened as a result of a voter approved California constitutional amendment (Prop. 132). During the 1990s, a major fishery developed for nearshore species including rockfishes, cabezon, and sheephead that were often marketed live for significantly higher prices. Concerns about sustainability of this new intense fishery provided much of the impetus for the Marine Life Management Act (MLMA) of 1998 and a moratorium on permits in the nearshore fishery. The southern California commercial lobster fishery continued to demonstrate higher catches during the 1990s resulting in record landings in 1997. California barracuda increased as a component of the recreational fisheries to the levels of the 1950s, and the white seabass population is showing signs of a recovery at the end of the century. The California halibut commercial fishery continued to sustain landings comparable to the 1980s, despite the gillnet closure.

Severe declines in abalone abundance resulted in total closure of recreational and commercial abalone fishing south of San Francisco, and there are serious concerns about the potential for extinction of the white abalone. Some major groundfish stocks, especially long-lived rockfishes, continued to decline. Quota reductions, seasonal and area closures, bag limit reductions and long-term stock rebuilding plans are causing major disruption in the commercial and recreational industries and communities dependent on groundfish.

Since the last edition was published, five California salmon populations have been listed under the federal Endangered Species Act (ESA): Sacramento River winter chinook, Central Valley spring chinook, California coastal chinook, California coastal coho (south of the San Francisco Bay), and steelhead (south of the Klamath-Trinity River system). The principal problem faced by these runs is the habitat degradation that has accrued from water uses that compete with the requirements of salmon. Primary among these is diversion of water for irrigation and domestic use. In addition, alterations of rivers and watersheds to enable navigation, provide power, control flooding, and otherwise accommodate the needs of humans have taken their toll.

While California's population continued to grow and diversify during the 1990s, participation in marine recreational fishing measured by license sales continued to be relatively stable. The number of active commercial passenger fishing vessels (partyboats) declined from 308 in 1989 to 300 in 1998. Other forms of marine recreation linked to the health of marine living resources such as ecotourism have grown significantly and have become an important segment of California's coastal dependent economy.

The public's interest and involvement in the management and conservation of marine living resources have increased substantially since the 1992 edition of *California's Marine Living Resources and Their Utilization*. Major federal and state legislation is altering the way marine resources are managed. The 1996 reauthorization of the Magnuson-Stevens Act specified a precautionary approach in federally managed fisheries. This resulted in establishing much lower catch limits and designing long-term stock rebuilding plans for many Pacific Coast groundfish species, especially the rockfishes. The MLMA also required the identification and protection of essential fish habitat.

This report was written during a period of extraordinary change in our state. The MLMA of 1998 significantly altered the way the state manages marine life. The MLMA provides the mechanisms whereby the management responsibility for commercial fisheries can be moved from the California State Legislature to the Fish and Game Commission. The MLMA mandates the development of fishery management plans incorporating peer-reviewed science, increased constituent involvement in marine life management, implementation of an ecosystem based research and management approach, and regular analyses of the status of California's fisheries such as those found in this publication. While the initial management plans mandated are for white seabass, nearshore fisheries, and emerging fisheries, it is anticipated that similar management plans will be developed for many other California marine fisheries.

Use of marine reserves and marine protected areas to preserve marine wilderness and manage fisheries is intensifying at both the state and national level. California's Marine Life Protection Act of 1999 requires development of a master plan for a network of marine reserves. On the federal level, intense discussions by panels of scientists and constituents have occurred regarding plans for marine reserves in large areas of the Santa Barbara Channel Islands. Although no consensus was reached by mid-2001, debate regarding MPAs was continuing at both the state and federal levels.

During the 1990s, overcapitalization was widely recognized as a major problem in some fisheries. The difficult task of designing restricted access programs to improve the balance between fleet fishing power and sustainable harvest levels has become a major component of fishery management plans seeking to sustain fisheries economically as well as biologically.

Earlier editions of this publication proved to be among the most valuable general reference works available on California's economically important marine species. The reports have been widely used by fisheries researchers and managers, policymakers, interested citizens, journalists, the fishing industry, enforcement officers, educators, and others. Publication of this edition is mandated by the MLMA of 1998. A primary purpose of the book is to provide a baseline of information for all concerned with managing living marine resources in California.

The editors of this edition have retained much of the style and format of earlier editions. Many of the conventions of scientific writing are foregone because it was felt that this style better serves the broad interests of readers. Each species article presented in this report contains a short list of general references for further reading. Detailed fish and shellfish landings statistics, which begin in 1916, have been updated through 1999.

Readers of earlier editions will notice some significant changes and new features. The publication is organized by marine ecosystems (bays and estuaries, nearshore, and offshore) rather than species-by-species. For species that occur in more than one ecosystem, the discussion appears in the ecosystem section where they spend most of their life and/or their principal harvest location. Descriptions of the three marine ecosystems used for this report are also included. Added or expanded chapters include a detailed description of the human dimensions of marine life management, California's ocean environment, marine law enforcement, water quality and pollution, and restricted access in fisheries. We have also taken advantage of new technologies to increase the use and effectiveness of maps, graphs and tables. For ease of use, historical landings statistics have been moved to the end of each appropriate chapter rather than being placed in large appendices. A new glossary of technical terms and acronyms as well as a fishing gear appendix have been addded.

Compiling a publication like this is a collaborative effort. The editors were fortunate to be able to recruit top experts from the California Department of Fish and Game, other state and federal agencies, universities, and private industry in the preparation of this report. Each section has been peer reviewed for accuracy. The author's name and affiliation appear at the end of the section they wrote. When significant portions of the text from the 1992 edition were left intact, the original author is credited. We want to thank the more that 200 authors and reviewers who volunteered their time and expertise. We also greatly appreciate the contributions of many photographers who allowed us to use their images to greatly enhance this publication.

All editors participated in the development of the overall design and layout of the report. Bill Leet served as the lead editor as he did for the 1992 edition. Rick Klingbeil served as project manager for the Department of Fish and Game. Christopher Dewees led the University of California's participation. Eric Larson coordinated the creation of the numerous statistical tables, graphics and maps found in the report. Principal publication production assistance was provided through a contract with the University of California, Davis. Tom Jurach from Repro Graphics Services and Marianne Post from Creative Communications Services organized the layout, design, and publication of the document.

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California's Variable Ocean Environment

The habitat of California's living marine resources is primarily the California Current system. This huge, open system is constantly changing in response to weather systems, seasonal heating and cooling processes, interannual episodes such as El Niño - La Niña events, and longer term or regime scale climatic changes.

Small organisms, and the young of most large ones, are impacted by the full temporal range of physical processes. Shorter time scale and local physical processes including intense wind storms, extended periods of calms, infusions of freshwater runoff, and shorter term variations in currents heavily impact the growth, survival, and distribution of most of these organisms. Short-term variations in primary production (*e.g.*, diatom blooms) coincide with upwelling, but the scale of phytoplankton production relates to the history of water masses and weather conditions. Seasonal scale fluctuations are so important to many organisms that their life-cycle is often largely adapted to the seasonal cycle and their abundance is often heavily influenced by variations from the seasonal norm. Longer term events, El Niños and regime shifts, appear to be primarily dependent upon physical processes that are centered elsewhere in the Pacific and their effects include alterations in the physical, nutrient, and biological content of the waters entering the California Current system. These events also result in alterations in local physical processes such as currents and upwelling that control local inputs of nutrients. El Niño events and regime shifts have extensive effects on kelp forests and zooplankton populations.

The adults of larger fishes and other marine vertebrates are somewhat buffered from the effects of weather and other short-term physical fluctuations, and extremely long-lived organisms, such as many of the deep benthic fishes, may have populations that are nearly independent of normal short-term environmental fluctuations. Many of California's marine fishes have life history adaptations such as extended spawning seasons, multiple spawnings, migrations, and extreme longevity that reduce the harmful effects of short-term adverse environmental fluctuations and even limit the effects of El Niño events at the population level. In contrast, organisms with shorter life spans, such as the market squid, that may be only slightly affected by environmental fluctuations at the shorter time scales appear to have extreme population declines during El Niño events. Decadal or regime scale climatic fluctuations that alter the basic productivity of the California Current system are common, repetitive events readily observed in paleo-sediment analyses that extend back several thousand years. They are also clearly evident in time series analyses of physical factors (*i.e.*, ocean temperatures) and indices of biological productivity (*i.e.*, zooplankton densities). These longer term events have been shown to greatly alter populations of the dominant pelagic fishes of the California Current and it is probable that they affect the populations of even long-lived benthic fishes and marine mammals.

A species physiology determines its preferred temperature range and its lethal temperature tolerances. The surface and bottom temperatures on the continental shelf off California make the northern portion of the state good habitat for sub-arctic and cold-temperate species (salmon, market crab, and petrale sole) and the southern portion good habitat for warm temperate and sub-tropical species (kelp bass, spiny lobster and California halibut). Many of the most abundant species of the California Current are transition-zone species that have the center of their distribution in California (Pacific sardine, Pacific hake, and northern anchovy). Temperature, like other physical oceanic factors, is highly variable on seasonal, annual, and longer time scales and it is the most easily studied. In addition, temperature is highly dependent upon large-scale ocean currents and local upwelling; it is therefore a rough index of the productivity of the lower trophic levels and an indicator of climatic processes that favor the colder or the warmer water faunas that occur in California. Temperature is thus the most commonly correlated climatic variable used to determine associations with biological processes. However, nearly any environmental factor that is associated with variations in the major currents will also be correlated with biological processes and temperature, and we do not know if alterations in currents or the resultant changes in temperature have the largest effect on biological processes in the California Current.

Table 1
Average Monthly Sea Surface Temperatures Off San Francisco

Month	Warm Years [1] Temperature (°F)	Cold Years [2] Temperature (°F)
January	56.18	5[illegible].51
February	56.01	51.67
March	56.66	51.87
April	55.77	51.19
May	56.0[illegible]	50.22
June	59.26	51.91
July	60.94	54.76
August	60.17	53.70
September	61.83	55.27
October	60.71	55.40
November	58.56	53.38
December	56.46	53.03
Average Temperature	58.24	52.83

[1] warm years, 1940, 1958, and 1992
[2] cold years, 1910, 1922, and 1975

Average Monthly Sea Surface Temperatures Off San Francisco
Sea surface water temperature offshore of San Franciso indicates a distinct summer upwelling pattern with cold sea surface temperatures nearshore, as well as large inter-annual variations. Within this strong upwelling cell, sea surface temperatures can be colder during the summer in cold years than they are during the winter in warm years.

The living marine resources of California evolved in a dynamic and changing ocean and most populations undoubtedly fluctuated in response to environmental alterations long before man exploited them. Many of these resources are now heavily exploited and those in the nearshore environment are also impacted by human induced environmental changes. Some species, such as bocaccio and lingcod, have been heavily overfished, and their current populations are at very low levels. A few very highly overfished stocks, such as Pacific mackerel and Pacific sardine, have suffered nearly complete population collapses from which they have recovered after one or more decades of protection by harvest moratoriums. As discussed below, there is considerable evidence that regime shifts exacerbated the effects of fishing and delayed the effects of the moratoriums.

Fishery and marine resource management is presently in the middle of a change in philosophy. In the past, our management has been based on the view that the environment can be considered to be constant with only minor and temporary perturbations which introduce "random noise" into our population assessments and management policies. This has resulted in a management system that has failed to protect exploited populations during extended periods of adverse environmental conditions. The information in the following sections indicates that physical factors and biological productivity in the California Current system are not stationary. It is clear that variations in these processes must be monitored by our research programs and built into our management systems if we expect to maintain healthy and diverse nearshore and offshore ecosystems.

Climatic Processes, El Niño Events and Regime Shifts

The California Current, one of the world's major eastern boundary currents, has its origin in the mid-latitude west-wind-drift region of the North Pacific, and it could be considered an equatorward flowing, surface extension of the North Pacific Current. The core of the California Current normally lies about 90 to 130 miles offshore of the shelf break or continental margin. The fauna and productivity of the California Current system are heavily dependent upon the input of cool, low-salinity, high nutrient and plankton-rich waters from the mid-latitude North Pacific.

The system also has a sub-surface, poleward current (the Davidson Current) that is often at a maximum just offshore of, and somewhat deeper than, the shelf break. In the fall, poleward flow often extends to the surface in the southern portion of the California Current and surface poleward flow is not uncommon in the nearshore region over much of the system. The advection of warm, high salinity, low-nutrient and plankton-poor water from the sub-tropics is largely responsible for the warm water flora and fauna and lower productivity characteristic of the nearshore region south of Point Conception.

Like other eastern boundary currents, the California Current has extensive coastal upwelling that is primarily driven by spring and summer winds resulting from temperature gradients between the relatively cool sea surface and the warming continental land mass. Equatorward winds, offshore Ekman transport, and coastal upwelling occur nearly all year off of Baja California and the offshore region of southern California; however, within the Southern California Bight wind velocities are lower and offshore transport is much reduced. Wind velocities and upwelling are variable but tend to be at a maximum in the spring to early summer in the region between Point Conception (34.5°N) and the Oregon border (42°N). The duration and strength of upwelling-favorable winds diminishes northwards. Off the State of Washington (48°N) upwelling is relatively minor and is largely restricted to the late spring to early fall; winter storms there result in intense downwelling events. Downwelling events diminish in both magnitude and seasonal duration to the south, below Point Conception they are uncommon and usually of minor magnitude.

Climatic fluctuations ranging from strong storms to seasonal cycles to El Niño/La Niña events to decadal changes or regime shifts alter the physical, chemical, and biological environment of California's marine waters. Average monthly sea surface temperatures (SST) in California waters range from a minimum of about 52°F in February off northern California to a maximum of about 68°F in August off southern California. The pattern of sea surface temperatures in the California Current varies from a clearly latitude dependent situation in the late winter, with isotherms being nearly east-west in orientation, to the distinct upwelling pattern of cold water near shore and warmer water offshore in the late summer. Most of the area has mild winter SSTs, and cool summer SSTs caused by the summer upwelling. This results in a very small seasonal variation in SST, no more than 4 to 7° F during the year. In contrast, the inter-annual variation in SSTs can be as large as the normal summer/winter difference; off San Francisco SST is colder during the summer in cold years than it is during the winter in warm years.

El Niño/La Niña Processes

El Niño is a term that describes large-scale changes in the atmospheric pressure system, trade winds, and sea surface temperatures of the entire tropical Pacific that occur at approximately three to four-year intervals. The cold water portion of the cycle is now referred to as La Niña. This cyclic process has traditionally been measured by the southern oscillation index (SOI), which is the difference between the atmospheric pressure at Tahiti (an approximation of the South Pacific High) and the atmospheric pressure at Darwin, Australia (near the Tropical Pacific Low). The SOI is therefore a measure of the variability of the atmospheric circulation in the South Pacific.

The effects of El Niño events in California include reduced input of cold, nutrient-rich waters from the north and increased advection of warm, nutrient-poor water of subtropical and tropical origin into the southern California area. There may or may not be a reduction in upwelling favorable winds; however, nutrient input to the surface waters from upwelling is decreased due to reduced nutrients in the subsurface waters and a depressed thermocline. Thus, during El Niños the California Current becomes more sub-tropical, and warm-water organisms enter the system in greater numbers. During La Niñas the environment is more sub-arctic and cold water organisms are favored.

Although California occupies a large geographical area, surface temperature anomalies on scales greater than a few weeks are common over the entire region. Time series of SST from northern, central and southern California are characterized by strong El Niño events such as those occurring in 1940, 1958, 1983, 1992, and 1997. In addition, there are decadal scale events where surface temperatures are above or below average for extended periods. Cold periods occurred prior to 1925, from about 1946 to 1956, and from 1962 to 1976. Warm periods occurred from 1938 to 1945, 1957 to 1961, and from 1977 to 1998. Waters of the Central Pacific, however, tend to vary in the opposite direction from the California Current system.

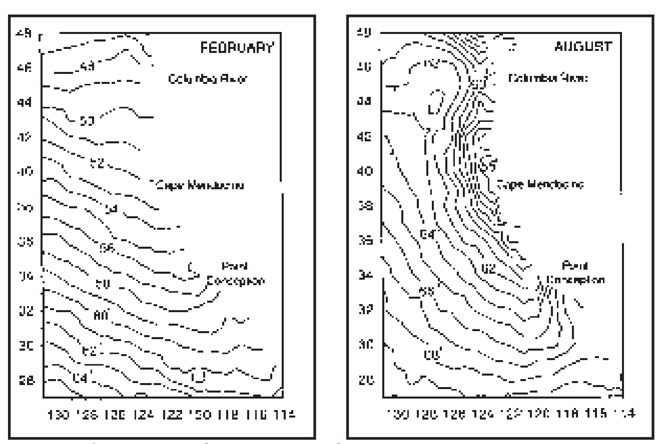
Surface temperature is not necessarily a good indicator of temperature below the upper mixed layer. In 1972, at the onset of a major El Niño, the surface temperature at Point Conception was the lowest since 1951, whereas the temperature at 330 feet was among the warmest recorded.

The 50 year time series of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) is probably the world's best data set for determining the effects of interannual physical variability on zooplankton populations, the primary food for larger stages of larval and some adult fishes. As with temperature, strong interannual signals occur over a very large spatial scale. Anomalies of zooplankton abundance, 10m temperature, 10m salinity, and southward transport are highly correlated in time from southern Baja California to north of San Francisco. On interannual time scales, zooplankton abundance is primarily influenced by large-scale variations in flow of the California Current. Increases in southward transport are associated with increases in zooplankton production, cold temperatures, and low salinity (La Niña events), whereas decreases in this transport result in unusually low zooplankton biomass, warm temperature, and high salinity (El Niño events).

In addition to substantial declines in zooplankton abundance during El Niño events, analysis of the samples taken during the years 1955 to 1959 showed a large rearrangement of the dominance structure of functional groups of macrozooplankton. The rank order of abundance for 18 groups, containing an estimated 546 species, changed over this period. Plankton community structure was similar in 1955 to 1957 but underwent an abrupt and dramatic change coincident with strong El Niño conditions in 1958-1959. In addition to changes in zooplankton, other characteristics of strong El Niño events include deepening of thermocline and nitricline by some 165 feet, and redistribution of phytoplankton biomass from the upper layers of the ocean to a deep chlorophyll maximum. Quarterly patterns of environmental variables and zooplankton biomass are now reported annually in the State of the California Current in CalCOFI Reports.

Decadal/Regime Scale Processes

During the last decade it has become increasing apparent that longer term decadal to multi-decadal climatic cycles are impacting populations of a wide variety of marine organisms in the California region, and that all trophic levels are affected. Analyses of fish scales in anaerobic sediments have shown that these cycles have been occurring for thousands of years (*i.e.*, independent of fishing), and that the most abundant fish stocks have



Winter and Summer Pacific Coast Sea Surface Temperatures
Average (1920-1992) February and August sea surface temperatures (°F). A cold summer upwelling core is apparent in northern California. Data extract from COADS as monthly means.

fluctuations which occur over an average period of about 60 years. The implications from a number of these paleo-sediment studies are that large-scale physical processes are forcing the biological fluctuations. Recent results from ocean/atmosphere models suggest that decadal climatic cycles are forced by air/sea interactions in the higher latitude North Pacific. Observed decadal to multi-decadal fluctuations in the mid-latitude atmospheric circulation in the Central Pacific have also been suggested to have physical and biological effects that appear to affect a large proportion of the North Pacific basin. A major regime shift occurred in 1976-1977 and the surface waters of the entire eastern Pacific Ocean from Mexico to Alaska became warmer. Since 1976, there has also been an increase in the frequency, duration and intensity of El Niño events in California waters.

The 1976 climatic shift is clearly seen in time series of California sea surface temperatures. Decadal and regime shift processes both are evident in a newly proposed index for the North Pacific, the northern oscillation index (NOI). This index is analogous to the southern oscillation index used to describe and predict El Niños. However, it is a better measure of the atmospheric circulation in the North Pacific because it is based on the difference between the average position of the North Pacific High (35°N: 130°W) and the Tropical Low near Darwin. When the three to four year scale El Niño processes are filtered out, using a 36-month moving average, the NOI exhibits the decadal cycles that researchers have predicted and the widely observed climatic shift that occurred in 1976-1977.

Zooplankton populations also exhibit strong interdecadal variability. CalCOFI data showed a 70 percent decrease in the biomass of macrozooplankton associated with warming of surface layers between 1951 and 1993. Averages of zooplankton biomass over the initial and final seven-year periods of this interval were computed for southern California grid lines . The differences between the two periods appeared to be uniform in space and at least twice the standard deviation of the seven-year mean at each station. Over this time period, lines 80 and 90 surface temperatures warmed by an average 2.2 and 2.8°F, respectively, but thermal changes at depth were small. Therefore, the vertical stratification of the thermocline substantially increased, resulting in a reduction in the transfer of nutrients to the surface.

Long-term trends in temperature and salinity of the upper 100m, zooplankton biomass, and transport from north to south through the present day CalCOFI grid indicate that interdecadal changes apparently have different physical forcing mechanisms than those associated with El Niño events. Because the surface layer has become warmer and fresher, the increase in stratification apparently results in reduced displacement of the thermocline and thus a shoaling of the source of upwelled waters. The effect is to decrease the fraction of the year when wind stress is strong enough to lift nutrient-rich waters to the surface near the coast. Because the increased stratification essentially insulates nutrient-bearing waters from the surface, a moderate degree of heating can greatly reduce the surface nutrient supply. These trends appear to be related to the strengthening of the North Pacific wintertime atmospheric circulation associated with the regime shift that began in 1976-1977.

Fish eggs and larvae are also sampled in CalCOFI zooplankton collections. Although both total larval fish and zooplankton abundance exhibit substantial interannual variability, there is no clear relation between the two time series. There are weak time-lagged correlations when zooplankton leads fish larvae by four to five months in three of four regions of the California Current, which would be expected if poor nutrition of adult fish has affected their reproductive success. Although zooplankton is well correlated with temperature, salinity, and transport, total fish larvae are poorly related to these physical parameters. Nor are larval fish clearly related to anomalies in longshore winds, the basis of coastal upwelling. Analyses of both larval fish and zooplankton data suffer from the obvious complications of lumping large numbers of taxa; studies of individual species may offer better opportunities of relating oceanographic variability to recruitment success. For example, there are inverse trends for northern anchovy and Pacific sardine spawning biomass and larval standing crop; the declines for anchovy and increases for sardines took place during a period of declining zooplankton abundance and warming temperatures associated with the regime shift. Clearly fishes are long-lived organisms with complicated life histories; mortality in poorly assessed stages such as juveniles may account for the poor relationships between physical parameters, larval abundance, and adult stocks.

Implications for Nearshore Ecosystems

The flora and fauna of California's nearshore communities are strongly affected by interannual variability in the physical environment including both El Niño-Southern Oscillation events and the regime shift that began in 1976-1977. Furthermore, large wave events in this region are highly correlated with strong El Niño events, so these two forms of disturbance often co-occur. Thus, in the southern and central regions of the state there has been considerable interdecadal-scale wave variability, with greatly increasing numbers of episodes with significant wave heights greater than 12 feet in recent years.

The most dramatic benthic effects of El Niño events are on kelp forests, ecosystems organized around the structure and productivity provided by giant kelp (*Macrocystis*) and bull kelp (*Nereocystis*). The two-fold effects include extreme winter storm waves, which may decimate kelp populations along the entire exposed coast, and anomalously-warm, nutrient-depleted waters, whose effects increase in severity with decreasing latitude. With their high growth rate, southern California *Macrocystis* populations depend on nutrients supplied by upwelling or internal waves. When these sources are rendered ineffective by depression of the thermocline, growth ceases, tissue decay leads to the loss of the surface canopy, and considerable mortality may follow. Kelp forests from the warmest regions of the state, Orange County south along the mainland and the southeastern Channel Islands, suffer massive losses. Further to the north, the addition of the El Niño temperature anomaly to normal summer-fall temperatures apparently maintains the environment within the range of suitability (*i.e.*, nutrients did not become limiting), although growth may be reduced.

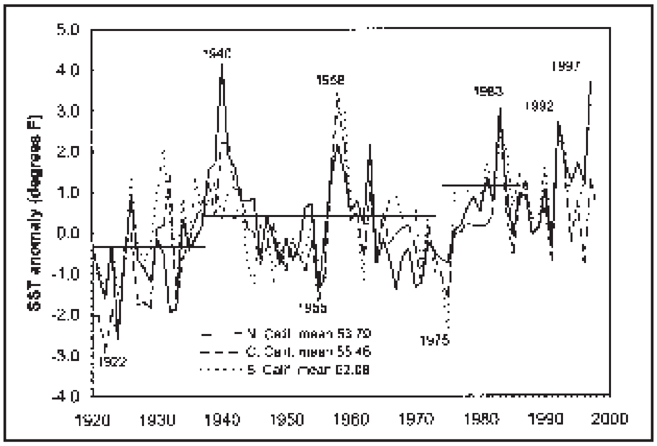
Sea surface temperature is the best predictor of kelp harvest and areal extent. The increase in mean SST since the 1976-1977 regime shift has been associated with large decreases in the size of *Macrocystis* plants as measured by number of stipes per individual. Furthermore, this secular increase in SSTs means that each El Niño event is adding to a higher temperature base; thus, successive events are characterized by increasingly severe temperature anomalies. Poor conditions for *Macrocystis* growth are associated with enhanced understory algae and reduced drift kelp production.

Aerial surveys illustrate huge variability in *Macrocystis* surface canopies in the Southern California Bight. The effects of the 1983 and 1998 El Niño winter storms are apparent in all areas, but the speed of kelp recovery varies with location. Cooler areas such as San Miguel Island recovered from the storms very quickly and had minimal impacts from the warm, nutrient-depleted waters that followed. In contrast, many of the *Macrocystis* populations on the coastline between Santa Barbara and Point Conception, which were largely set in sand, were devastated by the storms of the early 1980s and have not recovered. The 1988-1989 La Niña provided excellent growth conditions after a severe storm largely removed existing giant kelp populations in many areas; this combination led to peaks in kelp canopy biomass in the southeastern part of the bight in 1990.

While effects of El Niño and regime shifts on the kelps are relatively well known, the implications for higher trophic levels and community structure are only beginning to be understood. The effects of storms, warm, nutrient-depleted waters, and anomalous current patterns all appear to be important. Drift kelp is the primary food for sea urchins and abalones. With up to 60 percent of the biomass of a healthy *Macrocystis* forest in its canopy, the loss of the canopy and varying degrees of mortality of adult plants have huge effects on drift availability. With reduced food supplies, urchin gonad production is very low, often to the point of making processing uneconomical; because the product is the gonads. Many processors closed during the 1982-1984 El Niño, for example. Abalone reproduction and recruitment are also affected, leading to large gaps in size-frequency distributions. The loss of drift food may trigger destructive grazing by sea urchins, transforming kelp forests to barren grounds with cascading implications for other organisms in this community. Anomalously warm waters are also associated with disease outbreaks, especially for sea urchins, sea stars, and abalones.

Reductions in *Macrocystis* populations have critical implications for fishes dependent on giant kelp for foraging habitat and refuge from predators. Recruitment of young-of-the-year kelp bass is dependent on *Macrocystis* density. The presence of giant kelp has a positive effect on the recruitment of other rocky inshore fishes such as kelp rockfish, giant kelpfish, kelp surfperch, pile surfperch, and black surfperch. On the other hand, the striped surfperch, which feeds in foliose red algae, is adversely affected by the presence of *Macrocystis* because of the strong negative relationship between giant kelp and foliose algae. Thus, the structure of a kelp forest has significant effects on the species composition and local density of the fish assemblage, and that structure is strongly affected by ocean climate.

With greatly increased transport from the south, northern range extensions of subtropical, migratory species and larvae are very characteristic of El Niño events. Most



California Sea Surface Temperature Anomalies
Annual sea surface temperature anomalies (˚F) off northern, central, and southern California, with means of three time periods (1920-1937, 1938-1976, and 1977-1997). Data extract from COADS as monthly means.

migratory species are pelagic, but pelagic red crabs are conspicuous nearshore visitors. Spiny lobsters and sheephead, two important predators of sea urchins in the Southern California Bight, both have their centers of distribution off Baja California and recruit heavily to southern California (and sheephead as far north as Monterey) during strong El Niño events. Conversely, La Niña events with enhanced transport from the north result in increased recruitment of cool water fishes such as blue rockfish in southern California.

Observations of shallow water reef fish assemblages in the Southern California Bight from 1974 to 1993 indicate substantial changes in species composition and productivity that appear to relate to the increased frequency of El Niño events and the regime shift. At two sites off Los Angeles, species diversity fell 15 to 25 percent and the composition shifted from dominance by northern to southern species by 1990. By 1993, 95 percent of all species had declined in abundance by an average of 69 percent. Similar declines of surfperch populations off Santa Cruz Island were linked to declines of their crustacean prey and biomass of understory algae where the fish foraged. Recruitment of young-of-the-year at the three sites fell by over 90 percent, and the decline was highly correlated with the decrease in macrozooplankton abundance in the CalCOFI data. These changes in population abundances and trophic structure were apparently caused by lower productivity associated with the regime shift of 1976-1977.

Statistics from the commercial passenger fishing vessel rockfish fishery of southern California for the period 1980 to 1996 illustrate a substantial decline in catch-per-unit effort. Three species abundant in 1980 were absent by 1996. Catch of others such as bocaccio declined as much as 98 percent. On average, mean length declined due to the removal of larger size classes, and in the case of the vermilion rockfish, the take changed from primarily adults to almost entirely juveniles. On some trips, the catch now mostly consists of dwarf or small species of *Sebastes*. Such population declines probably result from poor long-term juvenile recruitment caused by adverse oceanographic conditions combined with overfishing of adults and sub-adults. This combination results in recruitment overfishing that reduces spawning stocks to levels too low to ensure adequate production of young fish for future fishing.

Dramatic effects on fish assemblages are reported in central California as well, where El Niño events are associated with improved recruitment of southern species, recruitment failures of rockfishes, and poor growth and condition of adult rockfishes. In addition to sheephead, blacksmith and bluebanded goby are southern species that were observed near Monterey. Reproductive success of many species of central California rockfish appears to be sensitive to El Niño conditions, because it was poor during 1983 and 1992. Poleward advection, downwelling, delayed and reduced phytoplankton blooms, and low zooplankton abundance appear to be important factors in reproductive failure during these periods. Modeling has demonstrated that fishery management practices can exacerbate El Niño effects if harvest is not decreased in response to the environmentally induced decrease in biomass.

In northern California, where the red sea urchin fishery is limited by poor recruitment, there has been strong interest in understanding the role of oceanographic variability on the temporal and spatial patterns of settlement. Recent studies have shown increased settlement in some sites during both the 1992-1993 and 1997 El Niños, but the sampling periods were short and settlement was not consistent among areas. Regional patterns of circulation in northern California and the delivery of larvae to the coast during upwelling relaxation are the best explanation for the observed pattern of recent recruitment for several invertebrate species. Understanding the role of larger scale processes will require longer time series.

Implications for the Offshore Ecosystem

California's marine fauna and flora are principally components of the subarctic, transition, and central (or subtropical) zones. Subarctic species are more common off northern California and subtropical species more abundant off southern California. With the exception of marine mammals, birds, and a very few fishes (tunas), marine organisms are cold blooded. They are therefore highly affected by temperature, making water temperature one of the most significant physical factors that marine organisms have to cope with. In fact, the most obvious effect of climatic variation in the California offshore ecosystem is the appearance of tropical species such as tunas and pelagic red crabs in association with El Niño events. As mentioned earlier, variations in the major current patterns greatly influence fluctuations in ocean temperatures.

Wind driven upwelling also alters temperature and transport patterns. In the California current, the most obvious consequence is the nearshore core of cold upwelled water that is at a peak in the Cape Mendocino region in the summer. Nearshore species that have pelagic eggs are highly susceptible to the offshore loss of their early life history stages by wind-driven surface transport. Many species are therefore unable to reproduce successfully in the region between Point Conception and Cape Blanco, Oregon (about 35-43°N), where upwelling and offshore transport are at a maximum. Many of the important species that are permanent residents of this region have reproductive adaptations that reduce the offshore dispersion of reproductive products. These include bearing live young (rockfishes and surfperches), demersal spawning (herring, lingcod and many littoral species), anadromous spawning (salmonids and true smelts), and late winter spawning (Dover sole, sablefish and most rockfishes) to avoid the intense upwelling season (late spring to early summer). The most abundant California Current fishes have pelagic eggs and larvae and these fishes have extensive spawning and feeding migrations (Pacific hake, Pacific sardine, Pacific mackerel, and jack mackerel). The adults of these stocks feed in the more northern portions of the region during the summer and fall, and then return to the area near, or to the south of Point Conception to spawn in the late winter and early spring.

El Niño - La Niña Fluctuations

The most obvious biological effect of El Niño Southern Oscillation events is that environmental factors, especially temperature, affect the behavior and distribution of larger marine organisms. These effects are most marked in the adults of pelagic, migratory, or nomadic species that are able to greatly expand or contract their ranges by actively moving among regions with seasonal cycles or other climatic fluctuations such as El Niño events. Southern species that have the center of their distribution south of California such as bonito, barracuda, white sea bass, and swordfish normally move into southern and central California during the late summer and fall. Both these fishes and tropical fishes such as yellowtail, skipjack, and yellowfin tuna move into southern California in larger numbers during El Niños. Major El Niño events also cause extended migrations of Pacific sardine, jack mackerel, and Pacific mackerel to as far north as Alaska. This migratory response to warmer surface temperatures is primarily behavioral and it may or may not be associated with increased population size of the individual species.

Sub-tropical species with limited swimming ability, such as pelagic red crabs and smaller zooplankton species, often occur in dense concentrations off of California, suggesting that advection also plays a significant role in community structure during El Niño events. El Niños are known to alter the population levels of zooplankton and other animals with short life spans. The market squid, which normally lives for no more than one year, appears to be heavily impacted by El Niños and the California fishery for this species has suffered near total collapse in major El Niño years. Population effects on longer-lived animals are likely, but population time series are lacking for most species. El Niños and other warm water events can result in decreased growth rates and reproductive output in fishes, and decreased size at maturity in market squid.

With the exception of the salmons, the colder water fishes are much less likely to make seasonal migrations. Most of the California groundfish and nearshore fishes make very limited geographical movements, other than the larval drift that occurs during their planktonic early life history stages. Once they settle in good habitat, individuals of these species tend to remain in relatively small areas. La Niña events therefore are not remarkable in the appearance of large numbers of the adults of cold water species moving down from Alaska and Canada. However, they may result in increased recruitment at the southern edges of the range of colder water species.

Regime Scale Climatic Variations

Longer-term climatic processes appear to be forced by factors outside of the California Current region. Early studies showed that sea surface temperatures are out of phase off of California and Japan. The dominant pelagic fishes of the California, Japan, and Peru/Chile regions have been shown to have strikingly similar population fluctuations, and paleo-sediment studies in both the California Current and the Peru Current suggest that regime scale climatic changes have been occurring for thousands of years. Salmon production in the Pacific Northwest (chinook and coho) has recently been related to interdecadal climatic patterns in the North Pacific and it is out of phase with production of pink and sockeye salmon in Alaska.

In contrast with short term La Niña events, cold water organisms are able to extend their populations into the southern portion of the state during extended cold periods. Many rockfishes that have the center of their distribution in the subarctic zone exhibit this pattern. The reverse pattern occurs in subtropical fishes. Some transition zone pelagic species move as far north as southern Alaska during very warm years but essentially abandon the area north of California during extended cold periods.

The California Current has recently been in its longest recorded period of warm water. During the last two decades, there have been marked population declines in a number of cold water species (salmon, lingcod, and rockfishes) and several stocks are now threatened or endangered. In contrast, several transition zone fishes that spawn off southern California and migrate to feeding grounds between northern California and Canada experienced large population increases following the shift to warm water conditions (Pacific sardine, Pacific mackerel and Pacific hake). It is clear that physical climatic factors may be as important as fishing in regulating the productivity of some exploited species.

Conclusions

The organisms of the California Current are adapted to an environment that varies on scales from local and short term to very large scale and multidecadal. Growth, reproduction, and larval survival may be depressed for variable periods during short-term adverse environmental conditions, but most adults of larger species survive. The addition of decades of intense fishing pressure onto long term climate disturbances such as those experienced since the 1976-1977 regime shift, however, makes population decline almost inevitable for species adversely affected by the changed environment. The challenge facing fishery managers is how to respond on time scales that will protect spawning stocks during periods of poor reproduction. One approach is to significantly decrease fishing effort on existing, heavily pressured stocks to create a buffer for hard times. El Niño events are being predicted with increasing skill; if fishing effort on sensitive species could be sharply curtailed in favor of species that thrive under warm conditions, the negative effects of these climatic events could be reduced. Another approach is to establish marine protected areas large enough to ensure surviving populations in every region. If some rockfish stocks had been protected in southern California during the present regime shift, for example, recovery during cold water periods would be far faster than the present situation that will largely depend on recruitment from depressed central California populations.

Too much of our fisheries management has been based on the assumption that environmental variability is not important. With 20/20 hindsight and the increasing prospects of human impacts on climate, we know that this cannot continue. It is clear that over the next decade a major research effort will have to be made to better understand the climatic connection and that fishery management will have to consider policies to reduce exploitation rates when species are impacted by adverse climatic factors.

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The Status of Habitats and Water Quality in California's Coastal and Marine Environment

Importance of Healthy Waters and Habitats to Marine Life

Clean water is essential to a healthy coastal and marine environment. Seventy-five percent of all commercial fish in the United States depend on estuaries and associated coastal wetlands for some portion of their life-cycle. Unfortunately, these are probably the most threatened of all habitats in California today.

Because pollution impairs the breeding grounds for many species of sea life, it is a substantial contributing factor to declines in these species. Impacts to coastal-dependent species include declines in the species' populations, reproductive problems, birth defects, behavioral changes, and increased susceptibility to disease. For example, illnesses and deaths of sea otters and other marine mammals from viruses, many of which had had little effect on the animals only a few years ago, are on the rise in California. Studies indicate that coastal pollution may be a significant factor in these increased illnesses and deaths, possibly due to its negative impacts on immune systems responses.

Pollution can come from direct discharges ("point sources") and runoff from land-based activities ("nonpoint source pollution"). Plumes of contaminated runoff can float on top of the heavier seawater and have been shown to extend 25 or more miles offshore. Nutrient pollution, such as from farms, can create toxic algal blooms, or "red tides," in marine waters. One 1998 toxic algal bloom produced domoic acid, a harmful biotoxin that affects the nervous system in animals and humans. This algal bloom resulted in the death of more than 50 California sea lions along California's central coast. Inland, nonpoint source pollution from logging and other activities impair critical habitats for marine life, including north coast streams essential to threatened and endangered species such as Pacific Coast coho salmon.

The health, safety, and welfare of California residents who use marine resources similarly depends upon clean coastal and ocean waters. Eighty percent of Californians live within 30 miles of the coast. Industries such as fishing and tourism that depend on a healthy coast and ocean contribute more than 17 billion dollars to the state's economy every year, and provide 370,000 jobs to California's citizens.

Health of Coastal and Marine Water Quality and Habitats

Monitoring and Assessment Information

Good water quality and healthy aquatic habitats depend upon the activities that occur nearby. Land use practices, population densities, point and nonpoint source discharges, agriculture, urbanization, industry, and recreation all influence the water quality and habitat of a specific locality or region. To determine the nature and extent of impacts that these activities have on water quality and habitat, monitoring and assessment programs are conducted at the state, federal, and local levels. The state's Bay Protection and Toxic Cleanup Program and Mussel Watch Program, the San Francisco Bay Regional Monitoring Program, the Southern California Bight Regional Study, and the National Oceanographic and Atmospheric Administration's Status, and Trends Program are but a few examples of the many programs underway in California. Monitoring and assessment information is used to determine compliance with state and federal statutes such as the federal Clean Water Act and the state's Porter-Cologne Water Quality Control Act, as well as with permit regulations and water quality standards protecting marine resources and their habitats.

Though monitoring efforts in the state are limited and can be much improved, some conclusions can be drawn about the health of certain state's waters. For example, existing data indicate that uses of 100 percent of the state's surveyed tidal wetlands, 71 percent of surveyed bays and harbors, 91 percent of surveyed estuaries, 78 percent of surveyed freshwater wetlands, 71 percent of surveyed lakes and reservoirs, and 81 percent of surveyed rivers and streams are impaired or threatened in some way by water pollution. Examples of uses that are being impaired or threatened by pollution include drinking water, fish consumption, aquatic life support, swimming, and aquaculture. It should be noted that these figures are only for those waters that are monitored, which may over-represent the more contaminated waters in the state. On the other hand, a recent federal report indicates that the number of impaired waters is likely much higher than that currently recorded.

The state's latest report on water quality generally describes the major water pollution concerns along the California coast. In the north coast region, nonpoint source pollution from logging and agriculture pose the most significant problems. In the San Francisco Bay area, point source discharges from petroleum refineries and cities along the bay, and nonpoint source runoff from Marin County dairies and farms in the Central Valley and Napa County, cause coastal pollution problems. Along the central coast, agriculture creates the most significant pollution problems. Along the densely populated southern California coast, storm-water pollution is a major problem, though agricultural runoff and sewage discharges also are important pollution sources.

States are required to identify water bodies within the state's jurisdiction that do not meet water quality standards. To this end, the State Water Resources Control Board, in conjunction with the state's nine Regional Water Quality Control Boards, has used monitoring data to develop a list of impaired water bodies for the State of California. A water body can be listed as impaired for any number of chemical constituents or conditions such as nutrients, heavy metals, petroleum products, sediment toxicity, bacteria, pesticides, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), etc. California has over 500 water bodies that are "impaired," that is, they are not meeting water quality standards under current regulations; many of these are coastal.

Waters from the Oregon border to north of San Francisco Bay are listed as "impaired" primarily because of sediments. There are, however, some northern embayments, (*e.g.*, Humboldt Bay and Tomales Bay) that have been identified as impaired by other assorted constituents such as heavy metals and nutrients. southern California, with a substantially higher number of impaired coastal waters, bays, and estuaries, faces problems from a much wider variety of sources and contaminants, with urban runoff playing a prominent role. A southern California example is Santa Monica Bay, which has been listed as impaired for several heavy metals, marine debris, sediment toxicity, chlordane, DDT, PAHs, and PCBs. San Pablo Bay, located in the northern San Francisco area, has been identified as impaired for several heavy metals, exotic species, diazinon, PCBs, chlordane, DDT, dieldren, dioxin, and furan compounds. In central California, Morro Bay is impaired because of heavy metals, sedimentation/siltation, and pathogens. San Diego Bay has been listed for copper, sediment toxicity, and benthic community effects; and Lower Newport Bay for a variety of pesticides, metals, nutrients and pathogens. In many of these areas, degraded subtidal and intertidal habitat has also been identified.

The coastal waters of California have been utilized for waste disposal for many years. Ocean outfalls for the discharge of treated sewage, power plant cooling waters, and various industrial discharges are common throughout the state. Add to this the substantial volumes of nonpoint source discharges and it becomes readily apparent that impacts to marine and estuarine resources are inevitable.

Some improvements, however, have been realized over the years as a result of additional controls and requirements applied to point source discharges, and due to phase out of particularly toxic chemicals. For example, a recent study reports that concentrations of DDT and PCBs in livers of bottom fish collected throughout the southern California coastal shelf are at concentrations 95 percent lower than 20 years ago, though health advisories still exist for these constituents. The major challenge remaining is the control of nonpoint source pollution.

Data Limitations/Gaps

Existing water quality and habitat data are not as complete or comprehensive as needed to assess the overall health of marine ecosystems. California does not yet have a system to comprehensively monitor water quality in the inland watershed, enclosed waters, or nearshore ocean zones, and the vast majority of California's waterways and small estuarine systems are not monitored by the state on a regular basis. For example, over 90 percent of California's rivers and streams and about half of the state's coastal shoreline are simply never monitored by the state. Sediment and water quality assessment programs such as the statewide Mussel Watch Program, Bay Protection and Toxics Cleanup Program and the San Francisco Bay Regional Monitoring Program, all need to be continued and expanded. These programs have, over recent years, supplied critical data on the health of the coastal, bay, and estuarine waters of the state. However, years of funding cuts have left the health of much of California's waters unknown.

Programs that will collect data on contaminants and marine life populations, as well as pollutant source identification, are necessary to ensure that adequate information is available to make sound regulatory and management decisions regarding water quality issues. In addition, a statewide baseline inventory of various habitats such as rocky intertidal, subtidal, kelp beds, rock reef, beach areas, mudflats, and subtidal vegetation is critical to make sound scientifically-based resource management decisions. Additional information also needs to be gathered on marine and estuarine habitat restoration and enhancement opportunities.

In 1999, the Legislature passed a law that required the State Board to prepare a comprehensive, statewide surface water quality monitoring program by November 2000. This will serve as the blueprint for much-needed improvements in coastal water quality monitoring.

Sources of Impairment of Water Quality and Habitats

Point Source Discharges

Point source discharges are generally those that have a discrete, identifiable source, such as a pipe carrying treated waste from a pulp mill or a sewage treatment plant. Point sources also include municipal, industrial, and construction storm water discharges and offshore oil well platforms.

Point source discharges into the marine environment contain a variety of contaminants. They include suspended and dissolved solids, heated water, petroleum hydrocarbons, heavy metals, nutrients, pesticides, chlorine, brines, fresh water, and oil and grease. All discharges into the marine or estuarine environment are required to be in compliance with provisions of the State Water Resources Control Board's California Ocean Plan or the respective Basin Plans developed by the Regional Water Quality Control Boards. Conditions on permitted discharges are supposed to be set so that discharge of pollutants will not be deleterious to fish, wildlife and other resources.

Point source discharges to marine waters of the state are substantial both in volume and pollutant load. Many millions of gallons of treated effluent from sewage treatment plants, cooling water discharges from power plants, storm water, and other point sources flow into marine and estuarine waters every day.

Historically, there have been many discharges of pollutants that, although discontinued, continue to have adverse impacts upon the environment. For example, in the 1960s and 1970s, regional industrial facilities discharged DDT and PCBs into what is now the County of Los Angeles Joint Water Pollution Control Plant, which discharged these toxins directly into the Pacific Ocean at the Palos Verdes shelf. Today, the discharge area is identified as a U.S. EPA superfund site and is undergoing extensive evaluation and remediation planning.

One of today's foremost issues with respect to ongoing coastal water quality and habitat impacts is storm-water discharge. Although storm water discharges are regulated by National Pollution Discharge Elimination System (NPDES) permits, the current contribution of pollutant load by this source to waters of the state is staggering. In the *National Water Quality Inventory: 1998 Report to Congress*, U.S. EPA found that urban runoff and storm sewers are the leading source of pollution in coastal waters. Urban runoff and storm water discharges include pollutants such as heavy metals, pesticides, salts, sediments, trash, debris, nutrients, bacteria, petroleum products, and sewage overflows. This problem is heightened in the City of San Francisco, which is one of the few major cities left in the nation that has a combined storm water and sewage system. This aging system frequently overloads during heavy storm events and discharges raw sewage to the Pacific Ocean.

Sewage treatment plants discharging into the marine environment are another significant pollution source. The discharges for those plants that provide secondary treatment to the waste stream contain low levels of heavy metals, pesticides, nutrients, and high volumes of fresh water. Some heavy metals, though discharged at low levels, bioaccumulate up the food chain. These have the potential to alter body burdens in fish and other marine life feeding in the vicinity of the discharge pipe. While levels at the end of the pipe in the water column may be considered relatively insignificant, over the reproductive life of the affected marine organisms, effects may be significant. This is particularly true in areas where discharges receive only primary treatment to remove solids. For example, San Diego uses only "advanced primary" treatment for the city's sewage, which it then deposits into the ocean.

Point source discharges lead to a variety of impacts. Beach closures, degraded bay and estuarine habitats, increased levels of contaminants in marine sediments, bioaccumulation of pollutants in the tissues of marine organisms, degraded benthic communities, loss of kelp beds, and sediment toxicity are some of the more notable impacts identified. Beaches are posted or closed for thousands of beach days each year due to point source discharges from combined sewer overflows and storm water. Nonpoint source pollution, which is not confined to a discrete and easily regulated source, plays an even greater role in water pollution and habitat degradation in California.

Nonpoint Source Discharges

Nonpoint source pollution occurs when water from rainfall, snowmelt, floods, or irrigation runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, bays, estuaries, nearshore coastal waters or groundwater. In California, nonpoint source discharges have been categorized into eight large groupings: agricultural, urban, silviculture, marinas and boating, grazing, mine drainage, on-site sewage treatment systems, and hydromodification.

According to the U.S. EPA, agriculture is the leading contributor nationwide to water quality impairments, degrading most of the impaired river miles and lake acreage surveyed by states, territories, and tribes. By contrast, runoff from urban areas is the largest source of water quality impairments to surveyed estuaries. The most common nonpoint source pollutants are sediments and nutrients.

Some examples of impacts from nonpoint source pollution in central California include agricultural runoff releases of DDT into the Salinas River Lagoon and Monterey Bay National Marine Sanctuary at levels that have been demonstrated to be deleterious to aquatic life; and severe oxygen depletion and eutrophication, as well as shellfish contamination, in Tomales and Bodega bays and their tributaries due to nutrients from dairy runoff. Data from the National Shellfish Register document that in 1995 (the most recent year reported) shellfish harvesting was prohibited for 9,000 out of 24,000 acres of harvesting areas in California due to water quality concerns. Coastal nonpoint source pollution, including both urban and agricultural runoff, also contributes to the thousands of days of beach closures and postings in the state each year.

Alteration of water flow (hydromodification) and channel erosion are two nonpoint source pollution categories that have been linked to the decline of anadromous fisheries (*e.g.*, chinook salmon), especially in habitat areas where spawning success is determined. The increased sedimentation, siltation, and turbidity resulting from these pollution sources lead to habitat loss and modification. These impacts may then adversely affect species population numbers.

Harbors and marinas provide their share of nonpoint source pollutants including oily bilge water, detergents from the washing of decks and hulls, runoff from shipyards with paint flakes containing heavy metals and organotins, and dish detergent and occasionally sewage material from live-aboards. Marinas and harbors also can add a significant sediment plume to local waters during dredging activities for channel and basin depth maintenance, as well as associated pollutant and sediment loads from the dumping of these dredged materials into coastal waters.

Spills

Oil Spills

Of all deleterious materials spilled into the marine environment, crude oil and refined petroleum products are the most common. Oil enters state waters from many sources, such as storm drains and runoff from roadways, as well as medium-to-large oil spills. Oil spills come in many forms, from the discharge of oily bilge water by tens of thousands of boats plying the waters of California, to breakage in oil pipelines due to earthquakes or age. From 1991 to 1998, "significant" oil spills released at least 18,650 barrels of oil into California's coastal waters. Data complied by U.S. EPA of significant California spills from 1971 to February 2000 record 627,415 barrels of oil spilled that resulted in identified environmental damage. The actual number of spills and amount of damage is likely much higher, but current resource limitations make full detection impossible.

In nearly all cases, wildlife are injured or even killed by contact with oil. Aquatic birds, shorebirds, and marine mammals, particularly sea otters, are the sea life most visibly affected. However, birds collected at an oil spill site often may die with no external signs of oil contact because they have ingested oil while cleaning it off their feathers. Once ingested, the oil is almost always fatal to the birds. Impacts to fish and other aquatic organisms are not often observed because the affected organisms sink out of sight.

The use of oil dispersants to prevent an oil slick from coming ashore generally serves to break up the spill's integrity. However, they allow the oil to remain emulsified in the water column, and add dangerous chemicals that may adversely affect water column communities below the surface. Oil spills that do come ashore impact coastal and marine wildlife as well as valuable rocky intertidal, sand beach, and coastal wetlands habitats.

In 1991, the California Department of Fish and Game created the Office of Spill Prevention and Response (OSPR) to implement legislation to address oil pollution issues in the marine environment. In 1997 (last year for available data), 767 marine oil spills were reported to OSPR. Again, these are only reported spills; the actual amount of oil discharged into coastal waters is likely far higher than reported. For example, these figures do not include the 8.5 to 20 million gallons of diluent released over many years at the Unocal/Guadalupe oil field near the City of San Luis Obispo.

Other Spills

Sewage spills are the most common of non-oil related spills. Effects can range from minimal losses to thousands of fish and other marine animals killed or impaired. A recent sewage spill into the Salinas River resulted in a portion of the river becoming completely depleted of oxygen and in the loss of hundreds of fishes, including steelhead trout (a federally listed species). Sewage spills also have the potential to release harmful chemicals into the environment, as the sewage has not reached the treatment plant where these chemicals normally are removed or reduced to non-toxic levels prior to discharge. Sewage spills are a significant source of beach closings and health advisories each year.

Even some chemical compounds commonly thought to be non-toxic can have an adverse effect on wildlife when spilled into an aquatic environment. For example, the release of 2,300 gallons of vegetable oil into Monterey Bay in 1997 impacted a variety of birds species. Among other things, birds were poisoned through ingestion of the oil, and oil on feathers made the birds less buoyant and more susceptible to hypothermia. Several hundred birds died, while hundreds more were rehabilitated and released.

Dredging and Disposal of Dredged Material

Dredging is the deepening or enlargement of a navigational channel, harbor/marina basin, or berthing area. Construction of new channels, basins, or berthing areas involves the removal of previously undisturbed sediment, while "maintenance dredging" removes accumulated sediment from previously dredged areas. Maintenance dredging also occurs at the mouths of coastal lagoons, creeks, and rivers where accumulated sediment is removed to keep the system open to the ocean.

At the ports of San Francisco, Oakland, Los Angeles, Long Beach, and San Diego, increasing global economic pressures have resulted in the need for larger, deeper draft ships to transport cargo. This has led to a demand for new construction dredging to widen and deepen channels, turning basins, berths, and slips to accommodate the larger vessels. Maintenance dredging has similarly increased. More often, dredging activities are permitted for annual or multiannual maintenance of previously dredged areas. Although infrequent, dredging activities are increasingly being used for wetland restoration and enhancement projects such as the dredging of Batiquitos Lagoon in San Diego County, the Port of Los Angeles' shallow water habitat, and the Port of Oakland's middle harbor enhancement area.

The selection of a disposal site for dredged sediments is dependent upon the physical and chemical characteristics of the material to be placed. Physically and chemically suitable material (*i.e.*, appropriate grain size and minimal contamination) may be disposed of at unconfined, open-water disposal sites authorized by the U.S. EPA and U.S. Army Corps of Engineers, such as the deep-ocean disposal site near the Farallon Islands off San Francisco.

In some instances, clean material may be beneficially reused for structural fill, wetland construction and restoration, habitat improvement and enhancement, capping material for sites with contaminated sediments, or for beach nourishment. Dredge material has been used in Los Angeles Harbor to regain acreage of shallow water habitat historically lost to past dredge and fill projects. In the Los Angeles Harbor project, clean dredge material was used to cap contaminated sediments. A recent Port of Oakland channel deepening project resulted in the creation of the Sonoma Baylands, a more than 300-acre tidal wetland restoration project located in Sonoma County. In San Diego Bay, the Navy has proposed a 30-acre shallow water habitat site to be built with dredge material from their homeporting project. Upland or aquatic disposal for beneficial reuse is encouraged throughout the state to minimize open-water unconfined disposal at authorized in-bay (*e.g.*, San Francisco Bay), nearshore (*e.g.*, Moss Landing) or ocean (*e.g.*, Los Angeles, San Diego, Eureka, etc.) disposal sites. Dredged material that is physically suitable, but is chemically unsuitable for aquatic disposal because of elevated levels of certain contaminants, may be used as fill, or in certain wetland construction and habitat improvement projects, provided the contaminated materials are confined (*e.g.*, parking lots, container piers, etc.).

Beach nourishment is one of the more common reuses of clean dredge material from routine dredging projects. Compatible material, which matches the receiving beach in grain size and quality, is usually pumped directly onto the beach and then spread by use of heavy equipment, or directly placed in the nearshore environment where it will be transported onshore through natural littoral processes. Large-scale beach nourishment projects, using material from offshore borrow areas, are currently being planned for southern California, particularly in San Diego County.

Dredging activities can cause significant negative impacts to marine life, including a direct loss of benthic habitat, as well as potential loss or injury to slow moving or immobile benthic species such as polychaete worms, crabs, seastars, clams, and bottom-dwelling fishes. Studies have shown that benthic invertebrate species can re-colonize in the dredged area as early as six months after a dredging project has been completed. However, this type of recovery can be delayed indefinitely if there is repeated dredging activity. Depending on the scale of dredging, there also could be a loss of marine plants such as eelgrass. In addition to the direct loss of habitat and associated infauna and epifauna, dredging operations displace mobile fish and invertebrates, affect the foraging habits of marine birds, and displace other water birds such as ducks, geese, terns, loons, grebes, and cormorants. Newly dredged substrate also is more susceptible for colonization by opportunistic and invasive non-endemic organisms.

Dredging may also result in the resuspension and redistribution of sediments, potentially increasing marine and estuarine life to exposure to chemical contaminants, as well as a temporary decrease in dissolved oxygen. Increases in turbidity and suspended solids decrease light penetration, resulting in reduced photosynthesis by phytoplankton, kelp, eelgrass, and surfgrass. Prolonged turbidity can clog the apparatuses of filter-feeding invertebrates and the gills of fishes. Turbidity also reduces the ability of sight-foraging birds, such as the federal- and state-endangered California least tern and brown pelican, to successfully capture prey items.

For small dredging projects, many impacts are assumed to be short term and temporary; however, the larger the dredging project, the longer the duration of the dredging and the greater the impacts to marine organisms. The method of dredging also affects turbidity and resuspension of sediments. For example, a clamshell dredge results in more turbidity at the dredging site than a hydraulic dredge, but at the disposal site the opposite occurs.

There are a number of ways to minimize some of the impacts associated with dredging. Mitigation measures include the use of silt curtains to contain fine sediments, water-tight clamshell buckets for minimizing the dispersion of contaminants, and seasonal restrictions (*e.g.*, no dredging during the nesting seasons of least terns and snowy plovers, or during the migration of endangered salmonid species).

Open-water disposal buries most immobile epibenthic and infaunal organisms within the footprint of the disposal site, and there are expectations that the site will be degraded over time. Approved ocean disposal sites are designed to minimize adverse impacts to living marine resources outside of the site boundaries. Beach replenishment can also have negative impacts on marine resources and their habitats. Sensitive and valuable habitats including kelp beds, rocky reefs, and surfgrass could be potentially buried by nearshore disposal operations. Direct placement of sand on the beach may also bury incubating California grunion eggs, destroy nests of western snowy plover and least tern, and preclude shorebird foraging.

Invasive Species

Invasive species are the number two threat to endangered and threatened species nationwide, second only to habitat destruction. Specific environmental threats include consumption of native species and their food sources, dilution of native species through cross-breeding, and poisoning of native species through bioaccumulation of toxics that are passed up the food chain. Commercial fishermen nationwide are seeing significant impacts to fish and shellfish populations due to invasive marine life. Moreover, unlike threats posed by most chemical or other types of pollution, biological pollution by non-indigenous species has permanent impacts, as aquatic invasive species are virtually impossible to eradicate once established.

Though many areas along California's coast have been impacted, San Francisco Bay has seen some of the most significant damage from invasive species. Extensive studies confirm that at least 234 alien plant and animal species now live in San Francisco Bay, and that recently introduced alien species are finding a viable niche in the bay and delta at the rate of one new species every 14 weeks. Those invasive species that have been positively identified as permanent residents of the bay include the Asian clam, the European green crab, the New Zealand sea slug, the Chinese mitten crab, several species of sponges, jellyfish, several species of fish, and numerous species of anemone, snails, mussels, clams, and barnacles.

It is widely accepted that the discharge of ballast water is the primary mechanism by which coastal invasive species are spread. For example, from 53 percent to up to 88 percent of the aquatic non-indigenous species introduced into San Francisco Bay in the last decade originated in ballast water discharges. Other sources include aquaculture imports and deliberate introductions (the possible source of the invasive Chinese mitten crab in the San Francisco Bay Estuary).

This topic is addressed in more detail in the chapter on invasive species.

Habitat Loss, Destruction and Alteration

Nearshore coastal and estuarine habitats are significantly impacted by fill, residential and commercial development, and flood control projects. Fill, or the placement of sediments, pilings, bulkheads, retaining walls, piers, etc. in marine waters, has occurred in every major port and many other developed coastal areas. The man-made Ports of Los Angeles and Long Beach were created by the dredging and filling of the former 3,450-acre Wilmington Lagoon. Large-scale fill projects continue today as increasing economic pressures dictate a need for additional container terminals. In fact, the Port of Los Angeles just recently completed an over 580-acre landfill project for its Pier 400 project. In the San Francisco Bay area, the San Francisco International Airport is proposing a runway reconfiguration project that would potentially fill up to 1,500 acres of San Francisco Bay.

The filling of marine waters with large volumes of sediment clearly has significant adverse impacts on the nearshore marine and estuarine environment, permanently eradicates benthic habitat, and likely kills most epibenthic and infaunal organisms within the footprint of the fill. Additionally, fill removes the surface-air interface, reducing foraging areas for surface feeding species, and reduces water column habitat, adversely affecting plankton, fishes, diving birds, and marine mammals.

Structures, such as wharves, piers, seawalls, groins, and breakwaters, also impact and modify the marine and estuarine environment. There is often a permanent loss of habitat from the fill used to install the structure, such as pilings for piers. Some overlying structures (*e.g.*, pier platforms) cover a portion of the water column, resulting in the loss of foraging habitat for sight-feeding marine birds such as terns and pelicans. Additionally, the structure may shade marine plants such as eelgrass, as well as algae and benthic invertebrates. Groins and breakwaters may deflect wave or water current energy and influence water currents, flushing, sedimentation, and normal sediment transport. Materials used to construct structures exposed to water may have negative impacts on water quality, such as creosote-treated wood products. The operation of the structure may also result in additional water quality impacts, such as runoff from piers and platforms.

In addition to the structures themselves, construction activities associated with projects also impact the marine environment, and, although the impacts are not permanent, they may have significant effects on resources. This is particularly true for large-scale or long-term projects or where there are multiple small project phases in the same area. Surface turbidity caused by dredging is one of the major impacts from in-water construction activities affecting marine plants, birds, and fishes. Shock waves from demolition and pile driving can further impact foraging birds by making prey more difficult to capture. They are also capable of breaking up concentrated schools of fish, forcing schools to seek deeper waters or avoid an area altogether. Noise associated with construction operations also displaces marine birds and mammals.

Groins and breakwaters convert one habitat type to another resulting in a change in community structure. For example, placement of riprap over subtidal/intertidal habitat converts a soft bottom surface to a rocky habitat. Habitat conversion becomes an issue when a majority of the habitat in the area has already been altered. For example, in San Diego Bay, only 26 percent of the bay's shoreline remains natural, whereas the remainder is covered with man-made structures.

Flood control projects can be another source of habitat loss and alteration. The natural hydrology of bays and estuaries has been greatly affected by human activities in an attempt to control flooding. Flood control methods such as channelization of rivers and streams have impacted or destroyed riparian habitat and increased the rate of sedimentation into bays and estuaries. Breaching of sand bars on coastal rivers and streams for the purpose of flood control has changed riverine habitat from fresh water to brackish or tidal. One of the many functions of wetland habitat is to provide flood control during high flow years, but development on coastal wetlands has, among other things, removed this natural benefit.

Coastal habitats such as wetlands and estuaries are vital to the survival of numerous invertebrates, fishes, birds, mammals, and plants. Already an essential component of commercial and sport fishing industries worth hundreds of millions of dollars, these habitats help fuel the state's economy and support California's diverse marine wildlife population. California's coastal wetlands also are valued for their capacity to recharge groundwater and cleanse runoff.

However, these habitats are an increasingly scarce resource. For example, 90 percent of California's coastal wetlands have been diked, paved over, developed or otherwise destroyed, and only five percent of the state's coastal wetlands remain intact. Development continues to pose a significant threat to the few remaining natural coastal wetlands. The vast majority of California's population lives within a short drive from the coast, and the number of people settling in coastal counties continues to grow.

Development not only can directly destroy coastal habitats, but also can contaminate them through the urban runoff and other discharges generated by the development activities. Increased controls on urban runoff will be implemented shortly through a new round of regulations on smaller municipalities, helping to control this problem somewhat, but it is unclear whether this effort will be outweighed by the sheer rate of growth in these areas.

The California Coastal Act limits the filling of wetlands and estuaries to certain types of projects including port, energy, and coastal-dependent industrial facilities, entrance channels for new or expanded boating facilities; new boating facilities in a degraded wetland; and restoration, nature study, and aquaculture. Despite these protections, coastal wetlands are still being developed today. Development projects are currently anticipated at Bolsa Chica, Ballona, and Los Cerritos wetlands, some of the few remaining wetlands in southern California.

Water Flow

Freshwater Discharges

The two principal sources of freshwater discharges into marine and estuarine habitats are sewage treatment plants and power plant cooling water. Sewage treatment plants discharge treated wastewater into coastal waters and bays. There, the freshwater dilutes the salinity of the receiving environment, impacting and changing that habitat. This problem is particularly acute in south San Francisco Bay, which has a low flushing rate.

With respect to power plant discharges, California has more power plants discharging into salt and brackish water than any other state. Although these plants use once-through cooling systems, the water is heated to several degrees above ambient during transit through the plant. Impacts from heated water can vary depending upon where the discharge structure is located. Discharges into environments that normally experience wide temperature ranges during tidal and annual cycles (*e.g.*, estuaries) are more resistant to changes from thermal effects than those that do not normally experience such changes. Power plant discharges can result in decreased diversity and density of species at the community and ecosystem levels. In addition to heat, power plant discharges can contain high levels of suspended solids, which decrease light penetration of the water column and affect adjacent kelp bed production.

Power plants also cause problems related to water flow. Electricity generating power plants take in billions of gallons of water on a daily basis. Diablo Canyon Nuclear Power Plant circulates 2.5 billion gallons of water per day, which pulls in creatures in the seawater en route to passing the water through the plant in its once-through cooling cycle. This water circulation causes temperature increases in the area of discharge (thermal pollution), impingement (marine animals caught on water intake screens), and entrainment (destruction of marine animals pulled inside the plant). Entrainment is generally limited to those organisms not capable of swimming against the intake current (*e.g.*, larval forms). Most energy company-sponsored studies of power plant entrainment limit analysis to effects on larval fish, arguing that plankton losses are too difficult to enumerate and analyze for ecosystem effects. It has been estimated, however, that plankton losses can significantly increase the estimates of overall wildlife losses due to entrainment. Larval entrainment losses are often estimated at 100 percent due to a multiplicity of factors, including physical changes in pressure, discharge velocity, turbulence, and temperature increase effects. If the power plant has a mechanism to return impinged organisms to the water (most do not), those losses are lower, but do contribute to the cumulative effects of power plants on the ecosystem.

Hydromodification

Dams in California range from large, permanent structures to small, temporary structures. Millions of gallons of water, often diverted from rivers that empty into the ocean or estuaries, are stored for agricultural use, drinking water supplies, flood control, or groundwater recharge. Dams change the landscape both at the construction site and the downstream conveyance to the ocean or estuary. Loss of upstream habitat due to water diversion has the effect of reducing the production capability of anadromous species that depend on continuous summer flows for rearing and transport of juveniles that travel downstream to the ocean for growth prior to returning to natal streams. Diversion of freshwater inflow to estuarine systems also reduces the productivity of the estuaries by reducing the nutrient input which diatom and other bottom trophic level organisms require. Dams also change stream morphology by altering sediment flow, by smothering gravels with silt during high flow releases, and by emptying summer rearing pools. Dams also contribute to poor water quality by releasing warm surface water that has been mostly depleted of oxygen; or by releasing water, through spillways, that may contain oxygen levels too high for fish survival (supersaturation). The lakes that are formed by large dams cover miles of former spawning riffles, and many dams have been built without passage facilities, blocking the upstream migration of anadromous fish trying to find suitable spawning habitat.

Water conveyance structures (*i.e.*, water canals) remove essential water from rivers and streams that historically produced the bulk of California's salmon runs. These structures not only remove water, they also alter existing habitat. For example, canals that leak repeatedly create riparian habitat entirely dependent on that leakage. When these canals are repaired, the ecosystem that has developed over the years is lost. Water canals also have the potential to transport fish between watersheds and introduce species into unfamiliar habitats. Many newly created reservoirs behind dams contain non-native fish that also have the potential to escape from the lake into the outlet stream, such as the in the case of the northern pike introduced into Lake Davis.

Recreational and Commercial Activities

Boating

Cruise ships, yachts, and other large recreational vessels discharge sewage, gray water, toxic chemicals, oil and gas, and air pollutants into sensitive coastal waters. Smaller vehicles also can do significant harm.

Jet Skis (Motorized Personal Watercraft)

For example, jet skis, more generically referred to as "motorized personal watercraft" (MPWC) can do significant nearshore harm. For example, their noise, which is rated at 85-105 decibels, can disrupt wildlife communities through alteration of behavior and nest abandonment. MPWCs also pollute more than other boats. From 25 to 33 percent of the oil and gasoline used by MPWCs is discharged unburned, impacting local water quality. A two-hour ride on an MPWC can discharge up to three gallons of unburned gasoline and oil, or the same amount of pollution as driving 139,000 miles in a 1998 passenger car. The impact of accumulated oil pollution in the marine environment is particularly significant in sensitive nearshore environments such as estuaries and bays. This pollution can have cumulative effects throughout the food web as the hydrocarbons bioaccumulate, posing a threat to larger marine life.

For these reasons, MPWC regulations have been established in sensitive areas such as the waters of the Monterey Bay and Gulf of the Farallones National Marine Sanctuaries. In justifying the regulation of MPWC, the National Oceanic and Atmospheric Administration noted that, "the small size, maneuverability and high-speed of these craft is what causes these craft to pose a threat to resources. Resources such a sea otters and sea birds are either unable to avoid these craft or are frequently alarmed enough to significantly modify their behavior such as cessation of feeding or abandonment of young." Indeed, the narrow draft and smaller size of MPWCs allows them to access the most fragile nearshore habitats, causing significant environmental impacts including: flight responses in shorebirds and alteration of nesting habits; destruction of critical bird and fish habitat, including eelgrass beds; and harassment of or collisions with marine mammals (several of which are federally protected species under the Endangered Species Act) and other wildlife. While these impacts are most critical in the nearshore environment, the risk of collision with or harassment of marine mammals and seabirds is significant throughout areas frequented by MPWC.

Fishing

There is growing evidence that fishing has a significant impact on coastal habitats. For example, the complexity of the marine habitat can be altered by the scraping, shearing and crushing effects of fishing gear. Physical effects of trawling include plowing and scraping of the sea floor and resuspension of sediments. Resulting benthic troughs can last as little as a few hours or days in mud and sand sediments over which there are strong tides or currents, to between a few months to over five years in sea beds with a mud or sandy-mud substrate at depths greater than 100 meters with weak or no current flow. Longline gear has similarly been observed to shear marine plants and sessile organisms from the bottom. Pot gear may damage demersal plants and animals as it settles, and longlined pots may drag through and damage bottom fauna during gear retrieval. Boat anchors also can inflict serious, though localized, damage in some areas.

In addition to directly altering the bottom habitat, fishing can result in lost gear that is left to "ghost fish," thereby causing additional habitat alterations. Fishing activities also affect the water column through discharge of offal from fish processed at sea. These discards in deeper water could redistribute prey food away from midwater and bottom-feeding organisms to surface-feeding organisms; in low-current environments, these discharges can decompose and create anoxic bottom conditions. The water column also can be impacted by fuel leaks from fishing boats. Measures to minimize these impacts include prohibiting the use of damaging gear in sensitive areas and modifying gear so that damage to bottom habitats is minimized.

Ecosystem-wide Implications

An ecosystem can be defined as the balanced and sustained interaction of a biological community with its physical and chemical environment. The fish, invertebrate, marine mammal, aquatic bird, and aquatic plant populations in California's coastal, bay, and estuarine waters are all components of a vast array of discrete and overlapping communities and ecosystems. Although most members of a biological community are linked through elaborate food webs based upon predation, competitive and mutualistic relationships also play an important role. Add to this complexity the myriad of effects on individual organisms and populations from changes in the chemical and physical environment, and measuring and evaluating ecosystem responses to these changes becomes a challenging task.

The current state of environmental science allows us to use both individual evaluation measures and combinations of measures depending upon the information at hand. These may include population numbers and structure, biological testing (*e.g.*, bioassays, bioaccumulation, etc.), concentration of contaminants in organisms or the surrounding habitat, movement of contaminants into aquatic ecosystems, and size and/or availability of habitat. Based upon these and other measurements, it appears that bay and estuarine ecosystems are much more threatened than those of the nearshore coastal environment with regard to habitat quality and quantity. This is particularly true with regard to contaminants in the water column and benthic sediments, and impacts from dredging and filling, point and nonpoint source discharges, oil spills, and nonindigenous species introduction. On a localized or regional basis, however, areas of the nearshore coastal environment may be in worse condition than our bays and estuaries with regard to specific contaminants or conditions. Examples include DDT-laden sediments in the area of the Palos Verdes shelf and radioactive waste dumped near the Farallon Islands.

Although California's population continues to increase, thereby putting added pressure on our limited resources and habitats, there are a number of efforts and initiatives underway in the state to begin to curtail impacts and improve the quality and quantity of our marine and estuarine habitats. These efforts include greater regulation of point and nonpoint source discharges, improved identification of toxic hot spots, increased emphasis on beneficial reuse opportunities for dredged materials, reduction of the frequency and extent of oil spills, development and coordination of large-scale water quality and habitat monitoring and assessment programs, restrictions on the import of non-indigenous species in ballast water, and increased marine habitat restoration and enhancement projects.

Regulatory Structure for Addressing Water Quality and Habitat Issues

Federal

Clean Water Act

The Environmental Protection Agency is the foremost federal agency with responsibility for protecting the health of the nation's waters. The Federal Water Pollution Control Act ("Clean Water Act") addresses the major categories of discharges into coastal and marine waters with varying degrees of stringency. California's State Water Resources Control Board (SWRCB) and Regional Water Quality Control Boards (RWQCB) currently hold the authority, delegated by U.S. EPA, to implement the Clean Water Act in state waters.

Permit Program

Section 301(a) of the Clean Water Act prohibits the discharge of "any pollutant by any person" into waters of the United States, unless done in compliance with specified sections of the Act, including the permit requirements in Section 402. Under the National Pollutant Discharge Elimination System (NPDES) set up under Section 402, U.S. EPA requires permits for most point source discharges of waste. These permits contain discharge conditions, including technology-based controls and water-quality-based effluent requirements, to ensure that the discharges meet all applicable standards set to protect uses of the water body, such as use by aquatic life and for fishing.

NPDES permits for discharges into the territorial sea also must comply with "ocean discharge criteria" specifically designed to prevent the degradation of those waters, pursuant to Clean Water Act Section 403. These permit requirements may increase in stringency in the near future due to a recent presidential Executive Order on this topic.

Nonpoint Pollution Program

Section 319 of the Clean Water Act sets up a voluntary program to control polluted runoff. This program was established through the 1987 Clean Water Act amendments, and states soon thereafter submitted nonpoint source pollution management plans to EPA in order to receive federal 319 funds for projects to control polluted runoff. Significant limitations of this program include low levels of funding in comparison with the significance of the problem and the fact that the programs are voluntary. As a result, over a decade after establishment of the "319 program," polluted runoff continues to be the major - and growing - source of pollution into the nation's waters.

Regulation of Discharges into Impaired Waters

Section 303(d) of the Clean Water Act requires states to identify specific water bodies where water quality standards are not expected to be met even after full implementation of required permit controls and other conditions imposed on point source discharges. States must then establish a priority ranking of those impaired waters and identify the pollutant stressors that are causing the water quality problems. In accordance with those rankings, the state must then establish limits on all pollution discharges, both point and nonpoint, in order to ensure attainment of water quality standards within a "margin of safety." These limits are referred to as the "total maximum daily loads" (TMDL) for the identified pollutants and waters. The state's impaired water body list currently tops 500, with more likely to be listed. Because many of these waters are vital to the health of the state's coastal ecosystems and wildlife, full and prompt implementation of these TMDLs is essential to a thriving marine ecosystem.

Discharges under Federal Licenses or Permits

Section 401 of the Clean Water Act requires a certification from a state that federal agency actions and permits comply with state water quality standards and other Clean Water Act requirements. Congress stated in enacting this provision that the purpose of Section 401 is to "provide reasonable assurance that no license or permit will be issued by a federal agency for any activity that through inadequate planning or otherwise could in fact become a source of pollution." When implemented fully, this adds an important layer of protection over existing regulations protecting coastal water quality and habitat health.

Dredge Disposal and Fill

Section 404 of the Clean Water Act grants the U.S. Army Corps of Engineers authority to regulate any project involving fill, construction, or modification of the waters of the United States. This would include, for example, dredging and filling of coastal harbors. Corps actions are subject to Clean Water Act Section 401 certification that the proposed activities will not violate state water quality standards.

U.S. EPA sets the standards for suitability of dredge material destined for federally approved sites in the ocean beyond three miles from shore. These standards are found in the 1991 Ocean Disposal Testing Manual, or "Green Book," which specifies the physical, chemical, and biological tests required to determine suitability. Disposal within state waters (*i.e.*, inside three miles) is authorized by state and federal agencies which use standards from the "Inland Testing Manual." State agencies involved in authorizing disposal within state waters through a permitting process include the Regional Water Quality Control Boards, State Lands Commission, California Coastal Commission, and the San Francisco Bay Conservation and Development Commission. Federal agencies involved in the permitting process for the disposal of dredged materials in state waters include U.S. EPA and the U.S. Army Corps of Engineers. Federal and state resource agencies such as the Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service act as consulting agencies on dredging projects.

Antidegradation

The Clean Water Act and accompanying regulations state that both point and nonpoint source pollution control programs must specifically address antidegradation, or preventing further pollution of the nation's waters. Water quality standards, which all waters must meet, consist of three elements: (1) the designated beneficial use or uses of a water body; (2) the water quality criteria necessary to protect the uses of that water body; and (3) an antidegradation policy. Both federal and state antidegradation policies must ensure that water quality improvements are conserved, maintained and protected.

Despite the fact that antidegradation in general, and protection of relatively clean waters in particular, is a specific component of the water quality standards, it is given relatively little attention in point source pollution control and permitting programs, and essentially no attention in nonpoint pollution control programs. A lack of attention to maintaining the health of cleaner waters threatens those waters with impairment that will be far more expensive to address than prevention. Water quality programs should contain specific descriptions of how new and continued discharges into all waters, both impaired and clean, will be reduced.

Ocean Dumping Act

Title 1 of the Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act), prohibits the unpermitted dumping of "any material transported from a location outside the United States" into the territorial sea of the United States, or into the zone contiguous to the territorial sea, to the extent discharge into the contiguous zone would affect the territorial sea or the territory of the United States. "Dumping" is defined broadly as "a disposition of material." The statute contains only a few, very specific exemptions from this term. The Act is administered by U.S. EPA and is on top of any Clean Water Act requirements.

The National Environmental Policy Act

The National Environmental Policy Act of 1969 is the basic national directive for the protection of the environment. NEPA requires that federal agencies prepare an Environmental Impact Statement (EIS) for "major Federal actions significantly affecting the quality of the human environment." In doing so, the agencies must provide a "full and fair discussion of significant environmental impacts" of the proposed project.

An EIS is intended to help public officials make decisions that are based on an understanding of the potential environmental consequences and decide whether to take actions that avoid these consequences. The EIS also must "inform decision makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts" and must analyze such project alternatives comprehensively. In addition, the EIS must discuss "appropriate mitigation measures not already included in the proposed action or alternatives." Finally, the lead agency must state at the time of its decision "whether all practicable means to avoid or minimize environmental harm from the alternative selected have been adopted, and, if not, why not."

Endangered Species Act

The federal Endangered Species Act (ESA) is the nation's charter for protection of threatened and endangered species, including coastal and marine life. The Endangered Species Act contains both consultation requirements and a substantive requirement prohibiting certain activities that threaten listed species. Under Section 7 of ESA "[e]ach Federal agency shall, in consultation with and with the assistance of the Secretary [of the Interior and/or Commerce, as appropriate], insure that any action authorized, funded, or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species . . . ." In addition, federal agencies must consult with the Secretary of the Interior and/or Commerce, as appropriate "on any agency action which is likely to jeopardize the continued existence of any species proposed to be listed . . . or result in the destruction or adverse modification of critical habitat proposed to be designated for such species."

Section 7 is an important tool that can be used to protect and conserve the habitats of threatened and endangered coastal and marine wildlife. ESA Section 7 is used, for example, to require the U.S. Army Corps of Engineers to consult with U.S. Fish and Wildlife Service and the National Marine Fisheries Service regarding how proposed Corps dredging projects will affect listed species.

In addition, Section 9 of ESA prohibits the transport or take of listed species, and Section 4 sets up a program to acquire lands and habitat associated with listed species to enhance recovery efforts.

Marine Mammal Protection Act

The federal Marine Mammal Protection Act (MMPA) protects the marine mammals that make their home in the waters off California's shores. One of the more significant provisions of the MMPA prohibits the "take" of marine mammals. "Take" is defined broadly to include actions that kill or "harass" marine mammals, where "harassment" refers to "any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including . . . feeding . . . ." As defined, "take" is not limited to a direct physical taking of the animal, but also other actions that indirectly harm the animal.

National Marine Sanctuaries Act

Title 3 of the Marine Protection, Research, and Sanctuaries Act is the National Marine Sanctuaries Act (NMSA), which protects the nation's most unique marine habitats, waters and wildlife. California is fortunate to have four National Marine Sanctuaries: Channel Islands, which lies nine to 46 miles offshore and encompasses 1,658 square miles of marine waters and habitats; Monterey Bay, which lies adjacent to the central coast and is 5,328 square miles; Gulf of the Farallones, which lies adjacent to shore along Marin County and extends 12 miles out to the Farallon Islands, encompassing 1,255 square miles; and Cordell Bank, the smallest at 526 square miles, which lies near the continental shelf seven to 23 miles offshore (adjoining the Gulf of the Farallones Sanctuary). The NMSA is designed to "maintain, restore, and enhance living resources by providing places for species that depend on these marine resources to survive and propagate." NOAA's Sanctuary offices use the NMSA to provide for "comprehensive and coordinated management" of these unique marine areas.

To meet these goals, the NMSA requires federal agencies to consult with sanctuary officials if federal actions are likely to injure sanctuary resources. So, for example, U.S. Army Corps of Engineers staff would need to consult with sanctuary staff on proposed dredging in sanctuary waters. The NMSA also makes it illegal to "destroy, cause the loss of, or injure any sanctuary resource managed under law or regulations for that sanctuary," with specified actions allowed under sanctuary permits or authorizations. Under the NMSA, management plans must be prepared for each sanctuary and reviewed every five years. These plans must take into account management of the diverse marine wildlife in California's sanctuaries.

Like the Ocean Dumping Act, the NMSA adds an extra layer of protection for marine resources in certain areas. For example, the San Francisco and Central Coast Regional Water Quality Control Boards report to the Monterey Bay NMS office on proposed new and revised permits for discharges into sanctuary waters and allow for staff review and comment. Sanctuary staff may in some instances place conditions on these permits as needed to protect Sanctuary resources. Violations of these permits is an infraction of both state water quality law and the NMSA, subjecting the violator to fines under both acts.

The Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) of 1972 established a federal-state partnership to manage development and use of the coastal zone. CZMA, which is administered nationwide by NOAA, provides federal funding for the development and implementation of state Coastal Zone Management Programs. The state agency charged with developing and implementing a state coastal plan in accordance with CZMA is the California Coastal Commission. Significantly, CZMA grants the commission the authority to review federal activities in the coastal zone and ensure they comply with California's Coastal Zone Management Program.

Coastal Zone Management Act Reauthorization Amendments of 1990

The Coastal Nonpoint Pollution Control Program, established by the Coastal Zone Reauthorization Amendments of 1990 (CZARA), addresses the control of nonpoint source pollution, which is the number one cause of water contamination in the state. The impacts of nonpoint source pollution in coastal areas include beach closings and advisories, loss of habitat, closed or harvest-limited shellfish beds, declining fisheries, red tides and other harmful plankton blooms, reduction in tourism revenues and threats to the drinking water of coastal communities.

The State Water Resources Control Board and the California Coastal Commission have submitted to U.S. EPA and NOAA a Nonpoint Pollution Control Program Plan that is intended to control nonpoint source pollution in accordance with CZARA Section 6217 requirements. The plan lays out a general outline of nonpoint source pollution management measures that will be implemented over the next 15 years.

U.S. EPA and NOAA approved California's plan in July 2000. Additional requirements on the contents of the Plan imposed under state law (particularly with respect to enforcement) should be completed by February 2001.

Magnuson-Stevens Fishery Conservation and Management Act

As amended and reauthorized in 1996, the Magnuson-Stevens Fishery Conservation and Management Act includes substantial new provisions designed to protect habitats important to all federally managed species of anadromous and marine fish. The amended Act defines "essential fish habitat" (EFH) as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

The act requires the eight regional fishery management councils around the country and the Secretary of Commerce to amend each regional fishery management plan to:

- Describe and identify EFH;
- Identify adverse impacts to EFH;
- Minimize, to the extent practicable, adverse impacts from fishing to EFH; and
- Develop suggested measures to conserve and enhance EFH.

Before a federal agency may proceed with an activity that may adversely affect a designated EFH, the agency must consult with NOAA Fisheries with regard to measures that avoid or minimize adverse impacts on the EFH.

The Pacific Fishery Management Council has defined groundfish EFH as waters of the entire Pacific Coast, and described the types of measures needed to protect the habitat from fishing and non-fishing impacts. However, the Council, like other councils nationwide, has required almost no protection for EFH from fishing itself, despite growing evidence that fishing often poses a significant threat to EFH.

Oil Pollution Act of 1990

The Oil Pollution Act (OPA) of 1990 streamlined and strengthened EPA's ability to prevent and respond to catastrophic oil spills. A trust fund financed by a tax on oil is available to clean up spills when the reponsible party is incapable or unwilling to do so. The OPA requires oil storage facilities and vessels to submit plans to the Federal government detailing how they will repond to large discharges. EPA has published regulations for above ground storage facilites; the Coast Guard has done so for oil tankers. The OPA also requires the development of Area Contingency Plans to prepare and plan for oil spill response on a regional scale.

State

California Environmental Quality Act

Like NEPA, the California Environmental Quality Act requires the state to take a hard look at the environmental impacts of projects that require state or local government approval. Unlike NEPA, CEQA also requires appropriate mitigation of projects that contain significant environmental impacts. Specifically, CEQA states that agencies must adopt feasible mitigation measures in order to substantially lessen or avoid the otherwise significant environmental impacts of a proposed project. A "significant" impact is a "substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the project including land, air, water, minerals, flora, [and] fauna…"

CEQA also mandates that the responsible agencies consider a reasonable range of project alternatives that offer substantial environmental advantages over the project proposal. CEQA adds that the agency responsible for the project's approval must deny approval if there would be "significant adverse effects" when feasible alternatives or feasible mitigation measures could substantially lessen such effects.

Porter-Cologne Water Quality Control Act

Under California's Porter-Cologne Water Quality Control Act "any person discharging waste, or proposing to discharge waste, within any region that could affect the quality of the waters of the state" must file a report of the discharge with the appropriate Regional Water Quality Control Board. Pursuant to the act, the regional board may then prescribe "waste discharge requirements" (WDRs) that add conditions related to control of the discharge. Porter-Cologne defines "waste" broadly, and the term has been applied to a diverse array of materials, including nonpoint source pollution.

When regulating discharges that are included in the federal Clean Water Act, the state essentially treats WDRs and NPDES as a single permitting vehicle. Where Porter-Cologne is more stringent than the Clean Water Act, such as for discharges of nonpoint source pollution, WDRs alone must be applied to or waived for such discharges. This requirement, however, is not implemented as it should be, and indeed is simply ignored in a number of cases, particularly with respect to nonpoint source pollution. A bill passed in 1999 now requires the state and regional boards to review existing waivers of WDRs in an effort to ensure that needed regulatory controls are properly imposed.

California Endangered Species Act

The California Endangered Species Act (CESA) generally parallels the main provisions of the Federal Endangered Species Act and is administered by the California Department of Fish and Game. Under CESA, the term "endangered species" is defined as a species of plant, fish, or wildlife that is in serious danger of becoming extinct throughout all, or a significant portion of its range and is limited to species or subspecies native to California. CESA states that it is the "policy of the state" that state agencies should not approve projects as proposed which would "jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat essential to the continued existence of those species," if there are "reasonable and prudent alternatives available consistent with conserving the species or its habitat which would prevent jeopardy." However, CESA goes on to add that, in the event "specific economic, social, or other conditions make infeasible" such alternatives, individual projects may be approved if "appropriate" mitigation and enhancement measures are provided.

McAteer-Petris Act

Under the McAteer-Petris Act of 1965, the Bay Conservation and Development Commission (BCDC) has authority to plan and regulate activities and development in and around San Francisco Bay through policies developed in the San Francisco Bay Plan. This is essentially the San Francisco Bay counterpart to the California Coastal Act.

California Coastal Act

The California Coastal Act of 1976 granted state authority to the California Coastal Commission, in conjunction with local governments, to manage the conservation and orderly development of coastal resources through a comprehensive planning and regulatory program for the coast (excluding areas covered by the McAteer-Petris Act). The state's management program for the 1,100-mile Pacific Coast program was approved in 1977 by NOAA as consistent with the requirements for planning in the federal Coastal Zone Management Act. NOAA's approval was made pursuant to an agreement between the Coastal Commission and the Bay Conservation and Development Commission to develop mechanisms to integrate their two programs.

The Coastal Act contains specific policies relating to management of coastal development activities that affect the marine environment and coastal land resources. These policies are the standards used in the commission's planning and regulatory programs to ensure that the commission meets the act's mandate that the state "[p]rotect, maintain, and, where feasible, enhance and restore the overall quality of the coastal environment and its natural and manmade resources." The act also delegates planning and permitting authority to local governments through the Local Coastal Plan process.

Oil Spill Prevention and Response Act of 1990

The state's Office of Spill Prevention and Response (OSPR) was created in the aftermath of the Exxon-Valdez oil spill and the American Trader oil spill at Huntington Beach. The Lempert-Keene-Seastrand Oil Spill Prevention and Response Act of 1990 created OSPR within the Department of Fish and Game. The bill provided funding for OSPR's work by levying a tax on oil brought into the state and another on oil transported across the state by rail, truck, or pipeline. OSPR's mandate is to work with other DFG units, interested public, other agencies, clean-up companies, and oil companies to prevent oil spills, to develop response plans, and to implement those plans when spills occur.

The U.S. Coast Guard is OSPR's federal counterpart and response partner for these efforts. In addition, OSPR has responsibility for determining injuries to living natural resources and seeking compensation and restoration through civil litigation. More recently, OSPR's role has expanded from a focus on oil spills to a broader focus on spills of any material deleterious to living natural resources, and has expanded from marine waters to spills that may happen anywhere in California.

In addition, the act makes the State Lands Commission responsible for ensuring that all marine terminals and other oil and gas facilities within their jurisdiction use the best achievable methods to prevent accidents and resulting oil spills. The State Lands Commission has jurisdiction over all of California's tidal and submerged lands. Management responsibilities extend to activities within submerged lands and those within three nautical miles of shore.

Regional

Numerous regional and local initiatives have been launched to protect marine resources and wildlife. A few of the more significant initiatives are highlighted below.

CALFED

The San Francisco Bay-Delta Estuary is a significant habitat for numerous coastal and marine species and directly impacts the viability of many of the state's coastal watersheds and resources. However, years of mismanagement of this invaluable resouce has left its health seriously threatened. State-federal cooperation to restore the estuary was formalized in June 1994 with the signing of a framework agreement by the state and federal agencies with management and regulatory responsibility in the Bay-Delta Estuary. These "CALFED" agencies include the state Resources Agency, the California Environmental Protection Agency, the Department of the Interior, the Environmental Protection Agency, the Department of Commerce, the U.S. Army Corps of Engineers, and the Department of Agriculture. The framework agreement pledged that the state and federal agencies would work together on implementation of water quality standards, coordination of State Water Project and Central Valley Project operations with regulatory requirements, and development of long-term solutions to problems in the Bay-Delta Estuary.

The long-term goal of CALFED is to develop a comprehensive and balanced plan that addresses all of the resource problems in the estuary. A group of more than 30 citizen-advisors selected from California's agriculture, environmental, urban, business, fishing, and other interests with a stake in finding long-term solutions for the problems of the Bay-Delta Estuary has been chartered to advise the CALFED program on its mission and objectives, the problems to be addressed and proposed actions.

The program is following a three-phase process to achieve broad agreement on long-term solutions. First, a clear definition of the problems to be addressed and a range of solution alternatives were developed. Second, environmental impact reports are being prepared to identify impacts associated with the various alternatives. The program's final EIS was released in June 2000, proposing more reliable water deliveries to the Estuary to protect habitats, water quality and wildlife. Environmental impact reports will be prepared for each element of the selected solution. Implementation of the final CALFED Bay-Delta Estuary solution is expected to take 30 years.

Monterey Bay National Marine Sanctuary Water Quality Protection Program

The proximity of the Monterey Bay National Marine Sanctuary to the coast and its sheer size make the sanctuary vulnerable to numerous pollution problems in the eleven watersheds that drain into it. The quality of the water in the sanctuary is directly linked to the quality of the rainwater runoff and irrigation water from mountains, valleys, rivers, streams, and wetlands on the adjacent coastline. Key problems identified in the sanctuary and its watersheds include sedimentation, toxic pollutants in sediments, fish and shellfish, high fecal coliform levels, fish population declines, low flows in rivers and streams, wetlands alteration, and habitat degradation.

Recognizing that water quality is a key to ensuring protection for all sanctuary resources, a memorandum of agreement (MOA) was signed by eight federal, state, and local agencies in 1992, committing the agencies to working together to develop a Water Quality Protection Plan for the sanctuary. Led by sanctuary staff, over two dozen federal, state, local agencies and public and private groups have developed much of the planned comprehensive Water Quality Protection Program, addressing urban runoff, marina and boating pollution, monitoring, and runoff from agricultural activities and rural lands, in order to enhance and protect the sanctuary's physical, chemical and biological conditions. Implementation has begun on many of the action items in the plans.

Local

Implementation of CEQA and NEPA

One of the more common ways that coastal and marine resources are protected on a local level is through implementation of environmental review requirements under CEQA and NEPA. Projects requiring local, state or federal approval are generally subject to the review requirements in these statutes. Local and state projects also are subject to required mitigation under CEQA.

Coordinated Resource Management Planning

Coordinated Resource Management and Planning (CRMP) is a community-based program established by the federal Natural Resource Conservation Service. It uses a watershed-based approach to manage upstream lands in order to improve downstream water quality. CRMP emphasizes direct participation by everyone concerned with natural resource management in a given planning area. The concept underlying CRMP is that coordinating resource management strategies will result in improved resource management and minimized conflicts among land users, landowners, governmental agencies, and interest groups. The goals of CRMP are to protect, improve and maintain natural resources by addressing resource problems based on resource boundaries and through those who live, work and recreate on a given piece of land, and by avoiding artificial constraints by individual, agency or political boundaries.

CRMPs work with University of California Cooperative Extension program and the Resource Conservation Districts, who are signatories to the CRMP Memorandum of Understanding and who support this process through technical and other assistance to the local CRMP groups.

Marine Protected Areas

Marine Protected Areas (MPAs) are special ocean areas that are protected in some way above other marine areas in order to minimize disturbance. Depending on the level of use of such areas, benefits include biodiversity conservation, ecosystem protection, improved fisheries, enhanced recreation, improved water quality and expanded knowledge and understanding of marine systems.

As a tool for enhancing ocean resources and wildlife, MPAs are becoming increasingly popular. In 1999, the legislature passed the Marine Life Protection Act, which sets up a system for evaluating and coordinating MPAs in the state. In May 2000, President Clinton issued an executive order supporting MPAs and further defining their purpose.

Regulatory Gaps

California has lagged in implementing federal and state laws designed to protect the health of the state's waters. Years of budget cuts and bond act failures have left California's water quality protection programs underfunded and poorly implemented. Until the recent passage of Propositions 12 and 13, of the $2.9 billion in water bonds approved by California voters since 1970, only $10 million had been earmarked for nonpoint source pollution, the number one source of water pollution in the state. In addition, acquisition funding for protection of the state's lands, which helps prevent increasing pollution from urban and other runoff sources declined 80-90 percent over the last 10 years.

As a result, use of the vast majority of the state's surveyed tidal wetlands, bays, harbors, and estuaries is impaired or threatened in some way by water pollution. Examples of uses that are being impaired or threatened by pollution include drinking, fish consumption, aquatic life support, swimming, and aquaculture. The primary source of pollution in these waters is nonpoint source pollution. The state's lack of a detailed, comprehensive approach for addressing nonpoint source pollution is a major stumbling block in our efforts to stem the continuing degradation of these water bodies.

These water-use impairment figures are even more alarming in light of the fact that many of the state's waterways are monitored only infrequently or not at all. California does not yet have a system to comprehensively monitor water quality in the inland watershed, enclosed waters, or nearshore ocean zones, and the vast majority of California's waterways and small estuarine systems are not monitored by the state on a regular basis. Because of these deficiencies, it is difficult to comprehensively determine the health of these water bodies. In other words, the number of impaired water bodies that we know about is the minimum number of polluted water bodies in the state.

Federal water quality control programs that are not being implemented fully include the Clean Water Act's storm-water permitting program; the Clean Water Act's Section 303(d) program; and the state and federal antidegradation programs, which are designed to prevent cleaner waters from sliding down towards contamination.

With respect to the storm-water permit program, the state has allocated far fewer staff and other resources than needed to ensure full compliance with federal requirements. For example, at the current rate of facility inspections, the Los Angeles Regional Water Quality Control Board will not be able to make even one full round of inspections of regulated industries in its jurisdiction in 100 years. Moreover, the regional board has not moved forward with more than a handful of enforcement actions against non-filing facilities, even though there are between 12,000 and 17,000 facilities in the Los Angeles region that have not filed permit applications as required by law. For this reason, several environmental groups recently petitioned U.S. EPA to take away the state's authority to conduct the storm-water permit program in that region.

The state has identified over 500 water bodies as impaired under section 303(d) of the Clean Water Act. The limited monitoring information available indicates that the number of impaired waters is likely to be much higher. However, the state has completed only a scattering of plans for reducing pollution into these impaired waters, with the pace of production of new plans extremely slow and implementation uncertain.

With respect to antidegradation, the state has paid virtually no attention to protecting its cleaner waters, choosing instead to spend much of its limited time and funds on already impaired waters. Protecting the state's waters from increased pollution is not only beneficial to the health of those waters and the people who depend on them, it is also more cost-effective than cleaning up contaminated waters. Regulations implementing the federal Clean Water Act as well as State Water Board Resolution 68-16, call on the state and regional water boards to consider and address the impacts of their decisions on the overall health of the waters affected. However, this mandate has not been implemented fully, particularly with respect to nonpoint source discharges, leaving cleaner waters and associated habitats vulnerable to pollution.

Other state programs that are not being implemented fully include the state water board's Bay Protection and Toxic Cleanup Program (BPTCP) and its program of issuing waste discharge requirements for nonpoint source pollution under the Porter-Cologne Water Quality Control Act, as well as the Department of Fish and Game's program for addressing pollution under Fish and Game Code Section 5650.

The Bay Protection and Toxic Cleanup Program required monitoring for toxic pollution, identification of cleanup priorities, and development of standards for toxics in sediment, plans for cleaning up the toxics, and a funding mechanism to ensure that the dischargers that created the problem will pay for the cleanup. Much of the BPTCP's goal of identifying "hot spots" of toxic coastal contamination has been completed, leading to significant new knowledge about threats to marine wildlife. However, the original goal of actually cleaning up these hot spots remains unmet, and is unlikely to be met in the foreseeable future.

With respect to Porter-Cologne, the state has the authority to issue waste discharge requirements for both point and nonpoint source discharges. However, the full extent of this authority has never been used, particularly with respect to nonpoint source discharges, where such requirements are routinely waived. Increased permitting would increase the number of conditions on discharges, which would reduce this significant source of pollution in coastal and marine habitats.

Finally, implementation of Fish and Game Code Section 5650 has been weakened through recent statutory amendments and a lack of allocated funding. This section stated broadly that "it is unlawful to deposit in, permit to pass into, or place where it can pass into the waters of this state…[a]ny substance or material deleterious to fish, plant life, or bird life." This language gave the department wide latitude to protect marine habitats from problem discharges. However, the program was amended recently to exempt dischargers who hold state or regional water board discharge permits, on the assumption that those discharges are already being controlled. But, as noted above, the regional water boards are behind on fulfilling state and federal permit mandates. As a result, there is no assurance that permitted discharges will not be "deleterious" to fish, plants and birds.

Linda Sheehan
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Human Ecosystem Dimension

Human Benefits of the Marine Ecosystem

Marine ecosystems provide opportunities for consumptive and non-consumptive uses of marine resources. Some activities, such as commercial, recreational and subsistence fishing, kelp harvesting and harvesting of marine specimens for aquarium use, are consumptive in the sense that they result in permanent removal of ecosystem resources. Other activities (tidepooling, marine mammal and bird watching, kayaking and observational diving) are more commonly characterized as non-consumptive. However, the distinction between consumptive and non-consumptive use is not always clear cut, as activities that are not necessarily intended to be consumptive may sometimes result in inadvertent injury to marine animals or disruption of their habitat.

Marine ecosystems also benefit people who may never use or even see marine resources but nevertheless value their existence. Non-use value may be motivated by the desire to have ecosystem resources available for future use or by the satisfaction of knowing that such resources exist, regardless of whether they are ever put to human use.

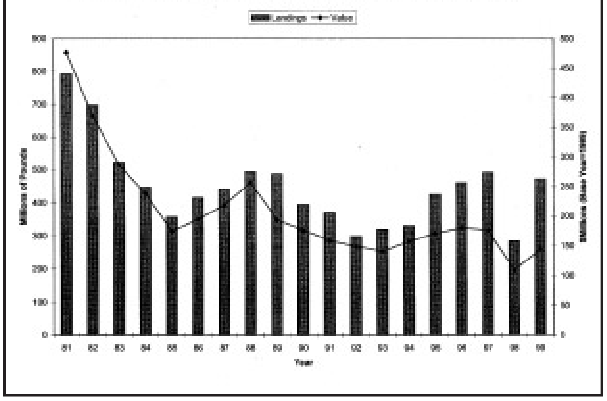
The remainder of this report focuses on the two major consumptive uses of marine resources— commercial and recreational fishing. The intent is not to diminish the importance of other sources of use and non-use value but rather to address informational and reporting requirements of the Marine Life Management Act.

Factors Affecting Commercial and Recreational Fishery Activity

Commercial and recreational fishery landings are affected by many factors. Landings tend to increase with stock abundance, as fish are easier and less costly to locate and harvest when they are at higher levels of abundance. The availability of some species on local fishing grounds may vary across seasons or years, depending on ocean temperature and other environmental factors. Weather conditions and economic circumstances (market demand and prices) may discourage or encourage fishing activity. Fishing behavior is also affected by regulatory restrictions, which are imposed for a variety of reasons and take a variety of forms.

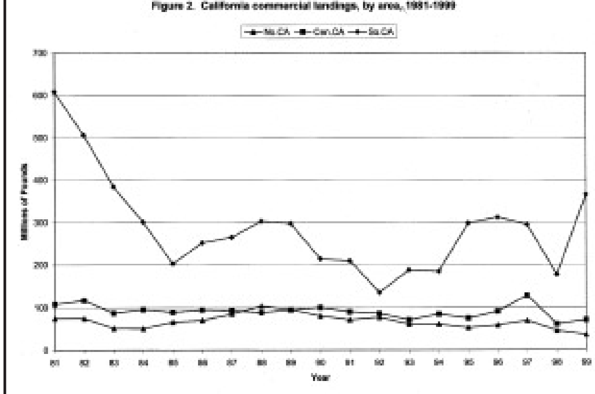
Regulations may be imposed for biological reasons. For instance, harvest restrictions may be imposed to protect a particular fish stock or to reduce incidental take of other stocks that are caught simultaneously with that stock. Regulations may be imposed to protect habitat or to reduce injury or mortality to marine mammals or seabirds that may result from interactions with fishing operations. Regulations may be imposed for economic reasons. For instance, seasons may be set to coincide with periods when a fish stock is in prime marketable condition or when market demand is high. Regulations may be imposed for social reasons, such as providing equitable harvest opportunities or reducing the potential for conflict among different sectors of a fishery.

Figure 1. Volume and ex-vessel value of commercial landings in California, 1981-1999



Regulations can take a variety of forms, including license and permit programs, harvest quotas, season closures, area closures, trip limits, bag limits (for recreational anglers), size limits and restrictions on quantity and type of gear. Reporting requirements such as landings receipts, logbooks or on-board observers may be imposed to ensure that fishery monitoring, management, enforcement and research needs are met. A particular type of regulation may serve different objectives, depending on the context in which the regulation is imposed. For instance, trip limits may be used to discourage targeting on a particular species while allowing a limited amount of incidental take of that species. Trip limits may be used to slow the harvest rate to enhance real-time monitoring capability in fisheries where quotas would otherwise be quickly exhausted. Trip limits may also serve economic objectives, such as lengthening the duration of the

Figure 2. California commercial landings, by area, 1981-1999



fishing season or ensuring that landings do not exceed processing capacity.

For fishing vessels and fish dealers, net economic benefit is properly measured as the difference between their gross revenues and economic costs. However, net economic benefits cannot be estimated for either of these fishery sectors, due to lack of complete economic data. Instead, landings by fishing vessels and landings receipts by fish dealers are described in terms of their ex-vessel value. Ex-vessel value overstates the economic value of the fishery to fishing vessels, as it does not include any consideration of harvesting costs. For dealers, ex-vessel value represents the cost of obtaining fish. Information on revenues earned from processing/marketing these landings is not generally available. In addition, some dealers may also process/market fish imported from other states or countries; the revenues and costs associated with these imported products are also not known.

Commercial Fisheries Landings and Ex-vessel Value

This section describes trends in the volume and ex-vessel value of California commercial landings. The harvest information presented here is based on landings receipts and therefore excludes discards and live bait catch. Fish may be discarded in commercial fishery operations for a variety of reasons. Discards may include fish that are of sublegal size, exceed a vessel's hold capacity or trip limit, or are not of marketable size or species. Information on the level of discards and discard mortality is generally not known. Live bait used by recreational fishermen is also not reported on landings receipts, since transactions between buyers and sellers of live bait typically take place at sea. Logbook data indicate that bait haulers harvest a maximum of 12 million pounds of live bait each year.

Figure 3. Ex-vessel value of California commercial landings, by area, 1981-1999

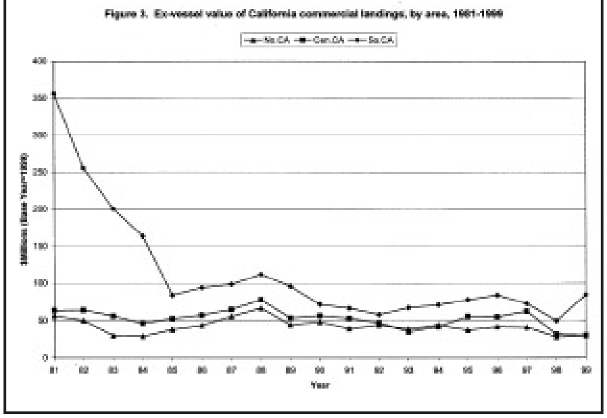
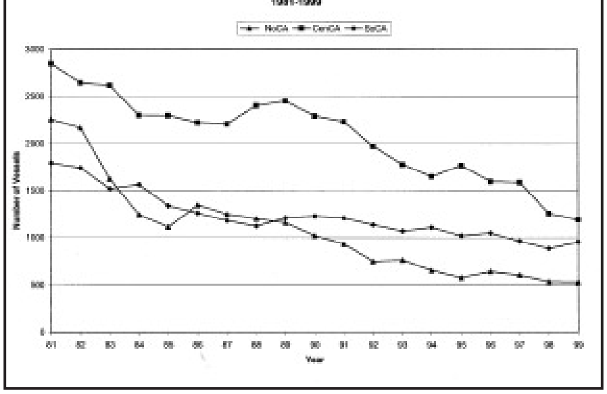


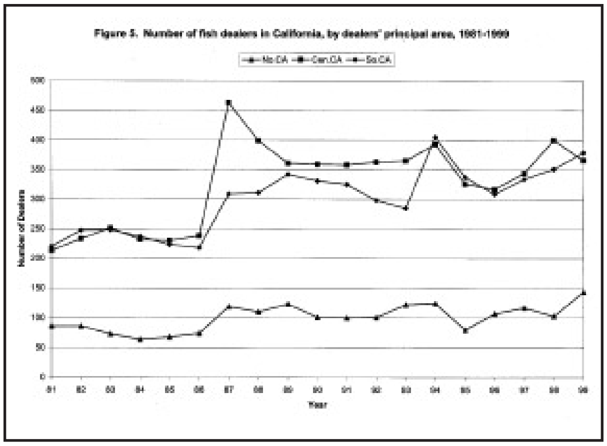
Figure 4. Number of commercial fishing vessels in California, by vessels' principal area, 1981-1999



Commercial landings in California decreased from 791.4 million pounds in 1981 to 472.1 million pounds in 1999. Ex-vessel revenues also fell during this period from $475.7 million to $144.4 million in 1999. All dollar values presented here and throughout the remaining of this report have been corrected for inflation to 1999 dollars. The precipitous decline experienced during the early-1980s was largely the result of a shift in tuna landings from California ports to less costly cannery operations in American Samoa and Puerto Rico. The decline in tuna landings and revenues has been compounded by declines in landings of species such as groundfish, urchin, shark and swordfish, salmon, abalone. Other species (*e.g.,* market squid, lobster, prawn, coastal pelagics) have been the target of expanding fisheries, while still others (*e.g.,* crab, Pacific herring, shrimp) exhibit no obvious pattern or trend in landings and revenues.

From 1995 through 1999, the species groups accounting for most of the ex-vessel value of California landings were (in descending order of value) groundfish, market squid, crab, albacore/other tunas, sea urchin, herring, shark/swordfish, salmon, coastal pelagics, lobster, prawn, shrimp and abalone. The species composition of landings and revenues varies significantly by area. Over 90 percent of the ex-vessel value of landings in northern California consists of groundfish, crab, shrimp and sea urchin. In central California, 90 percent of total ex-vessel value is contributed by groundfish, herring, salmon, crab, prawn, shark/swordfish and coastal pelagics. In southern California, 90 percent of total value is contributed by squid, albacore/other tuna, sea urchin, coastal pelagics, shark/swordfish, lobster and groundfish. Landings and revenues have historically been higher in southern California than in central or northern California. The major reason for this difference is the large contribution made by the high-volume squid and coastal pelagic fisheries to southern California landings and revenues.

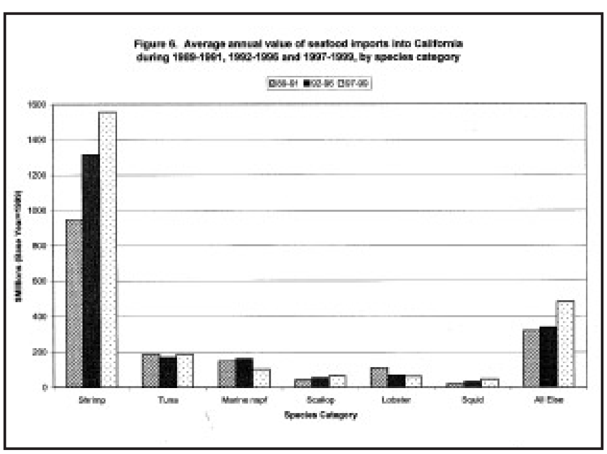
The State of California requires that all commercial fishing vessels, crew members, and fish businesses be licensed



to operate in the state, and further requires that all businesses and fishermen who accept seafood for commercial purposes maintain landings receipts. The state also imposes additional license and permit requirements that are specific to certain types of fishing activities. In addition, federal permits are required for vessels that qualify to participate in the groundfish and coastal pelagics limited-entry fisheries. Permits and licenses represent upper-bound estimates of fishery participation, as not all permit/license holders actively engage in fishery activity each year. The next two sections of this report describe the extent of actual participation in the harvesting and processing sectors.

Harvesting Sector

The number of commercial fishing vessels that land fish in California declined from 6,897 in 1981 to 2,690 in 1999. While the majority of these boats land fish solely at California ports, a significant minority also makes landings in Oregon or Washington. California boats may fish in other states as well (*e.g.,* Alaska); however, the extent of such activity is not known.



Categorizing vessels according to their "principal area" (*i.e.*, the area in which they made the plurality of their revenues from California landings), the statewide pattern of declining fleet size is evident in all areas. From 1981 to 1999, the number of boats declined from 2,256 to 532 (76 percent) in northern California, from 2,848 to 1,191 (58 percent) in central California, and from 1,793 to 967 (46 percent) in southern California. The number of boats has been consistently higher in central California than in the other two areas.

Just as some vessels engage in interstate fishing activity, a small but significant minority of vessels lands fish both inside and outside of their principal fishing area within California. From 1981 through 1999, 82 percent of vessels whose principal area was northern California made landings in northern California only, while the remaining 18 percent also made landings in other areas (mostly central California). Of vessels whose principal area was central California, 87 percent made landings in central California only, and 13 percent also made landings in northern and/or southern California. Of vessels whose principal area was southern California, 88 percent made landings in southern California only, and the remaining 12 percent also made landings in other areas (mostly central California).

The percent of boats earning less than $5,000 per year declined from 53 percent during the period from 1981 through 1985 to 34 percent during the 1995 through 1999 period, while the percent of boats accounting for 90 percent of the ex-vessel value of statewide landings increased from 20 percent (1981-1985) to 35 percent (1995-1999). The highly skewed revenue distribution characteristic of the early 1980s reflects the sizeable contribution of tuna fishery participants to total statewide revenues during those years. The tendency toward a less skewed distribution of revenue after the mid-1980s was apparent in northern, central and southern California as well as statewide. Nevertheless, the commercial fishery remains characterized by a large number of low-revenue vessels and a small number of high-revenue vessels, with hook-and-line

Street fish market, Fisherman's Wharf, San Francisco, CA
Credit: UC Davis Sea Grant

salmon and groundfish vessels disproportionately represented in the low-revenue segment.

From 1981 through 1999, ex-vessel revenue from California landings averaged $46,500 per boat and did not exhibit any consistent trend or pattern. However, the statewide average masks significant regional differences in this regard. From the 1981-1985 period to the 1994-1999 period, average revenue per boat increased significantly in northern California from $24,500 to $60,800, increased less dramatically in central California from $20,800 to $30,100, and declined in southern California from $126,000 to $74,900. The fishing opportunities that developed in southern California after the mid-1980s were not sufficient to compensate for the decline in revenues from the highly lucrative tuna fishery. Nevertheless, average revenue per boat is still higher in southern California than elsewhere in the state.

For the years 1995 through 1999, commercial landings and revenues were categorized into 23 different combinations of species and gear that depict major types of fishery activity in the state. Table II-7 describes average annual landings and revenues in each major fishery in northern, central and southern California during the 1995-1999 period, presented in declining order of revenue. For each fishery, the table also includes the number of participating vessels (defined as vessels who earned at least five percent of their California revenue from that fishery) and the number of participating vessels for whom the fishery is their "principal fishery" (that is, the fishery from which they derive the plurality of their California revenue).

Table II-8 characterizes the vessels in each principal fishery category in terms of average landings and revenues per year from the vessel's principal California fishery, from other California fisheries, and from Oregon and Washington fisheries. Average revenue per boat varies widely among fisheries, and tends to be lowest in the groundfish and salmon hook-and-line fisheries and highest in the trawl and seine fisheries. The distribution of average rev-

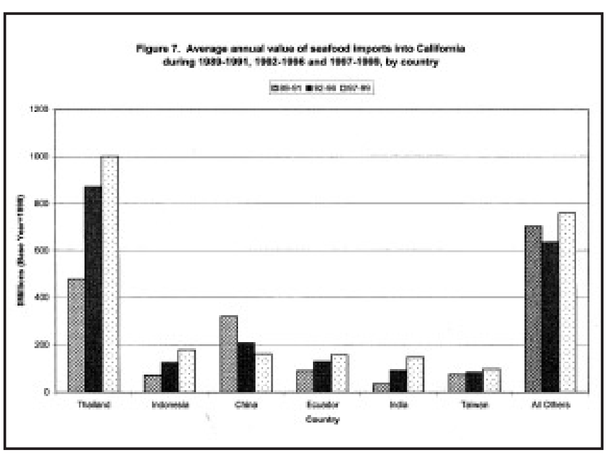


Figure 7. Average annual value of seafood imports into California during 1989-1991, 1992-1996 and 1997-1999, by country

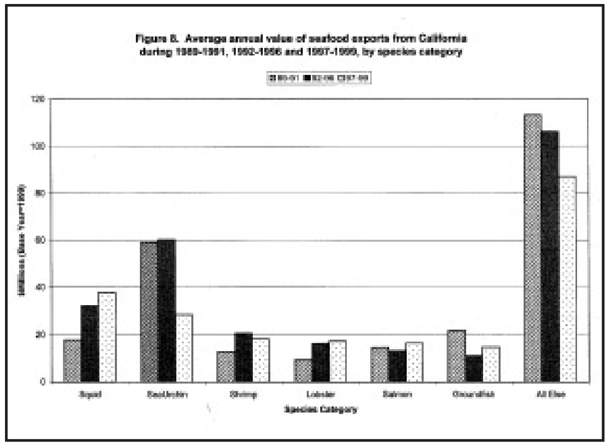


Figure 8. Average annual value of seafood exports from California during 1989-1991, 1992-1996 and 1997-1999, by species category

enue per vessel among fisheries is suggestive of vessels' economic dependence on their principal fishery relative to other California fisheries and to Oregon and Washington fisheries. For instance, some vessels (*e.g.*, shrimp trawl in northern California) earn more revenue from their out-of-state landings than their California landings. For these vessels in particular, adverse conditions in their out-of-state fisheries can result in a significant diversion of effort to the California fisheries in which they also participate, and vice versa. At the other end of the spectrum are vessels that derive most if not all of their revenue from their principal fishery (*e.g.*, urchin diving in central California). Because of this lack of diversification, such vessels are particularly vulnerable to changing conditions in the fishery in which they do participate. It should be cautioned that ex-vessel revenue comparisons are merely suggestive of differences in economic value, as such comparisons do not account for differences in operating costs across fisheries.

According to Tables II-7 and II-8, the highest-revenue fisheries do not necessarily support the largest numbers of boats or generate large ex-vessel revenues per boat. For instance, the salmon hook-and-line fishery is the third largest contributor to ex-vessel revenue in central California ($6.5 million) and serves as the principal fishery for 579 vessels, yet generates only $9,000 in ex-vessel revenue per boat per year. The tuna seine fishery is the third largest contributor to ex-vessel revenue in southern California ($9.6 million) and yields higher revenue per boat than any other fishery statewide ($914,600 per boat per year); yet tuna seine is the principal fishery for only 10 boats.

The Tables in II-3 describe the most common combinations of fisheries in which vessels participated from 1995 through 1999. The number in each rectangle represents the average annual number of vessels that participated solely in that fishery during the 1995-1999 period, and the number on each line connecting the rectangles represents the average annual number of vessels that participated

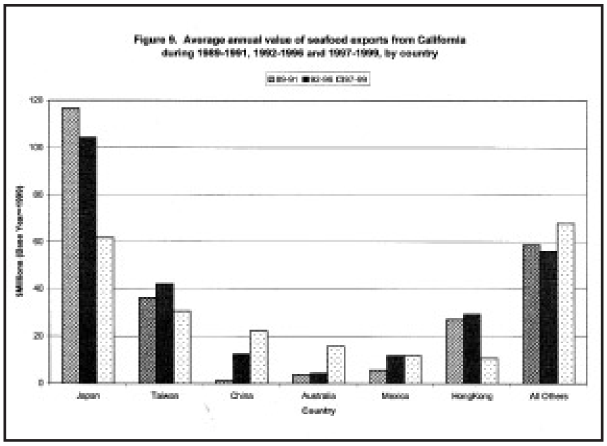


Figure 9. Average annual value of seafood exports from California during 1989-1991, 1992-1996 and 1997-1999, by country

in that particular two-fishery combination. The asterisks denote the most common three-fishery combinations. Only fisheries or fishery combinations that represent an annual average of at least three vessels appear in the figure. Since the abalone dive fishery has been closed to commercial fishing since 1998, the 1995-1999 statistics on that fishery included in Tables II-7, II-8 and II-3 include the recent years of zero fishing activity (1998-1999).

Patterns of behavior vary significantly by area. In northern California, crab pot is the predominant fishery in terms of the number of vessels that participate solely in that fishery (153) and the frequency with which crab pot vessels also engage in other fisheries. In central California, the largest numbers of vessels engage in the salmon hook-and-line (419), groundfish hook-and-line (332) and herring (121) fisheries. The most common combinations involve salmon and groundfish hook-and-line (92), and salmon hook-and-line and crab pot (88). In southern California, the largest numbers of vessels engage in the sea urchin (156), groundfish hook-and-line (119) and lobster pot (102) fisheries. Groundfish hook-and-line vessels are also notable in terms of the number of other fisheries in which they participate. While interactions exist among the prawn, groundfish and cucumber trawl fisheries, trawl fisheries in southern California are seldom pursued in combination with other gear types.

The Processing Sector

Between 1981 and 1999, the number of fish dealers increased statewide from 519 to 888. Categorizing dealers according to their "principal area" (*e.g.,* the area of California accounting for the plurality of the ex-vessel value of their landings receipts), the number of dealers increased from 86 to 143 (+66 percent) in northern California, from 213 to 366 (+42 percent) in central California, and from 220 to 379 (+72 percent) in southern California. The number of dealers has been consistently lower in northern California than in other areas of the state.

The increase in numbers of dealers has followed a distinctive pattern: a relatively stable number of dealers during the 1981-1986 period, followed by a stepwise increase in 1987 and relatively stable (albeit higher) numbers thereafter. The ex-vessel value of average annual landings receipts per dealer shows a parallel though opposite stepwise pattern. From the 1981-1986 period to the 1987-1999 period, the average annual number of dealers increased from 547 to 825, while the value of landings receipts per dealer decreased from $531,500 to $209,500 over the same period. The decline in average value per dealer is largely due to the post-1986 increase in the number of dealers for whom the value of landings was less than $5,000. Many of these small dealers are commercial fishing vessel operators who sell their landings directly to restaurants and markets rather than to a processor. The decline in annual value per dealer has been particularly severe in southern California (falling from $805,500 in 1981-1985 to $233,900 in 1986-1999), where the effect of the post-1986 increase in the number of small dealers was compounded by the drastic reduction in high-priced tuna landings experienced in that area through the early 1980s. Since the decline of the tuna fishery, northern California has generally replaced southern California as the area with the highest average value of landings per dealer.

The distribution of landings receipts among dealers is highly skewed, with 16 percent of the dealers responsible for 90 percent of the value of landings from 1987 through 1999. This pattern is repeated throughout the state, with 20 percent of dealers in northern California and 16 percent of dealers in central and southern California accounting for 90 percent of ex-vessel value in their respective areas of the state.

The Trade Sector

Generally speaking, imports into the U.S. are categorized by their initial port of entry, which is not necessarily their final destination. Thus, some imports that

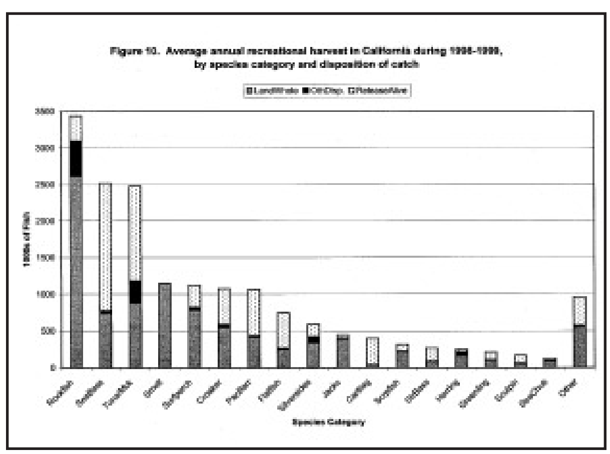


Figure 10. Average annual recreational harvest in California during 1996-1999, by species category and disposition of catch

enter the U.S. at Nogales, Arizona and Honolulu, Hawaii likely end up in California markets. For this reason, seafood imports into California should be considered suggestive rather than definitive estimates of California consumer demand for imported seafood.

Like imports, exports from the U.S. are categorized in terms of the port from which they left the U.S. Thus, not all exports from a state necessarily originate from fisheries in that state. California exports may include fish landed in Mexico and subject to additional handling or processing in California before being sold to a third country. Exports also include fish that were imported and not sold, then re-exported in substantially the same condition as when imported.

The dollar value attached to imports represents the Customs value, that is, the price actually paid for merchandise when sold to the U.S., excluding U.S. import duties, freight, insurance and other charges incurred in bringing the goods to the U.S. The dollar values attached to exports and re-exports is the "free alongside ship" value, that is, the value at the port of export, defined as the transaction price including charges and transportation costs incurred in bringing the merchandise to the port of exportation.

Between 1989 and 1999, the value of seafood products imported into California increased from $1.6 trillion to $2.4 trillion, while imports into the U.S. as a whole increased from $6.9 trillion to $9.0 trillion. About 30 percent of the value of U.S. imports enters the country at California ports. Shrimp imports, which have increased dramatically over the past decade, have consistently comprised about 60 percent of the value of California seafood imports. The average annual value of shrimp imports was $1.6 trillion during the 1997-1999 period. Significant though much smaller amounts of tuna ($187.6 million), unspecified marine fish ($104.1 million), scallop ($65.1 million), lobster ($62.2 million) and squid ($47.0 million) were also imported during that period. The countries from which California received most of its seafood imports

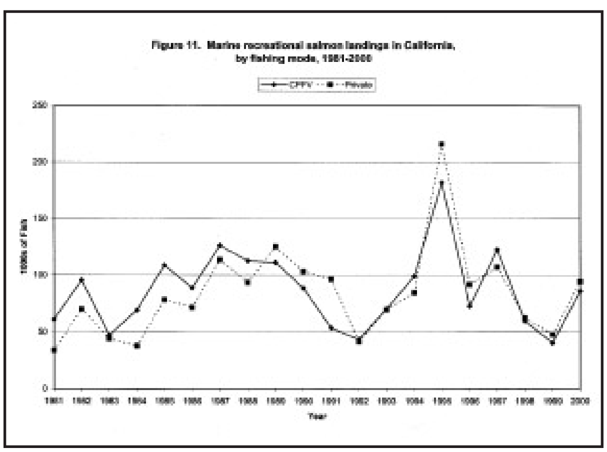


Figure 11. Marine recreational salmon landings in California, by fishing mode, 1981-2000

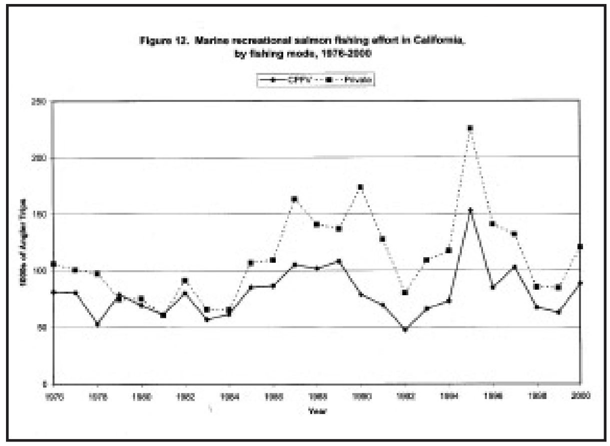


Figure 12. Marine recreational salmon fishing effort in California, by fishing mode, 1976-2000

during the 1997-1999 period (in order of declining annual import value) were Thailand ($999.6 million), Indonesia ($179.1 million), China ($162.5 million), Ecuador ($157.9 million), India ($148.6 million) and Taiwan ($99.4 million). Imports from all of these countries except China have been on a generally increasing trend over the past decade.

From 1989 through 1999, the value of seafood products exported from California and from the U.S. as a whole averaged $246.2 million and $3,215.3 million respectively. About eight percent of total U.S. seafood exports originated from customs districts in California. In recent years (1997-1999), squid has replaced sea urchin as California's major export. The major species groups comprising California exports during the 1997-1999 period (in order of declining average annual value) were squid ($37.9 million), sea urchin ($28.5 million), shrimp ($18.3 million), lobster ($17.4 million), salmon ($16.6 million) and groundfish ($14.7 million). Although exports to Japan have declined significantly over the past decade, Japan remains the major recipient of California exports. California's major seafood export trading partners from 1997 through 1999 (in order of declining annual export value) were Japan ($61.7 million), Taiwan ($30.6 million), China ($22.2 million), Australia ($15.7 million), Mexico ($11.9 million) and Hong Kong ($10.8 million).

Sport and Subsistence Fisheries

Some fishermen do not earn revenue from their catch but rather fish for pleasure and/or to provide food for personal consumption. The economic value of the sport/subsistence (hereafter loosely referred to as "recreational") fishery depends on which segment of the fishery is being considered. For instance, the value of fishing to anglers would be measured by consumer surplus, that is, the maximum amount that anglers would be willing to pay for the fishing experience over and above what they actually pay. The value of fishing to businesses that provide services to anglers, such as commercial passenger

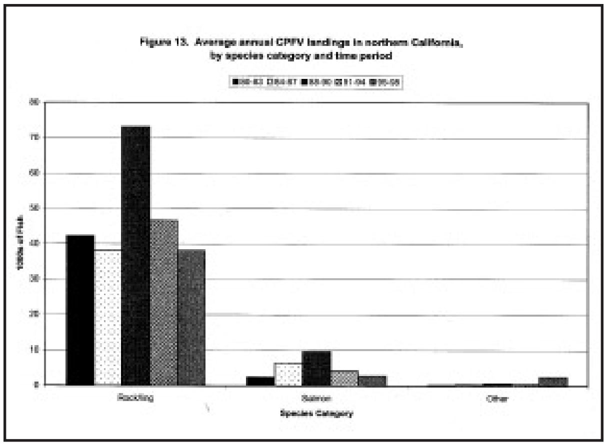


Figure 13. Average annual CPFV landings in northern California, by species category and time period

fishing vessels (CPFVs), would be measured by the difference between their gross revenues and economic costs. The economic impact of fishing on local economies would be measured by the multiplier effects on income and employment that occur as money spent by anglers moves through the economy. Collection and analysis of data needed to estimate these various types of economic effects are underway. Until such studies are completed, all that is available at this time are approximate estimates of angler expenditures.

Effort and Harvest

Approximately 4.7 million marine recreational angler trips were made annually in California during 1998-1999 — 2.9 million trips (61 percent) in southern California (Santa Barbara County and southward) and 1.9 million trips (39 percent) in central/northern California (San Luis Obispo County and northward). The proportion of total effort in each area associated with man-made structures (e.g., piers), beaches, CPFVs and private boats was 22 percent, 10 percent, 22 percent and 46 percent respectively in southern California, and 24 percent, 18 percent, nine percent and 49 percent in central/northern California. Approximately 17.8 million fish were harvested annually during 1998-1999, of which 9.6 million were landed in whole condition, 7.1 million were discarded alive, and 1.2 million were used as bait, filleted, given away or discarded dead.

Harvest levels vary significantly across species groups. During 1998-1999, the major components of harvest included rockfish (3.4 million fish), sea basses and tuna/mackerel (2.5 million fish each), and smelt, surfperch, croakers and Pacific barracuda (1.1 million fish each). Flatfish, silversides, jacks, sharks, rays, scorpionfish, striped bass, herring greenlings, sculpins and sea chubs made smaller though significant contributions to total harvest. The percentage of total catch retained by anglers or discarded dead (*e.g.,* not released alive) varies widely, ranging from a high of 85-90 percent for smelt, rockfish, jacks and herring to a low of 11 percent for cartilaginous fish.

Harvests vary across fishing modes and areas as well as species. During 1998-1999, annual harvests (excluding fish released alive) ranged from highs of 1,995,000 fish for CPFV anglers and 2,171,000 fish for private boat anglers in southern California, to lows of 344,000 fish for southern California beach anglers and 600,000 fish for central/northern California anglers fishing from man-made structures. Sea basses, tuna/mackerel, Pacific barracuda, California scorpionfish and jacks are much more commonly caught in southern California, while striped bass and salmon are more commonly caught in central/northern California. Rockfishes are an important component of boat-based harvests in southern California and the dominant component in northern California.

Recreational Fishery Expenditures

Based on the average annual number of marine recreational fishing trips made in U.S. waters during 1998-1999, aggregate annual trip-related expenditures were estimated to be approximately $202.0 million for southern California and $107.9 million for central/northern California. These estimates, combined with license, fishing gear and boat-related expenses of $128.4 million in southern California and $68.6 million in central/northern California, bring total annual statewide angler expenditures to $506.9 million.

Additional Information on the Salmon and CPFV Sport Fisheries

DFG sponsors a number of data collection programs that provide detailed information regarding certain segments of the marine sport fishery. One such program is the Ocean Salmon Project (OSP), which provides informa-

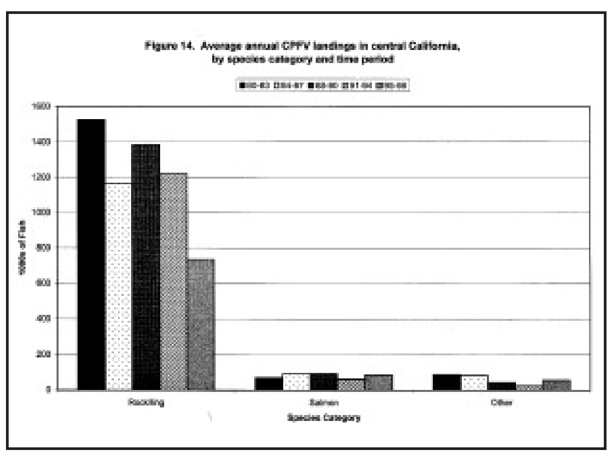
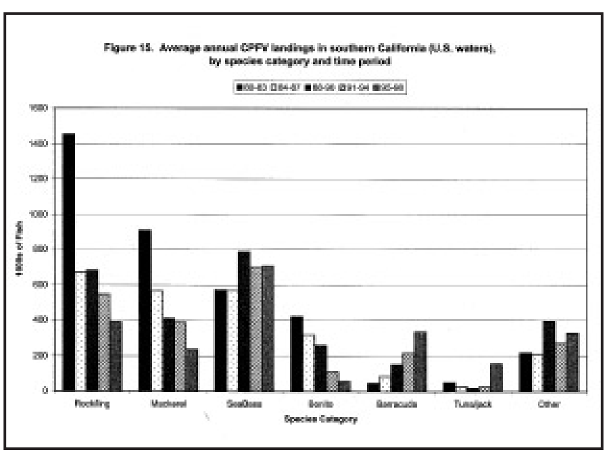


Figure 14. Average annual CPFV landings in central California, by species category and time period

tion on harvest and effort in California's ocean salmon fisheries (both recreational and commercial). It also sponsors a CPFV logbook program. Not all CPFVs participate in the program and the participation rate varies somewhat from year to year. Nevertheless, logbook-based estimates of effort and catch are generally considered to be useful indicators of trends in the CPFV fishery.

According to data collected in the OSP, recreational salmon landings and effort in both central and northern California were lower and less variable in the years prior to 1985 than they have been in subsequent years 1985 through 2000. Record low levels of landings and effort were experienced by both CPFV and private boat anglers in 1992 and record highs in 1995. While CPFV and private boat landings have been markedly similar over time, fishing effort has been consistently higher for private boats than CPFVs. From 1985 through 2000, annual salmon landings averaged 91,600 fish for CPFVs and 93,600 for private boats, while annual effort averaged 86,200 CPFV trips and 128,300 private boat trips. Neither landings nor effort exhibit any consistent long term trend.

According to data collected in CPFV logbooks, the number of CPFVs that participate annually in the marine recreational fishery averaged 297 boats from 1980 through 1998. Categorizing CPFVs according to their "principal area" (*e.g.,* the area in which they made the plurality of their fishing trips), the number of northern California CPFVs increased from an annual average of 18 boats during the 1980-1987 period to 30 boats during the 1988-1991 period, then decreased to an average of 13 boats during the 1992-1998 period. The number of central California CPFVs declined from an annual average of 137 boats during the 1980-1991 period to 105 boats during the 1992-1998 period. The CPFV fleet in southern California, many of which fish in Mexican as well as U.S. waters, increased in size from an average of 145 boats (1980-1994) to 183 boats (1995-1998). Of these 183 boats, 119 fished exclusively in U.S. waters, 58 fished in both U.S. and Mexican waters, and five fished exclusively in Mexican waters.



The number of CPFV angler trips in northern California averaged 6,782 (1980-1984), increased to 13,271 (1985-1991), then declined to 6,087 (1992-1998). In central California, fishing effort declined from an annual average of 206,121 angler trips (1980-1991) to 159,634 angler trips (1992-1998). For CPFVs based in southern California, fishing effort in U.S. waters experienced peaks in 1980-1982, 1990 and 1997-1998, while effort in Mexican waters peaked in 1984-1985 and 1997-1998. Fishing effort in southern California (in both U.S. and Mexican waters) displays no obvious trend over time.

Paralleling the changes in fishing effort, CPFV landings in northern California also increased through the 1980s, peaked in the late 1980s and early 1990s, then declined throughout the 1990s. This same trend was followed by both major components of northern California landings – rockfish/lingcod and salmon. Landings of "other" species, which have historically been very modest, were augmented by crab harvests from 1995 through 1998, when CPFVs began employing crab pots on fishing trips to help supplement declining harvests of finfishes. Central California landings, which ranged from 1.5 to 1.8 million fish during the early 1980s, have declined to well under one million fish in recent years. This decline has been largely driven by the precipitous decline in rockfish/lingcod landings. Salmon landings and landings of "other" species (including species such as crab, striped bass, sturgeon, flatfishes, mackerel, tuna, shark) followed no obvious trend. Landings associated with southern California trips in U.S. waters declined from well over four million fish during the early 1980s to around two million fish during the late 1990s. Increases in sea bass and barracuda landings during 1980-1998 were overshadowed by much larger declines in rockfish, mackerel and bonito landings. Tuna/jack landings do not follow any obvious long term trend, although they have been unusually high in recent years. "Other" landings include a diversity of species, including California scorpionfish, ocean whitefish, sea chubs, wrasses, croakers and flatfishes among others.

Since 1995, the CPFV logbook database has included information that allows fishing trips to be distinguished from diving trips and also allows trips to be distinguished by target species. From 1995 through 1998, diving trips comprise a very modest proportion of total CPFV activity in both northern and central California. CPFV fishing trips in northern California were targeted largely at salmon (39 percent), rockfish/lingcod (48 percent) and salmon and rockfish/lingcod combined (10 percent). CPFV fishing trips in central California were targeted at salmon (45 percent), rockfish/lingcod (35 percent), salmon and rockfish/lingcod (three percent), and striped bass/sturgeon, shark, tuna and other/unspecified species (17 percent). From 1995 through 1998, the contribution of salmon to total CPFV landings in northern and central California (seven percent and 10 percent respectively) was much lower than the proportion of trips targeted at salmon. Conversely, the rockfish/lingcod contribution to total northern and central California landings (88 percent and 84 percent respectively) was much higher than the proportion of trips targeted at rockfish/lingcod. Such marked disproportionalities between landings and effort highlight the large differences in catch-per-unit-effort that can exist among species groups. The singular reliance of northern and central California CPFVs on salmon, rockfish and lingcod harvests and the unprecedented regulatory restrictions on harvests of these species in recent years are significant contributing factors to the decline in effort and landings experienced in northern and central California in recent years.

Southern California CPFVs participate in a range of fishing and diving activities. From 1995 through 1998, about 79 percent of angler trips made by southern California boats involved fishing in U.S. waters, 14 percent involved fishing in Mexican waters, seven percent involved diving in U.S. waters, and less than one percent involved dive trips in Mexican waters. Of the 183 CPFVs that operated in southern California during 1995-1998, 63 fished in Mexican waters. Mexican as well as California fishing regulations are an important consideration for this significant minority of southern California CPFVs.

From 1995 through 1998, 91 percent of southern California CPFV fishing trips in U.S. waters were not targeted at any particular species, reflecting the prevalence of freelance trips on which anglers are provided with the opportunity to catch a diversity of species. Of the remaining nine percent of trips, two percent were specifically targetine tuna and seven percent rockfish/lingcod. About 55 percent of total rockfish/lingcod landings in southern California were made on trips specifically targeting rockfish/lingcod and the remaining 45 percent landed on freelance trips. This highlights one of the complexities associated with management of the southern California CPFV fishery, that is, how to meet harvest goals for managed species (like rockfish and lingcod) that are taken jointly with other species without unduly restricting harvests of these other species.

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Table II-1. Commercial landings (millions of pounds), by year and species group, 1981-1999.[1]

Year	Groundfish	Squid	Crab	Alb/Other Tuna	Urchin	Herring	Shark/Sword	Salmon
1981	94.4	51.8	11.8	337.1	26.5	13.1	4.8	6.0
1982	116.7	36.9	8.2	251.6	19.5	23.4	5.7	8.0
1983	90.0	4.0	6.7	248.7	17.8	17.7	5.8	2.4
1984	90.1	1.2	7.0	182.4	15.1	8.5	7.6	2.9
1985	95.0	22.7	7.9	68.2	20.1	17.6	8.9	4.3
1986	92.5	46.9	9.8	69.0	34.1	16.9	6.7	7.3
1987	91.8	44.1	8.6	80.6	46.1	18.6	5.3	8.8
1988	88.5	82.1	12.7	75.7	52.0	19.1	4.3	14.2
1989	94.4	90.2	7.2	55.5	51.4	20.6	4.5	5.6
1990	86.7	62.7	12.3	37.4	45.3	16.5	3.5	4.3
1991	79.7	83.2	6.0	19.0	42.3	16.3	3.1	3.7
1992	77.3	28.9	9.9	20.6	33.2	14.2	3.3	1.6
1993	62.4	94.4	13.5	24.9	27.0	9.6	3.5	2.5
1994	54.8	122.0	14.6	26.0	23.9	6.7	3.4	3.1
1995	63.5	154.9	10.4	26.1	22.3	10.4	2.4	6.6
1996	62.4	177.6	13.6	42.4	20.1	12.2	2.5	4.1
1997	65.5	155.1	11.3	37.2	18.1	20.8	3.1	5.3
1998	50.6	6.6	12.1	38.1	10.4	4.5	2.8	1.8
1999	33.1	201.8	9.6	24.6	14.2	5.2	3.8	3.8

Table II-1. Commercial landings (millions of pounds), by year and species group, 1981-1999.[1] (continued)

Year	CPS	Lobster	Prawn	Shrimp	Nearshore	Abalone	All Else	Total
1981	232.6	0.5	0.6	5.3	2.6	1.1	3.2	791.4
1982	215.7	0.5	0.4	5.4	2.3	1.2	3.2	697.8
1983	122.9	0.5	0.3	2.1	1.5	0.8	1.7	522.8
1984	123.7	0.4	0.6	3.0	2.3	0.8	1.5	447.3
1985	102.0	0.4	1.0	4.6	3.0	0.8	1.3	357.6
1986	120.8	0.5	0.8	7.0	2.1	0.6	1.1	416.1
1987	124.7	0.4	0.3	8.2	2.1	0.8	1.5	442.1
1988	129.2	0.6	0.3	11.5	2.3	0.6	1.7	494.8
1989	136.1	0.7	0.4	14.6	2.1	0.7	3.6	487.5
1990	106.2	0.7	0.4	10.3	2.0	0.5	6.0	394.9
1991	99.9	0.6	0.4	11.8	2.9	0.4	1.7	371.2
1992	85.7	0.6	0.3	19.6	1.8	0.5	1.3	298.9
1993	67.9	0.6	0.4	8.6	2.1	0.5	1.8	319.8
1994	57.6	0.5	0.6	12.1	3.1	0.3	1.7	330.4
1995	115.7	0.6	0.8	6.8	3.2	0.3	1.4	425.4
1996	107.5	0.7	1.1	10.6	3.4	0.2	3.3	461.6
1997	151.2	0.9	1.1	15.7	2.7	0.1	4.2	492.3
1998	147.2	0.7	1.3	3.0	1.4	0.0	3.3	283.9
1999	163.4	0.5	2.0	5.8	1.4	0.0	2.9	472.1

[1] "Nearshore" includes non-rockfish species caught in nearshore areas (*e.g.*, California sheephead, white croaker, white seabass).

Table II-2. Ex-vessel value ($millions, base year=1999), by year and species group, 1981-1999.[1]

Year	Groundfish	Squid	Crab	Alb/Other Tuna	Urchin	Herring	Shark/Sword	Salmon
1981	38.3	8.5	17.2	317.6	8.4	7.9	9.6	25.3
1982	46.5	5.6	13.6	198.7	5.6	15.8	12.5	31.5
1983	36.5	1.1	14.0	163.1	5.8	18.9	13.7	7.0
1984	35.8	0.4	14.3	118.2	5.3	2.8	20.7	11.4
1985	39.9	5.3	14.7	36.6	6.8	8.7	23.1	15.3
1986	42.8	6.2	17.9	38.3	13.4	7.6	20.8	20.2
1987	44.5	5.3	15.2	48.3	17.9	7.9	18.2	32.6
1988	40.1	10.2	21.0	55.1	25.2	7.4	15.2	52.5
1989	40.7	8.7	11.3	32.8	28.4	5.9	16.6	16.5
1990	37.2	5.7	21.8	18.4	29.7	10.5	10.7	14.1
1991	34.4	7.2	10.0	9.4	39.5	11.1	9.3	10.5
1992	34.9	2.8	14.1	11.5	33.9	10.5	9.6	5.1
1993	28.0	11.3	16.4	15.2	29.4	2.8	10.9	6.3
1994	28.2	15.6	21.4	16.5	27.7	3.5	11.5	7.0
1995	38.7	23.7	16.9	11.4	24.1	10.3	7.8	12.4
1996	37.8	22.8	19.5	23.5	19.6	15.8	7.1	6.3
1997	35.8	21.2	20.8	20.1	15.7	15.6	7.3	7.5
1998	25.0	1.7	21.8	19.0	8.0	0.6	6.7	3.1
1999	22.4	33.3	18.2	16.3	13.4	2.2	9.1	7.4

Year	CPS	Lobster	Prawn	Shrimp	Nearshore	Abalone	All Else	Total
1981	23.7	2.7	1.6	5.3	2.8	3.5	4.0	475.7
1982	21.1	3.0	1.7	5.4	1.2	3.6	4.0	369.6
1983	15.5	3.0	0.8	2.1	0.9	2.6	1.2	286.3
1984	14.7	2.6	0.8	3.0	1.1	3.2	1.2	238.4
1985	11.5	2.7	1.3	4.6	1.8	3.4	1.0	174.4
1986	12.7	3.1	1.5	7.0	1.3	2.6	0.9	194.7
1987	11.0	2.9	1.0	8.2	1.3	3.3	1.2	218.7
1988	12.7	4.2	1.3	11.5	1.4	2.6	1.3	256.7
1989	12.3	5.0	1.3	14.6	1.2	3.9	2.0	193.4
1990	7.9	4.8	1.9	10.3	1.2	3.0	3.6	176.5
1991	8.3	4.4	2.1	11.8	1.5	2.1	1.5	158.8
1992	7.1	4.4	1.7	19.6	1.0	3.2	1.4	149.3
1993	4.2	4.0	2.6	8.6	0.6	3.5	2.6	141.2
1994	4.1	3.8	3.2	12.1	2.0	2.9	2.0	157.0
1995	5.6	5.1	3.3	6.8	2.1	2.7	1.0	170.5
1996	5.6	5.3	4.4	10.6	2.0	2.3	1.4	180.5
1997	8.4	7.0	5.8	15.7	1.8	1.1	1.2	176.5
1998	6.8	4.8	6.4	3.0	1.6	0.0	1.3	109.0
1999	7.4	3.7	5.8	5.8	1.3	0.0	1.1	144.4

[1] "Nearshore" includes non-rockfish species caught in nearshore areas (*e.g.*, California sheephead, white croaker, white seabass).

Table II-3. Average annual landings and ex-vessel value during 1995-1999, by area and major species group.

Northern California

Species Group	Pounds x 1000	Percent	(Base Year $=1999)	Percent
Groundfish	30,233.7	57%	13,564.4	38%
Crab	8,067.0	15%	13,257.6	37%
Shrimp	6,425.7	12%	3,531.2	10%
Urchin	3,321.6	6%	2,724.9	8%
Albacore/Other Tuna	1,105.3	2%	951.8	3%
All Else	3,402.0	7%	1,467.9	4%
Total	52,555.3	100%	35,497.8	100%

Central California

Species Group	Pounds x 1000	Percent	(Base Year $=1999)	Percent
Groundfish	22,771.8	27%	14,985.8	32%
Herring	10,431.2	12%	8,800.1	19%
Salmon	4,131.5	5%	6,939.9	15%
Crab	2,428.0	3%	5,135.0	11%
Prawn	335.6	0%	2,279.0	5%
Shark/Swordfish	758.9	1%	2,093.4	5%
Coastal Pelagics	32,000.3	38%	1,499.2	3%
Albacore/Other Tuna	1,618.6	2%	1,448.6	3%
Shrimp	1,912.5	2%	1,314.0	3%
Market Squid	7,709.4	9%	1,197.8	2%
All Else	1,192.4	1%	1,181.2	2%
Total	85,290.2	100%	46,874.0	100%

Southern California

Species Group	Pounds x 1000	Percent	(Base Year $=1999)	Percent
Market Squid	131,468.9	45%	19,344.8	26%
Albacore/Other Tuna	30,924.4	11%	15,662.8	21%
Urchin	13,057.8	5%	12,906.9	18%
Coastal Pelagics	104,979.2	36%	5,261.4	7%
Shark/Swordfish	2,059.3	1%	5,229.5	7%
Lobster	683.1	0%	5,174.6	7%
Groundfish	2,007.4	1%	3,382.5	5%
Prawn	915.9	0%	2,813.2	4%
Crab	891.2	0%	1,067.1	1%
All Else	2,237.8	1%	2,974.6	4%
Total	289,225.0	100%	73,817.4	100%

Total California

Species Group	Pounds x 1000	Percent	(Base Year $=1999)	Percent
Groundfish	55,012.9	13%	31,932.7	20%
Market Squid	139,187.8	33%	20,546.4	13%
Crab	11,386.1	3%	19,459.6	13%
Albacore/Other Tuna	33,648.2	8%	18,063.1	12%
Urchin	17,040.0	4%	16,151.1	10%
Herring	10,628.9	2%	8,910.9	6%
Shark/Swordfish	2,915.3	1%	7,609.2	5%
Salmon	4,348.7	1%	7,347.7	5%
Coastal Pelagics	137,003.8	32%	6,764.9	4%
Lobster	683.2	0%	5,175.5	3%
Prawn	1,261.4	0%	5,157.7	3%
Shrimp	8,373.9	2%	4,876.8	3%
Abalone	121.7	0%	1,205.1	1%
All Else	5,458.6	1%	2,988.4	2%
Total	427,070.5	100%	156,189.2	100%

Table II-4. Number of vessels that make commercial landings in California, categorized according to whether or not they also make landings in Oregon or Washington, 1981-1999.

Year	CA Only	CA & OR	CA & WA	CA, OR & WA	Total
1981	5,832	787	135	143	6,897
1982	5,762	555	106	130	6,553
1983	5,257	396	83	94	5,830
1984	4,779	261	103	31	5,174
1985	4,451	235	87	37	4,810
1986	4,305	365	106	69	4,845
1987	4,162	352	104	76	4,694
1988	4,204	354	135	92	4,785
1989	4,376	309	125	64	4,874
1990	4,155	273	122	48	4,598
1991	4,032	214	102	40	4,388
1992	3,536	170	118	46	3,870
1993	3,271	196	93	58	3,618
1994	3,102	161	107	52	3,422
1995	3,074	184	83	35	3,376
1996	2,994	205	74	30	3,303
1997	2,857	190	96	20	3,163
1998	2,505	119	51	24	2,699
1999	2,495	128	45	22	2,690

Table II-5. Number of vessels by principal area, categorized according to whether or not they also make landings outside their principal area, 1981-1999.

	Principal Area=Northern CA				Principal Area=Central CA					Principal Area=Southern CA			
Year	No.CA Only	No.& Cen.	Other Comb.	Total	Cen.CA Only	No.& Cen.	So.& Cen.	Other Comb.	Total	So.CA Only	So.& Cen.	Other Comb.	Total
1981	1920	311	25	2256	2488	259	82	19	2848	1635	135	23	1793
1982	1842	289	36	2167	2274	232	110	29	2645	1566	155	19	1740
1983	1472	141	10	1623	2269	190	139	21	2619	1325	159	35	1519
1984	1066	160	16	1242	2008	177	102	15	2302	1313	230	20	1563
1985	891	198	23	1112	2033	147	105	13	2298	1160	152	24	1336
1986	1127	198	20	1345	1935	164	108	16	2223	1112	121	26	1259
1987	951	241	57	1249	1843	244	99	21	2207	1025	132	23	1180
1988	940	211	49	1200	2035	250	101	16	2402	979	90	53	1122
1989	858	240	60	1158	2069	296	69	20	2454	1056	89	64	1209
1990	842	130	48	1020	2011	184	84	14	2293	1111	76	40	1227
1991	767	127	40	934	1944	189	82	18	2233	1080	101	27	1208
1992	597	71	83	751	1778	90	83	18	1969	998	90	47	1135
1993	605	94	65	764	1562	132	63	20	1777	954	73	42	1069
1994	521	101	33	655	1370	155	101	23	1649	958	107	42	1107
1995	470	76	33	579	1539	97	116	14	1766	903	96	21	1020
1996	507	112	24	643	1428	92	70	7	1597	929	95	25	1049
1995	512	68	24	604	1406	88	84	9	1587	858	86	18	962
1998	445	76	17	538	1105	64	76	11	1256	806	64	17	887
1999	459	59	14	532	1057	56	74	4	1191	846	98	11	955

Table II-6. Average annual number of boats that make California landings, ex-vessel revenue per boat from California landings, number and percent of boats earning less than $5,000 per year from California landings, and number and percent of boats accounting for 90 percent of ex-vessel value of aggregate landings, by principal area and time period.

	1981-1985	1986-1994	1995-1999
Principal Area=Northern CA:			
Number of Boats	1,680	1,008	579
Ex-Vessel Revenue Per Boat	$24,500	$48,300	$60,800
#(%) Boats Earning <$5K Per Year	983(59%)	386(37%)	162(28%)
#(%) Boats Accting for 90% of Ex-Vessel Value of Northern California Landings	419(25%)	341(35%)	236(41%)
Principal Area=Central CA:			
Number of Boats	2,542	2,134	1,479
Ex-Vessel Revenue Per Boat	$20,800	$25,100	$30,100
#(%) Boats Earning <$5K Per Year	1,420(56%)	967(46%)	627(43%)
#(%) Boats Accting for 90% of Ex-Vessel Value of Central California Landings	727(29%)	737(34%)	512(35%)
Principal Area=Southern CA:			
Number of Boats	1,630	1,201	988
Ex-Vessel Revenue Per Boat	$126,000	$67,400	$74,900
#(%) Boats Earning <$5K Per Year	682(42%)	402(33%)	256(26%)
#(%) Boats Accting for 90% of Ex-Vessel Value of southern California Landings	290(18%)	401(34%)	382(39%)
Total California:			
Number of Boats	5,853	4,344	3,046
Ex-Vessel Revenue Per Boat	$50,600	$41,800	$50,700
#(%) Boats Earning <$5K Per Year	3,085(53%)	1,755(40%)	1,045(34%)
#(%) Boats Accting for 90% of Ex-Vessel Value of Total California Landings	1,119(20%)	1,375(32%)	1,072(35%)

Table II-7. Average annual 1995-1999 landings, ex-vessel value of landings, and vessel participation in major commercial fisheries, by area.

Major Northern CA Fisheries	Landings (1000 lbs)	Value ($1000s, Base Year=1999)	# Participating Vessels	# Vessels Participating As Principal Fishery
Crab trap	7,886.0	13,095.5	309	247
Groundfish trawl	28,683.7	11,322.9	71	56
Shrimp trawl	6,084.1	3,179.5	58	25
Urchin dive	3,318.9	2,742.1	64	61
Groundfish H&L	1,562.8	1,925.4	158	103
Tuna H&L	966.4	837.6	43	17
Salmon H&L	406.1	654.5	86	44
Groundfish/misc. trap	363.9	459.4	35	16
Shark/swordfish gillnet	102.0	308.9	9	4
Herring	121.1	104.4	5	4

Major Central CA Fisheries	Landings (1000 lbs)	Value ($1000s, Base Year=1999)	# Participating Vessels	# Vessels Participating As Principal Fishery
Groundfish trawl	17,406.2	9,097.8	73	61
Herring	10,014.2	8,585.5	149	136
Salmon H&L	3,847.1	6,512.4	704	579
Crab trap	2,564.3	5,209.2	207	127
Groundfish H&L	4,056.2	4,710.2	520	415
Prawn trawl	317.9	2,039.2	18	13
Shark/swordfish gillnet	581.9	1,683.5	30	21
Squid seine/other net	8,817.7	1,282.9	13	5
Tuna H&L	1,470.1	1,248.1	123	44
CPS seine	20,333.9	961.6	13	7
Shrimp trawl	985.7	956.9	19	10
Urchin dive	686.7	546.9	17	10
Groundfish/misc. trap	153.1	382.5	34	13
Abalone dive	31.8	313.1	9	8
Prawn trap	34.4	249.2	8	3
Shark/swordfish H&L	101.2	240.9	9	3

Table II-7 (continued).

# Vessels Major Southern CA Fisheries	Landings (1000 lbs)	Value ($1000s, Base Year=1999)	# Participating Vessels	Participating As Principal Fishery
Squid seine/other net	129,556.2	19,150.2	87	70
Urchin dive	13,007.9	12,835.5	223	207
Tuna seine	23,001.5	9,644.1	21	10
Tuna H&L	7,473.2	5,736.9	115	65
CPS seine	115,869.4	5,671.8	46	23
Lobster trap	680.7	5,157.5	202	168
Shark/swordfish gillnet	1,053.9	2,548.2	80	50
Groundfish H&L	1,588.5	2,193.8	205	157
Shark/swordfish H&L	795.6	1,875.9	42	27
Prawn trawl	745.3	1,679.9	27	19
Groundfish/misc. net	810.8	1,232.3	58	31
Crab trap	900.4	1,097.2	76	35
Prawn trap	135.1	1,011.9	28	18
Abalone dive	87.6	877.0	33	13
Groundfish/misc. trap	219.1	663.2	66	19
Shark/swordfish dive	119.3	632.0	24	20
Groundfish trawl	255.0	525.3	32	20
Cucumber dive	398.6	244.3	22	21
Salmon H&L	89.8	171.1	18	7
Cucumber trawl	236.4	167.1	12	5
Shrimp other net	63.5	22.2	3	3

Table II-8. Average annual 1995-1999 landings and ex-vessel revenue per boat from the principal fishery, from other California fisheries and from Oregon and Washington fisheries, by vessels' principal area and principal fishery.

	Landings/Boat/Year (1000 Pounds)				Ex-Vessel Revenue/Boat/Year ($1000s)			
Northern California Principal Fisheries	Principal Fishery	Other CA	OR/WA	Total	Principal Fishery	Other CA	OR/WA	Total
Crab trap	26.0	17.1	9.8	52.9	43.8	12.7	8.8	65.2
Groundfish trawl	473.1	61.1	385.7	919.8	185.1	37.2	44.8	267.2
Shrimp trawl	110.2	38.9	249.4	398.5	58.6	30.1	134.5	223.2
Urchin dive	54.2	0.7	2.7	57.6	43.9	1.5	2.5	47.9
Groundfish H&L	10.6	3.1	1.6	15.3	12.7	4.3	2.3	19.4
Tuna H&L	27.1	2.7	30.6	60.5	24.0	3.6	28.3	55.9
Salmon H&L	1.8	0.8	0.2	2.8	3.2	1.1	0.3	4.6
Groundfish/misc. trap	10.8	3.7	3.5	18.0	14.8	5.1	6.3	26.2
Shark/swordfish gillnet	13.2	10.3	107.6	131.0	42.3	11.3	102.9	156.5
Herring	25.9	1.2	0.0	27.1	19.4	1.2	0.0	20.5
Groundfish trawl	275.3	18.8	333.9	628.0	145.4	11.1	52.9	209.4
Herring	64.2	18.5	1.8	84.5	53.4	2.9	1.3	57.7
Salmon H&L	5.3	1.4	1.9	8.6	9.0	1.8	2.3	13.1
Crab trap	16.1	9.1	1.9	27.0	32.7	8.4	1.9	43.1
Groundfish H&L	8.6	0.8	0.2	9.6	10.2	1.1	0.2	11.5
Prawn trawl	23.3	44.7	87.4	155.4	153.8	34.0	46.3	234.1
Squid seine/other net	573.8	479.3	0.0	1053.1	85.7	46.0	0.0	131.6
Tuna H&L	17.1	2.7	17.9	37.6	14.4	4.0	16.7	35.2
CPS seine	2030.9	334.9	0.0	2365.9	99.2	53.2	0.0	152.4
Shrimp trawl	26.1	4.2	78.7	109.0	52.7	4.9	52.4	110.0
Urchin dive	60.3	1.1	0.0	61.4	47.6	2.2	0.0	49.7
Groundfish/misc. trap	8.1	2.2	0.0	10.3	20.8	4.3	0.0	25.1
Abalone dive	2.3	2.0	0.1	4.4	22.5	2.1	0.1	24.7
Prawn trap	8.1	16.2	0.9	25.2	59.8	12.6	0.5	72.8
Shark/swordfish H&L	11.2	2.7	0.7	14.6	27.0	7.5	1.9	36.4

Table II-8 (cont.)

Southern California Principal Fisheries	Landings/Boat/Year (1000 Pounds) Principal Fishery	Other CA	OR/WA	Total	Ex-Vessel Revenue/Boat/Year ($1000s) Principal Fishery	Other CA	OR/WA	Total
Squid seine/other net	1516.9	674.7	5.2	2196.7	226.0	44.9	4.5	275.4
Urchin dive	60.2	3.0	5.1	68.2	58.8	4.2	0.9	63.8
Tuna seine	1882.1	1288.6	4.9	3175.6	806.4	104.0	4.1	914.6
Tuna H&L	105.0	15.1	36.2	156.3	70.5	9.4	31.3	111.3
CPS seine	2475.8	482.5	0.4	2958.8	132.0	89.5	0.1	221.6
Lobster trap	3.7	3.8	0.1	7.6	28.2	6.4	0.1	34.7
Shark/swordfish gillnet	16.4	23.5	8.3	48.2	42.9	19.7	7.1	69.7
Groundfish H&L	8.9	1.7	0.3	11.0	12.2	1.4	0.3	13.9
Shark/swordfish H&L	26.8	6.7	3.0	36.5	62.8	15.3	2.4	80.4
Prawn trawl	32.5	9.2	56.5	98.2	79.4	11.6	12.2	103.2
Groundfish/misc. other net	17.5	12.1	0.6	30.3	28.1	10.6	0.5	39.2
Crab trap	15.1	1.4	0.0	16.6	18.3	4.7	0.0	23.0
Prawn trap	6.1	2.6	0.5	9.1	47.4	9.1	0.4	56.9
Abalone dive	2.1	9.1	0.4	11.7	21.4	9.7	0.3	31.5
Groundfish/misc. trap	4.6	2.9	0.0	7.5	14.0	7.2	0.0	21.3
Shark/swordfish dive	5.2	1.2	0.0	6.3	27.3	1.8	0.0	29.1
Groundfish trawl	9.0	8.0	7.9	24.9	20.9	6.0	2.7	29.6
Cucumber dive	2.6	4.0	0.5	32.9	15.1	9.8	0.0	24.8

Table II-9. Number of fish dealers by principal area, categorized according to whether or not they also receive landings outside their principal area, 1981-1999.

Year	Principal Area=Northern CA No.CA Only	No.& Cen.	Other Comb.	Total	Principal Area=Central CA Cen.CA Only	No.& Cen.	So.& Cen.	Other Comb.	So.CA Total	Principal Area=Southern CA So.& Only	Other Cen.	CA Comb.	Total	Dealers
1981	81	3	7	86	182	15	12	4	213	201	17	2	220	519
1982	77	8	1	86	209	9	11	4	233	227	18	2	247	566
1983	67	6	0	73	221	14	12	4	251	217	27	4	248	572
1984	53	11	0	64	211	8	9	4	232	207	28	2	237	533
1985	59	9	0	68	200	9	19	2	230	187	35	1	223	521
1986	65	7	2	74	213	4	18	3	238	188	24	6	218	530
1987	103	12	4	119	420	22	17	4	463	275	29	5	309	891
1988	102	6	2	110	361	21	15	2	399	272	29	10	311	820
1989	108	10	5	123	329	15	12	5	361	294	37	11	342	826
1990	85	11	5	101	322	14	21	2	359	285	34	12	331	791
1991	85	12	3	100	312	21	19	6	358	290	26	9	325	783
1992	85	10	6	101	307	21	24	11	363	257	26	15	298	762
1993	104	14	4	122	318	21	21	5	365	237	31	17	285	772
1994	98	14	12	124	333	24	27	9	393	331	59	15	405	922
1995	54	14	12	80	284	9	27	6	326	292	37	8	337	743
1996	88	13	6	107	274	19	18	6	317	267	30	12	309	733
1997	89	24	4	117	301	17	18	8	344	297	30	7	334	795
1998	78	19	6	103	360	16	19	5	400	312	29	10	351	854
1999	120	16	7	143	339	11	13	3	366	328	43	8	379	888

Table II-10. Average annual number of fish dealers, ex-vessel value of California landings receipts per dealer, number and percent of dealers accounting for less than $5,000 per year in California landings receipts, and number and percent of dealers accounting for 90 percent of ex-vessel value of aggregate landings receipts, 1981-1986 and 1987-1999, by dealers' principal area.

	1981-1986	1987-1999
Principal Area – Northern CA:		
Number of Dealers	75	112
Ex-Vessel Value of CA Landings Receipts/Dealer	$542,700	$380,300
#(%) Dealers With<$5K Per Year in CA Receipts	18(23%)	52(46%)
#(%) Dealers Accounting for 90% of Ex-Vessel Value of Northern California Landings	25(33%)	22(20%)
Principal Area – Central CA:		
Number of Dealers	233	370
Ex-Vessel Value of CA Landings Receipts/Dealer	$246,700	$138,800
#(%) Dealers With<$5K Per Year in CA Receipts	76(33%)	186(50%)
#(%) Dealers Accounting for 90% of Ex-Vessel Value of Central California Landings	50(21%)	58(16%)
Principal Area – Southern CA:		
Number of Dealers	239	344
Ex-Vessel Value of CA Landings Receipts/Dealer	$805,500	$233,900
#(%) Dealers With<$5K Per Year in CA Receipts	69(29%)	131(38%)
#(%) Dealers Accounting for 90% of Ex-Vessel Value of southern California Landings	28(12%)	55(16%)
All California:		
Number of Dealers	547	825
Ex-Vessel Value of CA Landings Receipts/Dealer	$531,500	$209,500
#(%) Dealers With<$5K Per Year in CA Receipts	163(30%)	369(45%)
#(%) Dealers Accounting for 90% of Ex-Vessel Value of Total California Landings	103(19%)	134(16%)

Table II-11. Volume and value of imports and exports of edible fish products at California customs districts and at all United States customs districts, by year, 1989-1999.

	Imports				Exports			
	Millions of Pounds		$Millions (Base Year=1999)		Millions of Pounds		$Millions (Base Year=1999)	
Year	Calif.	U.S.	Calif.	U.S.	Calif.	U.S.	Calif.	U.S.
1989	569.8	3,243.0	1,636.7	6,863.7	106.6	1,406.0	255.2	2,940.8
1990	627.4	2,884.6	1,808.6	6,289.9	99.2	1,947.3	231.7	3,463.1
1991	687.0	3,014.8	1,895.1	6,595.2	131.6	2,058.6	260.1	3,669.5
1992	710.3	2,894.0	2,015.5	6,491.3	105.2	2,087.6	223.6	3,942.7
1993	708.9	2,917.2	1,948.3	6,477.0	86.7	1,986.0	216.6	3,407.3
1994	777.1	3,034.8	2,325.8	7,207.3	135.9	1,978.5	284.8	3,390.6
1995	729.8	3,066.5	2,230.8	7,217.5	183.8	2,047.2	293.8	3,466.8
1996	759.6	3,169.8	2,222.9	7,017.3	218.7	2,112.1	281.8	3,161.9
1997	832.0	3,338.8	2,533.5	7,961.2	248.3	2,018.9	269.7	2,785.5
1998	911.1	3,647.0	2,513.8	8,289.2	142.6	1,663.9	158.9	2,291.8
1999	979.0	3,887.9	2,471.5	9,013.9	285.4	1,961.1	232.3	2,848.5

Table III-1. Average annual marine recreational fishing effort and harvest during 1998-1999 in southern and central/northern California, by fishing mode (1000s of fish).

Area/Fishing Mode	1000s of Angler Trips	Landed Whole	Released Alive	Other Disposition	Total
Southern California					
Man-made	624	837	644	233	1,714
Beach	281	327	247	17	590
CPFV	641	1,733	973	262	2,968
Private	1,324	1,960	4,075	211	6,246
Total	2,869	4,857	5,939	723	11,518
Central/Northern California					
Man-made	440	533	192	67	792
Beach	344	1,582	206	17	1,805
CPFV	168	1,131	122	171	1,423
Private	921	1,459	648	205	2,311
Total	1,872	4,705	1,168	460	6,331
Total California					
Man-made	1,064	1,370	836	300	2,506
Beach	625	1,909	453	34	2,395
CPFV	808	2,864	1,095	433	4,391
Private	2,245	3,419	4,723	416	8,557
Total	4,741	9,562	7,107	1,183	17,849

Source: Marine Recreational Fishery Statistics Survey.
Includes harvests in U.S. waters only. "Other Disposition" refers to fish used as bait, filleted, given away or discarded dead. All landings are in 1000s of fish.

Table III-2. Average annual marine recreational harvest (excluding fish released alive) during 1998-1999 in southern and central/northern California, by fishing mode and species category.

Southern California: Species Category	Southern California: 1000s of Fish (%)	Central/Northern California: Species Category	Central/Northern California: 1000s of Fish (%)
Man-Made			
Tuna/mackerel	413 (39%)	Silversides	185 (31%)
Croaker	204 (19%)	Surfperch	164 (27%)
Silversides	150 (14%)	Croaker	78 (13%)
Herring	145 (14%)	Herring	61 (10%)
Surfperch	71 (7%)	Anchovy	47 (8%)
Other	87 (8%)	Other	65 (11%)
Total	1,070 (100%)	Total	600 (100%)
Beach			
Surfperch	218 (63%)	Smelt	1,145 (72%)
Croaker	59 (17%)	Surfperch	343 (21%)
Silversides	24 (7%)	Silversides	41 (3%)
Sea chub	16 (5%)	Other	70 (4%)
Other	27 (8%)	Total	1,599 (100%)
Total	344 (100%)		
CPFV			
Rockfish	668 (33%)	Rockfish	1,204 (92%)
Sea basses	313 (16%)	Salmon	50 (4%)
Tuna/mackerel	281 (14%)	Greenling	21 (2%)
Pacific barracuda	269 (13%)	Other	27 (2%)
Calif scorpionfish	151 (8%)	Total	1,302 (100%)
Other	313 (16%)		
Total	1,995 (100%)		
Private Boat			
Sea basses	502 (23%)	Rockfish	1,034 (60%)
Tuna/mackerel	379 (17%)	Tuna/mackerel	89 (5%)
Rockfish	328 (15%)	Croaker	85 (5%)
Pacific barracuda	192 (9%)	Flatfish	80 (5%)
Jacks	168 (8%)	Striped bass	70 (4%)
Croaker	156 (7%)	Greenling	68 (4%)
Flatfish	125 (6%)	Salmon	55 (3%)
Calif scorpionfish	86 (4%)	Other	237 (14%)
Other	235 (11%)	Total	1,718 (100%)
Total	2,171 (100%)		

Source: Salmon harvest estimates obtained from DFG's Ocean Salmon Project. All other harvest estimates obtained from Marine Recreational Fishery Statistics Survey.

Table III-3. Estimated average annual expenditures by marine anglers during 1998-1999 in southern and central/northern California ($millions, base year=1999), by expenditure category.

Expenditure Category	Southern CA	Northern CA	Total CA
Trip-Related Expenses			
Man-Made	$ 18.1	$ 13.2	$ 31.3
Beach	9.8	15.1	24.9
CPFV	81.4	17.0	98.4
Private	92.7	62.6	155.3
Total	$202.0	$107.9	$309.9
Licenses/Fishing Gear	54.3	29.0	83.3
Boat-Related Expenses	74.1	39.6	113.7
Grand Total	$330.4	$176.5	$506.9

Source: Trip-related expenses based on average annual 1998-1999 effort estimates (Table III-1) and estimates of average expenditures per trip by fishing mode derived from Thomson and Crooke (1991) for southern California and from Thomson and Huppert (1987) for central/northern California and corrected for inflation to 1999 dollars. License/gear and boat-related expenses based on the observation from Thomson and Crooke (1991) that license/gear and boat-related expenses are 27 percent and 37 percent respectively of total trip expenditures in southern California, and extrapolating that result to central/northern California.

Table III-4. Number of CPFVs participating in the marine recreational fishery during 1980-1998, by vessels' principal fishing area.

Year	NoCA	CenCA	U.S.Only	SoCA:U.S. &Mex	MexOnly	Total	All Boats
1980	14	142	83	57	6	147	303
1981	15	125	85	52	14	151	291
1982	20	136	92	50	9	151	307
1983	21	145	96	52	6	154	320
1984	19	140	80	65	17	162	321
1985	17	142	78	58	19	155	314
1986	18	140	82	53	7	142	300
1987	22	134	76	45	10	131	287
1988	27	132	102	47	8	157	316
1989	41	146	83	55	14	152	339
1990	32	135	87	45	11	143	310
1991	21	125	87	23	15	125	271
1992	16	120	91	39	3	133	269
1993	16	107	90	32	6	128	251
1994	13	107	98	34	7	139	259
1995	13	99	117	47	6	170	282
1996	10	105	121	47	6	174	289
1997	11	105	125	66	4	195	311
1998	13	95	114	73	5	192	300

Source: CPFV logbooks. Southern California CPFVs distinguished according to whether they fish in U.S. and/or Mexican waters.

Table III-5. Number of CPFV angler trips, by year and area.

Year	NoCA	CenCA	SoCA	Total U.S. Waters	Mexican Waters	Grand Total
1980	5,665	204,146	492,290	702,101	59,739	761,840
1981	6,948	205,380	556,721	769,049	61,460	830,509
1982	6,694	213,206	503,280	723,180	52,756	775,936
1983	8,024	180,898	433,514	622,436	69,210	691,646
1984	6,577	188,275	415,036	609,888	91,666	701,554
1985	11,591	210,894	413,102	635,587	81,601	717,188
1986	11,064	189,780	407,614	608,458	51,755	660,213
1987	13,251	208,989	396,309	618,549	59,862	678,411
1988	12,496	217,284	427,610	657,390	53,967	711,357
1989	15,595	226,333	420,976	662,904	74,681	737,585
1990	14,724	222,149	474,761	711,634	57,433	769,067
1991	14,179	175,329	434,945	624,453	37,100	661,553
1992	7,586	164,792	407,831	580,209	55,258	635,467
1993	5,617	169,566	377,125	552,308	40,626	592,934
1994	4,949	161,637	364,774	531,360	51,765	583,125
1995	6,806	169,402	408,547	584,755	58,074	642,829
1996	6,021	137,312	435,940	579,273	74,846	654,119
1997	5,456	165,899	554,117	725,472	99,304	824,776
1998	6,175	133,133	483,420	622,728	106,504	729,232

Source: CPFV logbooks. "Mexican waters" pertains to trips departing from southern California ports to fish in Mexican waters.

Table III-6. Landings on CPFV fishing trips (1000s of fish), by year and area.

Year	NoCA	CenCA	SoCA	Total U.S. Waters	Mexican Waters	Grand Total
1980	24.2	1,545.4	4,517.1	6,086.6	321.2	6,407.8
1981	51.9	1,747.0	4,267.0	6,065.9	248.6	6,314.5
1982	42.4	1,781.8	3,363.5	5,187.7	182.9	5,370.6
1983	60.9	1,654.9	2,547.0	4,262.7	362.2	4,624.9
1984	33.5	1,485.3	2,249.5	3,768.3	404.0	4,172.3
1985	53.5	1,364.3	2,471.2	3,889.0	290.1	4,179.1
1986	41.6	1,198.9	2,617.9	3,858.4	217.1	4,075.5
1987	50.4	1,314.3	2,485.0	3,849.7	256.2	4,105.9
1988	56.9	1,390.1	2,651.2	4,098.2	254.2	4,352.4
1989	82.4	1,574.1	2,618.9	4,275.4	321.6	4,597.0
1990	111.1	1,606.5	2,824.5	4,542.1	243.5	4,785.6
1991	73.0	1,345.9	2,694.5	4,113.4	175.9	4,289.2
1992	69.7	1,526.7	2,275.7	3,872.1	219.6	4,091.7
1993	31.4	1,312.3	2,112.2	3,455.9	166.7	3,622.6
1994	30.8	1,049.1	1,945.7	3,025.6	189.4	3,215.1
1995	43.9	923.2	1,980.0	2,947.1	222.8	3,169.8
1996	32.1	743.7	2,350.6	3,126.5	249.0	3,375.5
1997	43.4	957.3	2,356.1	3,536.8	384.2	3,921.0
1998	53.7	882.8	2,008.1	2,944.6	377.9	3,322.5

Source: CPFV logbooks. "Mexican waters" pertains to harvests on trips that depart from southern California ports to fish in Mexican waters.

Table III-7. Annual number of CPFV boat and angler trips in 1995-1998, by area and trip type.

Area/Trip Type	1995	1996	1997	1998	Avg.
Northern California					
Total Fishing Trips:	6,806	6,021	5,456	6,175	6,115
Salmon	2,948	3,264	1,808	1,554	2,394
Rockfish/lingcod	3,222	2,161	2,839	3,410	2,908
Salmon/rockfish/lingcod	321	519	553	1,034	607
Other/unspecified	314	77	256	177	207
Total Dive Trips	26	15	0	10	13
NoCA Total	6,832	6,036	5,456	6,185	6,128
Central California					
Total Fishing Trips:	169,402	137,312	165,899	133,133	151,437
Salmon	86,899	56,567	78,202	48,645	67,578
Rockfish/lingcod	58,008	52,865	52,233	51,795	53,725
Salmon/rockfish/lingcod	5,098	3,408	5,135	3,777	4,354
Strbass/sturgeon	2,522	3,720	5,572	5,349	4,291
Shark	1,012	526	628	428	648
Tuna	140	1,127	6,500	4,014	2,945
Other/unspecified	15,723	19,099	17,629	19,125	17,894
Total Dive Trips	1,126	1,249	716	38	782
CenCA Total	170,528	138,561	166,615	133,171	152,219
Southern California					
Total Fishing Trips-CA:	408,547	435,940	554,117	483,420	470,506
Rockfish/lingcod	31,684	34,923	30,525	26,595	30,932
Tuna	12,006	2,992	13,586	18,124	11,677
Other/unspecified	364,857	398,025	510,006	438,701	427,897
Total Fishing Trips-Mex:	58,074	74,846	99,304	106,504	84,682
Tuna	35,691	34,692	56,029	62,164	47,144
Other/unspecified	22,383	40,154	43,275	44,340	37,538
Total Dive Trips-CA	37,089	43,128	44,938	33,014	39,542
Total Dive Trips-Mex	446	790	394	659	572
SoCA Total	504,156	554,704	698,753	623,597	595,303

Source: CPFV logbooks.

Marine Law Enforcement

Introduction

The *Fish and Game Code* states that "(t)he protection and conservation of the fish and wildlife resources of this state are hereby declared to be of utmost public interest. Fish and wildlife are the property of the people and provide a major contribution to the economy of the state, as well as providing a significant part of the people's food supply and therefore their conservation is a proper responsibility of the state."

In keeping with this responsibility, the Marine Region enforcement staff is charged with enforcing the regulatory aspects of marine resource management. This formidable challenge encompasses approximately 1100 miles of California coastline out to sea for 200 miles — 220,000 square miles. Marine Region law enforcement focuses its efforts on commercial fisheries (including fishing vessels, shore facilities and all fisheries-related infrastructures throughout the state), illegal commercialization of the public fishery resources, sport fisheries, market inspections and landing taxes. Enforcement efforts include the inspection of licenses, permits, catch, gear types, vessels, fishing activity records, fish businesses, accounting records, and importation. The enforcement staff also ensures that sport and commercial fishermen comply with regulations concerning seasons, size limits, bag limits, trip limits, fishing gear restrictions and design, quotas, closures, sales of fish, and prohibited species. Land-based and at-sea patrols are required to enforce all of the various regulations.

In addition to enforcing laws, the enforcement staff is very active in public outreach and education. The staff takes a proactive approach in recognizing emerging fisheries that may need management measures to ensure a viable commercial and recreational environment.

In consideration of the natural history of individual species, management and enforcement policies are tailored to ensure the sustainability of sport and commercial fisheries. Each species has unique regulatory needs, challenges, and issues, but the effective management of all is dependent on accurate recording and reporting of landed weights by fish businesses. Patrol efforts to insure accurate documentation of landings for all species is crucial. Enforcement is faced with identifying these needs and structuring enforcement activities to address such complex issues. Current enforcement effort is hampered by a lack of enforcement personnel and disinterest in prosecution by some court systems.

Resources

Personnel

The Department of Fish and Game's (DFG) Marine Region was established in December of 1997. This resulted in the consolidation of marine resource enforcement efforts which had been split between the three inland regions bordering the coastline. Initial staffing included 21 positions transferred from the department's Office of Oil Spill Prevention and Response (OSPER) (responsible for marine oil pollution regulation enforcement only).

In March 1998, 38 positions were transferred from DFG's inland regions. The law enforcement function was staffed with these 59 positions until October 1998 when the Marine Life Management Act (MLMA) was enacted by the State Legislature. This law provided 15 additional enforcement positions bringing the count to 74. In April 2000, in keeping with statutory obligations, the positions funded by the OSPR were removed from the Marine Region to ensure a dedicated spill prevention and response unit. Law enforcement personnel staffing in the Marine Region decreased to 53 positions. In July 2000, the state Legislature provided 10 additional positions. Entering 2001, the Marine Region's law enforcement staff consisted of 63 positions, still well below the staffing levels of the early 1980s when DFG had a Marine Resources Region with its own enforcement function.

Patrol Boats

In 1998, the Marine Region had two 65-foot patrol boats, the *Albacore* (an aluminum mono-hull) and the *Bluefin* (a fiberglass mono-hull), two 40-foot patrol boats (the *Yellowtail* and the *Tuna*), and 18 smaller patrol skiffs ranging in size from 13 to 28 feet.

Funds were provided later that year to increase the region's at-sea patrol capabilities. A 54-foot vessel was designed, contracted, built, and delivered in 1999. Named the *Thresher,* this patrol boat is a state-of-the-art aluminum foil-supported catamaran powered by twin 660 turbo diesels. The funds also enabled the purchase of three 24-foot, rigid-hull inflatable (RHI) patrol boats. These three boats joined two other similar boats to form the north coast rapid deployment force. The boats can be put on trailers and deployed quickly along the rugged north coast.

In July 1998, the MLMA provided for the purchase of the patrol boat *Marlin*, a sister vessel to the *Thresher.* This boat was delivered in July 2001. All six large patrol boats are equipped with an 18-foot RHI boarding vessel. In July 1999, additional funding provided for three more patrol boats, the *Swordfish, Coho* and *Steelhead*, identical to the previous two. Delivery is expected in January and April of 2002.

Teams

The Marine Region Law Enforcement function is organized along a traditional chain-of-command structure; however, in addition, self-directed work teams were instituted at the inception of the Marine Region. These teams include:

1. A Policy and Procedure Team responsible for interpreting commercial and sport fishing laws, rules and regulations in a consistent statewide basis and establishing standard operating procedures for marine law enforcement activities.
2. An Enforcement Legislative Team responsible for developing language for law, rule and regulation changes for legislative and commission consideration.
3. A Boat Team responsible for the deployment of the patrol boats and the at-sea operations of the patrol fleet.
4. A Law Enforcement Training Team which develops instructional designs for training modules to address the training requirements of enforcing complex commercial and sport fishing regulations.

These teams were developed to encourage fair and consistent enforcement of the laws and regulations throughout the region, clarify and make the regulations more enforceable, deploy and operate the patrol boats where they will be the most beneficial, and maintain a well trained and professional warden force to protect California's diverse marine resources for all of the people in the state.

Partnerships

The law enforcement function works closely with other government organizations concerned with the management of marine resources. The department has a Memorandum of Understanding with the Monterey Bay National Marine Sanctuary which allows wardens to be deputized to conduct federal law enforcement patrols in the sanctuary. This partnership provides $125,000 in operating expenses, over a three-year period, for the wardens working in the sanctuary. A similar partnership exists with the National Marine Fisheries Service (NMFS) which provides $300,000 to pay wardens overtime for groundfish enforcement. We can expect these partnerships to continue.

Enforcement personnel are actively working on memorandums of understandings with the Channel Islands National Marine Sanctuary and various units of the National Park Service in the Channel Islands and San Francisco Bay areas. These partnerships will provide the department with operating funds in exchange for law enforcement patrols in federal waters. The function also provides a law enforcement consultant to assist the Pacific Fisheries Management Council (PFMC) in its formulation of federal fishery management regulations.

In addition, the enforcement staff coordinates with 1) the NMFS in regard to Lacey Act violations for fish transported across state boundaries; 2) the US Coast Guard on enforcement; 3) the PFMC on fisheries management plans and fishing gear deployment; 4) the State Department of Weights and Measures in assuring the proper procedures for the weighing of fish and the completion of landing receipts; and 5) the State Department of Parks and Recreation, National Park Service, Harbor Patrol, local police and local sheriffs departments in matters of mutual enforcement efforts.

Fisheries-Specific Enforcement Efforts

Groundfish

Because of concerns about continuing declines of many groundfish populations, recent additional restrictions have been proposed and adopted to protect these resources. Enforcement of groundfish regulations is difficult due to the large number of species involved, their vast distributions, the frequently changing and sometimes complex regulations, and the various fishing methods utilized in the commercial fishing industry. Some species, such as lingcod, have been proposed as candidates for listing as threatened or endangered. The effectiveness of enforcement effort is dependent upon the accurate recording of landed weights.

Nearshore Fish

There are many species that can be considered as nearshore fish, but the species that this section addresses are those that are of primary concern to managers and were among the first to be addressed in the Nearshore Fisheries Management Plan. Included are black rockfish, black and yellow rockfish, blue rockfish, brown rockfish, calico rockfish, China rockfish, copper rockfish, gopher rockfish, grass rockfish, kelp rockfish, olive rockfish, quillback rockfish, treefish, California sheephead, greenlings, cabezon, California scorpionfish, and monkeyfaced "eels."

These species are targeted by sport and commercial fishermen. The primary commercial fishery is for the live-fish market. The live-fish market commands a much higher price per pound than traditional markets. The high price and low volume of fish being handled has resulted in the proliferation of small fish businesses. Many such businesses operate out of vehicles. The resulting highly-mobile fishery makes enforcement difficult.

Salmon

Enforcement problems in the sport salmon fishery include the use of barbed hooks and other illegal hooks, multiple poles, overlimits, group fishing, retention of Coho salmon, sorting and discarding of less desirable fish, (*i.e.,* "high grading") violations of the salmon punch card in the Klamath Management Zone, and sale of sport caught fish. There has been a trend among some sport salmon anglers toward the use of commercial type gear in an illegal manner.

Problems in the commercial fishery include the failure to record fish landings, violations of quota-landing limits, fishing closed areas, retention of Coho salmon, use of illegal gear such as barbed hooks or more than six troll lines, and fishing without a commercial salmon permit. Some of the tribal allotments of salmon are being sold outside the reservation, both in California and other states. This has created an enforcement problem, as there are currently conflicts between tribal law and California regulations.

Mid-season regulation changes, for both the sport and commercial fisheries, result in confusion and adverse public relations. While these changes are based upon the best biological information available, enforcement personnel often receive complaints about the complexity of the salmon regulations. Standardization and earlier publication of regulations, to the extent possible, would be well received by all fishermen. A greater effort towards public education regarding management of salmon and the basis for the regulations would also assist in this area.

Besides the federal fishery agencies, other entities involved in the management of salmon include the Hoopa and Yurok tribes. These tribes in the Klamath Management Zone are allocated fifty percent of the available annual harvest and have a tribal representative on the PFMC. The department works closely with these groups to manage the sport and commercial salmon fishery in ocean and inland waters of the state.

Halibut

There are minimum size limits for commercial and sport caught Pacific and California halibut. Commercial enforcement efforts center on the trawl and gillnet fishery. Efforts focus on net measurement, fish size restrictions, and documented landings. There are several closures for trawl and gillnets along the California coasts. Closures are very specific to depths and distance from shore. Specific electronic equipment capable of accurately measuring distances and depths is needed to monitor these fisheries for compliance. Personnel trained in the use of this equipment are essential to ensure successful prosecution through the legal system. Limited entry permits are also required for the use of gillnets to take halibut.

Striped Bass

Enforcement includes patrols directed toward such problems as night fishing from boats and multiple rod violations in San Francisco Bay, overlimits, gillnets, and market checks for illegal fish. There is also public concern over snagging of striped bass in ocean waters.

There is an active black market involving sport-taken striped bass entering the commercial market. Fish are caught with rod and reel and illegal gillnets. Black market striped bass then become mixed with legally imported fish from sources outside of California, primarily aquaculture fish.

Additional patrol time has been made available through the Striped Bass Stamp Fund. In addition, funding is available through state and federal water projects to mitigate impacts of those projects on this and other fisheries. Recipients of the additional funding are the Marine Region and the Delta Bay Enhanced Enforcement Project.

Pacific Herring

Enforcement is focused on compliance with gillnet mesh sizes, length of nets, number of nets used, limited entry permit requirements, quotas, and season dates. There are special requirements for herring buyers to ensure accurate recordings of the landings for the purpose of quota management. The roe-on-kelp fishery is subject to permit requirements, licensing of individuals working on kelp rafts, special reporting requirements, quotas, and raft size limits. The ocean harvest fresh fish permit may not be used during the time the roe fisheries are operating, and the herring taken in this fishery may not be sold for roe recovery. During the relatively short season, there is a strong enforcement effort, which requires the shifting of wardens from many other areas of the state.

Because of the numerous boats involved in the San Francisco Bay fishery, the Coast Guard is heavily involved

The department's marine patrol officers enforce the law by issuing a citation for taking horn sharks in a marine protected area.
Credit: Chamois Andersen, California Department of Fish and Game

in monitoring the setting of nets to avoid navigational hazards. The National Park Service is involved in some areas of the Golden Gate National Recreation area. The San Francisco Police Department becomes involved with nets or boats that are tied to prohibited structures.

Coastal Pelagic Species

Sardine/Anchovy/Mackerel

Enforcement involves monitoring and sampling loads for compliance with quotas and allowable levels of incidental catches. Incidental catches are allowed because these species often school together and are caught in the same net. Round haul nets are the primary gear used for taking these species.

Sampling techniques and monitoring of the unloading process are labor intensive. Monitoring the landings ensures accurate reporting of species and prevents under-reporting and/or landing of prohibited species. When quotas are close to being reached or are reached, a high incidence of unreported landings typically occurs making enforcement activity even more important.

Squid

Enforcement for market squid includes education about and enforcement of new regulations such as the restricted use of lights, documentation of fishing activity in logbooks, weekend closures, light-boat shielding, and wattage restrictions. Consistent statewide enforcement of new regulations is a priority. Accurate and consistent dissemination of information of regulation and policy changes to the fishermen and fish businesses is critical to gaining compliance throughout the fishery.

Abalone

The abalone fishery is currently the number one statewide enforcement priority and is expected to remain. Because of declining populations, all areas south of San Francisco have been closed to the sport and commercial take of abalone. The coastline north of San Francisco is open to sport fishing only. The sport season is April through November with the month of July closed. Restrictions added during the 2000 season were requirements for an abalone stamp and abalone report card. Of major concern is the sale of sport-caught abalone. Mariculture and importation are the only legal sources of abalone for the commercial markets. Enforcement problems arise when the source of abalone cannot be determined.

Besides the usual over limit/under-size problems, enforcement is directed at the illegal sale and export of abalone. This is a major problem in California, and because of the extremely high value for abalone, a significant black market exists. Traditionally, this violation revolved around small groups taking large numbers of abalone for sale. While this still may occur, more recent trends involve large numbers of individuals taking their daily limits and selling them. These individuals often make daily trips to the coast.

Every year significant cases are made involving the sale of sport-caught abalone. Patrol techniques used include directed enforcement details, undercover operations, and checkpoints. There is also DFG’s Special Operations Unit (SOU) which is a specially funded group of wardens who spend much of their time and effort detecting sale of sport-taken abalone. Enhanced enforcement levels, depend on continued stable funding from abalone stamp revenue or other sources.

Sea Urchin

Regulations relating to the allowable size limits, log books and permits for sea urchins are the primary focus for enforcement. Measuring the urchins is time-consuming and challenging because of the volume of urchins taken and the physical make-up of the urchin. Commercial vessels are often small, and it is sometimes difficult to find workspace for at-sea monitoring. The urchin industry also has specific time and area closures. Observing the divers while they are in the water is necessary to identify the divers that do not have a restricted access permit. Abalone share the same habitat as urchins and this creates additional enforcement efforts related to the illegal take of abalone by commercial urchin divers.

Shrimp/Prawns

Shrimp and prawn fisheries are generally divided into two gear categories. The first category includes golden, spot, coonstripe, and ridgeback prawns, which are taken by trawling or traps. The second category includes pink shrimp, which are taken only by trawl nets.

Enforcement focuses on trawl mesh sizes, trap construction including destruct devices, limited entry permits, incidental catch, and log books. With the shutdown of other fisheries, there were concerns that new fishermen would enter this fishery, so limited entry was established. Apprehension over incidental take of prohibited species has resulted in consideration of on-board observers and fish excluder devices. Changes in the design of traps are also under consideration.

Lobster

Current enforcement efforts include inspection of catch, compliance with season and area closures, gear restrictions, including trap construction and destruct devices, permits, size limits, out-of-season take, illegal importation, and log books.

Patrol techniques vary on the enforcement of lobster regulations. Techniques include routine uniformed patrols and undercover patrols, such as underwater surveillance, and use of marked lobster. DFG divers are also used to locate illegally-set lobster traps. Traps set in areas closed to commercial lobster fishing present a major problem for enforcement.

The majority of sport taken lobster are taken at night, requiring constant monitoring by enforcement personnel. The majority of violations committed by sport fishermen include out-of-season-take and taking undersize lobster.

Crab

Enforcement focuses primarily on commercial and sport fisheries for Dungeness or rock crab, with minor fisheries for tanner and stone crab. The sport fisheries are subject to minimum size limits, season and gear restrictions for all species of crabs.

Commercial Dungeness crab regulations include a minimum size limit, male crab only requirement, and limited entry permits. Commercial fishermen are allowed to bait and pre-set their gear a certain number of hours prior to the opening of the commercial Dungeness crab season. Detection of violation of the pre-soak regulation requires the use of directed enforcement. Rock crab have minimum size limits as the primary restriction. All traps are required to have escape rings and destruct devices built into the design to prevent lost traps from continued fishing. In most years, eighty percent of Dungeness crab landings are taken during the first three weeks of the season. This requires concentrated enforcement efforts during this peak period of landings.

Other Invertebrates

The "other invertebrates" category generally includes the large number of species for which specific permits are not required. However, a tidal invertebrate permit is required to take the following species for commercial purposes between the high tide line and 1,000 feet seaward of the low tide line: ghost shrimp, barnacles, chiones, clams, cockles, limpets, mussels, octopus, oysters, sand dollars, sea hares, starfish, and worms. These species, as well as scallops, turban snails and moon snails, may also be taken under a sport fishing license, in certain areas, with daily bag limit restrictions. There are few commercial restrictions on season, size, or bag limits for these species.

Because commercial take is permitted, unless restricted by law, new fisheries continue to develop for invertebrate species, which have not previously been taken for commercial purposes.

Enforcement of the take of invertebrates in the tidal zone occurs primarily from the shore. Enforcement of incidental take is commonly checked while monitoring another fishery. There are specific permits related to the scientific collection of invertebrates. These permits are very restrictive in specifying what can be taken, how many can be taken and who can do the collecting.

Marine Aquaria

The marine aquaria fishery involves the take of organisms for the live pet, hobby or display trade. Finfish include garibaldi, gobies and juvenile sharks. Invertebrates include coral, shrimp and octopus. The demand for the marine aquaria trade has led to species being harvested for the first time. The take of marine aquaria species occurs statewide primarily in nearshore waters with no seasonal closures. Illegal importation of marine aquaria species from Mexico has become prevalent.

Marine aquarium organisms cannot be taken in any marine life refuges, marine reserves, ecological reserves and state reserves. One identified enforcement problem is the killing of live-bearing adult sharks in order to remove unborn young for the aquarium trade. Another is the illegal fishing by release of harmful chemicals into ocean waters. The chemicals force the otherwise inaccessible species from their hiding places resulting in the death of many non-targeted as well as targeted species.

Aquaculture

Enforcement focuses on working closely with biologists to monitor aquaculture facilities.

Monitoring the collection of brood stock by the mariculture industry is necessary to ensure compliance with permits and regulations. Inspection of fish businesses purchasing mariculture products, is required to ensure that wild stocks are not used to illegally replace mariculture species in the commercial trade. Current regulations are not sufficient to properly monitor and enforce mariculture activities.

Commercial Fish Businesses

California's marine resources are a public trust. The conservation and protection of these resources have been entrusted to DFG. One means to monitor the lawful use of these resources is the inspection of businesses that commercialize the wild fish populations. Persons dealing in the sale of seafood are required to be licensed, to maintain adequate accounting records, and to comply with species restrictions. Wardens routinely conduct inspections of businesses to ensure compliance with all state and federal laws. Business inspections are also routinely conducted to ensure compliance with landing requirements and proper documentation.

Frank Spear and **Carmel Babich**
California Department of Fish and Game

A Review of Restricted Access Fisheries

Background

Restricted access programs in fisheries limit the quantity of persons, vessels or fishing gear that may be engaged in the take of any given species of fish or shellfish. Restricted access may also limit the catch allocated to each fishery participant through harvest rights such as individual or community quotas.

Without some form of restricted access, fisheries resources are available to anyone who wants to pursue them. Each individual fisherman or company is motivated to catch the fish before their competitors, which leads to overcapitalization of the fleet with too many vessels and too much gear. Overcapitalizaton usually results in reduced income to fishermen. Open access to fisheries often leads to problems with both biological sustainability and economic viability. Over the past 50 years, increased demand for fisheries products, big advances in fishing technology, and development of global fish markets have combined to intensify the "race for fish."

Restricting access has been used as a fishery management tool for thousands of years to improve resource sustainability, allocate catches among participants, and improve economic and social returns from fisheries. Restricting access to fisheries can 1) promote sustainable fisheries; 2) provide for a more orderly fishery; 3) promote conservation among participants; and 4) maintain the long-term economic viability of fisheries.

Great care must be taken in designing and implementing restricted access programs. First, broadly recognized goals for the fishery must be defined by managers, fishermen, and other constituents. Once these goals are identified, key restricted access elements can be identified to attain them. A primary purpose of restricted access programs is to balance the level of effort in a fishery with the health of the fishery resource. In most situations, except for harvest rights programs, this involves setting an appropriate fishery capacity goal (a combination of factors that represent the fishing power of the fleet).

History

Until recent decades, California did not restrict fishing effort. After World War II, fleet expansion, improved electronics and gear technology, new net materials, larger and faster vessels, plus increased fishing skills significantly increased fishing power. This trend of increased fishing capacity and adoption of new technology accelerated during the mid-1970s after passage of the Federal Fishery Conservation and Management Act of 1976 (Magnuson-Stevens Act). This act began phasing out foreign fishing and encouraged "Americanization" of fisheries, primarily for groundfish, within our 200-mile exclusive economic zone. Federal loan and tax programs proved to be powerful incentives for private investment in fishing fleet expansion.

By the late 1970s, it was clear to many in the fishing industry, California Department of Fish and Game (DFG) and the Pacific Fishery Management Council (PFMC) that there was a need to limit entry to fisheries. In California, the first limited entry program was established in 1977 for the abalone fishery. This was followed in 1979 with legislation requiring salmon limited entry permits in 1980. By 1983, this became a salmon vessel permit system. While these and other limited entry programs capped the number of fishermen or vessels and created more orderly fisheries, they generally had little effect on overall fishing capacity. Participants in these restricted fisheries often increased their fishing power with larger vessels, more gear and increased time fishing, or shifted to other fully developed open access fisheries.

Since the early 1980s, DFG has implemented restricted access programs at an accelerating rate. High value fisheries such as herring, sea urchin and Dungeness crab are now under restricted access. When demand from industry for restricted access programs intensified in the mid-1990s, DFG decided it was time to address restricted access in a comprehensive manner. In late 1996, DFG formed a limited entry review committee to develop a standard restricted access policy for the Fish and Game Commission. A draft policy was completed in 1998 and underwent major revision in 1999 with assistance from outside experts and consultation with constituents. After three public hearings and considerable public input, the commission approved the restricted access policy in June 1999.

California's Restricted Access Programs

The legislature, commission, and DFG have differing, but related roles in implementation of restricted access programs. Historically, most of California's programs were created through legislation. Examples include abalone (1977), salmon (1979), and pink shrimp (1994). Others such as herring (1986), sea urchin (1989), and the new pink shrimp program (2001) have been the responsibility of the commission. Since the passage of the Marine Life Management Act of 1998 and the commission's adoption of a comprehensive restricted access policy in 1999, more restricted access program responsibility has switched to the commission and department. The department works closely with constituent advisory committees and task forces to carefully design and evaluate restricted access plans for submission to the commission. The commission then conducts hearings for further public input. The restricted access plan is then returned for any necessary revision by the department and advisory groups before going before the commission for a final decision. The legislature is kept informed and involved for fisheries that require legislation to implement restricted access.

Restricted access programs active through 2000 are summarized in the table below. Some of these programs are revised versions of earlier programs. Restricted access was discontinued in 1998 in the abalone fishery after that fishery was closed. Herring round haul permits were phased out by 1998.

California's Commercial Fisheries Restricted Access Policy

The commission adopted its policy in order to guide future restricted access programs. The commission believes that restricted access programs can offer at least four benefits:

- Fostering sustainable fisheries by offering a means to match the level of fishing with the capacity of a fish population and by giving fishermen a greater stake in maintaining sustainability;
- Providing a way to fund total costs for administration and enforcement of restricted access programs;

California Restricted Access Programs Through 2000

Permit	Type	Ldgs. Req. to Renew	Year Begun	No. Permits First Year	No. Permits in 1992	No. Permits in 2000	Current Mgmt. Authority
General Gill/Trammel Net	Person	no	1985	1052	376	223	Commission
Drift Gillnet	Person	every other year	1984	226	149	126	Legislature
Dungeness Crab (Resident)	Vessel	no	1995	614	N.A.	589	Legislature
Dungeness Crab (Non resident)	Vessel	no	1995	67	N.A.	69	Legislature
Finfish Trap	Person	yes	1996	316	N.A.	142	Legislature
Herring Gillnet (Resident)	Person	no	1986	339	323	335	Commission
Herring Gillnet (Non resident)	Person	no	1986	72	97	121	Commission
Lobster Operator	Person	no	1996	298	351	251	Commission
Market Squid Vessel	Vessel	no	1998	242	N.A.	198	Legislature
Market Squid Light Boat	Vessel	no	1998	53	N.A.	49	Legislature
Salmon Vessel	Vessel	no	1983	5964	2974	1704	Legislature
Sea Cucumber Diver	Person	no	1997	111	N.A.	101	Legislature
Sea Cucumber Trawl	Person	no	1997	36	N.A.	30	Legislature
Sea Urchin Diver	Person	every other year	1989	915	537	407	Commission
Nearshore Fishery	Person	no	1999	1130	N.A.	1026	Commission
Pink Shrimp (discontinued)	Person	no	1994	307	N.A.	90	Commission
Pink Shrimp (new program in 2001)	Vessel	----	1994	8	N.A.	101	Commission

Source: California Department of Fish and Game License Branch Statistics

- Providing long term social and economic benefits to the state and fishermen, and;
- Broadening opportunities for the commercial fishing industry to contribute to management of the state's commercial fisheries.

The key elements of the policy are summarized below. A complete copy of the policy is contained in *Guide to California's Marine Life Managememt Act* by M. L. Weber and B. Heneman. It is also available at the commission's Web site at www.dfg.ca.gov/fg_comm/index.html

General: Restricted access is one of a number of tools for conserving and managing fisheries as a public trust resource, and may be adopted to achieve several purposes, including sustainable and orderly fisheries, conservation, and long-term economic viability.

Development: Fishermen and other citizens must be involved in the development of restricted access programs. The specific needs of a fishery must be balanced with the goal of increasing uniformity among such programs.

Review: Restricted access programs in individual fisheries and the Commission's policies on restricted access should be regularly reviewed.

Capacity Goal: Any restricted access program that does not assign harvest rights to individual fishermen must identify a "capacity goal" for the fishery to try to match fishing power to the resource. This goal, which should be developed collaboratively, may be expressed in such terms as size or power of vessels or number of permits. Where a fleet is above its capacity goal, the program must include a means of reducing the capacity in the fishery. A new restricted access program is not to allow fishing effort to increase beyond recent levels.

Participation: Eligibility for participating in a restricted access fishery may be based on the level of historical participation or on other relevant factors. In issuing permits, certain priorities should be followed. For instance, first priority should be given to licensed commercial fishermen or vessels with past participation in that fishery. In addition, fishermen licensed in California for at least 20 years may be included in new restricted access programs with qualifying criteria determined for each program by the commission. New permits should be issued only if a fishery is below its capacity goal.

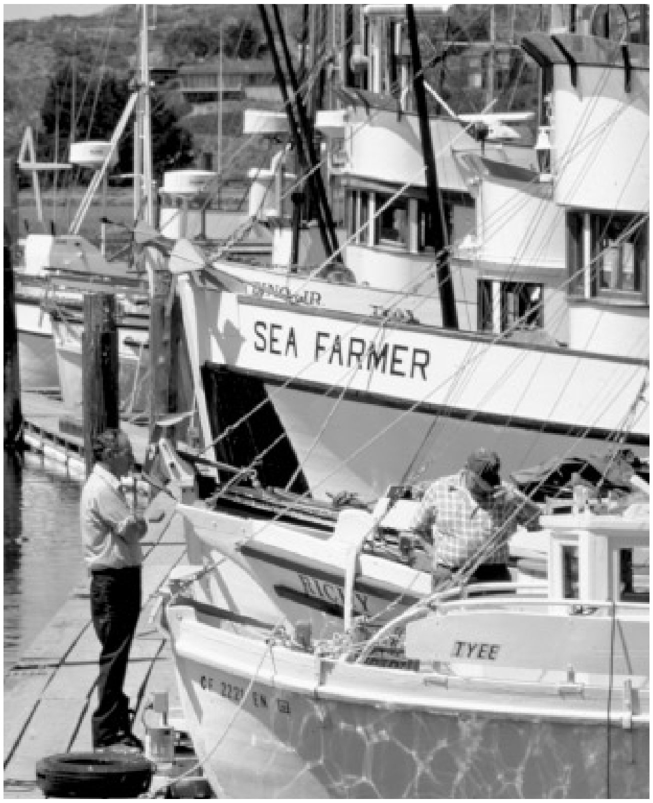
Permit Transferability: Where appropriate, permits may be transferable between fishermen or vessels, as long as there is a capacity goal and a program for achieving that goal in the fishery. Under certain conditions, permits may be transferred from retired to new vessels. Fees to offset the costs of management may be imposed on the transfer of permits.

Harvest Rights: In establishing restricted access programs based on the allocation of harvest rights to individual fishermen or vessels, the state should insure the fair and equitable initial allocation of shares, resources assessments, cost recovery, limits on aggregation of shares, and consider recreational fishing issues.

Costs and Fees: Administrative costs are to be minimized. Review or advisory boards may be established. Funds from restricted access programs may be deposited in a separate account of the Fish and Game Preservation Fund. Restricted access programs should deter violations, while minimising enforcement costs through the use of new technologies or other means. Administrative and enforcement costs are to be borne by each restricted access program.

The first restricted access program adopted under the commission's new policy is for northern pink shrimp fishery. This program, which replaced the pink shrimp program initiated by the legislature in 1994, took effect in 2001. It includes transferable and non-transferable vessel and individual permits.

Currently, there are restricted access plans under development and review for the nearshore finfish fishery, market squid, the spot prawn trap fisheries. These plans are created collaboratively by teams of constituents and DFG staff convened by the director.



Commercial fishing vessels in Bodega Bay.
Credit: Chris Dewees

Federal Restricted Access Programs

The federally managed groundfish fishery (includes 83 species) off Washington, Oregon and California is managed, in part, under a limited entry program developed by the Pacific Fishery Management Council (PFMC) and implemented by the National Marine Fisheries Service (NMFS) in 1993. The federal program has issued gear-specific permits to vessels using trawl, fixed longline and fishpot and allocates a proportion of the catch to each gear type. Those fish not allocated to the limited entry fleet continue to be allocated to open access vessels (primarily hook-and-line and fishpots) and those who take groundfish incidentally in other fisheries. NMFS was authorized by Congress in December 2000 to develop regulations for the limited entry fixed gear sablefish fishery which allow for stacking of up to three permits with cumulative landing limits. These management regulations would have effects similar to those of harvest rights systems.

Future Actions

The Marine Life Management Act (MLMA) requires evaluation every five years of existing restricted access programs and this will be an ongoing activity of the department and the commission. These evaluations and the increasing demand for restricted access programs means that the department will need expanded capabilities to collect and analyze economic and social data related to fisheries. These data, combined with biological data about fishery resources, will be critical in developing and evaluating restricted access policy options on a fishery-by-fishery basis. Restricted access will likely be an important component of fishery management plans required under the MLMA.

Experience with restricted access is growing statewide, nationally and internationally. As our knowledge base grows, new techniques for managing access to fisheries will become available. There is a growing trend toward implementing harvest rights systems in the form of individual and community-based quotas as currently used in Alaska, Canada and overseas. Transferable gear certificate programs are in place in trap fisheries in Florida and Georgia and this tool may have potential in California.

It will be important that DFG and the PFMC work closely to ensure consistency of state and federal restricted access programs affecting fisheries managed jointly off the California coast.

California needs to understand the interaction of restricted access programs with other primary types of fishery management systems such as marine reserves, spatial management and local co-management schemes. Finally it is important to take into account how restricted access programs in one fishery affect participation and fishing effort in other fisheries.

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California's Nearshore Ecosystem

California's Nearshore Ecosystem

California's nearshore ecosystem, defined as the area from the coastal high tide line offshore to a depth of 120 feet, is one of the most productive ocean areas in the world. This area, comprising only about 2,550 square miles, generates from the harvest of its resources, almost $40 million in ex-vessel revenue, a little less than one-third of the value of all California's fisheries. The area is home to a wide variety of fishes, giant kelp, marine invertebrates (spiny lobster, abalone, sea urchin, crabs), and marine mammals, as well as a large number of sea and shore bird species.

The nearshore area is composed of a variety of habitats ranging from high-relief rocky reef to broad expanses of sand and mud. There are distinct differences in the prevalent oceanographic conditions from north to south. Much of the state's shoreline is heavily influenced by the cold California Current, which sweeps south from the Gulf of Alaska. As a consequence, the extreme northern portion of the coast is inhabited by plant and animal species also found off Oregon and Washington. The nearshore area here is dominated by species commonly found off Oregon such as black rockfish and cabezon, redtail perch, and night and surf smelt. Along the central coast, south of Cape Mendocino, where rocky-reef habitat dominates, prevailing onshore northwest winds cause the upwelling of nutrient-rich waters from the ocean bottom and high biological productivity. Kelp beds, consisting of giant kelp to the south and bull kelp to the north, are home to a variety of nearshore rockfish, abalone and sea urchin. Sea bird nesting areas and marine mammals such as sea otters and sea lions are also important members of this community. South of Point Conception, warm waters from the south join with the cold California Current to provide habitat for a wide variety of seasonal sub-tropical visitors like yellowtail, white seabass, Pacific bonito, and California barracuda, all found in close association with the abundant stands of giant kelp found around the offshore islands and along the mainland. Major resident species such as kelp bass, sheephead, halfmoon and olive rockfish sustain a year-round nearshore fishery.

Major issues are the impact of environmental events like El Niño on animal and plant species, over-harvest of species such as abalone and nearshore rockfish, interactions between fisheries and marine mammals, pollution from human activities, and competition among user groups, both consumptive and non-consumptive.

Management authority for most species found in the nearshore continues to be split between the legislature and the Fish and Game Commission, with the legislature retaining the authority to manage commercial fisheries and the commission delegated the authority to set recreational angling regulations. Notable exceptions are the white seabass and nearshore finfish fisheries, which are subjects of fishery management plans under development by the department for adoption by the commission late in 2001. These two fisheries are being managed under the provisions of the Marine Life Management Act of 1998. This act establishes the framework for the eventual management of all the state's marine fisheries through the creation of fishery management plans and commission regulatory action. A key provision of this act is an overarching goal of sustainable use.

The next decade will be a critical one for the management of the resources of the nearshore, as we attempt to successfully address the major issues listed above.

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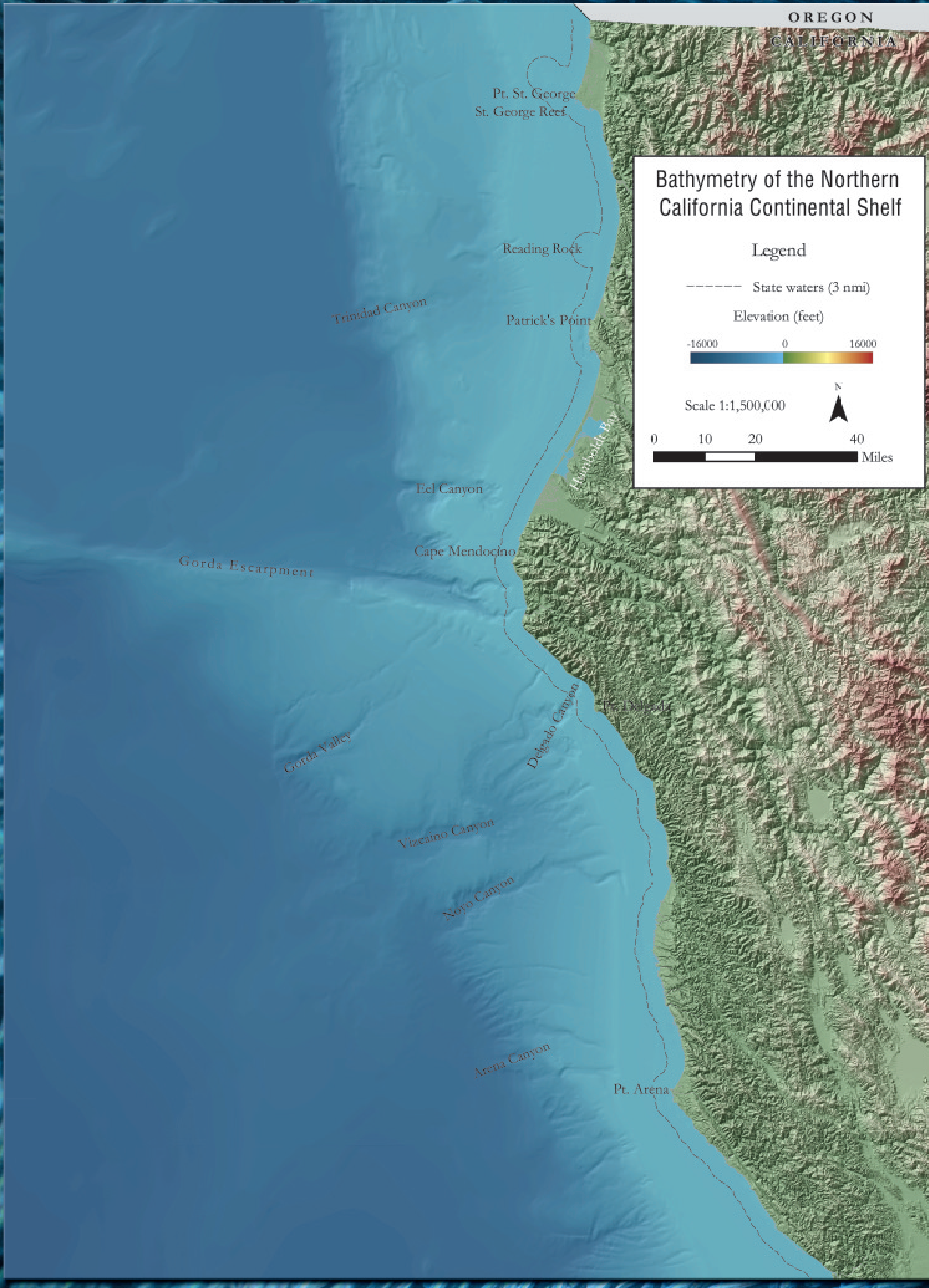
OREGON
CALIFORNIA
Bathymetry of the Northern California Continental Shelf
Legend
State waters (3 nmi)
Elevation (feet)
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0
16000
Scale 1:1,500,000
N
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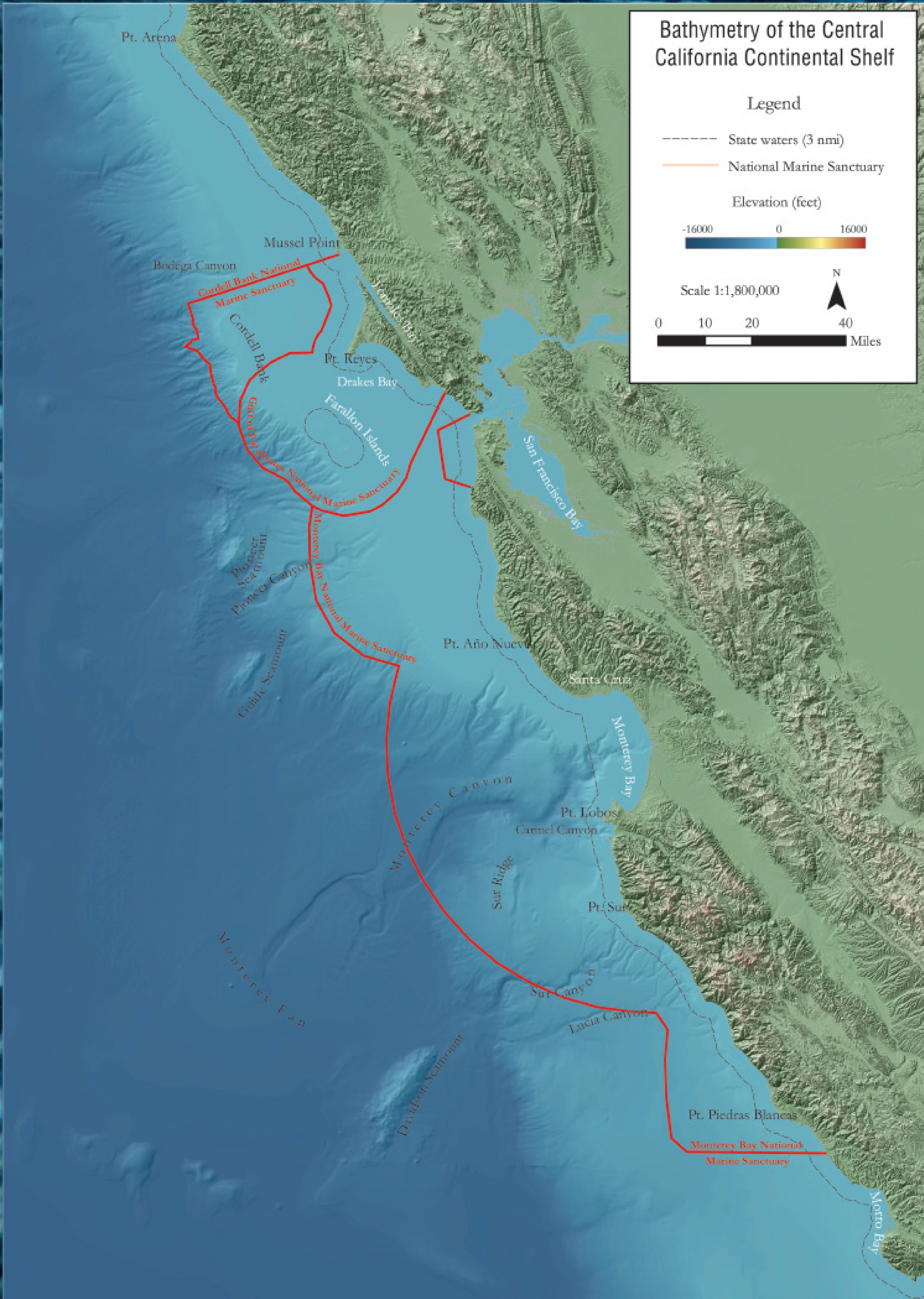
Miles
Pt. St. George
St. George Reef
Reading Rock
Trinidad Canyon
Patrick's Point
Humboldt Bay
Eel Canyon
Cape Mendocino
Gorda Escarpment
Delgado Canyon
Gorda Valley
Vizcaino Canyon
Noyo Canyon
Arena Canyon
Pt. Arena


Bathymetry of the Central California Continental Shelf
Legend
State waters (3 nmi)
National Marine Sanctuary
Elevation (feet)
-16000
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Miles
Pt. Arena
Mussel Point
Bodega Canyon
Cordell Bank National Marine Sanctuary
Cordell Bank
Pt. Reyes
Drakes Bay
Farallon Islands
Gulf of the Farallones National Marine Sanctuary
San Francisco Bay
Pioneer Seamount
Pioneer Canyon
Monterey Bay National Marine Sanctuary
Guide Seamount
Pt. Año Nuevo
Santa Cruz
Monterey Bay
Monterey Canyon
Pt. Lobos
Carmel Canyon
Sur Ridge
Pt. Sur
Monterey Fan
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Lucia Canyon
Davidson Seamount
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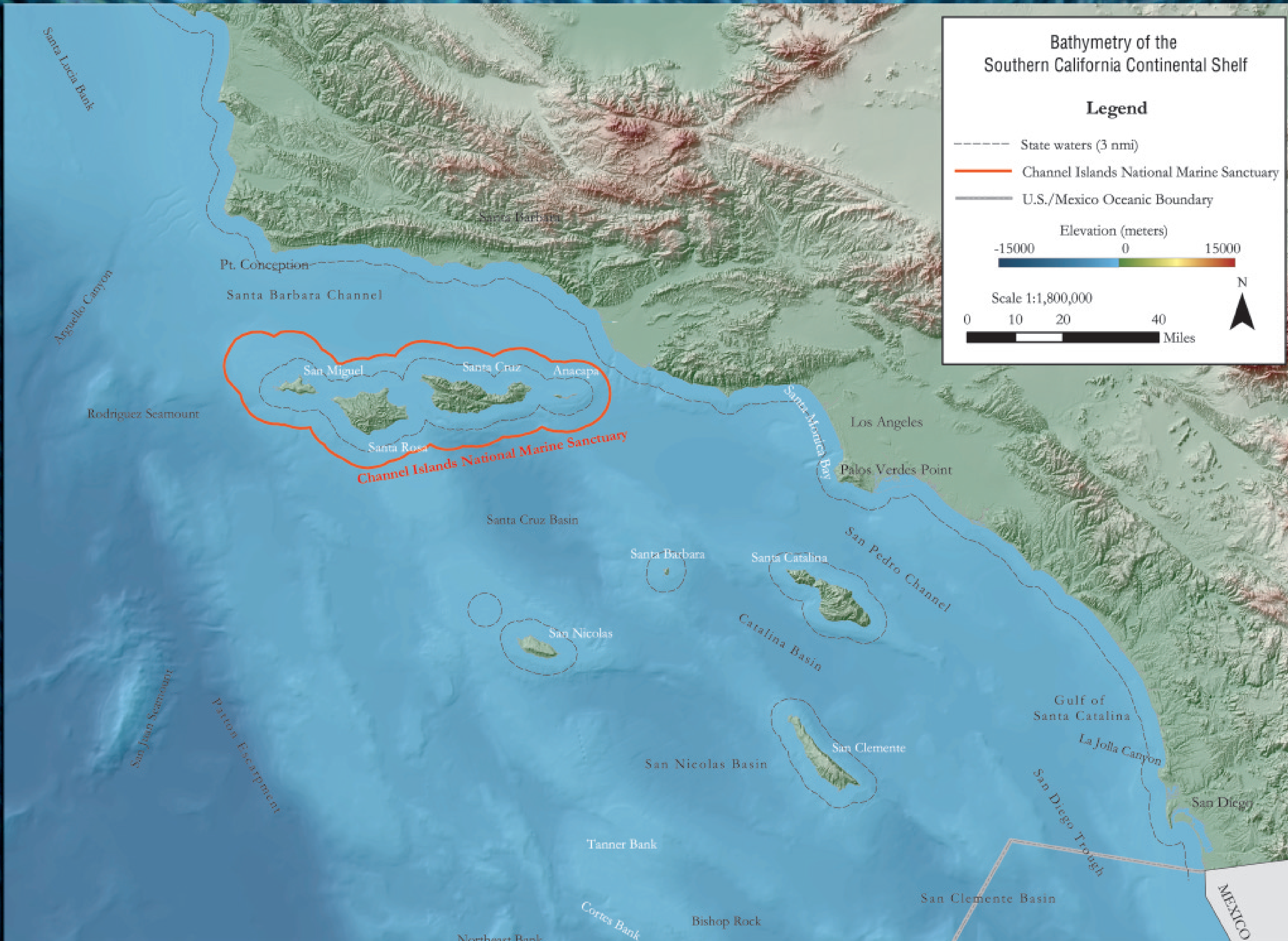
Morro Bay



Bathymetry of the
Southern California Continental Shelf
Legend
State waters (3 nmi)
Channel Islands National Marine Sanctuary
U.S./Mexico Oceanic Boundary
Elevation (meters)
-15000
0
15000
Scale 1:1,800,000
0
10
20
40
Miles
N
Santa Lucia Bank
Arguello Canyon
Pt. Conception
Santa Barbara Channel
Santa Barbara
Rodriguez Seamount
San Miguel
Santa Rosa
Santa Cruz
Anacapa
Channel Islands National Marine Sanctuary
Santa Monica Bay
Los Angeles
Palos Verdes Point
Santa Cruz Basin
Santa Barbara
Santa Catalina
San Pedro Channel
San Nicolas
Catalina Basin
San Juan Seamount
Patton Escarpment
Gulf of
Santa Catalina
La Jolla Canyon
San Clemente
San Nicolas Basin
San Diego Trough
San Diego
Tanner Bank
San Clemente Basin
Cortes Bank
Bishop Rock
Northeast Bank
MEXICO

The Nearshore Ecosystem Invertebrate Resources: Overview

California's marine invertebrate fisheries range among the crustaceans, mollusks, echinoderms and to a limited extent, the polychaetes. This section deals with most of them, with the notable exception of squid, classified as a coastal pelagic in this publication. Invertebrate resources usually associated with bays and estuaries are considered in another section. Commercial and recreational fishermen spend thousands of hours annually in pursuit of these species, which are among the most highly prized of our marine resources. Harvest methods include trawls pulled by large ocean-going vessels (shrimp), traps fished from smaller boats (lobsters, crabs, and prawns), ring nets, and bare hands (recreational lobsters and crabs). In 1999, commercial invertebrates (excluding squid) accounted for only about six percent of the state's total commercial catch by weight, but over 30 percent of its ex-vessel value at over $44 million. Commercial catch records for invertebrate species, like most of California's fisheries, are more complete than for their recreational counterparts. Spiny lobster is the only invertebrate fishery with both a substantial sport and commercial component. However the magnitude of the sport component of that fishery is poorly known. The Marine Life Management Act recognizes the importance of allocating marine resources fairly between commercial and recreational users and so an improved understanding of the amount of sport take and effort will be a necessity in the future. Many other species of invertebrates that are not the target of fisheries inhabit California's marine waters where they nevertheless form important functional components of marine ecosystems.

In 1999, over half of the marine crustacean catch of 16.4 million pounds consisted of Dungeness crab. Dungeness crab and Pacific ocean shrimp have comprised the majority of the crustacean catch each year since the 1950s. In recent years there have been over 330 boats taking Dungeness crabs in the center of the catch range from Crescent City to Fort Bragg. Boats average 200 crab pots each, but some carry as many as one thousand pots. In contrast, the spiny lobster catch was almost 500,000 pounds in 1999, and ranged from 600,000 to 800,000 pounds through most of the 1990s. Recreational harvests of crustaceans also center around crabs and spiny lobster. Dungeness and rock crabs are targets of scattered recreational effort throughout California. It is estimated that sport fishermen take less than one percent of the Dungeness crab catch and that the sport lobster catch, while significant, is substantially less than the commercial catch. While the size of the recreational lobster harvest is not known, a NMFS-sponsored survey estimated over 115,000 individual trips targeting spiny lobster in 1989. Divers catch most lobsters with their hands, although baited ring nets are also used, usually from skiffs, piers or jetties. A commercial passenger fishing vessel (CPFV) industry catering to divers schedules special trips during lobster season. CPFVs in the SF Bay area have in recent years been offering combo-trips for rockfish and Dungeness crabs, where crab pots are set at the beginning of the fishing trip and pulled on the way back to port. These trips could significantly increase the sport crab catch in this region. In addition to these major fisheries, sand crabs and red rock shrimp are the target of small but high value-per-unit bait fisheries.

California's nearshore echinoderm fisheries developed in the 1970s as a response to the growing demand for fishery export products but were little utilized domestically. They have been dominated by the red sea urchin fishery which saw almost 15 million pounds landed in 1999, the second lowest total during the 1990s, down from a high of 45 million pounds in 1990. Sea cucumber landings have averaged about 500,000 pounds during the 1990s, with cucumbers taken by both commercial divers and trawlers, mostly in southern California. There has been very little interest in the sport take of echinoderms, other than small amounts of sea urchins. Purple sea urchins, whose unregulated take can cause localized depletions, have been the target of scientific collectors for years.

Other species not considered in this section, such as limpets, jackknife clams, mussels and rock scallops, are frequently harvested by sport fishers and have been seriously impacted by California's expanding human population. Water quality problems, both natural and man-caused, may prevent commercial and sport harvest of bivalve mollusks, primarily clams and mussels. Since most bivalves are filter feeders, they ingest microscopic plant and animal matter from the water column. At certain times during the year, particularly during the spring and summer upwelling season, heavy plankton blooms occur in nearshore waters, and filter feeders may ingest and concentrate toxins, which are harmful to humans if consumed. The levels of toxic plankton are monitored by the California Department of Public Health and warnings are issued when appropriate.

Natural predation may significantly reduce a population if a prey species increases its density or range. A well-documented example is the return of the sea otter population to its historic range and its impact on central California's Pismo clam and abalone resources. Disease has not often been implicated in reducing populations of

California's mollusks. However, the "withering syndrome" in the black abalone population, coupled with fishing pressure, has resulted in a drastic decline in the southern California stock. Periodic oceanographic disturbances such as the warm-water event known as El Niño can have severe impacts on nearshore invertebrates, especially southern populations.

California's commercial abalone fishery was the leading molluscan fishery for the decades up until its collapse and closure in 1997. Indeed, the MLMA was drafted in part as a response to this tragedy. A robust recreational-only abalone fishery remains in northern California where an estimated 1.2 million pounds was taken by 33,000 divers annually during the past decade. A punch card reporting system was established in 1999, which should make tracking catch and effort in this fishery much easier in the future.

California's nearshore ecosystem has been the target of an onslaught of exploitation, both extractive and non-consumptive, since the end of World War II. California's population has exploded during that time period and concentrated along the coastal zones of central and southern California. Intertidal areas here, particularly rocky tidal pools, have been trampled and stripped of their flora and fauna despite the efforts of regulatory agencies to protect them. Offshore mineral extraction, pipelines and tanker traffic increase the likelihood of major fouling incidents along our coastline. Fisheries management agencies have been largely concerned with controlling the type and amount of marine organisms available for harvest. However, the demands of ecosystem management will require a greater vigilance over all the elements of nearshore ecology, including the habitats of the organisms.

The collection of timely and accurate biological and fishery information can be a costly and challenging endeavor. As a consequence, management of nearshore invertebrate resources in California has proceeded largely on an *ad hoc* basis. Measures such as minimum sizes, closed seasons, gear or equipment restrictions, bag limits and closed areas have been used in an effort to protect stocks, sustain harvests and allocate the resource. For some of our fisheries, management systems based on annual or seasonal quotas and a fixed harvest rate may be more desirable. Following a worldwide trend, during the last decade most of our commercial fisheries for invertebrates have come under limited access or entry regulations, and consequently opportunities for entry into these fisheries have been reduced.

A variety of life-history patterns, which need to be considered when making management decisions, are found among California's invertebrate resources. Some resources are long-lived and slow growing (spiny lobster, sheep crab, abalone, sea urchins); others have short life spans and can undergo rapid increases or declines in population size (ocean shrimp and ridgeback prawn). Separate subpopulations of Dungeness crabs and ridgeback prawns may exist within California. The spiny lobster population is shared with Mexico, and ocean shrimp and Dungeness crab populations span the Oregon border. Management and fishing practices in those political entities may affect California's portion of such shared resources.

Future management and research on California's invertebrate resources should focus on more frequent and efficient resource assessment methods and a better understanding of the various factors, both natural and human-induced, which determine population levels and patterns of change. With such information at hand, resource managers will be better able to match the growing demands on California's nearshore invertebrates with their productive capacity. Future management will undoubtedly address the issue of marine protected areas as a tool for ecosystem protection and enhancement of degraded areas.

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Abalone

History of the Fishery

Archaeological evidence indicates that California Indians fished abalones extensively from coastal areas and the Channel Islands prior to European and Asian settlement of California. During the 1850s, Chinese Americans started a fishery in California that targeted intertidal green (*Haliotis fulgens*) and black (*H. cracherodii*) abalones, with peak landings of 4.1 million pounds of meat and shell in 1879. The Chinese worked shallow waters with skiffs, gaffing abalones dislodged by a long pole with a wedge on the end. This fishery was eliminated in 1900 by closure of shallow waters to commercial harvest. Japanese divers followed the Chinese by exploiting virgin stocks of subtidal abalones, first as free divers from surface floats and later, more successfully, as hard-hat divers. California Department of Fish and Game statistics showed an increase in landings from 1916 to a peak in 1935 of 3,900,000 pounds followed by a decline to 164,000 pounds in 1942 as fishermen of Japanese heritage were moved to relocation camps during World War II.

The red abalone (*H. rufescens*) was the only species reported in the commercial landing figures from 1916 to 1943. They were recorded as unidentified abalone. By 1960, the center of the fishery had moved from Monterey to the Morro Bay area, where the regions from Cape San Martin to Cayucos in the north and Point Buchon to Pecho Rock in the south were fished. Declining stocks of red abalones, caused largely by the combined effects of fishing and a growing population of sea otters, forced a shift southward in the late 1960s. Landings increased in the San Francisco area, supplying 34 percent of the 1988 red abalone landings. Evidence, including successfully prosecuted court cases, indicates that many of these abalones were poached from noncommercial areas in northern California. By 1990, landings of red abalones declined to 17 percent of the 1931 to 1967 average of 2,135,000 pounds.

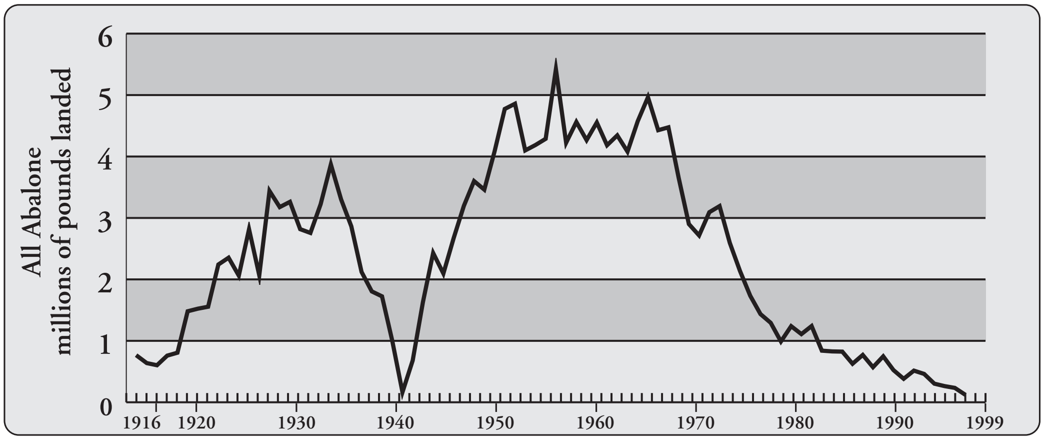
Commercial harvest of abalones was prohibited in southern California from 1913 through 1943, then reopened to increase wartime food production. The fishery has undergone successive development and decline as less desirable species were exploited. The abalone fishery underwent spatial and interspecific serial depletion following World War II. The fishery was managed as a single entity, and it was difficult to address the collapse of individual species in the face of stable landings. The fishery alternated from red to pink (*H. corrugata*) to green, white (*H. sorensensi*), and finally to black abalones, but the new target species could not provide the continuous demand. The combined-species landings reached a record 5,420,000 pounds in 1957. Pink abalone landings reached a maximum 3,388,000 pounds in 1952 and in 1990 were one percent of the 2,178,000 pounds averaged from 1950 to 1970. Green abalones peaked in 1971 at 1,090,000 pounds, declined rapidly to six percent of their 1968 to 1972 average catch of 488,000 pounds. White abalone was the shortest lived of the abalone fishery, beginning about 1968 peaking in 1972 with landings of 144,000 pounds, and quickly declining thereafter. Black abalones peaked in 1973 at 1,913,000 pounds, declining in 1990 to 13 percent of their 1972 to 1984 average catch of 687,000 pounds. Because the fishery was managed as a single entity, the total landings stabilized with the inclusion of the pink, green, white, and black landings, but each of these species quickly collapsed. Red abalone again became the dominant species with most of the landings originating from the southern part of central California, and the Channel Islands.

Complicating the issues was the effect of sea otter preempting the central California fishing areas. Red abalone, stocks were fully utilized around the historic center of the range, Monterey, and the fishery expanded southward. The expansion of the sea otter, also moving south, eventually removed much of the central California coast as a source of legal abalones.

Increased efficiency and effectiveness of the fishery, *i.e.*, faster boats and better diving technology, were factors which caused a continual expansion of the fishing grounds. None of these factors was adequately addressed, and necessary reductions in the fishing power in the fishery to protect the abalone resource never occurred.

Status of Biological Knowledge

In addition to the five species which have been commercially fished, flat (*H. walallensis*), threaded (*H. assimilis*) and pinto (*H. kamtschatkana*) abalones are also found in California; all have limited distributions and none is common. The threaded (*H. assimilis*) was once thought to be a separate species, but it has been included under the pinto as a southern sub-species. Depth and geographical distributions of all California haliotids are best described by seawater temperature. Black abalones are found from Oregon to southern Baja California and are largely intertidal, extending to a depth of about 20 feet in southern California. Red abalones, which also extend from Oregon into Baja California, are intertidal and shallow subtidal in northern and central California but are exclusively subtidal in southern California, where they are restricted to cooler upwelling locations along the mainland and the northwestern Channel Islands. Pink, green, white and threaded abalones are characteristic of the warmer waters south of Point Conception extending into Baja California and the southeastern Channel Islands. These species further sort out by temperature in their depth distributions: greens



Commercial Landings 1916-1999, All Abalone
Prior to 1949, commercial abalone landings consisted primarily of red abalone. Data Source: DFG Catch Bulletins and commercial landing receipts.

are centered at shallower depths than pinks, which are shallower than white abalones. Flat and pinto abalones are generally found in the cooler waters north of Point Conception.

California abalones feed primarily on algae, mostly the large brown kelps that form stands along the coast and islands. They feed on bacterial and diatom films when small, later switching to grazing on living plants and capturing algal drift, fragments of macrophytes moved by currents and surge. Most abalones feed preferentially on kelps but minor variations in preference appear to reflect the habitat where each is found. Specialization on drift algae puts abalones in competition with three species of urchins. Sea urchin grazing has been reported to limit kelp and abalone distributions in many regions of the state.

Seawater temperature also strongly influences abalone growth, and reproduction. Elevated seawater temperatures are low in nutrients and kelps, the food of abalone, do not tolerate these periods well. El Niño events bring warm seawater temperatures northward along the coast. This can have severe short and long-term effects on abalone populations through reduced food availability and the direct affects of warm water on the abalone. In red abalone, El Niño conditions have been observed to slow growth, and decrease settlement and recruitment. If sufficient stocks survive through the warm water period, reproduction will resume with the return of normal conditions, but several year classes may be absent. This will eventually be reflected in the future availability of fishable stocks.

Abalones are synchronous broadcast spawners, the males and females releasing their sperm and eggs directly to the sea. The duration and period of spawning varies with species. The fertilized egg sinks to the bottom, hatches and spends several days to a week in the plankton, depending upon temperature and species. Various oceanographic mechanisms are thought to keep the larvae in the vicinity of the adults. Nevertheless, settlement to the benthic existence appears to be hit or miss. To compensate, abalones produce millions of eggs. Additionally, broadcast spawners must be sufficiently close together to improve the chances of fertilization, which decrease with distance between spawners because of dilution. Distances greater that three or four feet may not support sufficient fertilization. While abalones can move and aggregate for spawning, often low numbers and physical barriers can prevent aggregation.

Recent research has shown that abalones may not successfully reproduce and recruit annually, likely because of all the reasons above. As abalones are removed during fishing, their numbers often will decrease to the point that few adults are sufficiently close for successful fertilization. In one Australian abalone, it has been shown that when stocks of abalone are reduced to about 40 percent of the virgin biomass, reproduction failure occurs. Most of the California abalones are well below that 40 percent mark.

Abalones, especially juveniles, are preyed upon by a wide variety of animals including crabs, lobsters, gastropods, octopuses, sea stars and fishes; larger abalones achieve a partial refuge in size from most of these. However, two predators, sea otters and humans, including the effects of human activity in and near the sea, are the keystone species that control the condition of the abalone resource.

Red abalone

Red abalone is the largest abalone in the world with a record maximum shell length of 12.3 inches. The shell color is brick red when red algae are part of the diet. A prominent muscle scar is visible on the inside of the shell. Typically three to four respiratory pores are open; these are slightly raised, tubular, and oval. The epipodium is smooth and black.

This abalone is associated with rocky kelp habitat ranging from Oregon into Baja California. In northern and central California they are found from the intertidal to the shallow subtidal depths. In southern California they are exclusively subtidal, restricted to upwelling locations along the mainland and the northwestern Channel Islands. Two canopy-forming kelps, bull kelp and giant kelp are primary components of the red abalone habitat and diet. Several other brown algae are reported as important food sources.

There is a clear distinction between juvenile and adult red abalone habitat, an indication that migration occurs as the abalone grow. There are two separate movement phases. The first phase corresponds with settlement as postlarvae on coralline algae and is ascribed to light avoidance (negative photoaxis) and/or downward attraction (positive geotaxis) into small spaces between rocks and under boulders. The second phase starts at 2.0 inches when they switch to feeding on drift kelp, moving from under boulders into crevices. Abalone in exposed crevices, under ledges, or on top of reefs are described as "emergent" with most red abalone emergent by six inches. Red abalone have been reported to move in response to environmental hazards such as sanding-in of reefs. They have been shown to move considerable distances of up to 0.4 miles. In northern California random movement in deeper, less intensely fished populations supports some of the replacement of the intertidal and shallow subtidal fished stocks.

Red abalone generally reach sexual maturity at a shell length of five inches, but may become mature as small as 1.6 inches for females and 3.3 inches for males in the wild. Fecundity ranges from a few thousand eggs at first spawning to up to six million eggs in large adults. Spawning is seasonal in northern and year round in southern California reflecting northern seasonal availability of kelp. A single spawning season from April to July with a peak in May was reported for northern California, based on histological evidence.

The optimal temperature for successful survival to settlement for red abalone larvae is 55° to 68° F. At these temperatures the average duration of the swimming larval phase is four days. Post settlement larval survival varies from year to year. Studies off southern and northern California showed occasional strong year classes followed by long periods of unsuccessful recruitment.

Growth is highly variable and depends on availability of food. Mark and recapture studies demonstrated higher yearly growth rates in southern California compared to northern California where food is seasonally available. An exception occurred during the 1982-1984 El Niño in southern California when kelp abundance declined dramatically. Recent evidence suggests abalone growth rates in the north have increased following the fishing down of their main competitor the red sea urchin.

Abalone are preyed upon by a broad range of predators including sea stars, octopus, crabs and lobster, and fishes, particularly sheephead, cabezon, and bat rays, all of which may be found in red abalone habitat. Sea otters are the major predator of red abalone in the current sea otter range from Año Nuevo (Santa Cruz) to south of Point Conception. Inside this range a few adult abalone survive in deep crevices.

In central and southern California, where species were serially depleted, red abalone had declined the least of all five species by the time the fishery was closed in 1997. Combined landings of red abalone declined during the period from 1969 to1982 stabilizing at 1/10 their historic average during the 14 year period before the 1997 closure. Detailed examination of catch by area and fishery independent assessments reveal that the stability in landings masked serial depletion by area, as successive areas declined by over two orders of magnitude. From 1952-1968 most red abalone were caught in central California, followed by southern mainland, Santa Cruz, Santa Rosa and San Miguel Islands. Catches declined first along the central coast under the combined effects of expanding sea otters and fishing pressure. Outside the sea otter range catches declined more slowly along the southern mainland than at Santa Rosa, Santa Cruz, and San Nicolas Islands. From 1983-1996, catch decreased off these three islands to three percent, for Santa Rosa, and less than one percent, for Santa Cruz and San Nicolas, of their respective peak catches by the 1997 closure. San Miguel Island and the north coast were the exceptions to this pattern. Catches from San Miguel Island, the farthest and most northern of the Channel Islands, and the north coast comprised 71 of the 87 tons landed in 1996 prior to the fishery closure in 1997.

A successful red abalone sport only fishery continues to the north of San Francisco county, where SCUBA has always been prohibited and commercial take was only allowed for a three year period during WWII. Breath-hold

Red Abalone, *Haliotis rufescens*
Credit: DFG

diving effort has increased in relation to shore picking beginning in the 1960s. In 1960, an estimated 11,000 diver-days were expended to take 118,000 pounds of red and black abalone, compared with 29,000 diver-days to take 192,000 pounds in 1972. By 1985 to 1989, average diver-days and shore picker-days per year were focused on red abalone in central and northern California. Estimated landings of red abalone in central and northern California for combined divers and shore pickers reached a high of 3,472,000 pounds in 1986 and had decreased to 1,161,000 pounds by 1989. In 1998 an abalone stamp was first sold to generate revenues for assessments. In 1998 and 1999 an average 33,000 stamps were sold showing effort levels are comparable to those estimated for the 1985 to 1989 period.

Pink abalone

Pink abalones occur from Point Conception to the central Baja California peninsula, Mexico. Its depth range extends from the lower intertidal zone to almost 200 feet, but most are found from about 20 to 80 feet. It has the broadest distribution of the southern California abalones. It may be identified by its nearly circular shell, black and white epipodium and black tentacles, and highly arched shell with protruding respiratory pores, two to four of which may be open.

In the early 1950s, pink abalone comprised the largest segment of the abalone fishery, about 75 percent, and had a significant effect on the total abalone landings (Figure 1). Commercial landings originated at the eastern northern Channel Islands (Anacapa, Santa Cruz), and the southern Channel Islands (San Nicolas, Santa Catalina, Santa Barbara, San Clemente). Because pink abalone are more fragile than others and grow more slowly, the level of take could not continue. The persistence of pink landings was due to expansion into unfished areas, but that occurred so quickly that depleted areas did not have time, or the ability, to recover. By the early 1980s the commercial pink abalone fishery had expanded throughout the available range and the landings dwindled to virtually nothing.

Pink abalone was important in the recreational fishery, being the second most taken species, after green abalone. This is not surprising as both species are easily targeted by sport divers. Since pink abalone inhabits areas south of Point Conception, until recently south of the range of the sea otter, its population condition has not been affected by that predator. The re-occupation of sea otter into southern California could have adverse consequences on the already depleted pink abalone.

Department research cruises to San Clemente, Santa Catalina, and Santa Barbara Islands in 1996 and 1997, were used to investigate pink, and other, abalones. The number of abalones sighted per unit of time was used to quantify stocks, and a factor was applied to estimate the number of commercially legal pink abalone that could be collected per hour. Estimates ranged from about one to 1.5 abalone per hour. Similar cruises conducted in 1999, estimated only 0.28 commercial legal pink abalone per hour. At Catalina Island, no commercial sized pink abalone were found. These estimates indicate how low the remaining numbers of abalone there are at the islands. The situation is no better on the front side of Santa Catalina Island, where it was closed to commercial take, but open to recreational fishing.

Fishery independent surveys conducted at the Channel Islands reveal a close association between the presence of small individuals and legal size sport and commercial sizes. The best locations were where refuges were present, *e.g.*, Anacapa Island. These areas supported higher numbers of legal sized abalone and had continued presence of smaller sizes. There needs to be large adults present to provide spawn for future generations, and the presence of the smaller sizes forms the potential fishable resource. This situation may point out that to have sustainable abalone resources the full size range must occur.

Natural climatic events may affect pink abalone both positively and negatively. Pink abalone is at the northern end of its range in southern California, so it would not be unusual for this species to be enhanced by the influx of warm water during an El Niño period, as was observed in 1982 to 1984. On the other hand, intrusion of nutrient-poor warm, El Niño-driven seawater severely depresses kelp, growth and survival, which limits the food of abalone. This may depress abalone growth and reproduction. Since pink abalone spawn throughout much of the year, they are able to overcome the detrimental effects of warm water and spawn successfully. Withering syndrome (WS), a lethal disease of abalones, is exacerbated by El Niño related sea water warming, and may cause severe local decline in numbers.

Green abalone

Green abalone is found on open coast shallow rocky habitat from Point Conception, California to Bahia Magdalena, Baja California, including parts of the Channel Islands that are influenced by warmer water regimes. The species is associated with the warm-temperate California region from Baja California to southern California. Green abalone were commonly found in rock crevices, under rocks and other cryptic cavities from the low intertidal to subtidal zones. They are mostly found between 10 and 20 foot depths, often associated with surf grass beds, but are sometimes seen at 50 and 60 foot depths.

The shell is brown with the surface marked by many low, flat-topped ribs which run parallel to the pores. The shell has five to seven pores with edges elevated from the surface and a groove that runs parallel on the outside edge of the pores. The edge of the foot, the epipodium, is mottled cream and brown, with a frilly edge and scattered tubercles. The tentacles are olive green in color. Green abalone attain a size of 10 inches but are usually smaller.

Sexual maturity occurs at about three and a half inch shell length (approx. 5 to 7 years). Individuals average about one half inch of shell growth per year for the first five to seven years. After maturity, shell growth slows down. The spawning season for green abalone is between early summer and fall and spawning often occurs several times during this period. Average fecundity for a population of greens at Santa Catalina Island was estimated to be about 2.5 million eggs per female per year.

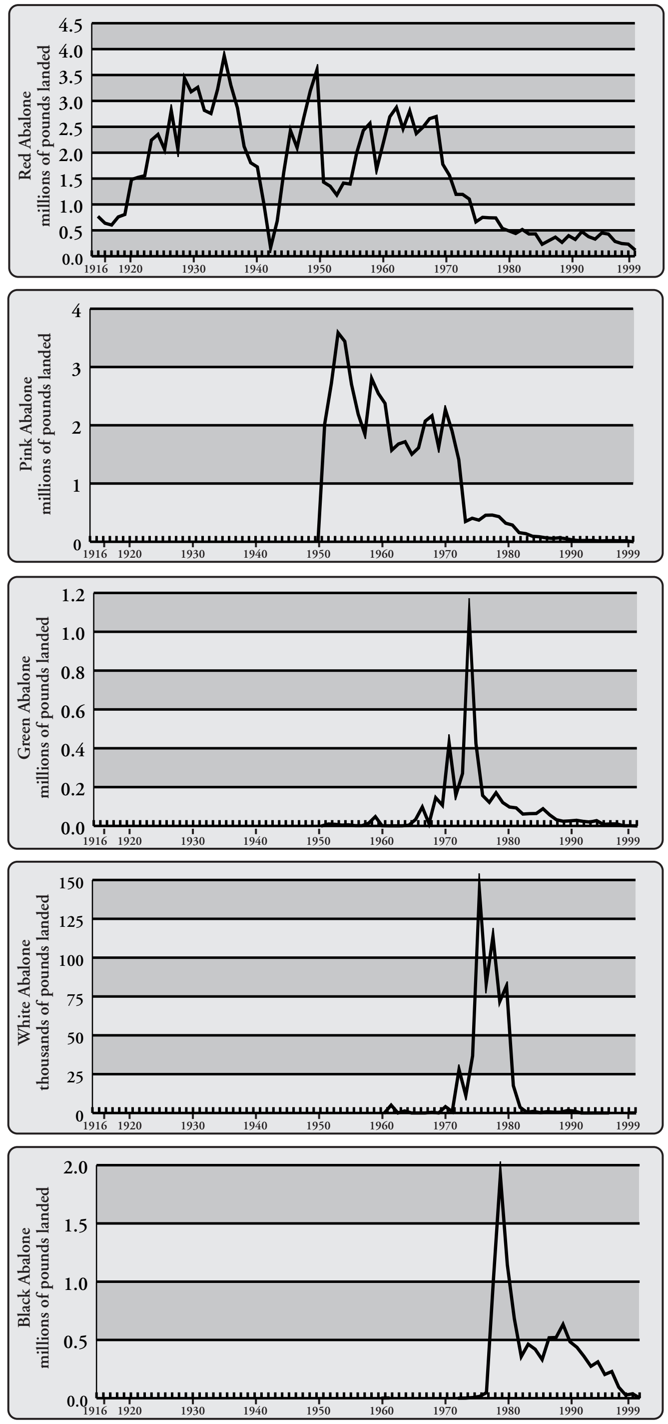
Green abalone are opportunistic drift algae feeders, and eat a wide variety of drift algae, but they prefer fleshy red algae. Predation of juveniles plays a major role in shaping adult population size. Abalone experience a high mortality early in life due mainly to predation. Some of the predators of juvenile abalone are crabs, lobsters, other gastropods, sea stars, octopuses, and fishes. The two spot octopus is the main predator of young green abalone at Santa Catalina Island. Larger individuals have a refuge in size from most of these predators. However, bat rays and sea otters prey selectively on larger abalones.

Since they prefer well sheltered, hidden niches, green abalone are able to exist in the high energy area of the low intertidal shallow subtidal areas where most other abalone species cannot exist. They are often concentrated in shallow subtidal surf grass beds where wave action facilitates a steady flow of drift algae.

Green abalone may occupy a particular site, called a homesite or scar. Abalone larger than one inch seldom leave their home scar to forage, relying on algal drift. Smaller individuals actively forage but return to their home scar in the day.

Black abalone

In black abalone the shell is smooth, black to slate gray in color, though some may have lost much of the outer layer leaving it white. This abalone has the most distinctive shell of the California species. The shell is usually clean though some have barnacles growing on them. There are five to nine open pores, which are flush with the shell. In more southern populations as many as 14 pores may be open. The epipodium has a smooth texture and is black.



Commercial Landings 1916-1999, Multiple Abalone

Data Source for all figures: DFG Catch Bulletins and commercial landing receipts. Graphs stacked to depict movement of catch effort from one abalone species to the next over time. Prior to 1949, identification of abalone species landed was not required. However, commercial abalone landings between 1916 and 1949 consisted primarily of red abalone. The data presented here for red abalone includes landings recorded as unspecified abalone during this time period. There were no commercial landings reported for pink or green abalone prior to 1950; no commercial landings are reported for white abalone prior to 1959; and no commercial landings are reported for black abalone prior to 1956.

The interior of the shell is silvery-white nacre (mother-of-pearl) and has a muscle scar.

Black abalone are reported from as far north as Oregon, but most are found south of San Francisco Bay to southern Baja California including the offshore islands. By the mid-1990s, only remnant populations existed at the Farallon and Channel Islands, and along the mainland southern California shoreline they were totally absent. Small populations exist in central and northern California.

Essential habitats includes rocky intertidal areas, often within the high energy surf zone. Consequently, it is exposed to a broad range of conditions, including wave wrack, exposure during low tides to hot, dry periods of direct sun, and to chilling cold winter conditions. Because natural populations of black abalone form exposed, easily accessible aggregations, protection from take is important, particularly along the mainland coast. In light of the growing human population in California, it is possible that coastal populations of black abalone will never return. Remote totally protected intertidal areas on the mainland and the Channel Islands may be required for reestablishment of natural populations.

It is not known whether subpopulations of this abalone exist. Because of the extensive distribution of suitable habitat, limited migration, and the method of reproduction, there may be genetic differences that have evolved among local populations, particularly at the extreme ends of the range, and between coastal and insular populations. Black abalone appear to recruit locally, but further examination of the recruitment pattern in this species is needed for better resource management and restoration.

Black abalone grow most quickly during the first five to 10 years. Growth varies between locations, and is likely affected by stress, including disease, food availability, and climatic variation. This abalone is a long-lived species, attaining an age of 25 years or more. Sexual maturity occurs at a relatively small size, with most individuals being mature at less than two inches. Spawning occurs in the spring and early summer, and a second period of spawning may occur in the fall.

Black abalone larvae settle onto hard substrate, and are often found in the vicinity of larger individuals. The newly settled larvae are cryptic, and remain so until they attain a length of four inches or greater. Small juveniles are found under rocks and deep in crevices, while larger black abalone in natural unharvested areas congregate on rocks and in tide pools, sometimes in great numbers. Newly settled and juvenile black abalone forage on bacterial films. As the abalone grows it shifts to larger drift algae brought into the intertidal areas by waves and currents.

Small black abalone are preyed upon by sea stars, octopus, and several crabs found in the intertidal areas. Larger individuals appear to be well protected from most predators, at least as long as they remain attached to the substrate. Sea otters are the main natural predator of this species. The absence of sea otters from southern California is the primary reason for the dense concentrations of abalone that developed in California and Mexico.

The recent commercial fishery in California began in approximately 1968 at the Channel Islands with the development of an Asian market. Landings peaked in the 1970s, and began a slow decline thereafter.

In 1985, weak, shriveled, and dying black abalone were observed by scientists in tide pools at the Channel Islands. Black abalone were literally falling off the rocks in large numbers at several of the islands. The disease is characterized by weight loss, pedal atrophy, weakness, and lethargy. Early experiments showed that once an abalone exhibited signs of this syndrome, it quickly died.

Withering syndrome (WS), caused by a Rickettsia-like procaryote is the causative agent of this catastrophic disease of abalone. It has ravaged all the Channel Islands and the remaining mainland populations of black abalone as far north as Pacifica, San Mateo county. Most locations experienced almost total loss of black abalone populations. A few individuals survive WS. These resistant abalone will be the basis of any natural recovery and are also utilized in captive breeding programs to develop resistant strains. In 1998, the NMFS added black abalone to the candidate species list for possible listing under the federal Endangered Species Act.

White abalone

White abalone inhabit deep, rocky substrata from 60 to 200 feet deep, from Point Conception, in southern California to Bahia Tortugas, in central Baja California, including the offshore islands and banks. Because it is found primarily in depths greater than about 75 feet, it wasn't described as a species until 1941.

The shell is high and oval in shape with a row of high pores spiraling to the highest part of the shell, the spire. Generally, the surface of the shell is free of heavy encrustation, but often the shell is covered with pink, coralline algae. There appears to be no harm to the abalone, and the algae often matches the shell to the surrounding habitat. The shell is considerably lighter in weight than the shells of other species. The interior of the shell is silvery-white nacre and lacks a muscle scar. Three to five of the largest pores are open, the rest being filled in during growth.

Little is known about natural growth of white abalone. Individuals settled in the laboratory grew at about 0.6 inch per year, less than that of other abalones. Estimates from a few individuals indicated that growth during the first five years averages about an inch per year slowing down thereafter, which is a similar growth pattern to other California abalones. The life span of white abalone was estimated at about 35 to 40 years. There is no evidence of a significant recruitment event since the late 1960s or early 1970s; thus the remaining individuals are likely approaching the end of their life spans.

Reproduction in white abalone is probably similar to other species. Successful reproduction depends upon population density, spawning period, and fecundity, and conditions conducive to successful settlement. White abalone spawn in the winter, with synchronous gamete release, but the cue is unknown. The release of sperm initiates egg release in some abalones. Abalone may reproduce annually, but evidence suggests that settlement of the larvae may be only occasionally successful. Because of the short larval life, and the discontinuous habitat there are likely to be genetic differences between remote locations, particularly at the extremes of its range.

Abalone are herbivorous, feeding on bacterial and diatom films when small, and foraging on attached and drift kelp later. White abalone are associated with deep living kelps, and have been observed feeding on these. They have also been observed near the interface of sand and rock, a position that would facilitate the capture of drift algae.

Abalone predators include sea stars, octopus, crabs, lobster, and fishes, particularly sheephead, cabezon, and bat rays, all of which have been observed in white abalone habitat. Sea otters are likely not significant predators of white abalone, and are not responsible for low white abalone population numbers. Otters have been absent from most of the areas where white abalone occur since well before the establishment of the white abalone fishery.

As the nearshore abalone resources declined throughout California, divers went farther and deeper, eventually encountering virgin stocks of white abalone. The commercial fishery for white abalone began about 1965, though whites were probably taken incidentally before then. The high quality of the meat and the knowledge of the resource spurred commercial landings to a peak in 1972 of almost 144,000 pounds. Thereafter landings declined and became insignificant in the mid-1980s. The recreational fishery also took white abalone, but landings are unknown, and probably far less than the commercial landings. Relative to the whole fishery, white abalone comprised a small part of the landings, but its high quality and value bolstered the fishery for a short time.

In 1997, the NMFS added the white abalone to the candidate species list to be considered for listing under the federal Endangered Species Act. This action required a status review, which concluded that overexploitation was the major cause of the decline. In May 2000, white abalone became the first marine invertebrate to be proposed for listing as endangered under the federal Endangered Species Act.

Status of the Populations

Currently, all five major species of abalone in central and southern California are depleted, a result of cumulative impacts from commercial harvest, increased market demand, sport fishery expansion, an expanding population of sea otters, pollution of mainland habitat, disease, loss of kelp populations associated with El Niño events, and inadequate wild stock management. The political/legislative climate and limited funding has prevented the department from establishing and managing to sustain yields for each species and area. Fish and Game Commission and California legislative action halted sport and commercial fishing for abalones in southern California in 1997. Sport fishing is allowed north of San Francisco Bay. It seems paradoxical that all fishing for abalone would be closed in the southern two thirds of California, while a viable sport fishery exists in the north. The difference between the two areas is centered on the way abalones are taken. In the south, scuba and commercial dive equipment made all abalone available to harvest, while in the north only skin diving and shore picking are allowed. In the deeper areas beyond free diving depth, the population is dense and individuals are large, conditions that maximize reproduction and recruitment. It is these *de facto* refuge areas that provide a sustainable resource that can be fished year after year.

The northern California abalone fishery provides insight into what is necessary to maintain a sustainable resource, upon which a fishery can be allowed. In the northern fishery significant areas of good abalone numbers are unavailable to the fishery, including individuals larger than minimum legal size. Such areas are maintained passively because most skin divers cannot get to them in the often severe oceanic conditions found there. In contrast, all areas in southern California were available to commercial and sport divers, and eventually the larger individuals were taken, leaving little for stock rebuilding.

The primary regulation of the abalone fishery was the size limit, which was set at a relatively large size, allowing individuals as old as 15 years (in red abalone) to reproduce before entering the fishery. Implicit in size limits is the assumption of regular reproduction and more importantly, settlement. To have reproduction and settlement there must be large numbers of adults close together. Such areas are exactly what is sought in the fishery. Management efforts to protect stocks through size limits and limits on the number of commercial abalone fishermen have been ineffective. Stock declines have led to near extirpation of three species with red and pink abalone reduced to remnant populations on islands in southern California.

The poor survival rates observed in most abalone seeding experiments suggest that seeding will not be an effective method for restoration of depressed stocks. Adult translocation to aggregate spawners may be the only hope to replenish depleted stocks or prevent extinction for some species. Unfortunately for most species, few adults remain to aggregate. Expensive artificial breeding programs may be necessary to obtain sufficient numbers of large abalones upon which to start rebuilding the resource. Additionally, unless stocks are reestablished in well-protected refuge areas, illegal take will undermine these efforts.

In northern California, red abalone stocks continue to provide abalone to an important recreational fishery. The continuation of this fishery depends upon the protection of the *de facto* deep water refuge, monitoring the annual harvest to assure that the resource can accommodate sport harvest, continued effective resource protection, education, and assessment. Recovery of the southern California abalone resource will likely require many years and the establishment of marine protected areas to encourage and protect dense populations of abalones.

Three natural phenomena will have a decisive effect on California's future abalone fisheries — disease, oceanographic events (El Niño), and sea otter expansion. Each is already influencing research and management decisions.

WS is a bacterial disease that has virtually eliminated black abalone from large areas of its habitat in southern California. The spread and effectiveness of the disease is enhanced by higher than average sea water temperatures. In black abalone, some individuals appear to be resistant to it, but because these individuals are healthy, they were often taken in the course of fishing. It is precisely these healthy individuals that are necessary to obtain natural recovery. After the discovery of WS, rather than establishing a general moratorium on the take of black abalone, each island was closed after populations had crashed. The continued fishing removed most of the potentially resistant abalones.

WS is known in each of the other California abalones, but little is known how it affects the other species, particularly along the mainland. Red abalone at San Miguel Island are infected, but incidence seems to be low. Green abalone, which overlaps with the distribution of black abalone, appears to have suffered from WS at some islands. A few northern California red abalone have been collected with WS pathogens, but it has not caused any symptoms. The cooler seawater temperatures off northern California are sufficient to prevent the occurrence of symptoms, but if environmental temperatures increase WS could become a problem.

WS has the capacity to eliminate abalones throughout large areas. A significant increase of the incidence could eliminate the remaining, already low, populations of abalones. Research is forthcoming about breeding resistant abalone and treating abalones held in captivity. Additionally, any management decisions about abalone must take disease effects into consideration.

Climatic and periodic oceanographic disturbances, particularly those that bring warm water northward can have severe effects on abalones, especially those in southern California. The effect of increased sea water temperature can affect disease susceptibility; lower growth in kelps, thus reducing abalone food sources; alter distribution patterns of marine animals; and bring storms which disrupt local habitats. Each of these could further place additional stress on abalone populations.

The southward movement of the sea otter into its ancient range in southern California would undoubtedly further reduce remaining abalone, and other invertebrate populations further. Along the central coast, sea otters have removed the larger emergent abalone populations, and restricted them to cryptic habitat.

Paradoxically, each of these three developments, are natural events with which abalone and all marine organisms, have endured to some extent in the past. The difference is that historically, populations were larger and more adaptable, and better suited to evolve strategies to cope with changing conditions. Today, populations are smaller, and they cannot respond sufficiently enough or quickly enough to adapt. In some cases, local, and perhaps total extinction of species will result.

Management Considerations

See the Management Considerations Appendix A for further information.

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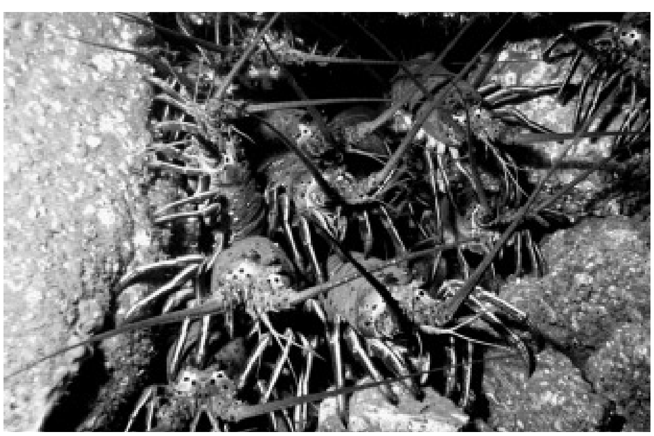
California Spiny Lobster

History of the Fishery

Since the late 1800s, there has been a commercial fishery for California spiny lobster (*Panulirus interruptus*) in southern California. Commercial fishermen use box-like traps constructed of heavy wire mesh to capture spiny lobsters. Traps of other materials, such as plastic, are allowed, but wire traps remain the most popular. About 100 to 300 traps per fisherman is common, but some fish as many as 500 at the peak of the season. The traps are baited with whole or cut fish and weighted with bricks, cement, or steel. They are fished on the bottom, and each trap is marked with a buoy bearing the fisherman's license number followed by the letter P. High-speed boats in the 20 to 40-foot size range are popular in this fishery, but everything from 15-foot skiffs to 50-foot fishing boats are used. Most trap boats are equipped with a davit and hydraulics to assist in pulling the traps.

Commercial lobster fishing occurs in shallow, rocky areas from Point Conception to the Mexican border and off the islands and banks (such as Cortes and Tanner banks) of southern California. Some marine life refuges and reserves are closed to the take of lobster, as are areas in Santa Monica and Newport Bays and at Santa Catalina Island. Sophisticated electronic equipment enables trappers to find suitable lobster habitat and relocate their traps there. Traps are fished along depth contours in waters less than 100 feet, or clustered around rocky outcrops on the bottom. At the beginning of the season the traps are usually very close to shore. By the end of the season they are in 100 to 300 feet of water.

Seasonal landings in the 200,000 to 400,000 pound range rose following World War II and peaked in the 1949-1950 season, with a record 1.05 million pounds landed. A general decline followed for the next 25 years, reaching a low of 152,000 pounds in the 1974-1975 season. Landings started back up the next season, but remained between 400,000 and 500,000 pounds for nine consecutive seasons from 1979-1980 to 1987-1988. The next nine years the landings ranged from 600,000 to 800,000 pounds with a peak of 950,000 in the 1997-1998 season. Landings dropped back down after that. The peaks and valleys that have characterized this fishery are not unexpected in a fishery that is strongly influenced by the weather, El Niño and La Niña events, and the export market.



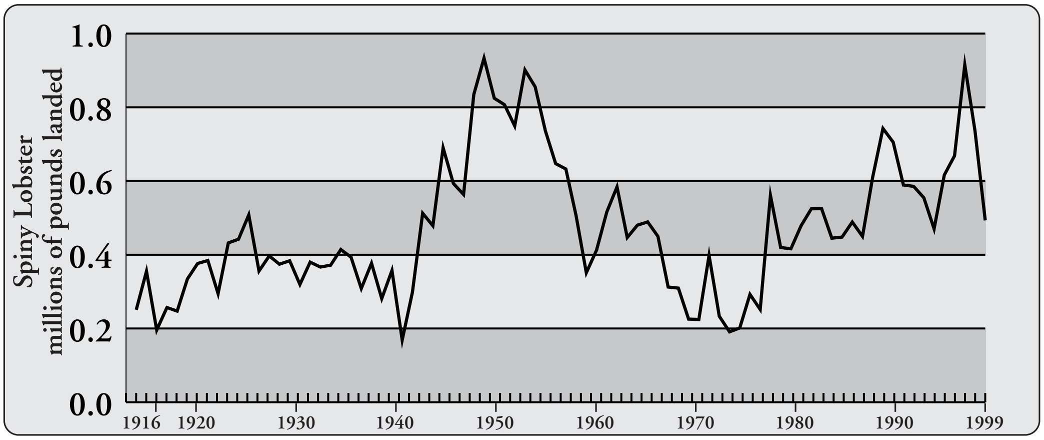
California Spiny Lobster, *Panulirus interruptus*
Credit: DFG

About 90 percent of the legal lobsters taken in the commercial fishery weigh between 1.25 and 2.0 pounds, which produces the size of tail desired for the restaurant trade. Most of the harvest in recent years has been exported to Asian countries and France. However, depressed economies overseas have resulted in an effort to re-establish domestic markets. The price paid to the fisherman is in the range of $6.75 to $8 a pound. The largest portion of the commercial and sport harvest is always taken during the first month of the season, October, which also is the highest month of trapping effort. The effort and catch drop off sharply in January through the middle of March (the season's end). San Diego County, being the most central to the spiny lobster's range, usually produces the highest landings, followed by Los Angeles/Orange, and Santa Barbara/Ventura counties.

Commercial and recreational lobster fishermen are restricted to a minimum size limit of 3 1/4 inches carapace length (CL). Historically, the season for both has run from early October to mid-March. Since 1992, the sport season has opened the weekend before the first Wednesday in October, the official commercial season opener. Commercial fish traps, including lobster traps, must have a destruct-device of a type approved by the Department of Fish and Game. This is to ensure that lost or abandoned traps do not continue to capture marine life indefinitely. Since the 1976-1977 season, it has been required that lobster traps be fitted with rectangular escape ports (2 3/8 by 11 1/2 inches) to minimize the retention of undersized lobsters. This requirement has been credited with reversing the long downward trend in landings previous to that.

A formal commercial restricted access program was initiated in April of 1997. All lobster fishermen are required to have an operator permit ($285). Deckhands that assist them must have a lobster crewmember permit ($125).

Recreational harvesters need a valid sport fishing license with an ocean enhancement stamp, and may use hoop nets or bare (gloved) hands when skin or scuba diving for lobster. No appliance, such as a fish spear or a short hooked pole, may be used to snag the animals from deep crevices or caves. The daily bag limit for sport fishing is seven lobsters, reduced from 10 in 1971.



Commercial Landings 1916-1999, Spiny Lobster
Data Source: DFG Catch Bulletins and commercial landing receipts.

Status of Biological Knowledge

The California spiny lobster ranges from Monterey Bay, California to Manzanillo, Mexico. There is also a small, isolated population of this species at the northwestern end of the Gulf of California. The majority of the population is found between Point Conception, California and Magdalena Bay, Baja California. Adult lobsters usually inhabit rocky areas from the intertidal zone to depths of 240 feet or more.

Spiny lobsters mate from November through May. The male attaches a putty-like packet of sperm, called a spermatophore, to the underside of the female's carapace. When the female releases her eggs, she uses the small claws at the end of her last (fifth) pair of walking legs to open the spermatophore and fertilize the eggs with the sperm inside the packet. Fertilized eggs are attached to the underside of the female's tail primarily in May and June. "Berried" females are generally in water less than 30 feet deep and carry their eggs for about 10 weeks. The larger the size of the female, the more eggs she produces. Females sampled at San Clemente Island carried between 120,000 (2.6 inches CL) and 680,000 (3.6 inches CL) eggs.

Spiny lobster eggs hatch into tiny, transparent larvae known as phyllosomas that go through 12 molts. They have flattened bodies and spider like legs, and drift with the prevailing currents feeding on other planktonic animals. They may drift offshore out to 350 miles, and may be found from the surface to a depth of over 400 feet. After five to nine months, the phyllosoma transforms into the puerulus or juvenile stage. The puerulus is still transparent, but now looks like a miniature adult with extremely long antennae. The puerulus actively swims inshore where it settles to the bottom in shallow water and starts to grow if the habitat is suitable.

The spiny lobster's outer shell serves as its skeleton, and is referred to as an exoskeleton. To grow, a lobster must shed its exoskeleton. This process of molting is preceded by the formation of a new, soft shell under the old one. An uptake of water expands the new shell before it hardens. Lobsters are vulnerable to predation and physical damage right after they molt, until their new shell hardens.

Molt rates for the California spiny lobster are assumed to be similar to those of the Japanese spiny lobster. A 0.24-inch CL specimen goes through 20 molts to reach 1.18 inches CL at the end of its first year. Four molts during the second year will result in a carapace length of two inches, and there are three molts in the third year. It takes a lobster from seven to 11 years to reach a legal size of 3.25 inches CL. Spiny lobsters molt annually, following the reproductive period, once they reach 2.5 inches CL. Growth rates, or the period between molts, are highly variable. They have been correlated with food availability, size, and sex. The larger an animal, the slower it grows. Injuries or disease will often result in a slowing or complete cessation of growth until the injury has been repaired.

Juvenile lobsters usually spend their first two years in nearshore surf grass beds. Sub-adults have also been found in shallow rocky crevices and mussel beds. Adult lobsters are found in rocky habitat, although they also will search sandy areas for food. During the day, spiny lobsters usually reside in a crevice or hole, dubbed a den. More than one lobster is usually found in a den. At night, the animals leave their dens to search for a wide range of food. Adult lobsters are omnivorous and sometimes carnivorous. They consume algae and a wide variety of marine invertebrates such as snails, mussels, sea urchins, and clams as well as fish, and injured or newly molted lobsters. Lobsters are eaten by sheephead, cabezon, kelp bass, octopuses, California moray eels, horn sharks, leopard sharks, rockfishes and giant sea bass.

A large portion of the spiny lobster population makes an annual offshore-onshore migration that is stimulated by changes in water temperature. During winter months, male and female lobsters are found offshore at depths of 50 feet and deeper, although individuals of both sexes have also been found in shallow water in winter. In late March, April, and May, lobsters move into warmer onshore waters less than 30 feet. The higher temperatures on shore shorten the development time for lobster eggs. Nearshore waters also have a more plentiful supply of food. In late October and November, the onshore waters cool, and most lobsters move offshore. Winter storms that cause increased wave action in shallow water encourage this movement. Lobsters generally move after dark and in small groups across the sand.

California spiny lobsters of both sexes reach maturity at five or six years and 2.5 inches CL. After maturity, male lobsters grow faster, live longer, and reach larger sizes than the females. Males can live up to 30 years, and females at least 20 years. There are records of male California spiny lobster weighing over 26 pounds and attaining lengths up to three feet. Today, lobsters over five pounds are considered trophy-size. Trophy-size animals are usually taken by recreational divers.

Status of the Population

Population size is unknown for the California spiny lobster. Commercial landings have fluctuated through the years and are influenced by some factors that are independent of the health of the population.

The closed season protects egg-carrying and molting female lobsters. The size limit ensures that there will be several year classes of broodstock, even if all legal-size lobsters are caught each season. The escape port has been effective in reducing the capture and handling of juvenile lobster. An illegal market has always existed for "shorts" (undersized lobsters). Public education and adequate warden enforcement are key elements in reducing this problem.

The Department of Fish and Game has had a commercial logbook system in place since 1973. Catch effort, the numbers of legal and short lobsters taken, number of traps fished, and depths where the traps are fished are required information on the logs. The presence of shorts is generally a good indicator of a healthy fishery.

Management Considerations

See the Management Considerations Appendix A for further information.

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Red Sea Urchin

History of the Fishery

The commercial fishery for red sea urchins (*Strongylocentrotus franciscanus*) has been one of California's most valuable fisheries for more than a decade. This fishery is relatively new, having developed over the last 30 years, and caters mainly to the Japanese export market. Archaeological evidence however, shows that sea urchins in California have been fished by coastal American Indians for centuries. The gonads of both male and female urchin are the object of the fishery and are referred to as "roe" or "uni," in Japanese. Gonad quality depends on size, color, texture, and firmness. Algal food supply and the stage of gonadal development affect quality and price. Ex-vessel prices during the season typically range from less than $0.20 to more than $2 per pound with the highest prices garnered during the Japanese holidays around the new year. Sea urchins are collected by divers operating in nearshore waters. Divers check gonad quality and are size selective while fishing to ensure marketability. In the last few years the red urchin fishery has become fully exploited throughout its range in northern and southern California. Because of sea otter (*Enhydra lutris*) predation, sea urchin stocks in central California occur at densities too low to sustain a commercial fishery. The purple sea urchin (*S. purpuratus*), which occurs over the same geographical range, is harvested in California, but only on a limited basis.

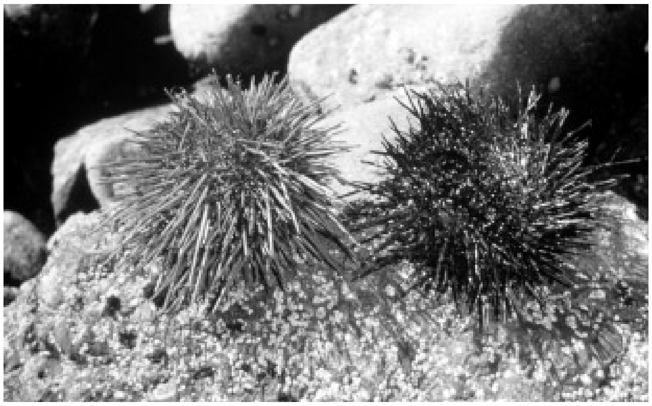
Southern California Fishery

The fishery in southern California began in 1971 as part of a National Marine Fisheries Service program to develop fisheries for underutilized marine species. The fishery was also seen as a way to curb sea urchins destructive grazing on giant kelp. There have been two periods of rapid fishery expansion in California. The first culminated in 1981 when landings peaked at 25 million pounds in southern California. Contributing to this rapid escalation of the fishery was a pool of fishermen and boats involved in the declining commercial abalone dive fishery. Sea urchin landings then decreased following the El Niño of 1982-1983, when warm water weakened or killed kelp, the primary food source for sea urchins. Catches did not recover until 1985-1986, helped in part by the strengthening of the Japanese yen relative to the U.S. dollar, favoring California fishermen and exporters. Prices for urchin from the south are typically higher than for urchins from northern California due to the longer market presence and consistently higher gonad quality of the former.

The majority of sea urchin landings in southern California have come from the northern Channel Islands off of Santa Barbara, where large and accessible stocks once occurred. During the period 1973 through 1977, 80 to 90 percent of the landings originated from these islands. In more recent years, however, there has been a decrease in the contribution from the northern Channel Islands as fishing effort has shifted south to San Clemente Island, San Nicolas Island, and the San Diego area. This spatial shift occurred at the same time that catches decreased throughout the region. In 1990, the southern California sea urchin catch peaked at over 27 million pounds, and has declined steadily to 10.9 million pounds in 1999. In the 1990s, the fishery was impacted by two El Niños and a weakening yen; both factors have contributed to reduce fishing effort and catches.

Northern California Fishery

The northern California commercial sea urchin fishery began in 1972, and remained insignificant until 1977, when 386,000 pounds were landed in the Fort Bragg region. The second major fishery expansion began in 1985, fueled partly by decreasing landings in southern California and favorable monetary exchange rates. The large and unexploited sea urchin biomass in northern California sparked a gold rush as hundreds of new fishermen enter the unregulated fishery. In northern California (Half Moon Bay to Crescent City) landings jumped from 1.9 million pounds in 1985 to 30.4 million pounds in 1988, far exceeding landings from southern California. Northern California sea urchin landings and catch-per-unit effort (CPUE) began a steep decline in 1989, before leveling off in 1996 at about three to four million pounds annually and about 700 pounds per fishing day per diver. Preliminary landings data for 1999 show a catch of 3.2 million pounds with an ex-vessel value of $2.4 million. In northern California, Fort Bragg has remained the center of the fishery, while the ports of Albion, Point Arena, and Bodega Bay accounted for about two-thirds of the catch in 1999. Rocky reefs around Crescent City also support a small fishery.



Red Sea Urchin, *Strongylocentrotus franciscanus*
Credit: Chris Dewees
CA Sea Grant Extension Program

Status of Biological Knowledge

Sea urchins are locally abundant subtidal herbivores that play an important ecological role in the structure of kelp forest communities. Sea urchins belong to the phylum Echinodermata, which includes sea stars, brittle stars, sea cucumbers, and sand dollars. They have a hard calcareous shell called a test, with spines and small pinchers called pedicellariae. Tube feet are located between the spines which are used in respiration, locomotion, and for grasping food and the substrate. On the bottom, or oral side, is the mouth, consisting of five calcareous plates making up a jaw structure called Aristotle's lantern. The mouth leads to the digestive system which voids through the anus on the top, or aboral, side.

Sea urchins are omnivorous, eating primarily foliose algae. The perennial giant kelp is the preferred food in southern California, whereas in northern California urchins feed on the annual bull kelp and perennial brown algae. The red sea urchin's ability to survive during periods of food shortages contributes to the its ability to persist in high densities in areas devoid of algae, known as urchin barrens. The formation of barrens in southern California can follow oceanographic events such as El Niño during which kelp beds die-off resulting in shortages of standing and drift algae. These food shortages may trigger urchins to aggregate and move in fronts denuding the remaining kelp forest. Based on examination of long-term aerial photos and on kelp forest ecology studies in northern San Diego county, sea urchin grazing at its most severe probably accounts for about 20 percent mortality in a given kelp bed. Conversely, the intense fishery for red sea urchins in northern California appears to have had a positive effect on kelp availability. Aerial photographs of surface kelp at one location during the period of concentrated urchin fishing, showed a 15-fold increase in the surface canopy from 1982 to 1989.

Red sea urchins may compete with abalone for both space and food. A recent study on competitive interactions between these species at sites in northern California concluded that there is an inverse relationship between red abalone and red sea urchin abundance at sites where urchin density is high. Sea urchins may be more successful in competing for limited food because of their aggressive foraging and ability to survive starvation conditions. Fishing abalone and sea urchins has no doubt altered these relationships.

Packing sea urchin gonads
Credit: California Sea Grant Extension Program

Several significant predators of red sea urchins are known. Sea otters, spiny lobsters, sea stars, crabs, white sea urchins, and fishes such as sheepshead eat red sea urchins. Within the sea otter's present range, the red sea urchin resource has been reduced to a level which precludes fishery utilization. Urchin diseases have decimated sea urchin populations in the Caribbean islands, however the dynamics of sea urchin diseases in California remain poorly understood. Sea urchins in southern California are susceptible to disease during warm water El Niño events.

There are no reliable methods of aging sea urchins since rings on the test plates are not laid down annually. Sea urchin growth rates vary depending on food availability. Growth rates must be determined by tagging and recapturing animals. Internal tags (PIT tags) or chemical (fluorescent) tags that bind to calcium have been used to successfully tag sea urchins. Tagging studies reveal that red urchins are long-lived, are certainly older than 50 years and large individuals may be older than 100 years. Growth to a harvestable size of 3.5 inches (test diameter, exclusive of spines) averages six to eight years. There are no patterns in growth along a latitudinal gradient from Baja California to Alaska, however there is a clear trend in population mortality rates. Mortality estimates for southern populations were found to be greater than for northern populations. Likely mechanisms include higher rates of disease and temperature-related stresses as one moves from north to south.

Red sea urchins become sexually mature at about two inches. The sex ratio in urchins about one to one. Sea urchin spawning is seasonal but can vary from year to year and from one locality to another. Food supply and ocean temperatures play a role in the timing and magnitude of spawning. In most southern California locations, spawning generally occurs in winter. In northern California, major spawning occurs in spring and summer, with some spawning activity also in December.

As for many marine invertebrates, fertilization is external and success is highly dependent on density. Subtidal studies suggest that red urchins at densities of less than two per square meter can have poor fertilization success. Females spawn up to several million eggs at a time. Larval development is dependent on temperature and the abundance of phytoplankton (single-celled algae) and is thought to extend for six to eight weeks. As the larvae mature they settle to the bottom and metamorphose into benthic juveniles. The long planktonic phase suggests that juvenile sea urchins may disperse long distances from the adults that have spawned them.

Settlement patterns have been studied for red and purple sea urchins on artificial substrates at sites in northern and southern California since 1990 and are similar for the two species. Peak settlement periods tend to be in spring and early summer although there is substantial year-to-year variation both in timing and intensity. Settlement tends to be less variable south of Point Conception and is depressed during El Niño events. However, El Niño events appear to favor settlement in northern California. Recruitment patterns of red sea urchins in northern and southern California generally mirror those of settlement. Recruitment in southern California appears to be relatively constant while in the north, recruitment rates are lower and more sporadic. The more variable pattern of settlement in the north is consistent with more energetic offshore advection of water during spring periods when larvae are available, especially around headlands.

Newly settled juvenile urchins are highly susceptible to mortality. Juveniles appear to suffer increased mortality in the kelp forest habitat, where micro-predators are presumably more abundant than in similar rocky habitats just outside of the kelp beds. Adult sea urchins and their spines are important structuring organisms in subtidal communities. The canopy formed by the spines is a micro-habitat in which juvenile sea urchins, shrimps, crabs, brittle stars, fish, abalone and other invertebrates can be found. The spine canopy is most likely an important habitat for juvenile sea urchins especially in areas where alternative cryptic habitats (*e.g.,* crevices and undersides of boulders) are rare or absent.

Status of the Population

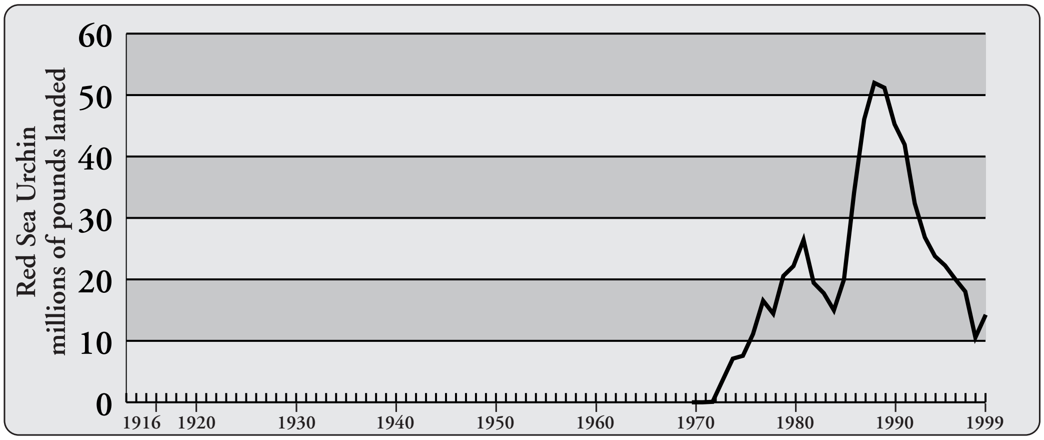
In southern California, the red sea urchin resource now produces about 10 million pounds annually, with harvestable stocks (defined as exceeding the minimum legal size and containing marketable gonads) in decline since 1990. Between 1985 and 1995, the percentage of legal-sized red sea urchins at survey sites in the northern Channel Islands declined from 15 percent to 7.2 percent. Although fishing has significantly reduced density in many areas and catch-per-unit of effort has decreased, localized juvenile recruitment has, thus far, somewhat mitigated fishing pressure. Consistent recruitment has been noted on artificial settlement substrates and along subtidal transects over the last decade at monitoring stations along the southern California mainland coast and the northern Channel Islands. This may be partly due to ocean current patterns in the Southern California Bight, where water retention may increase the chances for larvae to encounter habitat suitable for settlement. Continued recruitment at present levels, however, is not guaranteed; in fact, intensive sea urchin harvesting in northern California and Baja California could result in a decrease in sea urchin larvae in southern California in the future.

Catches in southern California have exhibited a pattern resembling the serial depletion that characterized the decline and collapse of the abalone fisheries in the mid-1990s. The northern Channel Islands have supplied most of the catch over the years, but beginning in 1992 catches in the northern islands began to decline as effort and harvests started to increase in the southern islands of San Nicolas and San Clemente, signaling a shift away from the northern islands. Recently, San Clemente Island catches have declined precipitously indicating that the fishable stock there may be largely depleted. Whether the harvestable stocks can recover to their previous levels in these heavily fished areas remains a concern, particularly if fishing effort remains largely uncontrolled.

The northern California fishery has been characterized by rapid growth to 30 million pounds in 1988 and decline to less than five million pounds in the late 1990s. Fishery dependent modeling of the sea urchin fishery during the period of rapid decline estimated that the 50,800 tons of red urchins harvested from 1988 through 1994 represented about 67 percent of the fishable stock available at the start of 1988. Effort declined during this period as the 126 divers who had worked exclusively in northern California during 1991 had dwindled to 69 by 1995. Annual catch per permittee declined by 57 percent from 1990 to 1995.

Densities of fishable stocks continue to be depressed at subtidal survey sites examined in the Fort Bragg area since 1988. From 1988 to 1997, legal-sized red urchins surveyed outside of reserves, declined from 47 percent to 20 percent of the population, and from 0.8 per square meter to 0.2 per square meter surveyed. In contrast, during this period densities in two area reserves averaged over 3.0 red urchins per square meter. These patterns were observed to continue during northern California surveys in 1999 and 2000. Episodic and infrequent recruitment combined with intensive harvesting on the north coast have had a serious impact upon catches, as the fishery has evolved into a recruitment fishery, with fishermen targeting harvest of newly recruited sea urchins. For example, in 1999, 47 percent of the catch was less than 3.9 inches, just over the 3.5-inch minimum size limit. The size limit and seasonal closures may help prevent fishery collapse but may not improve recruitment, particularly if its success is primarily a function of oceanographic factors, spine canopy micro-habitat and maintaining large spawners in the population.

Commercial Landings 1916-1999, Red Sea Urchin
Commercial Landings 1916-1999, Red Sea Urchin
Data Source: DFG Catch Bulletins and commercial landing receipts.



Management Considerations

See the Management Considerations Appendix A for further information.

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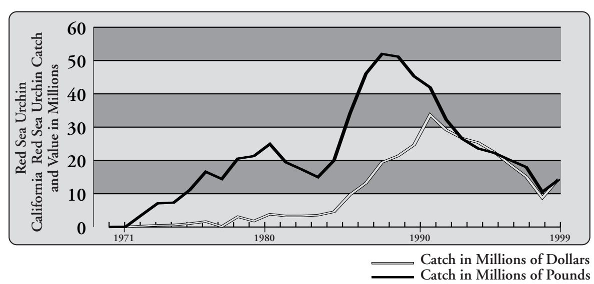
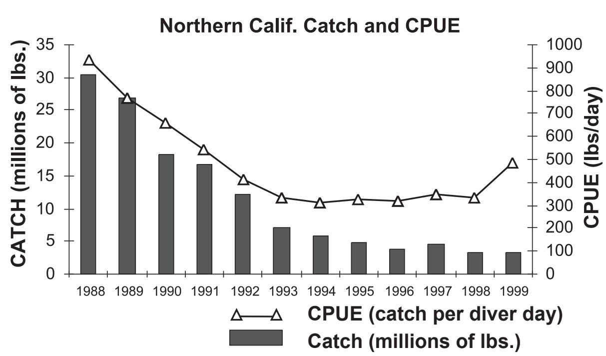


California red sea urchin catch (lbs) and ex-vessel value.
Data Source: market receipt database.



Northern California landings and catch per unit of effort (CPUE).
Data source: DFG logbooks.

Purple Sea Urchin

History of the Fishery

Purple sea urchins (*Strongylocentrotus purpuratus*) have been used by humans in California for thousands of years as shown by remains in middens left by American Indians along the coast. Prior to the early 1970s, few people harvested purple sea urchins and, along with red sea urchins (*Strongylocentrotus franciscanus)*, they were considered to be pests because they grazed kelp.

The purple sea urchin has fishery potential, its roe being reported to be very similar in quality to some of the highly desirable domestic Japanese species as well as being a desirable product in Mediterranean countries. However, it has been harvested only on a limited and experimental basis in California as an adjunct to the much larger and more lucrative red sea urchin fishery. All the requirements of the restricted access commercial sea urchin permit fishery apply to harvest of purple sea urchins except there are no minimum sizes or closed periods. A minor recreational fishery for purple urchins also takes place in southern California with a daily bag limit of 35.

Since 1990, annual purple sea urchin landings have ranged from 14,000 to 388,000 pounds, averaging 139,000. Landings were less than 50,000 pounds in five of those years, with the highest landings of 388,000 and 316,000 pounds in 1991 and 1992 when several attempts were made to develop a viable fishery for this species for the Japanese market. In recent years, purple sea urchins have also been exported to markets in the Mediterranean region. Harvesting has occurred in both southern and northern California with approximately 60 percent of the landings coming from northern areas since 1990. Unfavorable harvesting and processing economics and limited availability of harvestable quality purple sea urchins for the Japanese market have been the main impediments to growth of this fishery.

Status of Biological Knowledge

General biology of the purple sea urchin is very similar to the closely related red sea urchin and will not be repeated in detail here. In addition to external color differences, maximum size is much smaller for purple sea urchins and only rarely do they attain a test diameter over four inches. Purple sea urchins live primarily in shallow water and are the only abundant sea urchin in intertidal areas along the California coast. The maximum reported depth is 500 feet. The published range is from Cedros Island, Baja California, to Alaska.

Feeding habits and reproduction are quite similar to the red sea urchin. Age of first reproduction probably is one or two years. Larvae spend an uncertain length of time in the plankton, and it is probably at least six to eight weeks before metamorphosis takes place and juveniles are ready to settle to the bottom. Peak settlement periods tend to be in spring and early summer and there is substantial year-to-year variation both in timing and intensity. Settlement tends to be less variable south of Point Conception and is depressed during El Niño events. El Niño events appear to favor settlement in northern California, however. Energetic movements of water to the offshore in northern California have been associated with reduced recruitment.

Growth is highly variable and strongly linked with food availability. At one year of age, purple sea urchins can be between about 0.4 and 1.2 inches. After five years, size can range from 1.25 to 2.0 inches. Growth rates of very small individuals up to an age of one year are not well known.

Predators of purple sea urchins include those for red sea urchins but, because purple sea urchins are common in the intertidal zone, predators also include sea gulls, oyster catchers, and raccoons. Sea otters are able to reduce sea urchin populations to levels unsuitable for commercial or recreational fishing, but apparently not to levels that would threaten the species' continued existence.

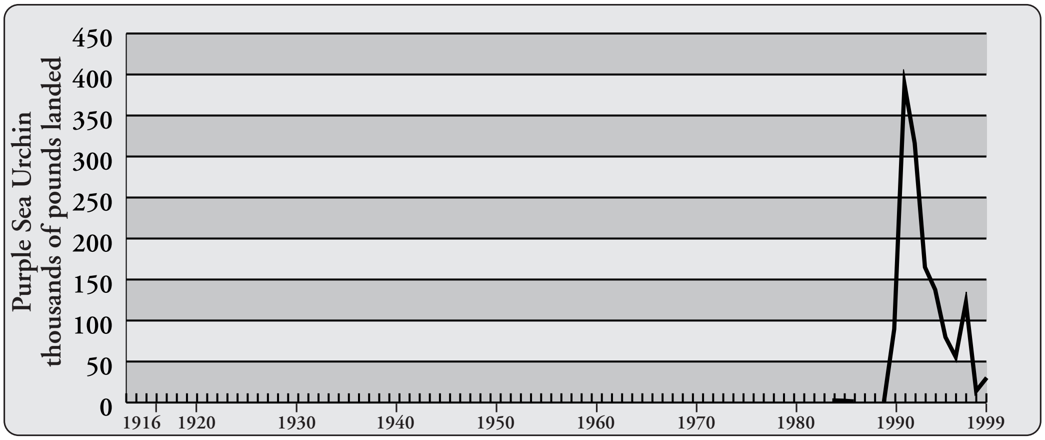
Purple sea urchins show increased mortality above 73˚F, which appears in part to be physiological stress, but elevated temperatures also promote development of one or more pathogens that can cause mass mortalities. Mass mortalities have been observed more frequently in southern than in northern California especially in association with elevated water temperatures during El Niño events.

Status of the Population

Larval settlement rates monitored at a number of locations in southern and northern California over the past 10 years do not indicate a change in larval production and recruitment patterns, which indicates that the status of this species appears to be stable.

Commercial Landings 1916-1999, Purple Sea Urchin

Commercial Landings 1916-1999, Purple Sea Urchin
Data Source: DFG Catch Bulletins and commercial landing receipts.



Management Considerations

See the Management Considerations Appendix A for further information.

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Dungeness Crab

History of the Fishery

Dungeness crabs (*Cancer magister*), also known as market crabs or edible crabs, were first taken commercially off San Francisco in about 1848. The fishery blossomed early, and now the California harvest of this important marine resource occurs from Avila to the Oregon border. Before the 1944-1945 season, the fishery was centered in the San Francisco area, and average annual statewide production was only 2.6 million pounds. The fishery expanded into the Eureka-Crescent City area as World War II ended. In the early 1940s, crab traps replaced the hoop net, leading to significantly increased landings with strong contributions from northern California. Annual statewide production since the 1945-1946 season has averaged about 10 million pounds and recent ex-vessel annual value has been about $15 to 20 million. Approximately 75 percent of the catch is sold as whole crab (live, fresh-cooked or frozen) and the remainder is picked and vacuum packed.

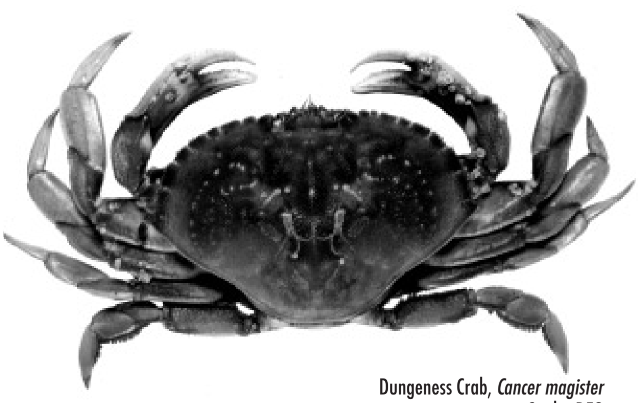
The commercial fishery for Dungeness crabs occurs in two areas: northern and central California. Central California fishing areas include Avila-Morro Bay, Monterey, and San Francisco-Bodega Bay. The Morro Bay and Monterey fisheries have been of minor importance and San Francisco has always been the center of this fishery. Central California landings were relatively stable from 1945-1946 to 1955-1956, and peaked at 8.4 million pounds in the 1956-1957 season. The fishery then steeply declined at a rate of more than one million pounds per season until 1961-1962, when only 710,000 pounds were landed. The central California fishery remained seriously depressed from 1962-63 through 1984-85 when annual landings averaged less than one million pounds. More recent landings have averaged closer to two million pounds.

The central California fishery utilizes an area of over 400 square miles, including the Gulf of the Farallones north to the Russian River. The fleet consisted of 200 to 230 boats during the 1950s. When the fishery declined in the 1960s, a reduction in the number of boats followed and the fleet now consists of about 100 vessels. The central California crab fleet has evolved from, but still includes, some old "Monterey" style vessels. Larger multiple purpose vessels are now the norm.

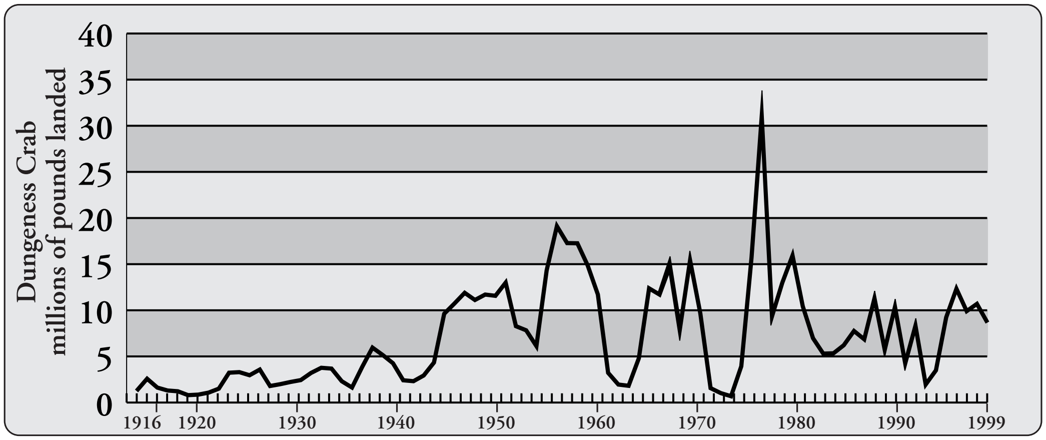
The northern California fishery increased substantially after 1945. Landings reached an initial peak in the late 1950s but, unlike the central California fishery, which peaked and then experienced low production levels for many years thereafter, the north coast fishery then exhibited three 10-11 year "cycles" of production. In these repeating cycles, about six years of good or outstanding landings (a record 25.6 million pounds in 1976-1977) were followed by about four years of poor or extremely poor landings (as low as 350,000 pounds in 1973-1974). Since 1982-1983, landings have fluctuated much less dramatically and have not been as clearly cyclic. Recent landings have ranged from 2.2 to 13.1 million pounds and have averaged about 6.7 million pounds.

Dungeness fishing grounds off northern California are over twice the size of those in central California. They extend from Fort Bragg to the Oregon border with the prime area between Eureka and Crescent City. The northern California fleet fluctuated between 100 and 200 vessels in the 1950s and 1960s, dropped to a low of 61 in 1973-1974, then peaked at 410 during 1976-1977. Since then, effort has been high, averaging 330 vessels per season. Before the mid-1970s, most vessels were converted salmon trollers 30 to 60 feet in length; however, the complexion of the fleet changed during the record production years of the 1970s. Vessels ranging in size from 22-foot dories to trawlers in excess of 100 feet entered the fishery.

The dividing line for management of the northern and central California areas is the Mendocino-Sonoma county line. Both fisheries are managed on the basis of simple "3-S" principles — sex, season, and size. Only male crabs may be retained in the commercial fishery (thus protecting the reproductive potential of the populations), the fishery has open and closed seasons, and a minimum size limit is imposed on commercial landings of male crabs. The central California season opens the second Tuesday of November and continues through June 30, whereas the northern California season opens December 1 and continues through July 15. The summer-fall closed periods are intended to prevent fishing on male crabs when they are soft-shelled. At this time, male crabs would be vulnerable to fishery-related handling mortality and would have market quality well below their potential. During open seasons, male crabs should be in prime condition (greatest meat content) for the market. The opening and closing are two to three weeks earlier in central California than in northern California, because crabs in central California molt earlier and achieve adequate market condition earlier than in the north. The director of the department



Dungeness Crab, *Cancer magister*
Credit: DFG



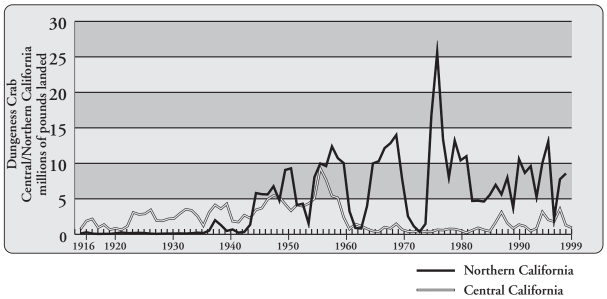
Commercial Landings 1916-1999, Dungeness Crab
Data Source: DFG Catch Bulletins and commercial landing receipts.

may delay the northern California season opening to as late as January 15, if market condition of crabs is not sufficiently high on December 1. Depending on crab condition, marketable crabs typically yield from 20 to 28 percent of their body weight as cooked meat.

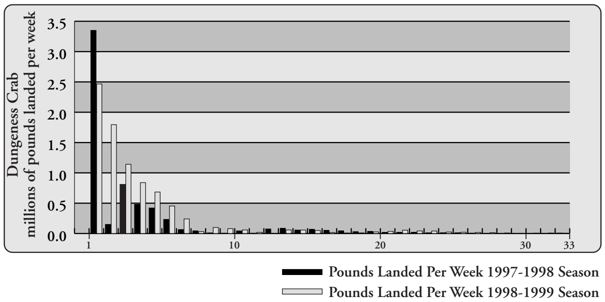
Commercial gear for Dungeness crab is essentially the same throughout California. It consists of a circular steel trap three to 3.5-feet in diameter weighing 60 to 120 pounds. Each trap is required to have two 4.25-inch diameter circular openings to allow sublegal male and small female crabs to escape. These escape ports are remarkably effective in reducing handling of undersize crabs as most male crabs that are retained are close to or exceed the minimum size limit for males of 6.25-inches across the back. Traps must possess a destruction device that causes traps to open allowing crabs to escape should traps be lost. The heavily weighted traps rest on the bottom and each is buoyed independently to the surface. Traps are left overnight or longer depending on fishing conditions. Most traps are fished at depths ranging from about 60 to 240 feet, but some traps are fished in shallower and in deeper waters.

Almost all of the California Dungeness crab catch is landed in the commercial trap fishery. Trawl vessels are allowed an incidental take of 500 pounds per trip during the regular season, but only a few thousand pounds of trawl-caught crabs are landed annually in California. (Commercial trawling is prohibited within three miles of shore, where the vast majority of Dungeness are captured.) There is limited sport use of Dungeness crabs in central and northern California. The sport size limit is 5.75 inches across the back for either sex, and a limit of 10 crabs of either sex may be possessed. The annual sport harvest is believed to be less than one percent of the commercial take, but there have not been any recent estimates of total sport catch.

Because California Dungeness crabs are caught almost exclusively within three miles of shore and because California, Oregon and Washington often undertake coordi-



Northern and Central California Landings Per Season 1916-1999, Dungeness Crab
Seasonal landings for northern California, including Eureka, Cresecent City, and Fort Bragg Landing, and central California including Bodega Bay, San Francisco Area, Monterey, and Morro Bay.
Note: data are recorded as seasonal landings, which differ from the DFG Catch Bulletin and commercial landing receipt data, which are reported on an annual basis.
Data Source: Seasonal Landings determined from reported commercial landings recorded by DFG Catch Bulletins and commercial landing receipts.



Commercial Landings by Week, Dungeness Crab
1997-1998 and 1998-1999, Dungeness Crab Catch data indicate consistent high early season landings of Dungeness crab.
Data Source: Seasonal landings determined from reported commercial landings recorded by DFG Catch Bulletins and commercial landing receipts.

nated management activities under the auspices of the Pacific States Marine Fisheries Commission, the fishery has remained under effective state jurisdiction despite repeated federal concerns regarding harvests beyond three mile state jurisdictional authority. Although total landings are not restricted by quota, beginning in 1995 California implemented a limited entry program that is designed to achieve an eventual reduction in the number of fishery participants. As of March 2000, limited entry permits have been granted to 604 California residents and 70 non-residents.

Status of Biological Knowledge

Dungeness crabs range from the eastern Aleutian Islands, Alaska, to perhaps Santa Barbara; however, the species is considered rare south of Point Conception. Temperature apparently determines the distribution, and the 38° to 65° F surface isotherms are considered the limits of the range. The geographic range of the species probably depends more on the restricted thermal tolerance range of larvae than of adults. Optimal temperatures for larval growth and development are 50° to 57° F.

This species has a preference for sandy to sandy-mud bottoms but may be found on almost any bottom type. Dungeness crabs may range from the intertidal zone to a depth of at least 750 feet, but are not abundant beyond 300 feet.

The resource off California has been demonstrated by tagging experiments to consist of five subpopulations: one each in the areas around Avila-Morro Bay, Monterey, San Francisco, Fort Bragg, and Eureka-Crescent City. As noted above, only the latter three are of commercial importance. DFG surveys indicate the combined San Francisco and Fort Bragg populations are not as large as the population extending from Eureka into Oregon. Little or no intermixing occurs. Tagging studies have also demonstrated random movement by both sexes. At times, an inshore or offshore migration is observed, but most movement is restricted to less than 10 miles. Travel up to 100 miles has been noted for individual males, but female movements seem much more limited.

Female molting and mating occur from February through June in California. Male crabs are able to sense when females are about to molt (presumably through detection of pheremones released by females) and carry such females in a protective pre-mating embrace for several days until they molt. Hard-shelled males then mate with the freshly molted, soft-shelled females. Sperm deposited by males are stored in a spermatheca inside the female. Fertilization of eggs takes place when internally-developing eggs are extruded between October and December. Thereafter, they are carried beneath the abdominal flap of the female. The smallest females carry about 500,000 eggs and the largest from 1.5 to 2.0 million. Freshly molted females carry larger numbers of eggs than do gravid females that have missed a molt. "Skip-molt" females that have extruded eggs but have not molted recently must rely on stored sperm for fertilization of their eggs. Females may store viable sperm for at least 2.5 years. The eggs range in diameter from 0.016 to 0.024 inches and are bright orange after extrusion, becoming progressively darker as they develop. Hatching occurs between November and February.

The newly hatched larvae pass through five zoeal and one megalops stage before metamorphosing into the adult form. Larval development is inversely related to water temperature, and in central California 105 to 125 days are required to complete the larval stages. Zoeae are hypothesized to have an offshore movement regulated by factors such as depth, temperature, salinity and ocean currents. They are found near the surface at night and as deep as 80 feet in daytime. Megalopae are transported to nearshore waters beginning in April. Metamorphosis occurs from April to June. Estuarine areas such as Humboldt Bay and San Francisco Bay are important nursery areas for young Dungeness crabs, but most rearing must take place in nearshore coastal waters.

Growth is accomplished in steps through a series of discrete molts. In northern California, Dungeness crabs of both sexes molt an average of six times during their first year and attain an average width of one inch. Six more molts are required to reach sexual maturity at the end of their second year, when they are approximately four inches across. Once maturity is reached, growth of females then slows as compared to males. Females molt at most once per year after reaching maturity and rarely exceed the legal size of males. Maximum female size is about seven inches. Male crabs usually molt twice during their third year and once per year thereafter. The average size of males three, four and five years of age is about six, seven and eight inches, respectively. Males may undergo a total of 16 molts during a lifetime, reaching a maximum size of nine inches and age of six to eight years.

Dungeness crabs are opportunistic feeders not limited by abundance or scarcity of a particular prey. Clams, fish, isopods and amphipods are preferred, and cannibalism is prevalent among all age groups. Predators on the various life stages of Dungeness crabs, especially pelagic larvae and small juveniles, include octopuses, larger crabs and as many as 28 species of fish, including coho and chinook salmon, flatfishes, lingcod, cabezon and various rockfishes.

Status of the Population

Dungeness crab populations in California have been fully exploited for at least 40 years and intensity of fisheries is extreme. In most years, from 80 to 90 percent of all available legal-sized male crabs are captured in the fisheries. Although such high exploitation rates on adult males might give rise to concerns that female mating success might be reduced as a consequence, recent studies have shown that essentially all molting females receive attention from males in northern California. Usually one or no more than two year-classes of male crabs dominate annual landings. Thus, since about 1960, annual landings provide a reasonable notion of abundance of legal-sized males and also provide a strong signal of variation in year-class strength of recruited crabs. The dramatic decline in Dungeness crab catches in the central California fishery during the late 1950s focused considerable research attention on this resource during the 1970s. No definitive cause for the decline in the central California fishery has been established although researchers have assessed the possible effects of changes in ocean climate on survival and development of crabs eggs and larvae, the role of nemertean worm predation on egg survival, the effects of pollution on survival of juvenile crabs in San Francisco Bay, and possibly unstable internal population dynamics. Of these possible causes, a shift to warmer waters during and following the decline during the late 1950s seems the most plausible. If correct, the abundance of crabs in the central California fishery may improve over the next two decades if California coastal water temperatures remain cooler as a consequence of apparent ocean regime shifts.

The dramatic and periodic landings cycles that were exhibited in the northern California fishery from about 1945 to 1982 have caused this fishery to receive even greater attention from population dynamics modelers. Possible causes for the fluctuations in this fishery have included the nemertean egg predator, various internal density-dependent processes reflecting fluctuations in the abundance of unharvested females or cannibalism by adults on juveniles, and combinations of internal density-dependent controls and variable oceanographic factors. There seems little doubt that crab populations, with their extremely large fecundities and extremely vulnerable early larval stages, are prone to large natural fluctuations in abundance and that variable oceanographic factors (temperature, wind, currents) have important impacts on survival of year-classes.

Although many crustacean fisheries throughout the world have been overexploited and are now at low abundance levels compared to historic levels, Dungeness crab populations off northern California, Oregon and Washington have produced landings that have fluctuated around a fairly stable long-term mean for more than 30 years. One might therefore consider this resource to have a healthy status. Compared to other fisheries of similar importance and economic value, however, the Dungeness crab has received less attention than other species. Among other things, no formal fishery management plans or stock assessments have been produced for any west coast populations. Fishery management has rested on the very simple, though biologically sound, 3-S principles and typically restrictive fishery regulations such as landings quotas have never been imposed on this fishery. A casual assessment of healthy status therefore rests on limited information.

Although imposition of limited entry in California should prevent any further increases in the total number of vessels that participate in the Dungeness crab fishery, it does not prevent increases in fishing effort – numbers of traps fished and the intensity with which they are fished. With declines in abundance and allowable landings of salmon and groundfish, many larger multipurpose vessels now devote greater attention to the Dungeness crab fishery and fish upwards of 1,000 traps. In the early season, these larger vessels fish continuously, day and night, even in heavy seas. Total annual landings are largely unaffected by such increases in trap-days of fishing effort, but increased fishing effort has produced substantial shifts in the distribution of catch over time. Prior to about 1980, crab landings were normally spread throughout the entire open season. In a typical recent season in northern California, more than 80 percent of total landings are made during the month of December.

Uncontrolled increases in the numbers of traps fished by individual vessels and the resulting front-loading of annual landings may have important consequences with respect to allocation of fishery income among limited entry permit holders. Also, the shortened period of substantial crab landings means that live Dungeness crab, the most valuable product, are available over a relatively short time period, thus possibly diminishing total economic value of the fishery.

These fishery economics issues are the subject of current research efforts.

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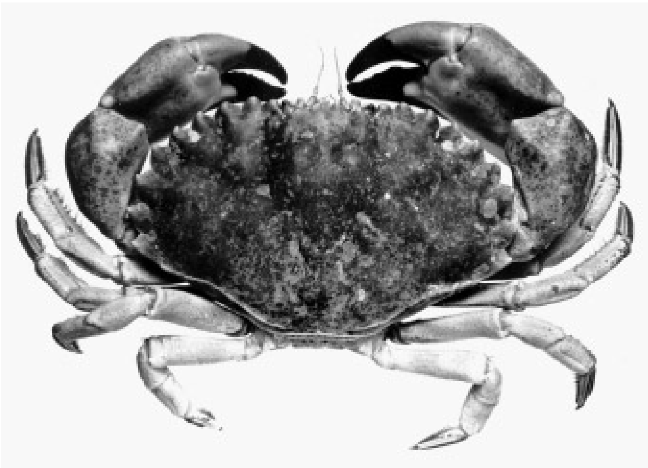
Rock Crabs

History of the Fishery

Rock crabs are fished along the entire California coast. The catch is made up of three species — the yellow rock crab (*Cancer anthonyi*), the brown rock crab (*C. antennarius*), and the red rock crab (*C. productus*). The commercial fishery is most active in southern California (from Morro Bay south), where 85 to 90 percent of the landings occur, and of lesser importance in northern areas (Monterey, Halfmoon Bay, and Eureka yield 10-15 percent), where a fishery for the more desirable Dungeness crab takes place. A major recreational fishery has not developed, but recreational crabbing is popular in many areas and is often conducted in conjunction with other fishing activities.

In 1950, a separate reporting category for commercial rock crab landings was established. Since then, landings have risen from 20,000 pounds to over two million pounds in 1986. Landings increased by 10 percent per year from 1957 to 1971, jumped nearly 50 percent in 1972, and continued a steady increase to two million pounds in 1986. Prior to 1987, a portion of the landings calculated whole-crab weights based on landings of claws only. Since then, whole crabs and claws have been reported separately, and whole crab landings have showed a commensurate decline. Rock crab landings for 1999 were 790,000 pounds and have averaged 1.2 million pounds per year since 1991, including the landings of claws converted to whole weight.

Commercial crabbing has expanded from nearshore areas around major ports such as San Diego, San Pedro, Santa Barbara, and Morro Bay to more distant mainland areas and the Channel Islands. Most rock crabs are landed alive for retail sale by fresh fish markets. Often the crabs are cooked and eaten on site and, depending on the tastes of the consumer, muscle tissue, as well as other organs (ovaries in particular) are consumed. Rock crab meat has not been successfully marketed frozen or canned. During 1999, ex-vessel prices for whole rock crabs and crab claws averaged about $1.25 per pound



Yellow Rock Crab, *Cancer anthonyi*
Credit: DFG

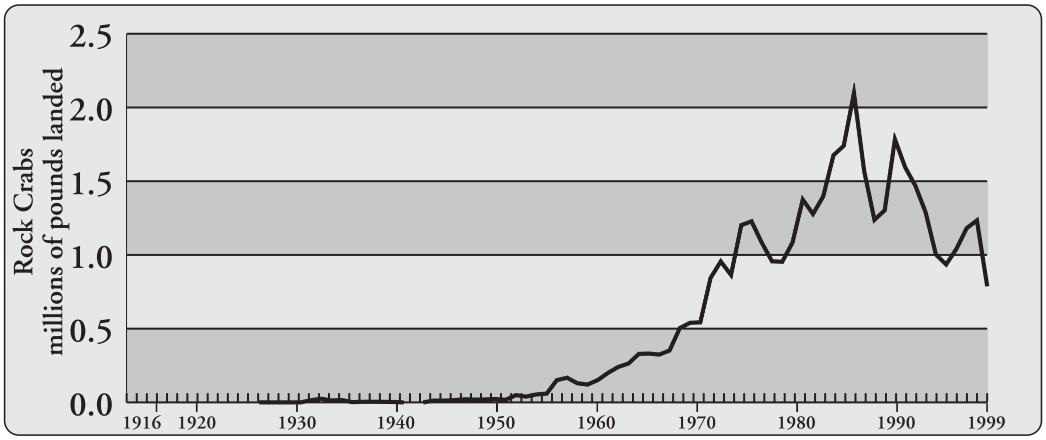
Several trap designs and materials are used in the rock crab fishery. The most popular are single chamber, rectangular traps of two by four-inch or two by two-inch welded wire mesh. Several types of molded plastic traps are used by some fishermen because the traps are collapsible or nest together on a boat deck. Traps are set and buoyed singly or, perhaps, in pairs if loss to vessel traffic is a concern. Most trapping occurs in depths of 90 to 240 feet on open sandy bottom or near rocky reef-type substrate. Two hundred or more traps may be fished by one boat, with a portion pulled up and emptied each day. Traps are usually "soaked" for 48 to 96 hours prior to pulling. Commercial crab boats are usually small, ranging from skiffs to vessels of 40 feet or more.

Recreational gear ranges from a diver's or shore picker's hand to baited hoop nets, collapsible star traps, or traditional traps (north of Point Arguello) fished from piers, jetties, and boats. Most of this effort takes place along the shallow, nearshore open coast and in bays. Some increased recreational take has occurred in central and northern California in recent years as combination fishing and crab trips aboard commercial passenger fishing vessels have developed. Traps, primarily targeting Dungeness crabs, are set and pulled during these trips. However, depending on location and season, rock crabs (brown and red) are often taken as well.

Commercial regulations have been enacted to protect crabs below reproductive size. Present regulations require a minimum harvest size of 4.25-inch carapace width and escape rings measuring 3.5 inches in diameter in each trap. Due to the multi-species nature of the fishery, the minimum size was chosen to accommodate the different characteristics of the three rock crab species. The recreational take is controlled by a four-inch minimum carapace width and a personal bag limit of 35 crabs per day.

Status of Biological Knowledge

Yellow rock crabs range from Humboldt Bay into southern Baja California, brown rock crabs from northern Washington to central Baja California, and red rock crabs from Kodiak Island to Central Baja California. All three species inhabit waters from the low intertidal zone down to depths of 300 feet or more. Although these species may occur together throughout much of their range, yellow rock crabs are most abundant in southern California, brown rock crabs in central California and red rock crabs in northern California. Yellow rock crabs prefer open sand



Commercial Landings 1916-1999, Rock Crabs
Data Source: DFG Catch Bulletins and commercial landing receipts.

or soft bottom habitat, while brown and red rock crabs prefer rocky or reef-type substrate.

Rock crabs, like other crustaceans, grow in a step-wise fashion with each molt of the external shell. Yellow and brown rock crabs molt 10 to 12 times before reaching sexual maturity at about three inches carapace width. Crabs of this size may molt twice a year, while crabs as large as six inches carapace width or more may molt once a year or less. Growth-per-molt, as a percentage of size, decreases as the crab increases in size and age. Males of all three species attain sizes 10 to 15 percent larger than females. Yellow rock crabs grow to exceed seven inches in carapace width, brown rock crabs 6.5 inches, and red rock crabs eight inches. While the longevity of rock crabs is not well known, many crabs may reach five or six years of age.

Mating takes place after the females molt and are still in the soft-shell condition. In southern California, mating is most common in the spring, but occurs throughout the year. About three months after mating, the eggs are laid, then fertilized from a sperm packet left by the male during mating. The developing eggs are carried in a mass under the abdomen of the female. Depending on size and species, nearly four million eggs may be carried by a female rock crab. After six to eight weeks, the eggs hatch into planktonic larvae, which undergo seven developmental molts before settling to the bottom as juveniles.

Rock crabs are both predators and scavengers, feeding on a variety of other invertebrates. Strong crushing claws allow them to prey on heavy-shelled animals such as snails, clams, abalone, barnacles, and oysters. The olfactory sense of crabs is well developed and allows them to detect and locate food at a distance.

Rock crabs, especially juveniles, are preyed upon by a variety of other marine organisms. Fishes such as cabezon, barred sand bass and several species of rockfish are known to feed on rock crabs. Important invertebrate predators include the octopus and certain sea stars. As rock crabs grow larger, they become less susceptible to predators except during the soft-shell post-molt period; however, the sea otter is one animal that is an effective predator on large rock crabs.

Rock crabs do not appear to migrate or to undertake large-scale movements. Tagged adults have moved several miles, but no pattern was apparent. Some local movements also may occur in relation to mating or molting. Egg-bearing yellow rock crabs are known to congregate in rock-sand interface habitats.

Status of the Populations

Information is not available on stock sizes, recruitment and mortality rates, the effects of different oceanographic regimes, or potential yield of rock crab populations. The commercial fishery, however, has had a localized effect on crab abundance and size. Fishing areas intensively exploited over an extended period show a lower catch-per-trap and a reduced size-frequency distribution compared to lightly exploited areas. In Santa Monica Bay, an area closed to commercial crab fishing for decades, experimental catch rates were higher, crab sizes larger and size-frequencies broader than in adjacent areas open to commercial trapping. Future research should be aimed at a better understanding of fishery-related rock crab population parameters.

Management Considerations

See the Management Considerations Appendix A for further information.

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Sheep Crab

History of the Fishery

Until 1984, the sheep crab (*Loxorhynchus grandis*) was of little commercial or recreational value. Before that, they were occasionally landed as by-catch and were also taken by some recreational divers. Santa Barbara fishermen and processors began to experiment with marketing them and by 1984, 30,000 to 40,000 pounds of whole crabs were landed. The fishery for this underutilized species expanded rapidly, stimulated by development of a market for claws. The fishery peaked in 1988 with landings of 107,609 pounds of live crabs and 385,886 pounds of claws (combination of sheep and rock crab claws; 75 percent and 25 percent respectively). The sheep crab was the only fishery in the United States with sizable landings of claws and whole crabs. However, a 1990 California State Initiative banned the use of gillnets in shallow water. Subsequently, landings of sheep crab claws plummeted to an average of only 5,000 pounds annually once gillnets were completely phased out in 1994. During this same period, landings of live, whole crabs remained fairly constant and relatively low, averaging approximately 75,000 pounds annually.

The California sheep crab fishery is centered in the Santa Barbara Channel and off the northern Channel Islands. The bulk of the landings are in Santa Barbara and Ventura counties although most of the crabs are marketed in the San Pedro and greater Los Angeles area. The fishery primarily operates over sandy bottom, where gear is set in shallow waters (30-70 feet) in spring and summer and then moved to deeper waters (120-240 feet) in fall and winter months. Both male and female adult crabs are taken for the live, whole body fishery. The claw fishery is supported solely by large adult male crabs, as the claws of adult female crabs and small adult males do not reach market size.

Crab and lobster trap fishermen supply the bulk of live crabs. Modified rock crab or lobster traps with an enlarged funnel are used, permitting entry of large adult male and female crabs. Set gill-netters supply the claw market, usually killing the crab in the claw removal process. Sheep crabs are a nuisance to gillnet fishermen because they become tangled in the gear and their removal from the nets is time consuming, usually resulting in damage to the animals. However, with the development of the claw fishery the crabs became a valuable resource for gill-netters.

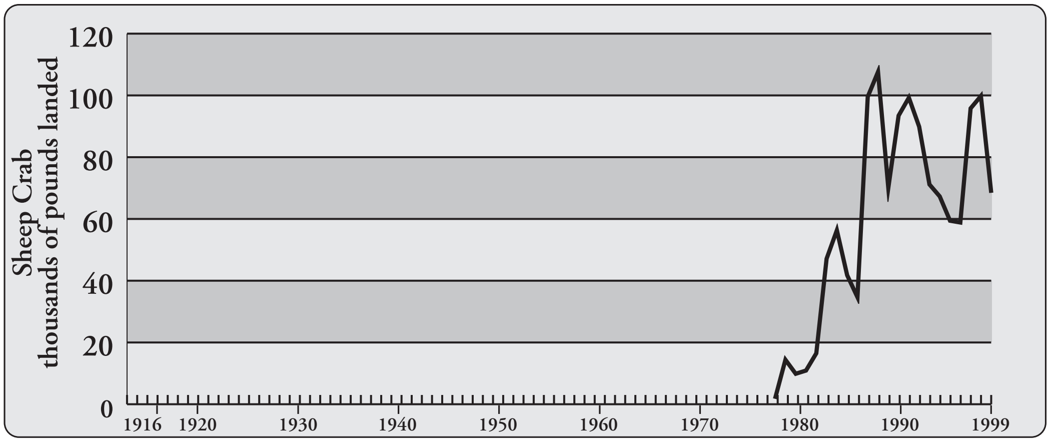
At the peak of the fishery, the retail value of the combined catch was about $1.9 million per year, with claws being sold for $5.75 per pound and whole crabs going for $3 per pound live and $4.25 per pound cooked. Claw landings and value far exceeded those of the whole body fishery. However, with the banning of gillnets in shallow water and the subsequent decline in claw landings, the retail value has substantially decreased. In 1999, the retail value was approximately $310,000, with whole crabs being sold for up to $4 per pound live and claws up to $3 per pound.

An increase in claw landings seems unlikely given the nature in which the fishery was developed (*i.e.*, to provide some value to a by-catch species). In fact, prior to 1991, rock crab and spider crab claw landings were combined in the landings data, with spider crab claws comprising 75 percent of the landings. In 1991, a size limit went into effect for rock crabs, and fishermen were prohibited from taking any "part" of those crabs. However, the loss of supply of rock crab claws has not been compensated for by an increase in landings of spider crab claws. This is most likely because implementation of the rock crab regulations coincided with the banning of gillnets in shallow water.

Fishing effort for, and landings of whole crabs remain relatively low since fishermen generally have to establish their own live markets and be able to hold the crabs alive for up to a week or more. In addition, because of the heavily calcified carapace of the crab, processing the body meat is presently uneconomical. Thus, current landing patterns may increase if new marketing efforts expand

Sheep Crab, *Loxorhynchus grandis*
Credit: Diane Pleshner
CA Seafood Council

Commercial Landings 1916-1999, Sheep Crab
Sheep crab landings are recorded by DFG as spider crab. Data Source: DFG Catch Bulletins and commercial landing receipts.



economically feasible. Such expansion seems likely given the continued interest in the California fishery and the recent development of an experimental sheep crab fishery off Baja California.

Status of Biological Knowledge

Sheep crab is the common name of one species within a family of crabs (Majidae), which collectively are often called spider crabs. Consequently, the sheep crab is often called a spider crab and is the largest member of the California majid crabs. They range from Cordell Bank (Marin County) south to Cape Thurloe, Baja California, in depths of 20 to 410 feet. It is not known whether the entire resource consists of just one or of a number of different populations. Sheep crabs are apparently most abundant off southern California.

Longevity is currently unknown, but many adults appear to be at least four years old. In contrast to most other commercially important crustaceans, most majid crabs are believed to cease molting upon reaching maturity. Studies of molt staging, limb regeneration, and molting frequency support the existence of a terminal molt in sheep crab. After this molt, crabs do not increase in size nor do they regenerate limbs. This phenomenon is an important biological characteristic that may require development of a management scheme different from those of other California crab fisheries.

Maturation is defined only in morphometric terms. At maturity the relative width of the abdomen of females and the length of the claw of males increase markedly when compared to a standard measure of body size such as carapace length. Females become morphometrically mature between 4.2 and 6.8 inches carapace length (from margin of orbit). Adult males range in size from 4.2 to 9.6 inches. However, morphometrically juvenile male crabs can reach a length of 6.8 inches; thus, size alone is insufficient to determine maturity. The presence of a gap in the serrated gape of the claw of adult male crabs distinguishes them from juvenile males. It is uncertain how morphometric maturity relates to physiological and behavioral maturity.

The abundance of berried females peaks in late spring and remains high throughout the summer, although they can be found throughout the year. Adult females are able to mate when soft or hard shelled. Sperm storage allows for multiple broods to be oviposited even in the absence of males. Egg numbers probably increase with size of brooding female crabs. Small broods contain 125,000 eggs, whereas large broods can have as many as 500,000 eggs. Laboratory observations suggest that sheep crabs feed on a variety of prey. They readily eat dead fish, crushed mussels, and kelp. Cannibalism of newly molted animals occurs in the laboratory when crabs are not well fed. No observations are available on foraging behavior in nature, nor have gut contents been analyzed.

Predatory interactions have not been observed in the field either, but it is likely that small crabs are preyed upon by cabezon, sheephead, octopus, sharks and rays. Small sheep crabs disguise themselves by decorating their carapace with algae, sponges, or other encrusting materials. Large crabs probably have few predators.

Two parasitic infections could potentially impact recruitment — an undescribed species of nemertean or ribbon worm and a rhizocephalan barnacle. The former consumes the developing embryo in the egg. The latter eliminates reproductive output and also inhibits growth of the crab. Preliminary observations indicate that certain areas contain a high prevalence of individuals parasitized by the rhizocephalan and that crabs are infected as juveniles.

Male crabs winter in deep water. Both sexes migrate onshore in early spring, and piles of adult females have been observed in spring and summer. Large adult males have been seen on the perimeter of these aggregations. The biological significance of the piles is apparently related to mating, as the majority of females are gravid, the males often exhibit competitive behavior for mates and there are many obstetrical pairs (a mating behavior where a male and female crab are hooked together back-to-back by the males back limbs). Similar aggregate mating phenomena have been reported for other spider crabs.

Status of the Population

The abundance of sheep crabs is unknown. Abundant populations have been reported off Los Angeles and San Diego. Furthermore, although this spider crab has been a by-catch for many years, there is no evidence of declining populations in the Santa Barbara Channel where most fishing takes place. However, some have reported a decrease in overall crab size. Such a phenomenon could be due to the immense fishing pressure on large males both for claws and whole body. Because this species undergoes a terminal molt, removal of large crabs may leave only small animals to contribute to the gene pool. If the terminal molt is genetically regulated, this could result in a population of smaller crabs.

Management Considerations

See the Management Considerations Appendix A for further information.

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Ocean Shrimp

History of the Fishery

The commercial fishery for ocean shrimp (*Pandalus jordani*), also called pink shrimp, started in 1952 after commercial quantities were found by DFG research vessels in 1950 and 1951. The California Fish and Game Commission established regulations for the new fishery in 1952, including net type with mesh restrictions and a season. The first catches were made later that same year. Three regulation areas were also designated and catch quotas established for each. The three regulatory areas were Area A, Oregon border to False Cape; Area B, False Cape to Pigeon Point; and Area C, Pigeon Point to the Mexican border. In 1956, Area B was divided into two areas; B-1 extended from False Cape to Point Arena and B-2 from Point Arena to Pigeon Point.

Catch quotas governed the shrimp take from 1952 to 1976. Quotas were based on recommendations by DFG and were set each year by the Fish and Game Commission. In 1976, all quotas were dropped in favor of four criteria believed to protect the resource. The criteria were: 1) a season from April 15 through October 31, designed to protect egg-bearing females; 2) a net mesh size of 1 3/8 inches, to allow escapement of small zero- and one-year-old shrimp; 3) a count per pound of 170 or less, intended to protect one-year-old shrimp; and 4) a minimum catch rate of 350 pounds per hour to protect shrimp when the population is at a low level. If these requirements were not met, the DFG had the option to close the fishery. In 1981, the regulations were changed again to bring them into accord with an agreement with Oregon Department of Fish and Wildlife and Washington Department of Fisheries to have coast-wide uniform regulations. The new regulations included a season from April 1 through October 31, a maximum count per pound of 160, and a minimum mesh size of 1 3/8 inches measured inside the knots. These regulations are still in effect. From 1952 to 1963, shrimp fishermen were limited to the use of beam trawls with a minimum mesh size of 1.5 inches between the knots. In 1963, shrimpers were permitted to use otter trawls with the same size mesh. The mesh size was reduced from 1.5 inches to 1 3/8 inches in Areas A, B-1, and B-2 in 1975.

Catch of Ocean Shrimp, *Pandalus jordani*
Credit: DFG

Prior to 1974, all shrimp boats in California pulled a single rig of one net and two doors, but starting with the 1974 season, vessels towing a double rig from outriggers, one on each side of the boat, entered the fishery. The double-rigged vessels are approximately 1.6 times more effective than single-rigged vessels.

During the first year of the fishery, only six boats participated. The number of boats increased to 27 by 1960, then averaged 24 boats per season over the next 16 years. The record catch in 1977 started a rapid influx of boats into the shrimp fishery and reached a high of 104 vessels during 1980, but the number declined to 33 during 1983 when the catch fell to a low of 1,176,000 pounds. As the catch recovered from that El Niño-induced low, many boats reentered the fishery. The number of vessels per season averaged 88 from 1983 through 1999. A record-high 155 boats shrimped during the 1994 fishery, the first year of a moratorium on new shrimp permits —ß probably the cause of the large increase in the number of vessels.

California landings have averaged 4,843,000 pounds annually from 1952 through the 1999 season, ranging from a low of 206,000 pounds in 1952 to a high of 18,683,000 pounds in 1992. Average landings have increased each decade since the start of the fishery in the 1950s: 969,000 pounds in the 1950s, 1,810,000 pounds in the 1960s, 5,679,000 pounds in the 1970s, 5,871,000 pounds in the 1980s and 9,127,000 pounds in the 1990s. Area A has been the most consistent producer and, since 1954, has had the highest annual landings. The only exception was the El Niño year of 1983, when Area C had the highest landings. Since the inception of the fishery, 86.8 percent of the shrimp have been landed in Area A ports, 5.4 percent in Area B-1, 2.9 percent in Area B-2, and 4.9 percent in Area C.

The price paid to the fishermen (ex-vessel price) has ranged from a low of $0.07 per pound in 1955 to a high of $0.87 per pound in 1987. The ex-vessel price remained fairly constant at $0.10 per pound during the 1950s and 1960s, increased in price from $0.12 per pound to around $0.30 per pound in the 1970s, and since has fluctuated around $0.50 per pound.

The largest portion of ocean shrimp landed in California is picked and individually quick-frozen. Small amounts are sold fresh whole, as cooked picked meat or packed in vacuum cans. Most of California's shrimp catch was hand picked until 1969, when machines were introduced in the Eureka area. Shrimp machines have enabled the shrimp industry to pick much smaller shrimp than was possible with hand picking.

Status of Biological Knowledge

Ocean shrimp are found from Unalaska in the Aleutian Islands to off San Diego, California, at depths from 150 to 1200 feet. In California, this species is generally found from depths of 240 to 750 feet. Spawning probably occurs throughout the range, but commercial harvest is limited to the area between Vancouver Island, British Columbia, and Point Arguello, California.

Concentrations of shrimp generally remain in well-defined areas or beds from year to year. These areas are associated with green mud and muddy-sand bottoms. Although there is some evidence of minor onshore-offshore and coast-wide movement within the confines of a bed throughout the year, no convincing evidence of migratory behavior has been produced. Horizontal movements probably are governed by feeding activities and prevailing currents. Ocean shrimp also exhibit vertical migrations. These movements toward the surface during periods of darkness appear to be associated with feeding on plankton. Adults from the different beds probably intermix rarely, but the planktonic larvae undoubtedly intermingle, as there are no indications of genetically distinct subpopulations. Genetic stock identification work on ocean shrimp has failed to isolate any genetic differences between ocean shrimp from off the coasts of California, Oregon, Washington and British Columbia.

Ocean shrimp feed mostly at night on planktonic animals. The stomach contents of shrimp taken at night indicated that the most common food items were euphausiids and copepods, while the stomachs of shrimp collected during daytime contained little food. Identifiable food items included polychaete worms, sponges, diatoms, amphipods, and isopods.

Many species of fish prey on ocean shrimp. Major fish predators include Pacific hake, arrowtooth flounder, sablefish, petrale sole and several species of rockfish.

Ocean shrimp are protandric hermaphrodites; that is, during their first year and a half of life most will function as males, then pass through a transitional phase to become females. During some years, large percentages (up to 60 percent) of the one-year-old shrimp become females and never mate as males. Female shrimp usually carry between 1,000 and 3,000 eggs. Small individuals in their second year have been found carrying as few as 900 eggs, whereas larger shrimp in their third or fourth year of life have been found with up to 3,900 eggs. Mating takes place during September and October, and the external fertilization of the eggs takes place when the females begin extruding eggs in October. The female carries the eggs between the posterior swimming appendages until the larvae hatch. The peak of hatching occurs during late March and early April. Ocean shrimp go through a larval period that lasts 2.5 to three months. The developing juvenile shrimp occupy successively deeper depths as they develop, and often begin to show in commercial catches by late summer. Shrimp grow in steps by molting or shedding their shells. Growth rates for ocean shrimp vary according to region and also by sex and year class. There is a clear pattern of seasonal growth despite the variations mentioned, with very rapid growth during spring and summer and slower growth over the winter. The growth rate decreases as the shrimp age. Shrimp growth rates increased markedly in Oregon after 1979, suggesting a density dependent growth response to fishing. Ocean shrimp may reach 5.5 inches in total length, but the average catch size is about four inches. In California, few shrimp survive beyond their fourth year.

Studies on natural mortality estimate that the survival between fishing seasons (over winter) is 46 percent, 76 percent, and 43 percent for ocean shrimp during their first, second, and third winters of life, respectively.

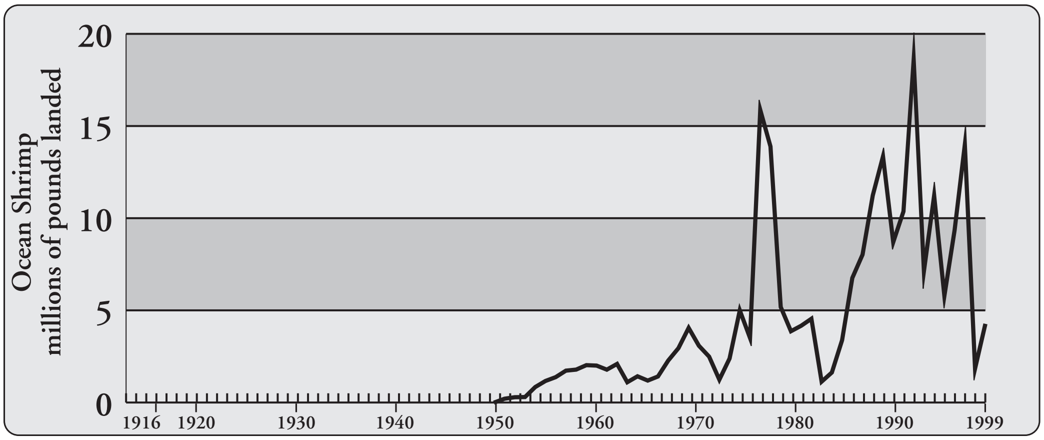
Status of the Population

Population estimates of the various shrimp beds were obtained by department sea surveys from 1959 to 1964; catch quotas were set at one quarter of the estimated population. Area A sea survey continued until 1969. The highest Area A population estimate from sea surveys was 10,700,000 pounds in the fall of 1967. Because the cost of sea surveys was quite high, another method of estimating population was needed. A mathematical population model, designed by department statisticians, was used to estimate the population size and set the quota from 1969 until 1976, when the model was dropped and no further attempts to estimate the population were made.

It was established that the ocean shrimp population abundance off California is determined by environmental conditions, which causes natural fluctuations in recruitment that are apparently unrelated or minimally related to commercial fishing effort. Since the abandonment of quotas, the shrimp population, as evidenced by the commercial catch, has gone through two extreme highs (1977 - 15,600,000 pounds; 1992 - 18,683,000 pounds) and two lows (1983 - 1,200,000 pounds - primarily in Area C; 1998 - 1,836,000 pounds). The population appears to be headed up again since the 1998 low.

Investigations of the population dynamics of shrimp off Oregon suggest shrimp are inherently resistant to overfishing. Annual recruitment success has been shown to be

Commercial Landings 1916-1999, Ocean Shrimp
Data Source: DFG Catch Bulletins and commercial landing receipts. No commercial landing are reported for ocean shrimp prior to 1952.



linked to the strength and timing of the spring transition in coastal currents immediately following larval release. An early, strong transition produces large year classes. Shrimp are short-lived and exhibit flexible rates of sex change that act to maintain a roughly balanced sex composition, despite highly variable mortality rates. Other evidence also suggests that shrimp exhibit density-dependent growth. In combination, these biological traits increase the fishing pressure a stock can withstand without suffering decline. Nonetheless, some evidence has been presented recently suggesting shrimp are periodically "recruitment-overfished" in a manner that delays the stock's rebound from El Niño-related recruitment failures. However, overfishing in such a short-lived resource has relatively minor impacts on yield and changes in management await additional research on how fishing is altering yield.

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Spot Prawn

History of the Fishery

The fishery for spot prawn (*Pandalus platyceros*) originated nearly 68 years ago in Monterey when prawns were caught incidentally in octopus traps. It was a minor fishery with landings averaging around 2,000 pounds annually until the early 1970s. In 1974, trawl fishermen fishing out of Santa Barbara caught over 182,000 pounds. Trawl landings steadily grew as more fishermen entered this new fishery and new areas were explored reaching a peak of more than 375,500 pounds in 1981. Landings fell drastically in the next few years causing concern by fishermen and DFG biologists. An area and season closure was instituted between Point Conception and Point Mugu during the peak egg-bearing months of November, December and January in 1984. Following the implementation of an area closure, trawl landings remained low until 1993 averaging about 54,000 pounds annually. The low catch rates for the trawl fleet were due in part to the development of other fisheries such as ridgeback prawn, sea cucumber and the increased demand for fresh fish, which caused growth in the groundfish trawl fishery.

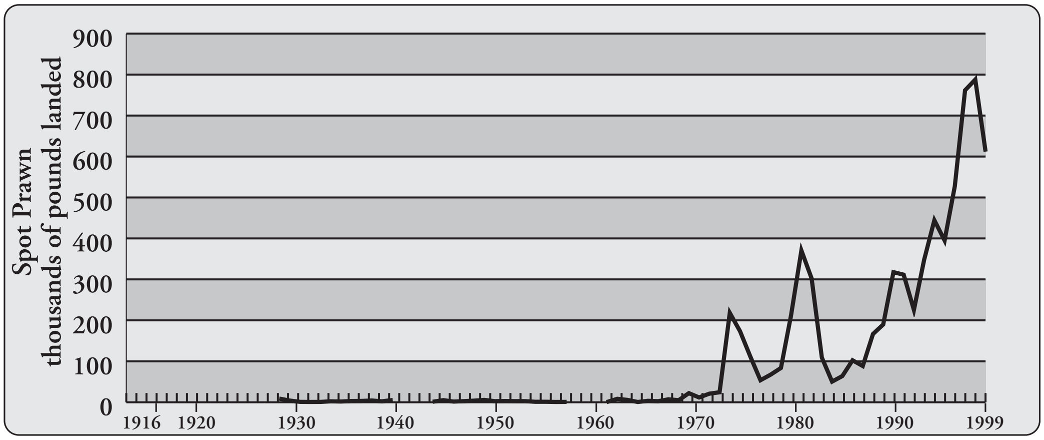
In 1985, a trap fishery for spot prawn developed in the Southern California Bight. The trap fishery was concentrated around all of the Channel Islands and along coastal submarine canyons in water depths between 600 and 1,080 fathoms. Fishing was now occurring in areas of southern California that the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

Two years of declining landings in the trap fishery and the continued low landing levels by the trawl fleet lead fishermen and biologists once again to address management of California's spot prawn resource. The Fish and Game Commission, with the support of the trap and trawl fishermen, expanded the trawl area and season closure to include the entire Southern California Bight in 1994. They also instituted the first regulations for the trap fishery by requiring a one inch by one inch trap mesh size, limiting traps per vessel to 500, and initiating an area and season closure for the same area and time period as the trawl fishery.

Following these management measures, the spot prawn fishery underwent significant changes in composition and statewide growth. The spot prawn fishery was now comprised of four fishery components: northern California trawl, northern California trap, southern California trawl and southern California trap. From 1994 until 1998, statewide landings nearly doubled from 444,000 pounds to a historic high of 780,000 pounds. All of the fishery components showed some growth with the northern trawl fishery experiencing a 14-fold increase in landings while southern trawl and northern trap showing a four-fold increase and southern trap almost doubling its landings. There were several reasons for this rise including increased market demand, which raised the average price for live prawns from $6 per pound to $8; increased effort by California and Washington fishermen displaced from other fisheries; changes in gear design, specifically the use of large rollers (rock hopper gear) on the groundline of the trawl nets; and increased availability due to strong spot prawn recruitment in 1996 and 1997.

The advent of rock hopper gear allowed fishermen to fish areas once off limits because of the rocky nature of the bottom. These areas had previously acted as de facto reserves, providing new recruits for adjacent areas traditionally worked by trawl vessels. The rise in the number of participants and a 21 percent decline in statewide 1999 landings, prompted fishermen once again to ask for further regulation and a limited access plan. An ad-hoc committee of trap and trawl fishermen and department biologists developed several management recommendations, which included a limit on the size of roller gear to 14-inches. In 2000, the Commission adopted some but not all of the proposed regulations with slight modification. Instead of a simultaneous closure for trap and trawl fisheries north of Point Conception, a May to August closure for the trap fishery was selected by the Commission. While northern California trappers can catch prawns during the peak egg-bearing season, they are limited to 300 traps within state waters. Other regulations adopted by the Commission for this fishery included a requirement for bycatch reduction devices on trawl nets, and an observer

Spot Prawn, *Pandalus platyceros*
Credit: DFG



Commercial Landings 1916-1999, Spot Prawn
Data Source: DFG Catch Bulletins and commercial landing receipts.

program for all components of the spot prawn fishery. A control date for limited entry was established, but the rest of the plan was put on hold.

The 1999 price for live prawns ranged from $6 to $10 per pound, whereas dead (heads-on) prawns bring only $4.50 to $5.50 per pound. Live prawns are now taken by trap and trawl vessels and account for 95 percent of landings. The change from a trap-only live fishery follows experimentation by trawl fishermen on net design and tow duration, which maximizes prawn catch while reducing or eliminating incidental take of non-target species.

The trawler fleet consists of approximately 54 vessels operating coast-wide from Bodega Bay to the United States-Mexico border. Most vessels operate out of Monterey, Morro Bay, Santa Barbara, and Ventura, although a number of Washington-based vessels participate in this fishery during the fall and winter. The vessel length of the trawl fleet ranges from 28 to 85 feet with an average vessel length of 47 feet. Standard gear is a single-rig shrimp trawl of a semi-balloon, or Gulf Shrimp Act, design. Occasionally, double-rig or paired shrimp trawls are used. The body of the trawl net is typically composed of a single layer of 2.5- to three-inch meshes with a 36-square inch bycatch reduction device, and a minimum codend mesh size of 1.5 inches. Many fishermen prefer to use a double codend composed of two- to three-inch mesh. A variety of roller gear is added to the groundline of the trawl net, which keeps the ground off the bottom and prevents a variety of benthic invertebrates such as sea stars, sea fans, and anemones as well as rocks from being scooped into the net. Standard roller gear, which spins freely around the groundline, varies in size from eight-inch disks to 28-inch tires.

The spot prawn trap fleet operates from Monterey Bay to southern California. The northern trap fishery continues to produces prawns, although it has never reached the large volume of the southern California fishery. Monterey-area boats are about 30 to 60 feet in length and usually fish for salmon during the summer. Currently, there are about six boats fishing the Monterey Bay area, and they fish 10 months a year. The southern California trap fleet ranges between 30 and 40 boats depending on prawn availability. These boats range in size from 20 to 75 feet with an average of 34 feet. Trap designs are limited either to plastic oval-shaped traps or to the more popular rectangular wire traps. The dimension of the single chamber plastic traps is approximately 2.5 feet by 1.5 feet while the typical size of the wire traps is 3.0 feet by 1.5 feet by 1.0 foot with two chambers. Normally, a fisherman will set 25 to 50 traps attached to a single groundline (string) with anchors and buoys at both ends. In both fishing areas, traps are set at depths of 600 to 1,000 feet along submarine canyons or along shelf breaks.

Status of Biological Knowledge

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

Spawning occurs once a year, and each individual mates once as a male and once or twice as a female. Females spawn at a carapace length of 1.75 inches. Spawning takes place at depths of 500 to 700 feet. September appears to be the start of the spawning season, when the eggs are extruded onto the female's swimmerets. She carries the eggs for a period of four to five months before they hatch. By April, only 15 percent of females still carry eggs. Fecundity varies with size, ranging from 1,400 to 5,000 eggs for the first spawning down to 1,000 eggs for the second spawning. Eggs hatch over a 10-day period and the larvae are planktonic. As they develop into the juvenile stage, they begin to settle out at depths as shallow as 175 feet, but move deeper as they reach adulthood.

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

Status of the Population

Exploratory surveys conducted by the DFG during the 1960s revealed the presence of prawns along the coast, but no estimates of population size were made. During the 1980s, additional surveys were conducted in southern California to further define distribution and range. The development of the southern California trap fishery in the mid-1980s detected sizable aggregations of this species, which were previously unknown. The introduction of roller gear on trawl nets in the 1990s led to the exploration of even more areas and location of additional habitat suitable for spot prawns. Thus, it appears that this species is more numerous and widespread than previously believed as attested by the geographic expansion and rise in total landings.

Management Considerations

See the Management Considerations Appendix A for further information.

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Ridgeback Prawn

History of the Fishery

Intermittent catches of small numbers of ridgeback prawns (*Sicyonia ingentis*) in Santa Barbara-area fish trawls led to the development of regulations to allow the take of prawns with small mesh trawl nets. Enactment of these regulations in 1965 resulted in the landing of 30,200 pounds of prawns the following year; however, landings quickly slumped when prawns proved difficult to market. Annual landings were below 5,000 pounds from 1974 to 1977, except in 1975 when they were 28,000 pounds. The catch increased to 356,000 pounds in 1979, but declined to 129,000 pounds three years later. In 1985, landings peaked at nearly 900,000 pounds, but they subsequently declined to 142,000 pounds in 1988 following several year-class failures. Landings reached a low of 64,000 pounds in 1992, but increased to 607,000 pounds in 1996. After a dip to 387,000 pounds in 1997, ridgeback prawn landings reached a new high of about 1,391,000 pounds in 1999.

The fishery is centered in the Santa Barbara Channel and off Santa Monica Bay. In 1999, 32 boats participated in the fishery. Traditionally, a number of boats fish year round for both ridgeback and spot prawns, targeting ridgeback prawns during the closed season for spot prawns and fishing for spot prawn during the ridgeback closure. Most boats typically use single rig trawl gear (only one boat was noted to be using double rig gear in 1999). The average trawler length is 45 feet with a range of 28 to 76 feet. Six of these boats are over 50 feet in length.

Following the 1981 decline in landings, a summer closure (June 1 through September 30) was adopted by the California Fish and Game Commission to protect spawning female and juvenile ridgeback prawns. An incidental take of 50 pounds of prawns or 15 percent by weight is allowed during the closed period. During the season, a maximum of 1,000 pounds of other fish may be landed with ridgeback prawns. Any amount of sea cucumbers may be landed with ridgeback prawns as long as the vessel owner/operator possesses a sea cucumber permit. Other regulations include a prohibition of trawling within state waters (three-miles from the mainland shore and islands), a minimum fishing depth of 25 fathoms, a minimum mesh size of 1.5 inches for single-walled codends or three inches for double-walled codends and a logbook requirement.

Ridgeback Prawn, *Sicyonia ingentis*
Credit: David Ono, DFG

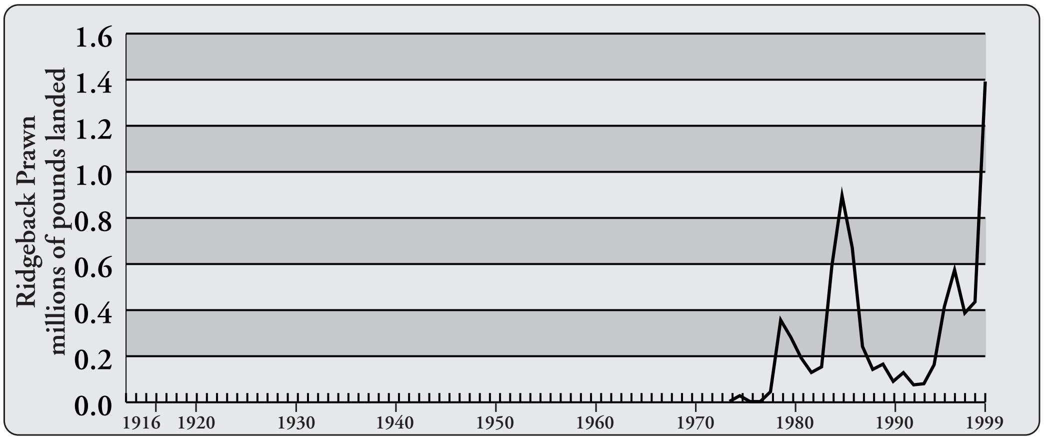
Demand for this resource continues to be high, as its sweet flavor and low price make it a favorite among fresh fish buyers. As this species does not freeze well, it is primarily sold as fresh whole prawns; however, prawns are often landed live to supply a secondary live prawn market, and also to prevent discoloration from a black pigment that forms after death, which lowers consumer appeal. In 1999, live prawns accounted for 28 percent of the landings, but have been as high as 68 percent in 1997. The median ex-vessel price in 1999 for all ridgeback prawn was $1.30 per pound. Live prawns sold for a median price of $2 per pound, with a range of $1 to $5 per pound, while fresh dead prawns sold for a median of $1 with a range of $0.20 to $3.35 per pound.

Status of Biological Knowledge

Ridgeback prawns occur from Monterey, California to Cedros Island, Baja California, at depths ranging from less than 145 feet to 525 feet. Major concentrations occur in the Ventura-Santa Barbara Channel area, Santa Monica Bay, and off Oceanside. One study found ridgeback prawns to be one of the most common invertebrates to appear in its trawls, occurring in 59 percent of tows along the mainland shelf within the Southern California Bight. Other pockets of abundance are found off Baja California. This species occurs on substrates of sand, shell and green mud. As these animals are relatively sessile, little or no intermixing occurs. Their maximum life span is five years and sexes are separate. Females reach a maximum length of 1.8 inches carapace length (CL), and males 1.5 inches CL.

These shrimp are free spawners, as opposed to other shrimps, which carry eggs. Both sexes spawn as early as the first year, but most spawn during the second year at a size of 1.2 inches CL. The spawning period is more seasonal than with other penaeid shrimp. Studies suggest that this species undergoes multiple spawning from June through October. Following spawning, both sexes undergo molting and continue molting throughout winter and spring. The number of eggs produced averages 86,000.

The food habits of the ridgeback prawn are unknown, but it may be a detritus feeder like closely related species. In Baja California, ridgeback prawns are preyed on by several species of sea robins. In southern California, it is presumed other groundfish such as rockfish and lingcod



Commercial Landings 1916-1999, Ridgeback Prawn
Data Source: DFG Catch Bulletins and commercial landing receipts.

prey on them as well. Other likely predators include octopus, sharks, halibut, and bat rays.

Status of the Population

Yearly sea surveys between 1982 and 1991 documented relative abundance and year-class strengths of juvenile ridgeback prawns. Relative abundance in terms of numbers of animals per 15-minute tow began increasing from 66 animals per tow in 1982 to 1,200 animals per tow by 1984, but began to decline in 1985 when the catch fell to 132 per tow. These trends mirrored the rise and fall of yearly commercial catches. The population of ridgeback prawns in the Ventura area increased dramatically during 1983 to 1985, but then began declining.

Ridgeback prawn trawl logs, required since 1986, show an average of 147 pounds of ridgeback prawn caught per tow/hour, dropping to a low of 32 pounds per tow/hour in 1992, and steadily increasing to 213 pounds per tow/hour in 1999. This increase is in addition to an increase in the number of vessels (from 17 in 1992, a high of 43 vessels in 1995, to 32 in 1999), and more effort directed at ridgeback prawns during the spot prawn closed season.

Potential causes for this increase are the effects of El Niño, which may have provided optimum conditions for growth and recruitment; reduced predator populations; and regulatory restrictions on the fishery. No population estimates were available for any of the major fishing grounds, although the majority of catches consisted of two- and three-year-old animals.

Management Considerations

See the Management Considerations Appendix A for further information.

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Red Rock Shrimp

History of the Fishery

The red rock shrimp (*Lysmata californica*) fishery has been sporadic and of small magnitude since the late 1950s. It has persisted, however, due to the relatively high market value of this species for recreational fishing bait. Fishermen typically receive up to $25 a pound (about 100 shrimp per pound) when sold to retail bait stores. Bait stores will then sell the shrimp either by the dozen or the ounce at approximately twice the wholesale price. Red rock shrimp are highly regarded by anglers as the bait of choice for opaleye, black croaker, rubberlip surfperch, pile perch and other fish found along breakwaters, jetties and sea walls. In order to bring a premium price, the shrimp must be delivered to the bait stores alive. This requires special handling on the part of the fisherman as well as by the bait store. The shrimp are kept in aerated bait tanks or in floating "receivers" by the fisherman until delivery to the store. The bait stores are able to keep the shrimp alive for 24 to 48 hours by covering them with rags soaked in seawater. Dead shrimp can be salted or sugar cured but are then usually sold at a lower price. A secondary market for the shrimp is the aquarium trade. Pet and aquarium stores that sell marine fish will often buy red rock shrimp to sell to their customers. Wholesale prices may range up to ten dollars per shrimp. The shrimp must be in excellent condition, which requires special care in handling.

The red rock shrimp fishery is concentrated in shallow waters along breakwaters and sea walls where the shrimp congregate in rock crevices. This makes the fishery ideally suited to small fishing boats, usually around 20 feet long. A small boat is easier and safer to maneuver in the shallow, rocky waters. However, fisherman can only carry about 20 traps on a boat of that size. The traps are typically made of 1 1/4-inch wood lath, spaced about 1/8-inch apart. Traps measure about 18 inches on a side. A funnel-shaped opening enters the trap from the bottom. About 20 pounds of concrete, either poured or in the form of blocks, is added to each trap to keep it firmly on the rocky bottom. Fishermen have also experimented with pegboard and fiberglass frames, which add strength while weighing less than waterlogged wood. Additionally, modified metal minnow traps have also been tried but catch rates rarely equal those of the lath traps. Because the traps are set in shallow water and are often visible from shore, vandalism is a problem for the fisherman. Up to 25 percent of traps are vandalized per week of fishing.

The traps are baited with whatever fish or fish trimmings may be available to the fishermen. Occasionally unbaited traps will also have good catches since shrimp will enter the traps for cover. Traps are usually left to soak for 24 to 48 hours. Catch rates average one pound per trap, but occasionally a very good catch will be four to five pounds per trap. Bycatch in the traps consists primarily of octopus, rock snails, sea cucumber, and an occasional clingfish. Purple sea urchins and Kellet's whelks are often found clinging to the underside of the traps.

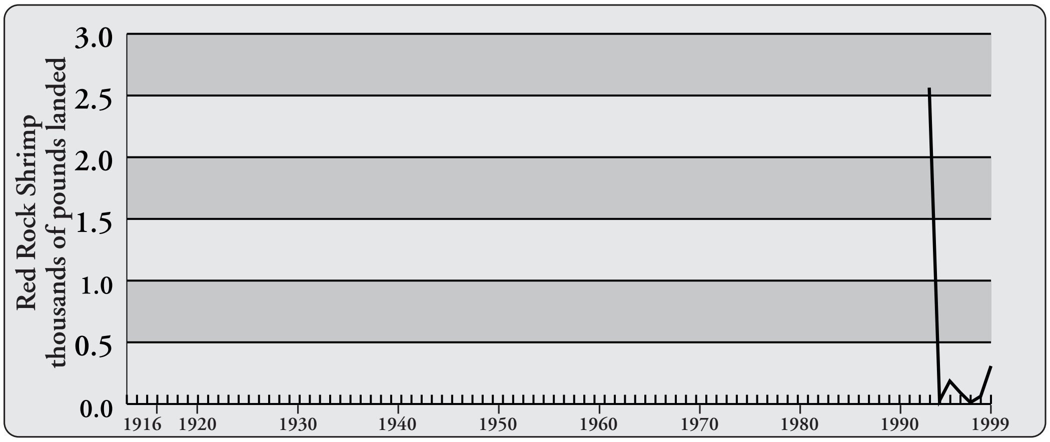
The fishery is seasonal, from October to April, for several reasons, including: 1) market competition from more plentiful summertime baits, such as sand crabs; 2) higher rates of trap vandalism due to increased shoreline recreational fishing activity during summer months; 3) participation in other commercial fisheries during the summer such as barracuda, white seabass and tunas; and 4) decreased shrimp availability in traditional trapping areas beginning in the spring.

The red rock shrimp fishery is regulated by the Fish and Game Commission. Prior to 1986, a tidal invertebrate permit and a general trap permit were required. Regulations include marking traps with buoys, servicing traps once every 96 hours, and trap destruct-devices to prevent ghost fishing of lost gear. Legislation enacted in 1986 generally restricted the use of trap gear for shrimp and prawns to water 50 fathoms or greater. This included the harvest of red rock shrimp. As a result, fishermen have had to apply to the Fish and Game Commission for an experimental gear permit to harvest red rock shrimp. Under this permit, a fisherman has five years to establish a viable fishery, with annual requests for renewal. In recent years the commission has required fishermen to take onboard observers supplied by the Department of Fish and Game, report their fishing activity through submission of fishing activity logs, including any bycatch, and immediately returning all incidental species to the sea. In addition to the experimental gear permit, fishermen must also follow the general trap and tidal invertebrate regulations.

Status of Biological Knowledge

Red rock shrimp occur from Santa Barbara, California, south to Bahia Viscaino, Baja California. They are often found in low intertidal pools and crevices and extend subtidally to a depth of more than 180 feet. They tend to occur in groups of several hundred, dispersing somewhat at night but regrouping in sheltered areas during the day. It should be noted that since about 1990 a population of red rock shrimp has appeared annually in the open ocean filter housing of the Monterey Bay Aquarium (MBA). The MBA staff has conducted surveys of the local intertidal and subtidal areas, but has not discovered any other populations of red rock shrimp. The exact mechanism for this occurrence north of the normal range has not been determined but suggests that oceanographic events can significantly affect the distribution of this species.

Commercial Landings
1916-1999,
Red Rock Shrimp
Data Source: DFG Catch Bulletins and commercial landing receipts. Landing data not available prior to 1993.



These shrimp grow to a length of about three inches. They are conspicuously colored with longitudinal broken stripes of red on a transparent body. Red rock shrimp may be simultaneous hermaphrodites like several other species of *Lysmata*. Captive berried females will continue to produce viable clutches following removal of the larvae. Eggs on ovigerous females are red following initial deposition on the pleopods and turn pea green just before hatching. Eggs have been noted as early as April but are more common in May, June, and July. Preliminary examination of berried females has shown that each female carries about 4,000 eggs. California's red rock shrimp is one of the larger, but less specialized, of the "cleaning" shrimp. They are often seen sharing crevices with, and cleaning, California morays. They are also known to perform cleaning activities on divers' hands when placed in their vicinity, paying particular attention to areas around fingernails or scratches on the skin.

The "cleaning" activity does not seem to be highly evolved and probably only supplements the diet. Most of the diet seems to come from scavenging scraps of decaying tissue on rocky surfaces or, when the opportunity arises, feeding on carcasses of dead fish and invertebrates.

Status of the Population

There are very few data available regarding population size and distribution of red rock shrimp. At the present time, the bait fishery for red rock shrimp appears to have little effect on the population. Diver observations suggest that they are widespread throughout southern California. Fishing effort, however, is very limited and concentrated at only a few locations such as breakwaters and sea walls. Since these shrimp are relatively short lived, there are probably large fluctuations in annual abundance.

Management Considerations

See the Management Considerations Appendix A for further information.

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Coonstripe Shrimp

History of the Fishery

The commercial fishery for coonstripe shrimp *(Pandalus danae*) occurs off Crescent City, California primarily in depths ranging from 23 to 28 fathoms. This species, also known as dock shrimp, is often caught incidentally in ocean shrimp trawl nets and Dungeness crab traps along the northern California coast. Early efforts to develop a targeted commercial trap fishery were unsuccessful prior to 1995. The first significant commercial landings of 2,488 pounds were made in 1995. The developing live market and high price led to effort yielding 79,269 pounds in 1997. Landings dipped to 64,718 pounds in 1998 and then climbed to 75,540 pounds in 1999. Two vessels pioneered this fishery in 1995, while effort through 1999 ranged from eight to 20 vessels per year. The initial ex-vessel value in 1995 was $1.50 per pound. However, since this species was destined for the live market, coonstripe shrimp quickly rose in value, averaging over $4 per pound in 1998. Coonstripe shrimp ranked eighth in single species value for the Crescent City port during 1997 and 1998. The ex-vessel value rose again in 1999 to an average of $4.22 per pound with some businesses paying as much as $7.50 per pound.

The coonstripe shrimp trap fishery uses various trap configurations. The most common design is a rectangular trap covered in 1 3/8-inch mesh shrimp trawl webbing, with two circular openings. The traps are set in areas of high currents, such as along Saint George Reef from May through October. The traps are set in strings composed of between 20 and 30 traps per string. Fishermen report using 300 to 400 traps during the fishing season. Many types of bait are used including small pelagic fish such as herring, sardine, and mackerel.

To participate in the commercial fishery, a fisherman must be a registered commercial fisherman, have a commercial vessel registration and a general trap permit. In addition, a commercial coonstripe shrimp trapper must comply with all trap regulations regarding size of traps, destruct devices, marking the trap, and trap servicing. Currently, there are no other management restrictions on this fishery.

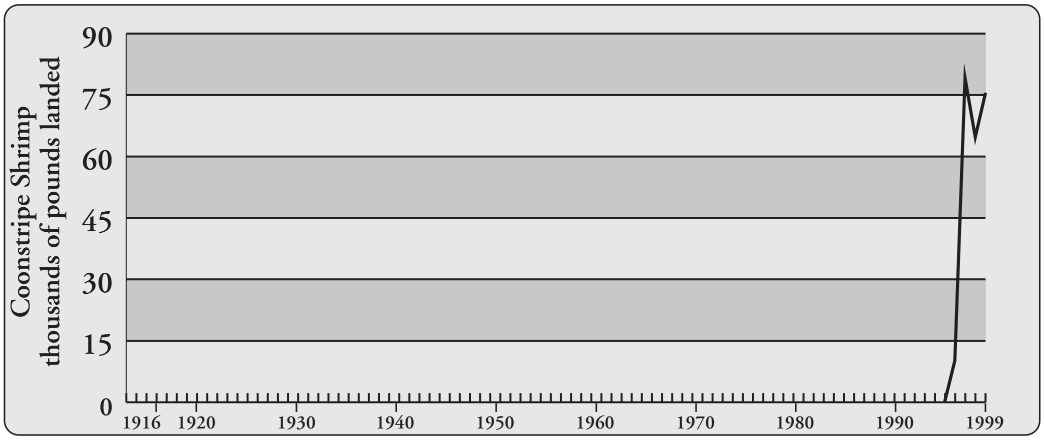
The developing commercial fishery led to an interest in a sport fishery for this resource since the shrimp are close to shore and are caught in small, lightweight traps. The sport fishing daily bag and possession limit was increased from 35 shrimp to 20 pounds per day in 1997. Data are not available on sport harvest, but take is thought to be minimal.

Status of Biological Knowledge

Coonstripe shrimp, called dock shrimp in Oregon, Alaska and Canada, are red-brown shrimp and derive the name "coonstripe" from the irregular, black-edged brown or red striping found on the abdominal area. The surface of the species is finely pitted and has 10 to 12 median dorsal spines. The rostrum is a little longer than the carapace. They range from Sitka, Alaska to San Luis Obispo Bay, California in 10 to 100 fathoms, and prefer sand or gravel substrate in areas of strong tidal current. Exploratory trap surveys conducted in northern California yielded catches off Tolo Bank, False Cape, Patrick's Point and the Saint George Reef. Coonstripes have also been found in trawl surveys ranging in depth from 11 to 100 fathoms off the Eel River, Table Bluff, Humboldt Bay, Mad River, Trinidad Head, Big Lagoon, Patrick's Point, Redding Rock, Klamath River and Point Saint George. This species is a protandrous hermaphodite - initially maturing as male and then undergoing transition to female. Egg bearing females may be found throughout the year, but gravid females primarily occur from November to April. Average fecundity is 1,140 eggs, and a progression of five larval stages occurs near the place of hatching. Research off British Columbia, showed that metamorphosis takes place by late June. Growth is rapid until October, when most shrimp mature as males at an average size of 0.50-inch carapace length (CL). Primary females, those maturing directly as females, also may be found. Some shrimp remain as males for another year and average 0.68 inch CL. Shrimp that transition to females over the first winter average 0.71 inch CL. Second year females average 0.85 inch CL. All shrimp are females by the third year and probably do not survive into the fourth year. Off Crescent City, count per pound for trap-caught females taken during the 1997 spring period ranges from 25 to 30 and males from 40 to 65. Large shrimp attain a length of five inches.

Data are lacking on the specific food habits of coonstripe shrimp, but most likely their diet is similar to that of other shrimp, feeding on planktonic and small benthic organisms. It is assumed that various species of fish such as lingcod, rockfish, flounder, hagfish, sole, or whiting, which prey on other shrimp species, are major predators. Like spot prawns, coonstripe shrimp undergo an onshore-offshore spawning migration pattern; however, along-shore movement within their range is unknown.

Commercial Landings 1916-1999, Coonstripe Shrimp
Commercial landing for Coonstripe Shrimp were not reported prior to 1996. Data Source: DFG Catch Bulletins and commercial landing receipts.



Status of the Population

Due to the recent development of this fishery, there is too little fishery dependent data to determine what effect the commercial fishery has had on the coonstripe shrimp population or on the size composition of the population. To date there has been no fishery-independent estimates of population or structure.

Management Considerations

See the Management Considerations Appendix A for further information.

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Sea Cucumbers

History of the Fishery

Two species of sea cucumbers are fished in California – the California sea cucumber (*Parastichopus californicus*) also known as the giant red sea cucumber, and the warty sea cucumber (*P. parvimensis*). The warty sea cucumber is fished almost exclusively by divers. The California sea cucumber is caught principally by trawling in southern California, but is targeted by divers in northern California. Sea cucumber fisheries have expanded worldwide, and on this coast there is a dive fishery for warty sea cucumbers in Baja California, Mexico, and dive fisheries for California sea cucumbers in Washington, Oregon, Alaska, and the coast of British Columbia, Canada.

The first recorded commercial landings of sea cucumbers in California were made in 1978 at Los Angeles area ports. Divers fishing sea cucumbers at Santa Catalina Island were the first to make landings, but they were soon joined by trawl vessels. Annual landings remained under 100,000 pounds until 1982 when the principal fishing area shifted to the Santa Barbara Channel. In that year, 140,000 pounds were landed with an ex-vessel value of about $25,000. Recorded landings fluctuated between 52,350 to 160,000 pounds over the next eight years, and in 1991 reached more than 577,390 pounds. Through the first 18 years of the fishery, trawl landings composed an average of 75 percent of the annual sea cucumber harvest. In 1996, combined trawl and dive sea cucumber landings reached an all time high of 839,400 pounds with an ex-vessel value of $582,370. Between 1997 and 1999, sea cucumbers landed by divers accounted for more than 80 percent of the combined dive and trawl landings. During that time period, trawl effort declined substantially, due primarily to court cases pursued by the department which ruled that 16 trawl fishermen had fraudulently obtained their sea cucumber permits. Those fishermen were subsequently excluded from the fishery. Diver effort and landings, in contrast, increased markedly during those three years, driven by both a 1997 moratorium of the abalone fishery, a sea urchin fishery depressed by El Niño conditions, and a poor Japanese export market. Beginning in 1997, many commercial sea urchin or abalone divers, who also held sea cucumber permits, targeted sea cucumbers more heavily than before.

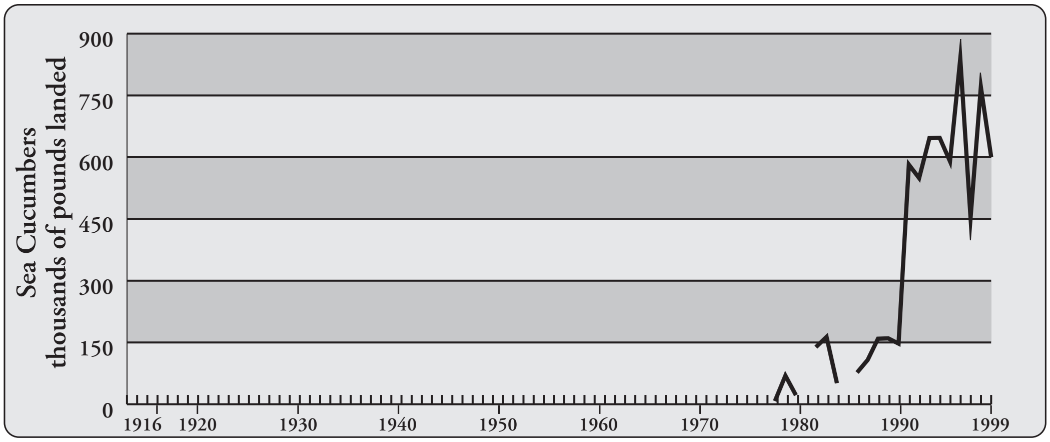
Most of the California and warty sea cucumber product is shipped overseas to Hong Kong, Taiwan, China, and Korea. Chinese markets within the United States also purchase a portion of California's sea cucumber catch. The majority are boiled, dried, and salted before export, while lesser quantities are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

There is no significant sport fishery for sea cucumbers in California. Few sport fishermen have shown an interest in sea cucumber as a food item, and sport fishing regulations forbid their take in nearshore areas in depths less than 20 feet.

A special permit to fish for sea cucumbers commercially was required beginning with the 1992-1993 fishing season. Qualifications for the permit were based upon meeting a minimum 50 pound landing requirement during a four-year "window" period. In 1997, legislation was enacted that imposed a new regulatory regime on the sea cucumber fishery. The major regulatory changes included creating separate permits for each gear type, and limiting the number of permittees in the sea cucumber fishery. The maximum number of permits allocated was based on the number of permits issued during the 1997-1998 permit year, and the meeting of a minimum landing requirement. There are currently 113 sea cucumber dive permittees and 36 sea cucumber trawl permittees. A permit transfer procedure and transfer fee of $200 was also initiated by the 1997 legislation. Sea cucumber dive permits can be transferred only to other dive fishermen, while sea cucumber trawl permits can be transferred to either trawl or dive fishermen.

California Sea Cucumber, *Parastichopus californicus*
Credit: DFG

Commercial Landings 1916-1999, Sea Cucumbers
1916-1999, Sea Cucumber
No commercial landings are reported for sea cucumber prior to 1978.
Data Source: DFG Catch Bulletins and commercial landing receipts



Status of Biological Knowledge

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

The California sea cucumber reaches a maximum length of 24 inches and is red, brown or yellow in color with red-tipped papillae. The warty sea cucumber is 12 to 16 inches in length and chestnut brown with black-tipped papillae on the ventral surface. Size however, is difficult to determine, as sea cucumbers can contract, making length measurements unreliable, and they can take up water, rendering body weights unreliable.

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

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

Sea cucumbers can reach moderately high densities and are thought to be important agents of bioturbation. During feeding and reworking of surface sediments, sea cucumbers can alter the structure of soft-bottom benthic communities. The California sea cucumber crawls an average of 12 feet per day with no directional bias, presumably due to the even distribution of detrital food. Tagging studies are difficult since external tags are frequently lost and internal tags can be shed through the body wall. Sea cucumbers are also known to have a predator escape response involving a rapid creeping or swimming behavior propelling the sea cucumber away. Water can also be taken up in the respiratory tree and then forcefully discharged. Predators include sea stars, various fishes such as kelp greenlings, sea otters and crabs. Comparatively few studies have been done with sea cucumbers, and as recently as 1986, a new species, *P. leukothele*, was described that is distributed from Pt. Conception, California to British Columbia, Canada.

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

(51 to 91 days post-fertilization) into newly settled pentactula. Pentactula have five primary buccal tentacles, and attach to the substrate using a single pedicle. In the field, juveniles recruit to a variety of substrates including rock crevices, polychaete worm tubes, and filamentous red algae. Growth is slow in sea cucumbers. Juveniles become reproductively mature at four to eight years.

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

Status of the Population

There is presently very little known about populations of California and warty sea cucumbers in California. The distribution of these species on rocky or sandy substrates is characterized as patchy, without any apparent seasonal aggregating, spawning, or feeding behavior. Sea cucumbers undergo sporadic recruitment, have a relatively high natural mortality, and are slow growing. Species with these life history traits tend to have a low maximum yield per recruit and are particularly vulnerable to overfishing.

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

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

Management Considerations

See the Management Considerations Appendix A for further information.

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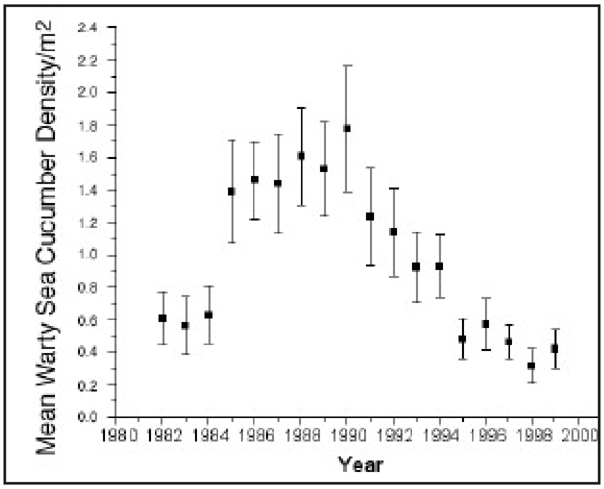
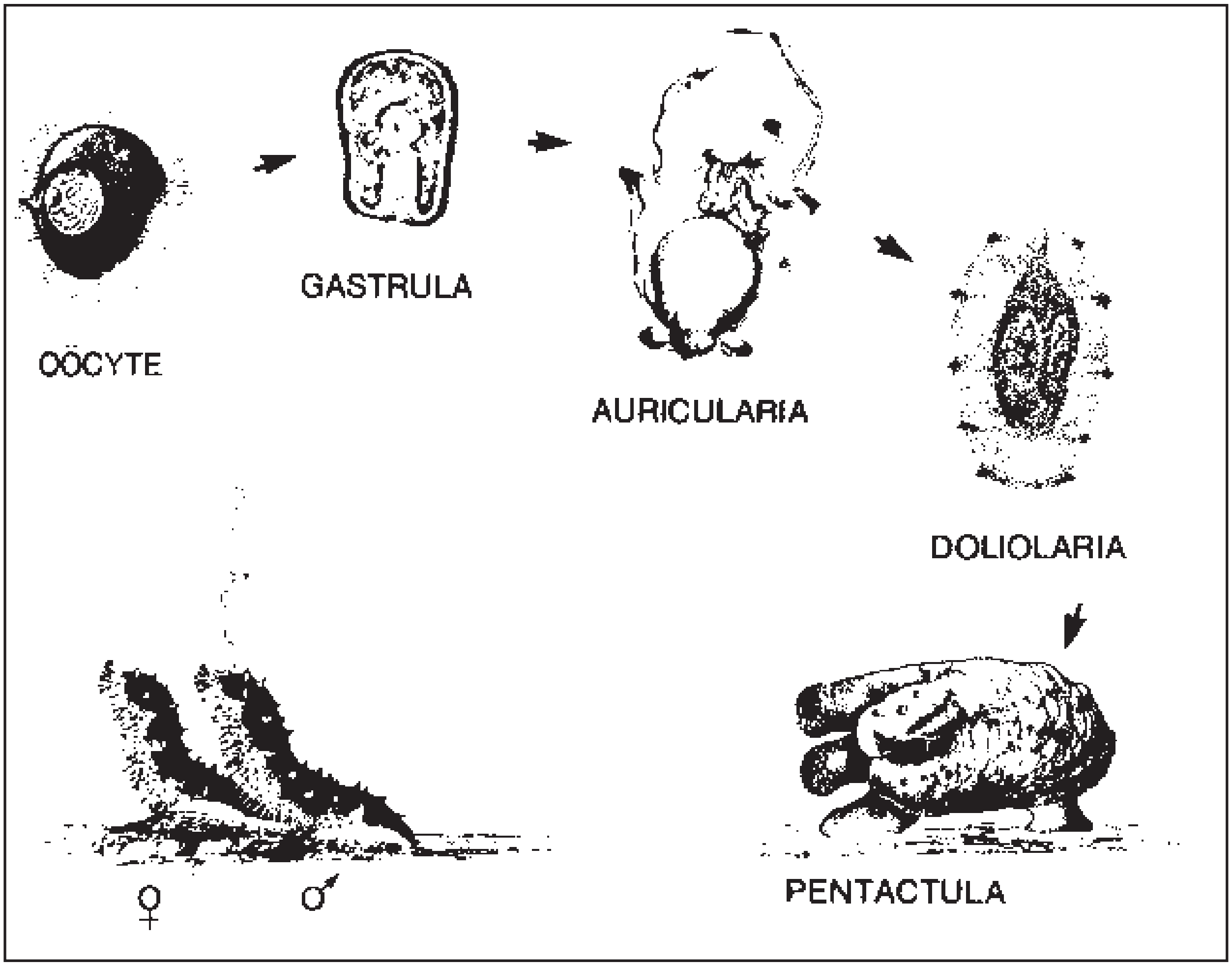


Density of Warty Sea Cucumber, 1982 to 1999
Density of warty sea cucumber from 16 Channel Islands National Park sites at five of the northern Channel Islands, San Miguel Island, Santa Rosa Island, Santa Cruz Island, Ancapa Island, and Santa Barbara Island from 1982 to 1999.
Data Source: California Department of Fish and Game



Representative of spawning and development through settlement and metamorphasis of P. californicus. Development does not deviate significantly from that expected for an aspidochirote holothurian with planktotrophic larvae.
Drawing not to scale.

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Pismo Clam

History of the Fishery

Humans and other predators have utilized the Pismo clam (*Tivela stultorum*) resource for thousands of years. The Pismo clam has been found in 25,000-year-old Pleistocene (ice age) deposits and in American Indian kitchen middens 200 to 2,000 years old. Indians used the clam for food and the shells for digging, scraping and ornaments. The name Pismo is derived from the Indian word *pismu* meaning tar. Natural deposits of tar are found in the Pismo Beach area.

Records of the commercial harvest of Pismo clams began in 1916, and were kept through 1947 when the commercial fishery in California was prohibited. During that period, approximately 3,137 tons were commercially harvested. The majority was harvested from the Pismo Beach and Morro Bay areas, with a small percentage from Monterey Bay. Annual landings ranged from a high of 332.8 tons in 1918 to a low of 13 tons in 1945. The average annual harvest was approximately 98,600 clams (average two pounds each) with a high of 334,700. The clams were purchased by restaurants, were sold whole and canned in markets, and were used as bait and animal food.

The importation of Pismo clams from Baja California occurred as early as 1919 and most likely continues to this day. After 1962, clam imports from Mexico into the United States have not been identified by species. From 1919 through 1962, 232 tons of Pismo clam, mostly canned, were imported into the United States. In Baja California Norte, from 1990 through 1999 Pismo clam landings ranged from a low of 411 tons in 1994 to high of 1,025 tons in 1992, with a 10-year average of 434 tons. In Baja California Sur, from 1978 through 1995 landings ranged from a low of 1,213 tons in 1984 to high of 6,505 tons in 1981, with a 18-year average of 3,234 tons.

The usual method of collection by recreational clammers is by using a four- to six-tined garden fork. During a low tide the clammer selects a section of beach with exposed wet sand or water of wading depth and probes in the sand until encountering a clam. Another method is to shuffle one's bare feet along the bottom until a siphon or shell is felt. Pismo clams can also be found by looking for the half-inch-long tufts of the commensal hydroid (*Clytia bakeri*) which attaches to the shell and is exposed above the sandy surface. Divers search for the clams by probing with a knife or looking for exposed shells, siphons, or tufts of hydroids.

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

Recreational clamming is regulated by bag limit (10), a minimum size (5.0 inches north of and 4.5 inches south of the San Luis Obispo/Monterey county line), the immediate measuring and reburial of sub-legal clams, and closed seasons and areas. The objectives of these regulations are to prevent the depletion of the clam population and to maintain a population of sexually mature clams that have a chance to spawn several times before being harvested.

Status of the Biological Knowledge

The Pismo clam shell is thick, heavy, and strong, and the outside is smooth with fine concentric growth lines. The inside of the shell is white and the outside has a varnish-like periostracum, usually yellowish, tan or greenish. Shells of individual clams vary considerably in both color and pattern, ranging from pale beige to brown, occasionally with brown radiating marks running from the umbo to the margin on a light background.

The historic range of the Pismo clam is Half Moon Bay, California to Socorro Island, Baja California Sur, Mexico, including two of the Channel Islands (Santa Cruz and Santa Rosa Islands). However, it has not been found at Half Moon Bay for decades and its present range extends northward only to Monterey Bay. It is found in the intertidal zone and offshore to 80 feet on relatively flat, sandy beaches of the open coast. Occasionally, it is also found in entrance channels to bays, sloughs and estuaries. Because of its short siphons, the Pismo clam generally lives close to the surface of the sand and seldom burrows deeper than six inches, but it has been found eight to 12 inches deep in southern California. The clam characteristically orients vertically with the hinge and excurrent siphon toward the ocean, the mantle edge and incurrent

Pismo Clam, *Tivela stultorum*
Credit: DFG

siphon toward the beach, and the ligament at the center of the hinge oriented up. Burrowing is accomplished by moving the foot rapidly to loosen the surrounding sand. Then jets of water eject the loosened sand up along the shell sides, and the weight of the clam and pull of the foot together drag the clam down through the sand.

The age of Pismo clams has been determined by observation of marked individuals and by growth rings on the shell. In California, a growth ring is generally formed during the winter months when water temperatures are cool and food abundance is relatively low. In Baja California, most clams form a growth ring during the August-October period, although some may form a ring at any time of the year.

The Pismo clam is about 0.009 inch at metamorphosis and may grow to more than 7.3 inches in length. Growth is continuous throughout the clam's life, with the average length increasing by approximately 0.84 inch per year for the first three years. Increases in shell length are greatest in spring, summer and early fall. Growth of older clams is slower. At age 10, the increase in shell length is usually not more than 0.2 inch per year. A 4.5-inch clam may be from five to nine years old. At Pismo Beach, clams reach 4.5 inches between ages seven and eight.

In California, the largest Pismo clam reported was 7.32 inches long and estimated to be 23 years old. The oldest Pismo clam was estimated to be 53 years old. In Baja California, the largest Pismo clam reported was 7.36 inches long and estimated to be 26 years old. Several Pismo clams from Baja have been aged to be 43 years old. The smallest Pismo clam reported from the wild was 0.24 inch long.

In the majority of Pismo clams, the sexes are separate with equal numbers of males and females. Fertilization occurs externally when the male releases sperm and the female releases eggs into the surrounding water. Pismo clams are mature at one year in southern California and two years in central and northern California. The smallest known mature clam in southern California was 0.7 inch and in northern California was 0.5 inch.

Spawning can occur anytime, but the majority spawn from June to September. The number of eggs per female increases with increased shell size and ranges from 10 to 20 million eggs per female, with an average of 15 million per five-inch female. In laboratory-held clams, egg numbers were roughly proportional to clam size. The number of eggs ranged from as many as 4.7 million in a 2.9-inch female to 0.4 million in a 1.2-inch female. Eggs range in diameter from 0.00296 to 0.00324 inch.

The larvae metamorphose, settle to the sandy bottom, and attach themselves to the sand grains by means of byssal threads. After several months, when the clam is more able to maintain a position on the sandy bottom, the byssal threads degenerate. In laboratory culturing experiments, fertilized eggs hatched into larvae in approximately 48 hours. Larvae 60 to 72 hours old displayed the behavior of settling to the bottom and remaining benthic or near-benthic throughout larval development. If larval Pismo clams in nature also exhibit a benthic phase, larval transport by nearshore currents may be limited. Larvae larger than 0.009 inch and 22 to 50 days old have completed metamorphosis, developed a foot, and buried themselves in the sand. At day 120, post-larval clams (0.048 inch) have the triangular appearance of an adult. No byssal threads were observed on laboratory-cultured post-larval Pismo clams.

Little is known of post-larval conditions in nature; however, in laboratory cultures post-larval growth was relatively slow, and survival generally poor. Although spawning probably occurs every year, it is not always measurably successful. In some years, virtually no young-of-the-year clams settle on beaches. Recruitment success appears to be influenced by oceanographic conditions (water temperature, currents), which in turn influence phytoplankton availability. Unfortunately, the necessary conditions for optimum spawning success are not known.

The Pismo clam is a filter feeder. Water taken in through the incurrent siphon passes over the gills, where food particles are removed. Food includes organic and inorganic particles such as phytoplankton, bacteria, zooplankton, eggs, sperm, and detritus from the disintegration of plants and animals. The inhalant siphon has a very fine net of delicately branched papillae across the opening, forming a screen that excludes the entrance of large particles but permits the intake of water and food particles. Despite this elaborate system, half of the stomach contents is sand. An actively feeding three-inch clam filters as much as 15 gallons of water per day.

Pismo clams have many predators, including moon snails, rock crabs, sharks, rays, some surf fishes such as the California corbina in southern California, gulls, sea otters, and humans. Otters were estimated to have eaten 520,000 to 700,000 Pismo clams in one year at Monterey Bay. A single sea otter was observed to eat 24 clams in 2.5 hours. The extension of the sea otter's range to Monterey Bay in 1972, Morro Bay in 1973 and Pismo Beach in 1979 has precluded the recreational fishery for Pismo clams in those areas.

Parasites of the Pismo clam include a polychaete worm that bores into the clamshell, and larval cestodes, which have been found inside the clam as 0.15-inch diameter yellowish-white cysts. The cestodes can impair the clam's sexual development but are not harmful to man if eaten. Trematodes have been reported in some clam populations. A commensal hydroid is often found attached to the external shell of the clam, and commensal pea crabs are occasionally found in the mantle cavity and feed on food particles collected by the clam's gills.

Status of the Population

Pismo clam populations have been highly variable over the years and from beach to beach. Settlement and recruitment have also been highly variable from year to year. The Department of Fish and Game first examined Pismo clam recruitment in 1919, and annual surveys have been conducted from 1923 to 2000 to obtain information on age, recruitment, year class strength, and exploitation trends. Through 1948, only Pismo Beach was surveyed. Since 1948, beaches in Morro Bay, Cayucos, Monterey County, and from Santa Barbara County to San Diego County were subsequently included.

During the storms of 1982-1983, Pismo clam populations along southern California beaches were severely depleted, resulting in limited recreational fisheries after 1983. The Pismo Beach clam populations had three successive strong year classes (1986, 1987, and 1988), resulting in the largest number of sublegal clams ever recorded from surveys on Pismo Beach. Because of the exceptional recruitment in the Pismo Beach area and low abundance in southern California, 10,000 clams were transplanted from the Pismo Beach area to Huntington State Beach in 1989. The first follow-up survey found only 142 clams, the second only 14 clams and three partial shells. Biologists are uncertain as to the fate of the clams. At the same time, approximately 1,000 clams were transplanted within the Channel Island National Park.

In 1990, abundance of young Pismo clams appeared to be a widespread phenomenon along southern and central California from San Diego to Pismo Beach. Densities were documented at Ventura County and Pismo Beach of five clams per square foot (one- to three-year olds) and 26 clams per square foot (one- to six-year olds), respectively.

From 1990 to the present, recreational fishing for Pismo clams continues on a few southern California beaches. From 1990 to 1993 a recreational fishery occurred in the Pismo Beach area for the first time since 1982. During this period, sea otters were foraging off shore and in other areas. In 1992, sea otters were again observed foraging in the Pismo Beach area and in 1993 the last take of a legal size Pismo clam was reported there. Pismo clam surveys in the Pismo Beach and Morro Bay areas from 1992 through 2000 indicated low levels of recruitment.

No population estimates have been made for the total Pismo clam resource in California. Whether successful recruitment will result in ongoing recreational fisheries in light of continuing human growth and the expansion of the sea otter's ranges is unclear.

Management Considerations

See the Management Considerations Appendix A for further information.

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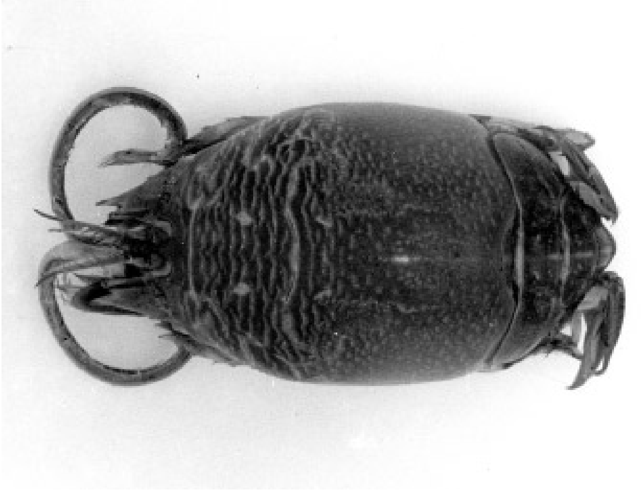
Sand Crab

History of the Fishery

The first complete commercial catch records for sand crabs (*Emerita analoga*) were collected in 1963, when 4,673 pounds were landed. By 1967, reported landings totaled over 8,300 pounds of sand crabs worth $17,152 to fishermen. Since 1977, catch records indicate a greatly reduced utilization of sand crabs for bait; the annual catch has ranged from zero to 96 pounds averaging only 22 pounds per year. This reduced catch should not be interpreted as a reduction in the size of the sand crab population. Sand crab populations are still robust, though they fluctuate annually depending on oceanic and climatic conditions. Instead, the reduced catch is probably due to reduced harvest effort and replacement of sand crabs with other bait such as ghost shrimp, clams and mussels.

Sand crabs are collected in 30 to 36-inch wire mesh nets by sport and commercial fishermen. Mesh size varies from 0.25 to 0.50 inch. The fishermen wade into the surf and place the net on the bottom as a wave begins to recede. The backwash carries the sand crabs into the net, from which they are removed and placed in a container held on a belt around the fisherman's waist. Usually only "soft shelled" crabs (those that have molted recently) are saved. Commercial fishermen usually sell sand crabs by the dozen. The size of sand crabs varies widely depending on season and location where they are taken. Because of this, the price per dozen may go up or down based on the size of the crabs available. Demand for sand crabs is often higher through the winter months because of weather-related shifts in fishing effort from offshore species to nearshore species. The demand is also increased when bait stores sponsor perch fishing contests. In winter, when soft-shelled sand crabs are difficult to find, hard-shelled crabs are also sold. These are often sold by the gallon (further complicating commercial catch landing records).



Sand Crab, *Emerita analoga*
Credit: DFG

Based on recent catch records, there appears to be potential for expanding the current market for sand crabs as bait.

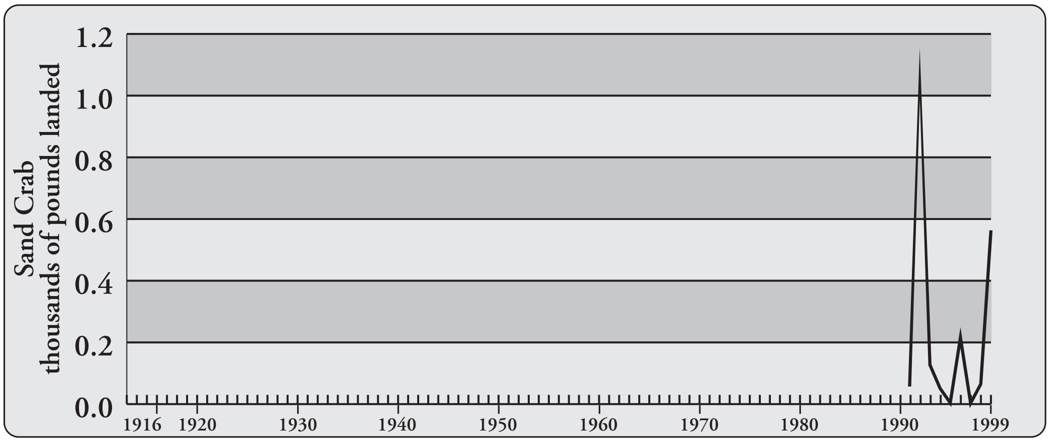
Status of Biological Knowledge

The sand crab occurs from British Columbia to Magdalena Bay, Baja California. Although found on nearly all open-coast sandy beaches, there are gaps in this range where no sand crabs can be found.

When feeding, sand crabs burrow tail-first into the sand leaving only the tip of their heads and their large, feathery antennae protruding. The antennae are extended into the backwash of a receding wave and strain food particles from the water. Food particles are transferred to the mouth by wiping the antennae through the mouthparts. The extended antennae produce characteristic V-shaped ripple marks on the beach that indicates the presence of sand crabs.

Mating occurs mostly in spring and summer, but some mating and egg-bearing females are seen year-round. Females are larger than males, reaching 1.5 to two inches in length; males seldom exceed 0.75 inch. A two-inch female may produce as many as 30,000 eggs. The number of eggs varies with the size of the animal as well as with temperature and food availability. The eggs are carried on the female's abdomen (pleopods) until hatched. It takes the young two to four months to pass through nine to ten larval stages before they resemble adults. During their various larval stages the young *Emerita* drift at the mercy of the currents and may be carried for long distances. Shifting currents, which carry the larvae "off course," may account for population fluctuations on a given beach. In southern California, the megalops larvae arrive on the beach in the greatest numbers from April to July. Sand crabs reproduce during their first year of life in southern California, and may not live more than two or three years. Sand crabs that settle in sub-optimal habitat may not survive their first winter. Sand crabs in colder waters might not reproduce in their first year.

Shore birds, sea gulls, surf scoters, otters and other marine mammals include sand crabs in their diet. In addition, many fish eat sand crabs, including surf fish such as corbina, yellowfin croaker, spotfin croaker and barred surfperch. For this reason, they make excellent bait for sport fish, especially for fishing from sandy beaches. They also make good bait for fishing from rocky shores or breakwaters for opaleye.



Commercial Landings 1916-1999, Sand Crab
Data Source: DFG Catch Bulletins and commercial landing receipts. Landings data not available prior to 1992.

Status of the Population

The reported harvest in 1967 was 8,303 pounds or about two million sand crabs. Most of the catch came from about 20 miles of beach in the southern part of the state. Southern California has more than 200 miles of sandy beaches, and the total population of sand crabs, while undetermined, is extensive. Since only the recently molted, soft-shelled sand crabs are usually taken and the hard-shelled crabs are returned, there is little danger of overfishing. A high market demand for hard-shelled crabs, however, perhaps for purposes other than bait, could result in a fishery that would be detrimental to the population. Though extensive in range, sand crabs are vulnerable to capture because of their habit of forming dense aggregations near piers and jetties, especially at night. Although population sizes are not well known, and the number of sand crabs on any given beach may fluctuate from year to year, the resource appears to be in good condition. Although sand crab commercial landings have been low in recent years, casual observations indicate that the population is as strong as it was in the 1960s. There does not appear to be any reason why annual harvests could not equal the 8,000 pounds that were harvested in 1967 when no apparent detriment to the population was detected.

Management Considerations

See the Management Considerations Appendix A for further information.

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Wavy Turban Snail

History of the Fishery

The California commercial fishery for wavy turban snails (*Megastrea undosa*) is a small emerging fishery that began in the early 1990s. Today, turban snails are of commercial value in southern California and Baja California, Mexico. Although still in its infant stages with a small number of participants and a limited market, this fishery has the potential for rapid growth in light of the snail's increased market value and the closure and decline of other dive fisheries. Archaeological evidence suggests that native peoples fished wavy turban snails prior to European and Asian settlement of California.

Wavy turban snails are harvested by divers, and the fishing gear is identical to gear used in the commercial fishery for red sea urchins. Participants in the fishery are also commercial sea urchin harvesters. Recorded landings of this species began in 1992 with overseas markets for the meat (foot) and the shell (made into buttons). Landings peaked in 1993 and crashed the following year with the loss of market demand. Landings fluctuated between 1995 and 1997 with the development of new markets and peaked again at a higher level in 1998. The snail fishery is centered in the area off San Diego with most of the landings coming from Point Loma.

Current market demand for the species is for the foot, which is processed and sold to restaurants as an abalone-like product called wavalone. Other potential markets occur in Mexico, where a fishery for this species "caracol panocha" has existed for years. In Mexico, the wavy turban snail fishery produces a canned meat product. Future expansion of the California fishery may rely on export of snails to Mexico for the canned product market.

In California, the wavy turban snail fishery has virtually no regulations governing the harvest of the species. Fishery participants need only a valid California commercial fishing license to harvest these snails. The only regulations that restrict harvesting are the commercial tidal invertebrate regulations that prohibit the harvest of any snail species within 1,000 feet of the low tide mark on shore. This regulation has prevented expansion of the fishery from the San Diego area to the Channel Islands where most of the snail habitat occurs within this restricted zone.

Wavy Turban Snail, *Megastrea undosa*
Credit: DFG

Status of Biological Knowledge

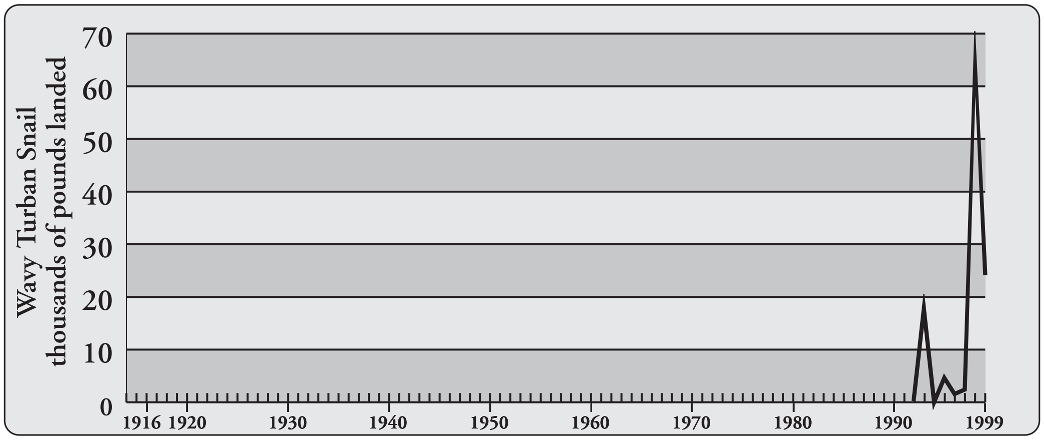
Little is known about the biology of the wavy turban snail. Its classification is problematic, as there have not been analyses of related genera worldwide. This results in a question of whether *Megastraea* is proposed as a full genus, as we have done here, or is recognized as a subgenus of *Astraea*. A closely related species is *M. turbanica,* which was first discovered on the outer coast of Baja California, Mexico.

This species of snail is one of the largest turbinid gastropods living in California waters. Shells reach six inches in diameter and have heavy, sculptured, undulating ridges. The base of the shell is flat and the operculum is hard, thick, oval, and uncurved, with well-defined rough ridges. The shell is covered with a fibrous periostracum that gives the shell a light brown or tan color. The periostracum is often covered with coralline algae and other epiphytes. Wavy turban snails are commonly found on rock substrate from Point Conception, California to Isla Asuncion, Baja California. They range in depths from the intertidal zone down to over 250 feet.

The wavy turban snail is a herbivorous generalist and individuals have been observed feeding on kelp and coralline algae. Predators of this snail are likely the sea stars and the Kellet's whelks based on demonstrated escape responses in laboratory experiments. Other predators include octopuses, lobsters, and fishes.

Wavy turban snails exhibit differential distribution in size and density by depth, which may be correlated with physical (water motion) and biological (intraspecific competition, predation) processes. Smaller snails are found in shallow areas with a high density of individuals, and larger snails are found in deeper depths at lower densities. In extreme shallow (less than 10 feet) and deep portions of the depth range, snail densities are also very low. To escape predation within kelp forests wavy turban snails crawl or migrate up into the canopy of the giant kelp plants each night. Large snails can be found in deep water. For example, a six-inch diameter snail weighing 2.7 pounds was recently collected from Farnsworth Bank, near Santa Catalina Island, in 120 feet of water.

A growth study on a population of wavy turban snails at Santa Catalina Island indicates that these snails are



Commercial Landings 1916-1999, Wavy Turban Snail
Prior to 1996, there was no specific species code for wavy turban snail landings on the DFG Commercial Landing Receipts. Therefore, wavy turban snail data for 1992-1996 were derived from commercial landing receipts that were recorded under the miscellaneous sea snail and commercial dive gear codes. Data Source: DFG Catch Bulletins and commercial landing receipts.

slow growing. Growth rates in this study varied both by snail size and density. As is typical for many marine invertebrates, growth rates are higher for smaller sized snails and progressively slower as size increases. Aside from a slow growth rate, this study also reports sexual and seasonal variations in growth. Two different growing periods during the year were identified, a low growth period in the spring and summer months and a high growth period in fall and winter. Sexual differences in growth rate were observed with females growing more slowly than males.

Studies on reproduction conducted in Baja California suggest that reproductive activity is year-round with major peaks in the spring and fall. Immature gonads were observed in juveniles less than 2.2 inches in shell diameter. Fully mature gonads were observed in females with shell diameter greater than 3.5 inches and males greater than 3.1 inches. Histological examination of gonad samples showed that the snails might spawn either completely, partially, incompletely, or not at all. In shallow water, partial spawners were more abundant than in deeper water (60 feet). Complete spawners were dominant. Three reproductive phases occur during the year. Gonad growth and maturity take place during the spring and early summer, followed by spawning in late summer. Somatic growth occurs during the fall and winter. Recruitment of new juveniles has been observed from January to April.

Status of the Population

Almost nothing is known about the population densities of wavy turban snails in California. Estimates of population abundance of wavy turban snails are made periodically by the Channel Islands National Park Kelp Forest Monitoring Program each year. These fishery-independent surveys from the northern Channel Islands and Santa Barbara Island have been conducted since 1982. Density surveys indicate interesting temporal patterns in abundance with abundance in 1998 and 1999 the greatest in the time series.

Management Considerations

See the Management Considerations Appendix A for further information.

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Rock Scallop

History of the Fishery

Purple-hinge rock scallops (*Crassadoma gigantea*, referred to in earlier literature as *Hinnites multirugosus*) are very popular among sport divers and shore collectors in California, Mexico, and the Pacific Northwest. The shellfish is prized for its flavorful, almost sweet, meat (adductor muscle). No commercial taking of rock scallops has been allowed in California. The California Department of Fish and Game (DFG) determined several decades ago that these mollusks were patchy in distribution and commercial exploitation would endanger their survival. Thus, rock scallops have remained in the domain of the non-commercial collector. Large numbers of rock scallops are taken by collectors at low tides and by divers near shore or aboard sport diving vessels in southern California.

It is difficult to estimate landings of rock scallops since many are taken incidentally. However, records of the DFG 1978-1987 indicate an average of 928 were taken per year by divers from commercial passenger sport diving boats operating largely at the Channel Islands.

The scallops are usually pried from their attachment surfaces with an "abalone iron." The large adductor muscle is easily shucked from the opened shells and separated from mantle and viscera. Divers often eat the scallops fresh from the shell, either underwater or above! As part of a research program at San Diego State University, rock scallop adductor muscle samples were analyzed by a professional taste panel, compared to common brands of commercial scallops. By almost all criteria, rock scallops ranked superior to others.

Status of Biological Knowledge

The purple-hinge rock scallop is distinctive, typically having an irregular oval outline, a rather rugose upper free shell (left valve) and a tentacle-bearing mantle, usually orange or gray. The interior aspect of the hinge line on both valves bears a zone of purple pigment. Adults typically are firmly attached to the substratum, in contrast to most other scallops that live free on sand or mud bottom. After passing a free-living juvenile life, attachment is achieved by temporary byssal threads. Permanent attachment occurs once the young scallop reaches a size of about one-inch through deposition of shell material by the right valve in conformity to the microrelief of the substratum.

Throughout its range from Sitka, Alaska, to Magdalena Bay, Baja California, Mexico, the rock scallop is generally found from the lower intertidal to depths as great as 100 feet. Offshore reefs are typically populated, but concrete pier pilings and jetty rock at entrances to bays in southern California have become favored habitats. Commonly this shellfish measures five to six inches in shell diameter, but occasionally individuals exceeding eight inches are found.

Sexes are separate although cases of hermaphroditism have been reported. An increase in number of females relative to males among larger adults has suggested protandry (functioning early as males, but later becoming females). Other possible explanations for this finding include differential growth rates and/or survival. southern California rock scallops exhibit a bimodal annual reproductive cycle with spawning periods in late spring-early summer and again in mid-fall.

Rock scallops are filter feeders deriving the bulk of their nutrition from phytoplankton. Dinoflagellates appear to dominate the diet. Detritus may also be utilized as food. Predation may limit numbers of rock scallops chiefly due to losses of early free-living and newly cemented juveniles to sea stars and crabs, but adults enjoy a high degree of immunity to such activity by virtue of their ability to close sharp margined valves quickly. However, sea otters may succeed in breaking the shells of adult rock scallops using their favored tools, cobble stones.

An intensive study of the biology and aquaculture potential of the rock scallop was undertaken in the mid-1970s by researchers at San Diego State University, supported by the UC Sea Grant Program. Basic biological information was gained concerning reproduction, culture, foods, and environmental requirements. Under the most favorable conditions, growth rate of juveniles and young adults held in the sea in suspended culture exceeded two inches per year. It was established that the rock scallop could be reared from the microscopic egg to marketable size (four to five inches) in about two and a half years.

Rock scallops proved intolerant of salinity reduction greater than 30 percent. Thus, the species is not found in estuaries and bays where freshwater dilutes the saline water to levels below 25 parts per thousand. In areas with well-circulated oceanic water, adults proved amazingly hardy; survival from juvenile to adult stages was usually close to 100 percent.

For many years, oyster farmers at Point Reyes have reared rock scallops in pens for sale at a local retail market. Juveniles set naturally among the oysters under cultivation in Drakes Estero are recovered and placed in submerged mesh cages for rearing to a size of about five inches (about two years). These scallops are sold for about $1 each. The adductor muscle in scallops of that size weighs about a tenth of a pound. Rock scallop meats, therefore, were valued (1982) at $10 per pound.

While rock scallops in southern California show two spawning peaks during the year, some northern populations spawn only once a year. Year-round spawning can be achieved in the hatchery. Larvae are reared through their planktonic stages (about five weeks) and fed unicellular algae until settlement and the onset of metamorphosis. Early juvenile stages at 1/16- to 1/8-inch cling to the substrate by byssal threads. These anchoring filaments may be detached by the young scallop, allowing swimming for brief periods and relocation if necessary. When the juvenile scallop reaches one-half to one inch (about six months), attachment becomes permanent through cementation. Usually firm substrates such as rock and shell are preferred in nature. Specially formed plastic surfaces are provided for cementation in aquaculture.

Through experiments conducted at San Diego State University, it was found that metamorphosing young rock scallops may be collected from the plankton using "spat collectors" developed in Japan for the Japanese sea scallop. The spat collectors, onion bags packed with monofilament gillnetting, are now known to be attractive to larvae of many species of scallops, regardless of adult habitat. As an alternative to production of young in a hatchery system, the simple placement of spat collectors at intermediate depths in the ocean for several months' time is an economic advantage. Several aquaculture groups in California, Washington state, and British Columbia, have tested the concept of rock scallop spat collection. The principal difficulties encountered so far are coincident collection of pink and spiny scallops and in northern waters, and kelp scallops in southern waters, making separations tedious. Typically, a single spat collection bag, approximately one cubic foot, immersed at a depth of 20 feet for two months, will yield between 100 and 500 juvenile scallops, perhaps 25 percent being rock scallops. Until commercial hatcheries are developed to produce substantial numbers of juvenile stock available to growers at a few cents each, the use of spat collectors seems a preferred practice. In addition, commercial hatcheries in Washington state and Alaska have produced commercial quantities of seed for their own use. The seed is available to other shellfish growers for purchase at reasonable prices.

Generally, rock scallops have not been subject to problems associated with pollutants. The adductor muscle is usually all that is consumed. That tissue is not a storage organ for metabolites or toxins. A single case of paralytic shellfish poisoning was reported in 1980 during a red tide off northern California. In this instance, which was fatal, a diver consumed viscera in addition to the adductor muscle from several scallops. This unique case is thought to have been exacerbated by alcohol consumed by the victim at the same time.

Status of the Population

This shellfish is locally common, especially on offshore reefs, but in no case is it numerous. Heaviest take of rock scallops occurs at spots frequented by sport diving vessels. Larger adults are becoming rare in these locations and individuals as small as two inches are being taken in large numbers. The present bag limit is 10, but rock scallops may benefit from some size, bag, and seasonal limitation.

Management Considerations

See the Management Considerations Appendix A for further information.

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Commercial Landings - Nearshore Invertebrates

Year	Black Abalone Pounds	Green Abalone Pounds	Pink Abalone Pounds	Red Abalone Pounds	White Abalone Pounds	Unidentified Abalone Pounds	All Abalone[1] Pounds	Purple Sea Urchin Pounds	Red Sea Urchin Pounds
1916	- - - -	- - - -	- - - -	- - - -	- - - -	762,001	762,001	- - - -	- - - -
1917	- - - -	- - - -	- - - -	- - - -	- - - -	637,780	637,780	- - - -	- - - -
1918	- - - -	- - - -	- - - -	- - - -	- - - -	602,919	602,919	- - - -	- - - -
1919	- - - -	- - - -	- - - -	- - - -	- - - -	759,203	759,203	- - - -	- - - -
1920	- - - -	- - - -	- - - -	- - - -	- - - -	806,716	806,716	- - - -	- - - -
1921	- - - -	- - - -	- - - -	- - - -	- - - -	1,481,170	1,481,170	- - - -	- - - -
1922	- - - -	- - - -	- - - -	- - - -	- - - -	1,523,394	1,523,394	- - - -	- - - -
1923	- - - -	- - - -	- - - -	- - - -	- - - -	1,555,134	1,555,134	- - - -	- - - -
1924	- - - -	- - - -	- - - -	- - - -	- - - -	2,241,812	2,241,812	- - - -	- - - -
1925	- - - -	- - - -	- - - -	- - - -	- - - -	2,352,861	2,352,861	- - - -	- - - -
1926	- - - -	- - - -	- - - -	- - - -	- - - -	2,060,770	2,060,770	- - - -	- - - -
1927	- - - -	- - - -	- - - -	- - - -	- - - -	2,816,530	2,816,530	- - - -	- - - -
1928	- - - -	- - - -	- - - -	- - - -	- - - -	2,066,243	2,066,243	- - - -	- - - -
1929	- - - -	- - - -	- - - -	- - - -	- - - -	3,438,858	3,438,858	- - - -	- - - -
1930	- - - -	- - - -	- - - -	- - - -	- - - -	3,176,513	3,176,513	- - - -	- - - -
1931	- - - -	- - - -	- - - -	- - - -	- - - -	3,262,166	3,262,166	- - - -	- - - -
1932	- - - -	- - - -	- - - -	- - - -	- - - -	2,817,345	2,817,345	- - - -	- - - -
1933	- - - -	- - - -	- - - -	- - - -	- - - -	2,756,188	2,756,188	- - - -	- - - -
1934	- - - -	- - - -	- - - -	- - - -	- - - -	3,223,492	3,223,492	- - - -	- - - -
1935	- - - -	- - - -	- - - -	- - - -	- - - -	3,870,921	3,870,921	- - - -	- - - -
1936	- - - -	- - - -	- - - -	- - - -	- - - -	3,302,195	3,302,195	- - - -	- - - -
1937	- - - -	- - - -	- - - -	- - - -	- - - -	2,863,175	2,863,175	- - - -	- - - -
1938	- - - -	- - - -	- - - -	- - - -	- - - -	2,121,468	2,121,468	- - - -	- - - -
1939	- - - -	- - - -	- - - -	- - - -	- - - -	1,804,440	1,804,440	- - - -	- - - -
1940	- - - -	- - - -	- - - -	- - - -	- - - -	1,724,084	1,724,084	- - - -	- - - -
1941	- - - -	- - - -	- - - -	- - - -	- - - -	1,002,330	1,002,330	- - - -	- - - -
1942	- - - -	- - - -	- - - -	- - - -	- - - -	164,462	164,462	- - - -	- - - -
1943	- - - -	- - - -	- - - -	- - - -	- - - -	680,274	680,274	- - - -	- - - -
1944	- - - -	- - - -	- - - -	- - - -	- - - -	1,630,402	1,630,402	- - - -	- - - -
1945	- - - -	- - - -	- - - -	- - - -	- - - -	2,429,312	2,429,312	- - - -	- - - -
1946	- - - -	- - - -	- - - -	- - - -	- - - -	2,095,762	2,095,762	- - - -	- - - -
1947	- - - -	- - - -	- - - -	- - - -	- - - -	2,669,285	2,669,285	- - - -	- - - -
1948	- - - -	- - - -	- - - -	- - - -	- - - -	3,195,852	3,195,852	- - - -	- - - -
1949	- - - -	- - - -	- - - -	- - - -	- - - -	3,599,998	3,599,998	- - - -	- - - -
1950	- - - -	9,958	2,019,710	1,431,071	- - - -	- - - -	3,460,739	- - - -	- - - -
1951	- - - -	8,367	2,719,381	1,352,317	- - - -	- - - -	4,080,065	- - - -	- - - -
1952	- - - -	4,186	3,587,636	1,182,022	- - - -	- - - -	4,773,844	- - - -	- - - -
1953	- - - -	5,852	3,439,657	1,412,948	- - - -	- - - -	4,858,457	- - - -	- - - -
1954	- - - -	1,223	2,703,219	1,394,595	- - - -	108	4,099,145	- - - -	- - - -
1955	- - - -	1,225	2,189,039	1,996,511	- - - -	- - - -	4,186,775	- - - -	- - - -
1956	660	14,002	1,845,006	2,428,393	- - - -	- - - -	4,288,061	- - - -	- - - -
1957	1,950	47,880	2,804,111	2,566,813	- - - -	- - - -	5,420,754	- - - -	- - - -
1958	- - - -	905	2,545,709	1,677,404	- - - -	- - - -	4,224,018	- - - -	- - - -
1959	- - - -	560	2,375,531	2,180,658	5,075	- - - -	4,561,824	- - - -	- - - -
1960	- - - -	455	1,572,096	2,693,857	- - - -	- - - -	4,266,408	- - - -	- - - -
1961	- - - -	526	1,678,275	2,873,628	1,337	- - - -	4,553,766	- - - -	- - - -
1962	- - - -	3,710	1,717,271	2,462,200	- - - -	- - - -	4,183,181	- - - -	- - - -
1963	- - - -	33,319	1,502,639	2,807,920	- - - -	- - - -	4,343,878	- - - -	- - - -
1964	- - - -	97,273	1,612,376	2,369,564	- - - -	- - - -	4,079,213	- - - -	- - - -
1965	- - - -	12,129	2,071,242	2,490,875	438	- - - -	4,574,684	- - - -	- - - -
1966	- - - -	145,420	2,162,941	2,656,408	- - - -	- - - -	4,964,769	- - - -	- - - -
1967	200	106,545	1,619,746	2,697,610	4,100	- - - -	4,428,201	- - - -	- - - -
1968	700	427,135	2,270,108	1,776,054	845	- - - -	4,474,842	- - - -	- - - -
1969	4,991	157,263	1,900,206	1,564,205	28,009	- - - -	3,654,698	- - - -	- - - -
1970	15,327	270,200	1,408,921	1,194,788	11,212	- - - -	2,900,448	- - - -	- - - -
1971	46,650	1,089,706	347,983	1,193,948	36,741	- - - -	2,715,189	- - - -	200
1972	1,014,892	424,808	403,709	1,104,462	143,819	- - - -	3,093,558	- - - -	76,457
1973	1,912,519	156,804	371,352	663,919	83,112	- - - -	3,192,730	- - - -	3,594,695
1974	1,145,396	121,563	455,324	751,060	113,765	- - - -	2,594,993	- - - -	7,101,815
1975	684,793	170,927	458,235	742,769	71,821	- - - -	2,135,839	- - - -	7,567,154
1976	356,951	120,489	431,143	739,621	81,907	- - - -	1,733,147	- - - -	11,106,426
1977	463,301	97,457	318,494	537,450	17,603	- - - -	1,435,172	- - - -	16,536,295
1978	420,045	92,987	287,052	488,800	3,633	- - - -	1,293,058	- - - -	14,427,547
1979	331,489	61,166	156,491	439,476	502	- - - -	989,389	- - - -	20,558,950

Commercial Landings - Nearshore Invertebrates, cont'd

Year	Black Abalone Pounds	Green Abalone Pounds	Pink Abalone Pounds	Red Abalone Pounds	White Abalone Pounds	Unidentified Abalone Pounds	All Abalone[1] Pounds	Purple Sea Urchin Pounds	Red Sea Urchin Pounds
1980	518,619	63,234	139,267	516,304	1,071	- - - -	1,238,566	- - - -	22,167,108
1981	521,007	64,003	94,257	429,922	162	112	1,109,494	- - - -	26,433,986
1982	633,400	88,696	86,282	430,902	907	256	1,240,455	- - - -	19,441,151
1983	484,366	56,910	67,239	230,973	482	55	840,074	- - - -	17,756,472
1984	436,620	31,945	57,495	300,173	498	1,156	827,966	2,575	14,978,869
1985	359,898	24,152	68,914	368,689	1,655	1,015	824,329	2,260	19,998,191
1986	273,927	25,943	51,872	267,709	1,228	6,048	626,787	1,430	34,134,025
1987	311,666	28,985	31,631	396,705	2	1,550	770,546	- - - -	46,061,653
1988	203,443	23,521	19,025	324,461	2	75	570,526	- - - -	51,987,994
1989	228,955	20,150	22,554	475,264	22	775	747,719	1,500	51,188,502
1990	94,193	27,333	23,268	378,915	17	217	523,942	89,633	45,269,659
1991	27,220	8,162	12,883	330,975	3	2,812	382,057	388,000	41,938,120
1992	37,714	10,304	18,229	448,841	- - - -	- - - -	515,088	316,134	32,366,557
1993	2,031	10,858	19,933	428,591	- - - -	- - - -	461,414	165,032	26,852,646
1994	- - - -	992	15,575	285,990	47	15	302,664	137,613	23,770,707
1995	- - - -	1,073	16,398	245,524	37	- - - -	263,079	79,802	22,260,967
1996	- - - -	56	4	233,816	- - - -	138	234,020	55,701	20,066,110
1997	- - - -	- - - -	- - - -	124,808	- - - -	- - - -	124,808	122,004	18,020,774
1998	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	14,068	10,554,835
1999	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	29,797	14,173,288

- - - - Landings data not available.

1 Prior to 1949 commercial abalone landings consisted primarily of red abalone. Since identification of species landed was not required prior to 1950, the data presented here indicates that the species was unidentified. The Commercial abalone fishery was closed after 1997.

2 Sheep Crab landings data recorded by DFG as Spider Crab

3 Prior to 1996 there was no specific species code for wavy turban snail landings on the DFG Commercial Landing Receipts. Therefore, wavy turban snail data for 1992-1996 was derived from commercial landing receipts that were recorded under the miscellaneous sea snail and commercial diving gear codes.

Data was compiled from DFG Catch Bulletins and DFG Commercial Landing Receipt data.

Commercial Landings - Nearshore Invertebrates, cont'd

Year	Sea Cucumber Pounds	Dungeness Crab Pounds	Rock Crab Pounds	Sand Crab Pounds	Spider Crab [2] Pounds	Spiny Lobster Pounds	Coonstripe Shrimp Pounds	Ocean Shrimp Pounds	Red Rock Shrimp Pounds
1916	- - - -	1,296,912	- - - -	- - - -	- - - -	250,632	- - - -	- - - -	- - - -
1917	- - - -	2,580,840	- - - -	- - - -	- - - -	355,259	- - - -	- - - -	- - - -
1918	- - - -	1,619,280	- - - -	- - - -	- - - -	195,750	- - - -	- - - -	- - - -
1919	- - - -	1,304,904	- - - -	- - - -	- - - -	256,894	- - - -	- - - -	- - - -
1920	- - - -	1,220,568	- - - -	- - - -	- - - -	247,156	- - - -	- - - -	- - - -
1921	- - - -	800,952	- - - -	- - - -	- - - -	334,271	- - - -	- - - -	- - - -
1922	- - - -	860,328	- - - -	- - - -	- - - -	376,310	- - - -	- - - -	- - - -
1923	- - - -	1,075,800	- - - -	- - - -	- - - -	384,381	- - - -	- - - -	- - - -
1924	- - - -	1,506,816	- - - -	- - - -	- - - -	294,356	- - - -	- - - -	- - - -
1925	- - - -	3,234,312	- - - -	- - - -	- - - -	432,059	- - - -	- - - -	- - - -
1926	- - - -	3,296,280	- - - -	- - - -	- - - -	442,198	- - - -	- - - -	- - - -
1927	- - - -	2,960,712	- - - -	- - - -	- - - -	508,123	- - - -	- - - -	- - - -
1928	- - - -	3,574,464	270	- - - -	- - - -	355,800	- - - -	- - - -	- - - -
1929	- - - -	1,792,776		- - - -	- - - -	396,764	- - - -	- - - -	- - - -
1930	- - - -	1,992,384	12	- - - -	- - - -	374,450	- - - -	- - - -	- - - -
1931	- - - -	2,231,384	56	- - - -	- - - -	383,697	- - - -	- - - -	- - - -
1932	- - - -	2,433,987	145	- - - -	- - - -	319,307	- - - -	- - - -	- - - -
1933	- - - -	3,208,494	14,818	- - - -	- - - -	380,014	- - - -	- - - -	- - - -
1934	- - - -	3,768,081	24,570	- - - -	- - - -	366,651	- - - -	- - - -	- - - -
1935	- - - -	3,680,188	12,817	- - - -	- - - -	371,661	- - - -	- - - -	- - - -
1936	- - - -	2,311,802	16,202	- - - -	- - - -	414,183	- - - -	- - - -	- - - -
1937	- - - -	1,627,753	1,710	- - - -	- - - -	393,242	- - - -	- - - -	- - - -
1938	- - - -	3,873,600	3,847	- - - -	- - - -	308,378	- - - -	- - - -	- - - -
1939	- - - -	5,953,361	3,984	- - - -	- - - -	376,928	- - - -	- - - -	- - - -
1940	- - - -	5,151,014	3,460	- - - -	- - - -	281,102	- - - -	- - - -	- - - -
1941	- - - -	4,260,340	2,645	- - - -	- - - -	357,334	- - - -	- - - -	- - - -
1942	- - - -	2,414,110	80	- - - -	- - - -	168,641	- - - -	- - - -	- - - -
1943	- - - -	2,315,338	- - - -	- - - -	- - - -	298,377	- - - -	- - - -	- - - -
1944	- - - -	2,934,776	540	- - - -	- - - -	512,490	- - - -	- - - -	- - - -
1945	- - - -	4,334,383	12,188	- - - -	- - - -	478,619	- - - -	- - - -	- - - -
1946	- - - -	9,624,368	11,600	- - - -	- - - -	690,272	- - - -	- - - -	- - - -
1947	- - - -	10,733,398	15,244	- - - -	- - - -	593,401	- - - -	- - - -	- - - -
1948	- - - -	11,892,891	20,938	- - - -	- - - -	563,520	- - - -	- - - -	- - - -
1949	- - - -	11,115,476	18,636	- - - -	- - - -	834,658	- - - -	- - - -	- - - -
1950	- - - -	11,704,648	20,007	- - - -	- - - -	933,449	- - - -	- - - -	- - - -
1951	- - - -	11,568,353	22,592	- - - -	- - - -	824,611	- - - -	- - - -	- - - -
1952	- - - -	12,997,451	16,977	- - - -	- - - -	807,070	- - - -	205,485	- - - -
1953	- - - -	8,278,519	49,300	- - - -	- - - -	749,245	- - - -	287,410	- - - -
1954	- - - -	7,829,651	39,058	- - - -	- - - -	901,293	- - - -	296,797	- - - -
1955	- - - -	6,119,320	54,051	- - - -	- - - -	855,416	- - - -	838,656	- - - -
1956	- - - -	14,320,549	59,171	- - - -	- - - -	735,869	- - - -	1,168,519	- - - -
1957	- - - -	19,118,484	151,131	- - - -	- - - -	647,281	- - - -	1,376,641	- - - -
1958	- - - -	17,282,766	166,962	- - - -	- - - -	632,618	- - - -	1,728,680	- - - -
1959	- - - -	17,262,261	129,534	- - - -	- - - -	505,947	- - - -	1,785,228	- - - -
1960	- - - -	14,876,148	120,903	- - - -	- - - -	351,032	- - - -	2,026,787	- - - -
1961	- - - -	11,711,327	151,782	- - - -	- - - -	412,453	- - - -	2,002,709	- - - -
1962	- - - -	3,222,580	200,304	- - - -	- - - -	515,816	- - - -	1,782,955	- - - -
1963	- - - -	1,951,461	240,611	- - - -	- - - -	584,192	- - - -	2,093,063	- - - -
1964	- - - -	1,815,363	263,885	- - - -	- - - -	446,655	- - - -	1,100,147	- - - -
1965	- - - -	4,803,906	328,686	- - - -	- - - -	480,325	- - - -	1,422,364	- - - -
1966	- - - -	12,376,390	330,843	- - - -	- - - -	489,088	- - - -	1,190,197	- - - -
1967	- - - -	11,716,488	324,386	- - - -	- - - -	449,874	- - - -	1,412,513	- - - -
1968	- - - -	16,015,581	351,657	- - - -	- - - -	312,483	- - - -	2,274,770	- - - -
1969	- - - -	7,938,996	504,076	- - - -	- - - -	309,472	- - - -	2,947,563	- - - -
1970	- - - -	15,413,589	539,579	- - - -	1,032	225,399	- - - -	4,047,589	- - - -
1971	- - - -	9,662,265	542,732	- - - -	- - - -	224,486	- - - -	3,080,583	- - - -
1972	- - - -	1,563,006	843,530	- - - -	- - - -	398,217	- - - -	2,489,970	- - - -
1973	- - - -	1,022,873	955,788	- - - -	- - - -	233,179	- - - -	1,239,976	- - - -
1974	- - - -	685,000	864,033	- - - -	52	190,950	- - - -	2,387,366	- - - -
1975	- - - -	3,934,663	1,201,867	- - - -	- - - -	201,412	- - - -	4,998,369	- - - -
1976	- - - -	15,726,774	1,227,766	- - - -	- - - -	292,534	- - - -	3,500,788	- - - -
1977	- - - -	33,647,863	1,083,015	- - - -	- - - -	251,568	- - - -	15,871,332	- - - -

Commercial Landings - Nearshore Invertebrates, cont'd

Year	Sea Cucumber Pounds	Dungeness Crab Pounds	Rock Crab Pounds	Sand Crab Pounds	Spider Crab [2] Pounds	Spiny Lobster Pounds	Coonstripe Shrimp Pounds	Ocean Shrimp Pounds	Red Rock Shrimp Pounds
1978	8,780	9,362,197	956,874	- - - -	1,919	560,986	- - - -	13,887,379	- - - -
1979	69,438	12,978,505	953,590	- - - -	14,402	419,529	- - - -	5,182,703	- - - -
1980	23,060	15,934,778	1,083,957	- - - -	9,869	416,249	- - - -	3,868,214	- - - -
1981	- - - -	10,435,441	1,375,227	- - - -	10,914	478,863	- - - -	4,164,495	- - - -
1982	139,487	6,973,679	1,277,872	- - - -	16,495	524,710	- - - -	4,543,806	- - - -
1983	163,495	5,301,828	1,397,109	- - - -	47,108	525,087	- - - -	1,132,742	- - - -
1984	52,354	5,340,088	1,676,298	- - - -	56,338	444,998	- - - -	1,628,992	- - - -
1985	- - - -	6,210,272	1,739,835	- - - -	41,777	447,848	- - - -	3,381,117	- - - -
1986	77,967	7,758,277	2,097,408	- - - -	34,678	488,804	- - - -	6,757,818	- - - -
1987	107,678	6,857,118	1,567,138	- - - -	99,556	449,778	- - - -	8,023,390	- - - -
1988	159,106	11,297,300	1,237,934	- - - -	107,609	610,859	- - - -	11,236,298	- - - -
1989	160,011	5,717,145	1,302,687	- - - -	70,066	742,571	- - - -	13,351,218	- - - -
1990	147,284	10,367,719	1,784,135	- - - -	93,451	705,341	- - - -	8,700,916	- - - -
1991	581,974	4,246,029	1,594,010	- - - -	99,269	589,240	- - - -	10,364,782	- - - -
1992	549,191	8,327,150	1,468,309	57	89,871	585,556	- - - -	18,682,775	- - - -
1993	646,210	11,958,039	1,287,378	1,072	71,173	554,438	- - - -	7,126,933	2,564
1994	646,926	13,491,363	1,002,397	127	67,290	470,144	- - - -	11,225,390	27
1995	589,888	9,236,191	935,535	51	59,427	616,382	- - - -	5,784,944	186
1996	839,382	12,331,365	1,040,812	4	58,852	668,453	10,142	9,351,086	94
1997	452,640	9,908,520	1,181,159	216	95,801	915,272	79,173	13,983,357	12
1998	770,679	10,692,760	1,234,160	3	99,797	735,703	64,718	1,843,246	63
1999	600,875	8,713,702	790,437	65	68,621	493,201	75,540	4,241,744	308

- - - - Landings data not available.

[1] Prior to 1949 commercial abalone landings consisted primarily of red abalone. Since identification of species landed was not required prior to 1950, the data presented here indicates that the species was unidentified. The Commercial abalone fishery was closed after 1997.

[2] Sheep Crab landings data recorded by DFG as Spider Crab

[3] Prior to 1996 there was no specific species code for wavy turban snail landings on the DFG Commercial Landing Receipts. Therefore, wavy turban snail data for 1992-1996 was derived from commercial landing receipts that were recorded under the miscellaneous sea snail and commercial diving gear codes.

Data was compiled from DFG Catch Bulletins and DFG Commercial Landing Receipt data.

Commercial Landings - Nearshore Invertebrates, cont'd

Year	Ridgeback Prawn Pounds	Spot Prawn Pounds	Wavy Turban Snail[3] Pounds
1916	- - - -	- - - -	- - - -
1917	- - - -	- - - -	- - - -
1918	- - - -	- - - -	- - - -
1919	- - - -	- - - -	- - - -
1920	- - - -	- - - -	- - - -
1921	- - - -	1,006	- - - -
1922	- - - -	- - - -	- - - -
1923	- - - -	- - - -	- - - -
1924	- - - -	- - - -	- - - -
1925	- - - -	- - - -	- - - -
1926	- - - -	- - - -	- - - -
1927	- - - -	- - - -	- - - -
1928	- - - -	- - - -	- - - -
1929	- - - -	- - - -	- - - -
1930	- - - -	8,736	- - - -
1931	- - - -	4,114	- - - -
1932	- - - -	982	- - - -
1933	- - - -	798	- - - -
1934	- - - -	910	- - - -
1935	- - - -	2,351	- - - -
1936	- - - -	1,861	- - - -
1937	- - - -	3041	- - - -
1938	- - - -	3,285	- - - -
1939	- - - -	4,271	- - - -
1940	- - - -	2,361	- - - -
1941	- - - -	5,357	- - - -
1942	- - - -	- - - -	- - - -
1943	- - - -	43	- - - -
1944	- - - -	- - - -	- - - -
1945	- - - -	1,452	- - - -
1946	- - - -	5,175	- - - -
1947	- - - -	1,687	- - - -
1948	- - - -	2,771	- - - -
1949	- - - -	3,952	- - - -
1950	- - - -	5,790	- - - -
1951	- - - -	2,694	- - - -
1952	- - - -	3,016	- - - -
1953	- - - -	2,723	- - - -
1954	- - - -	2,695	- - - -
1955	- - - -	1,182	- - - -
1956	- - - -	1,233	- - - -
1957	- - - -	767	- - - -
1958	- - - -	911	- - - -
1959	- - - -	- - - -	- - - -
1960	- - - -	147	- - - -
1961	- - - -	- - - -	- - - -
1962	- - - -	694	- - - -
1963	- - - -	8,445	- - - -
1964	- - - -	5,775	- - - -
1965	- - - -	697	- - - -
1966	- - - -	3,575	- - - -
1967	- - - -	2,590	- - - -
1968	- - - -	7,239	- - - -
1969	- - - -	5,073	- - - -
1970	- - - -	22,259	- - - -
1971	- - - -	11,773	- - - -
1972	- - - -	20,970	
1973	- - - -	24,384	- - - -
1974	4,015	218,167	- - - -
1975	28,522	173,498	- - - -
1976	3,130	112,069	- - - -
1977	2,972	53,838	- - - -
1978	45,716	67,547	- - - -
1979	356,715	83,778	- - - -
1980	281,661	213,826	- - - -
1981	192,637	370,536	- - - -
1982	129,402	302,268	- - - -
1983	153,779	109,096	- - - -
1984	589,998	50,464	- - - -
1985	896,816	63,941	- - - -
1986	670,573	102,486	- - - -
1987	241,872	88,535	- - - -
1988	142,694	166,670	- - - -
1989	165,527	189,878	- - - -
1990	90,842	317,655	- - - -
1991	128,732	311,431	- - - -
1992	75,757	225,441	324
1993	80,532	347,792	17,777
1994	162,761	444,354	1
1995	414,660	394,986	4,640
1996	574,724	527,581	1,571
1997	387,549	761,605	2,414
1998	435,837	787,857	65,605
1999	1,392,370	613,129	24,276

- - - - Landings data not available.

1 Prior to 1949 commercial abalone landings consisted primarily of red abalone. Since identification of species landed was not required prior to 1950, the data presented here indicates that the species was unidentified. The Commercial abalone fishery was closed after 1997.

2 Sheep Crab landings data recorded by DFG as Spider Crab

3 Prior to 1996 there was no specific species code for wavy turban snail landings on the DFG Commercial Landing Receipts. Therefore, wavy turban snail data for 1992-1996 was derived from commercial landing receipts that were recorded under the miscellaneous sea snail and commercial diving gear codes.

Data was compiled from DFG Catch Bulletins and DFG Commercial Landing Receipt data.

Nearshore Ecosystem Fish Resources: Overview

About 450 species of finfish occupy California's nearshore ecosystem within the limits of the continental shelf. The 60 plus species addressed in this chapter exhibit a wide range of distribution, habitat preferences, movement patterns, reproductive characteristics, age, and growth. Their contributions to the fisheries of California are varied as well. As a group these fish inhabit all available nearshore habitats (*e.g.,* kelp forests, rocky intertidal, sandy bottom, open water) in the nearshore ecosystem at some stage in their life-cycle.

The kinds and distributions of fish occupying the nearshore ecosystem off California are influenced by several environmental factors, water temperature being perhaps the most important. California's lengthy coastline spans nearly 10 degrees of latitude resulting in waters varying from cool-temperate in the north to warm-temperate in the south. Warmer waters off southern California and Baja California, Mexico, support several game fish and other locally important fish that are found infrequently if at all, north of Point Arguello, the northern reach of the Southern California Bight. By contrast, species common north of Point Arguello may find preferred water temperatures to the south by moving deeper in the water column. In addition, seasonal, annual, and decadal changes in water temperature (*e.g.,* El Niño) result in northerly movements of fish that might otherwise be found mostly off Baja California, or southern California. Besides water temperature, habitat preferences and general ecological requirements control distributions.

Nineteen species, mostly rockfish, have been included in the Nearshore Fisheries Management Plan required by the Marine Life Management Act of 1998. These species occur coast-wide, but some are rarely seen in southern California (*e.g.,* quillback, China and black rockfishes, kelp greenling and monkeyface prickleback), while others are rare north of Point Conception (*e.g.,* California sheephead, California scorpionfish, calico rockfish and treefish). Collectively, these species are relatively long-lived, slow-growing fish that take several years to reach maturity and spawn. Most of the species were seldom harvested commercially until the development of the live-fish fishery during the early 1990s. No estimates of abundance exist on a coast-wide basis for any of the species. Managers, fishermen, and scientists are all concerned about the sustainability of the fishery. These concerns have resulted in the imposition of several recent management measures to balance harvests with available resources, reduce sport-commercial conflicts, and stabilize the nearshore fishery pending completion of a more comprehensive Nearshore Fishery Management Plan. The status of most nearshore fishes is still uncertain, and it is expected to take time to determine the effects of current management of individual stocks.

Non-rockfish species have differing affinities (generally defined by their adult behavior) to the nearshore ecosystem habitats. They include the open-water, coastal-migratory species (*e.g.,* yellowtail, California barracuda, white seabass, and Pacific bonito); the nearshore sandy-bottom dwellers (*e.g.*, California halibut, sanddabs, starry flounder, Pacific angel shark, skates and rays); kelp and/or rocky reef inhabitants (*e.g.*, kelp bass, giant sea bass, lingcod, opaleye and halfmoon); and those that spend most of their lives in or near the surf-zone (*e.g.*, California corbina, surfperches, grunion, and the croakers). Most of these species are commercially harvested, but a few have been designated for sport fish use only (*e.g.*, kelp bass, barred sand bass, spotted sand bass, California corbina, and spot and yellowfin croakers). Giant sea bass has been managed under a moratorium on both commercial and recreation take since 1982. While very little has been done to assess the population size of most of these species, catch and landing trends can often be used to gauge the health of the resource. For example, California halibut catches have been remarkably stable over the last two decades, and, while both lingcod and Pacific bonito catches show precipitous declines in landings, California barracuda sport fish catches have increased to the levels of the 1950s. However, the status of most is uncertain. This uncertainty stems from a lack of historic and current fisheries data useful in stock assessments, absence of life history and recruitment data, as well as insufficient understanding of habitat relationships and requirements, and the probable effects of habitat alterations (including pollution) on stocks.

Commercial fisheries for these species utilize a variety of gear, which has been made more efficient over the past century through the introduction of modern net, line, and

Surf
Credit: Darrel Deuel

trap materials, modified fishing techniques and strategies, improved deck machinery and hydraulics, and advances in fish finding electronics. Some gear determined to be too effective or not sufficiently selective has been prohibited. Historically and currently used commercial gear includes five general types as follows: 1) traps; 2) hook-and-line; 3) gill and trammel nets; 4) trawl nets; and 5) round haul nets.

Traps: The finfish trap is a relative newcomer to nearshore commercial fisheries. During the late 1980s, finfish traps were introduced into nearshore waters off southern California for taking several shallow-water species (including California sheephead, cabezon, kelp and rock greenling, California scorpionfish, several species of rockfish, and moray eel). The finfish trap fishery has since expanded in number of participants and number of species harvested, and has progressed northward to nearshore waters off central and northern California. Traps accounted for about seven percent of the statewide live/premium fish landings during 1999. The finfish trap fishery off southern California has operated under a finfish trap permit as a limited entry fishery since 1996. North of Point Arguello a finfish trap permit is not required, but a recent moratorium on issuing general trap permits restricts entry pending evaluation of comprehensive limited access measures.

Hook-and-Line: A variety of commercial hook-and-line gear (vertical and horizontal setlines, troll lines, rod and reel, and "stick gear") is employed to take a variety of finfish in the nearshore ecosystem. Of most immediate interest (and concern) is the live fish hook-and-line fishery that employs primarily rod-and-reel and "stick" or "pipe" gear. In general, this gear is used to harvest the same species of live/premium fish as finfish traps and is conducted under the same nearshore fishery permit. Seventy percent of the statewide live/premium fish landings were caught on hook-and-line gear. The number of nearshore hook-and-line fishery participants increased during the past decade, with about 1,130 permits issued during 1999. This number is expected to remain stable with recent adoption of the moratorium on new permits. Commercial vessels using fishing lines within one mile of the mainland shore are limited to a maximum of 150 hooks per vessel and 15 hooks per line. These restrictions were enacted in 1995 to address initial concerns for the rapidly expanding commercial hook-and-line fishery that included some vessels employing thousands of hooks. Other hook-and-line gear include troll lines used to harvest California halibut in the San Francisco Bay area and rod-and-reel used to take redtail surfperch in northern California.

Gill and Trammel Nets: The use of gill and trammel nets to harvest rockfish, California halibut, white seabass, California barracuda, soupfin shark, angel shark, white croaker, and other nearshore species, increased during the 1960s and peaked during the 1980s (1,122 General Gill and Trammel Net Permits issued during 1985). However, these nets have since been largely restricted to deeper waters from one to ten miles offshore, and prohibited in the inshore rockfish fishery. They are also prohibited north of Point Reyes, Marin County. Restrictions on the use of this gear were enacted to address problems with accidental entanglement and drowning of seabirds and marine mammals and to address sport-commercial fishery allocation conflicts. Gill and trammel net use in the nearshore ecosystem has declined since the mid-1980s (presently about 220 permits issued annually), but the gear is still used to varying degrees to take lingcod, white seabass, California barracuda, California halibut, and rockfish in waters seaward of areas closed to its use. California halibut and rockfish taken in gill and trammel nets have increasingly appeared in the live/premium fish fishery, while nets (trawl and gill and trammel nets) accounted for about 23 percent of 1999 landings of live/premium fish. Restrictions on the use of gill and trammel nets include minimum mesh sizes for several species, limits on the length of net that may be fished for various species, and several depth closures.

Trawl nets: Early commercial trawls such as paranzella and beam trawls have been largely replaced by otter trawls used to take bottom and midwater fishes including rockfish, lingcod, California halibut, and other flatfishes. Trawl nets are presently authorized for use to take finfish three or more nautical miles offshore, and to take California halibut in the halibut trawl grounds off southern California. Restrictions on trawl nets include minimum cod-end mesh sizes to enable the release of sub-adult fishes.

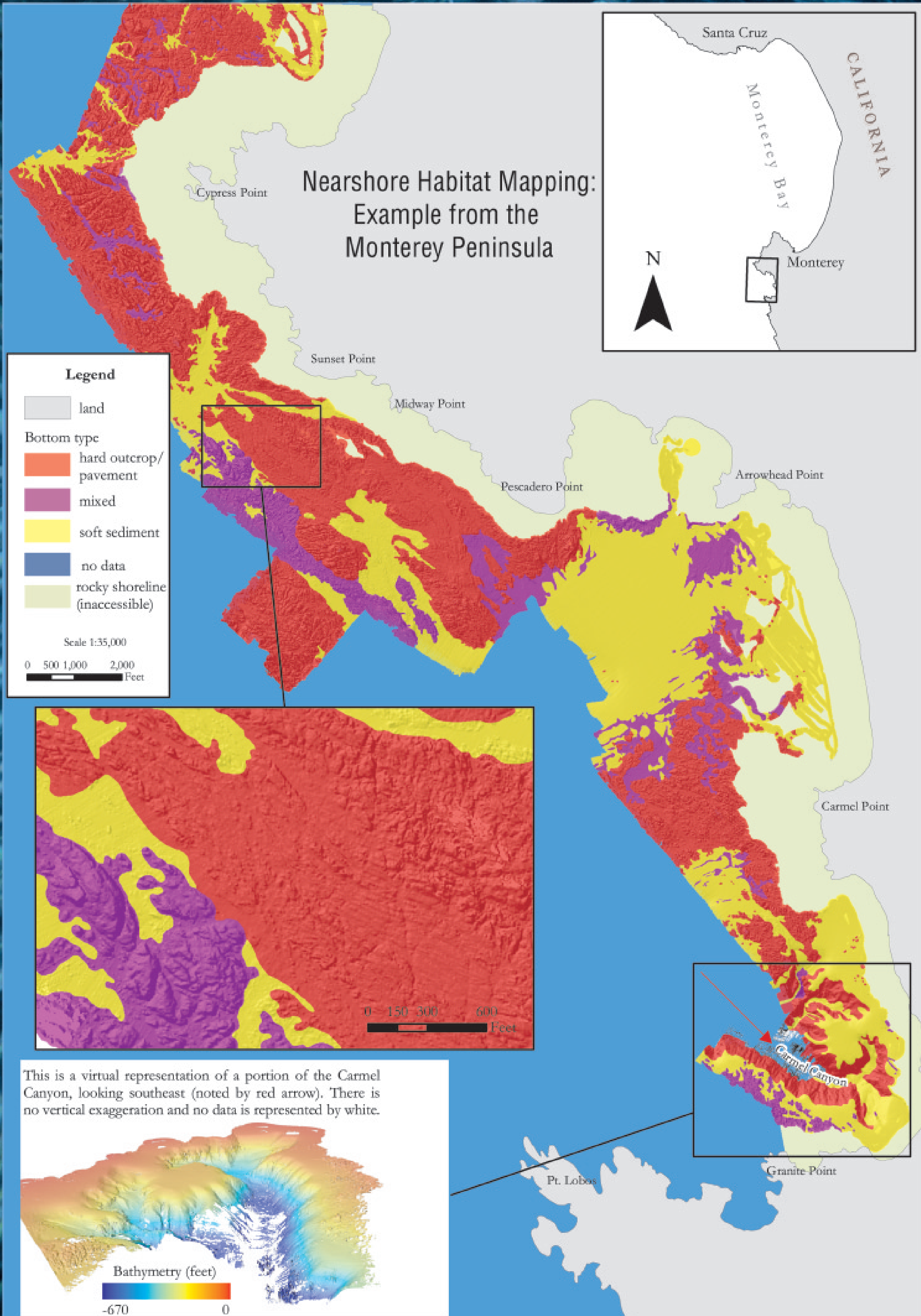
Round Haul Nets: Round haul gear (purse seine and lampara) used during the 1920s to harvest millions of pounds of white seabass, barracuda, and yellowtail is now prohibited for these species. Presently, smaller scale round haul gear in the form of lampara and drum seines (bait nets) is used to take white croaker, perch, and bait species that include smelt, white croaker, and queenfish, but this take is relatively small.

Early recreational fishing during the late–1800s off California targeted giant sea bass, tuna, white seabass, and yellowtail using handlines and early rod-and-reel fishing gear from private or chartered craft. During the 1920s and 1930s, early commercial passenger fishing vessels (CPFV) began to carry anglers to nearby popular fishing grounds, enabling catches of game fishes that were not as readily available to those fishing from fishing barges, piers, jetties, and beaches. Following World War II, the number of CPFV increased dramatically to serve a public eager to go fishing. In southern California, the CPFV fishery expanded during the 1960s into winter fishing for rockfish and lingcod to make year-round what had been a spring-through-fall fishery. Also, improved rod-and-reel fishing equipment, the introduction of skin and SCUBA diving equipment, and accelerated private boat ownership beginning in the 1950s helped to increase the recreational take of fish during the latter half of the 1900s. By the 1950s, ocean sport fishing was becoming a recognized factor in the potential over-harvest of some species, and regulations affecting the take of popular nearshore fishes were promulgated along with commercial restrictions to maintain stocks of fishes in the nearshore ecosystem.

Other hook-and-line gear types include handlines that still are seen occasionally on piers, and the "poke pole" used in intertidal areas along the north coast to capture cabezon, greenling, and an occasional shallow water rockfish or prickleback. Most commercial forms of nets and traps are prohibited for sport use. However, baited hoop nets are permitted for taking certain species, and beach nets may be used to take surf smelt north of Point Conception. Spears, harpoons, and bow-and-arrow fishing tackle may be used to take all varieties of skates, rays, and sharks (except white shark) and grunion may be taken only by hand. Recreational divers operating from shore or from vessels use spearfishing equipment with or without aid of SCUBA gear. Anglers seeking game fish generally use live bait when available (anchovy, sardine, squid, and small croakers), but are often equally effective with the extensive arsenal of artificial lures available ranging from shrimp flies to one-pound or greater hexagon steel bars tipped with a single or treble hook (often used for lingcod). A variety of sand worms, sand crabs, mussels and squid are favored bait for shore fishing while squid is the standard for most rockfishes.

The outlook for sustaining healthy nearshore fish stocks and fisheries has generally improved in the eyes of managers with enactment of California's recent landmark legislation, the Marine Life Management Act of 1998. Fishery management plans for nearshore fish and white seabass should be close to adoption by the California Fish and Game Commission as this report nears publication date. The draft master plan, which is also a required by MLMA, calls for additional FMPs to be developed for California halibut, skates and rays, surfperches, kelp bass and barred sand bass.

Don Schultze
California Department of Fish and Game



Nearshore Habitat Mapping: Example from the Monterey Peninsula
Santa Cruz
CALIFORNIA
Monterey Bay
Monterey
N
Cypress Point
Sunset Point
Midway Point
Pescadero Point
Arrowhead Point
Carmel Point
Granite Point
Pt. Lobos
Carmel Canyon
Legend
land
Bottom type
hard outcrop/ pavement
mixed
soft sediment
no data
rocky shoreline (inaccessible)
Scale 1:35,000
0 500 1,000 2,000
Feet
0 150 300 600
Feet
This is a virtual representation of a portion of the Carmel Canyon, looking southeast (noted by red arrow). There is no vertical exaggeration and no data is represented by white.
Bathymetry (feet)
-670
0

California Sheephead

History of the Fishery

Although the commercial catch of California sheephead (*Semicossyphus pulcher*) dates back to the late 1800s, a renewed interest in this fishery has developed only recently. Today, it is exploited by sport divers, anglers, and especially by a growing live fish commercial industry.

In the late 1800s, Chinese fishermen took large quantities of sheephead for drying and salting. Since that time, except for brief periods, sheephead was not a targeted species until the 1980s. In the recently developed live fish fishery, the fish are trapped and taken live to supply Asian seafood restaurants. Because small fish, usually females, are easier to keep alive in small aquaria, prereproductive individuals have often been taken. A recent minimal size limit of 12 inches should reduce this possibility.

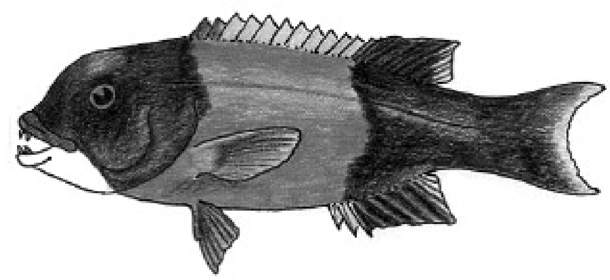
The largest commercial catches of California sheephead were from 1927 to 1931, peaking in 1928 at more than 370,000 pounds. During and shortly after World War II (1943-1947), the sheephead catch increased from 50,000 to 267,00 pounds, probably because of easy availability close to port. Since the 1940s and until the late 1980s, the average annual landing has been about 10,000 pounds and the price of this catch was under $0.10 per pound. During the 1980s, the price and catch increased slightly until the live fish market began in the late 1980s. The price of live fish has reached as high as $9 per pound. Between 1989 and 1990, the catch quadrupled and reached a peak in 1997 of 366,000 pounds and a market value of $840,176. During 1994 to 1999, the live catch varied between 87.8 percent and 73.7 percent of the total sheephead landings. The catch has decreased from 1997 to 1999, but the market value has remained high.

The estimated recreational catch of sheephead between 1983 and 1986 averaged 312,400 pounds with a maximum estimate of 448,800 pounds for 1986. Commercial passenger fishing vessel data from 1947 to 1998 indicate an average take of 28,030 fish per year with a maximum in 1983 of about 69,000 fish. Using an average weight of two pounds per fish (a low estimate) the sport catch, except in the cited maximal periods, often exceeds the commercial catch. During the 1930s, sheephead were considered "junk fish" by most recreational anglers and were not kept because of their soft flesh. However, the large size, fine flavor, and use as a lobster substitute in salads and other recipes has more recently made them a preferred and even targeted species by anglers and divers.

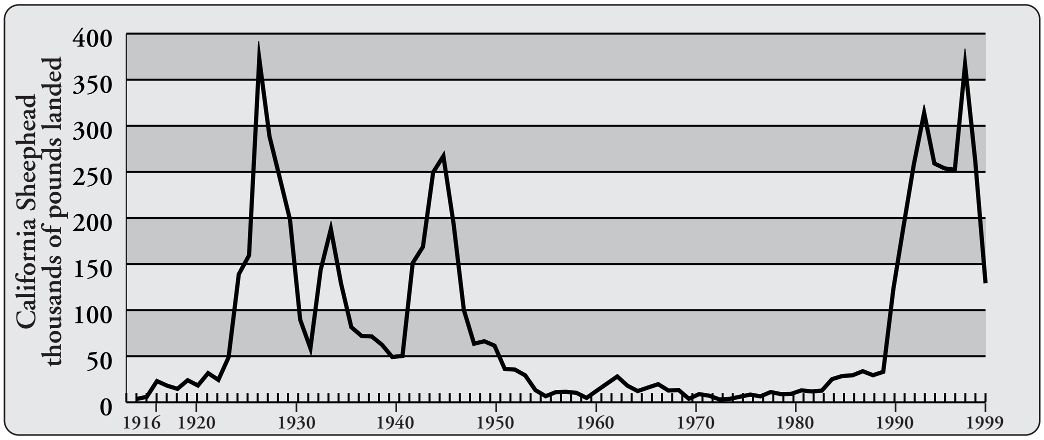
Status of Biological Knowledge

The California sheephead and two other common Southern California species, the rock wrasse and the senorita are members of the mostly tropical, worldwide wrasse family Labridae. All have protruding canine-like jaw teeth and large cycloid scales. The sheephead is easily distinguished from the others by its color pattern, greater body depth, and large size. Males have a black head and tail separated by a reddish middle section. The chin is white in both sexes but females are uniformly pinkish. Young-of-the-year are bright reddish orange with a lateral longitudinal white stripe and large black spots at the rear of the dorsal fin and upper caudal. Although the sheephead ranges from Monterey Bay, California to the Gulf of California, it is not common north of Point Conception. It is a protogynous hermaphrodite, beginning life as a female with older, larger females developing into secondary males. Female sexual maturity may occur in three to six years and fishes may remain female for up to fifteen years. Timing of the transformation to males involves population sex ratio as well as size of available males and sometimes does not occur at all.

Males have been aged at around 50 years, and can achieve a length of three feet and a weight exceeding 36 pounds. As growth rates are higher and mortality lower at the northern end of the range, the sexual transformation occurs later there and the males are larger. Batch spawning occurs between July and September, and estimates of yolky oocytes present in the ovary vary from 36,000 to 296,000 for fish from eight to 15 inches. Larval drift ranges from 34 to 78 days with two settlement patterns. Most larvae settle at about 37 days, but some slow their growth at this time and may continue as pelagic larvae for another month. Settlement size remains between 0.5 and 0.6 inches. The sheephead has a broad diet with crabs, barnacles, mollusks, urchins, polychaetes and even bryozoa occasionally dominant. There appears to be no evidence of its preference for abalone and lobster as cited in earlier literature. Because of its large size of adult males, there are few known predators. The sheephead is a rocky reef, kelp bed species found to depths of 280 feet. Adults are usually solitary, but sometimes are seen in large schools, perhaps associated with spawning aggregations.



California Sheephead (male), *Semicossyphus pulcher*
L.Sinclair
Miller & Lea

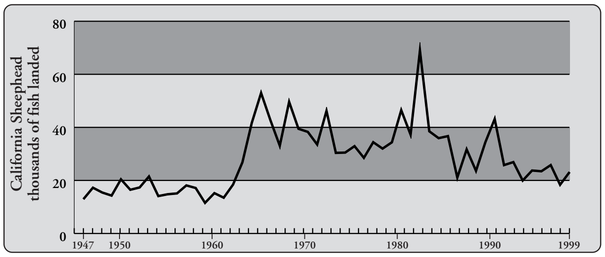


Commercial Landings 1916-1999, California Sheephead
Data Source: DFG Catch Bulletins and commercial landing receipts.

They are considered resident species and no systematic movements have been described.

Status of the Population

There has been no ongoing analysis of the status of the California sheephead. Long-term studies at two localities in southern California, Palos Verdes Point and the King Harbor breakwater, have shown that the species was not abundant in the cool period of the early 1970s. The population increased at both sites with the onset of the little El Niño of 1977-1978. At King Harbor, the population peaked in 1978, decreased through the end of the great El Niño of 1982-1983, and remained low until the early 1990s when it again reached a large size (1994 and 1998). With the exception of 1982-1983 El Niño, the population seems to increase during El Niño conditions and this is reflected in increased recruitment. At Palos Verdes, the population peaked in 1981, then declined until 1983, but has remained relatively stable since. At maximum, the density of sheephead at the Palos Verdes kelp bed was three times that of the King Harbor breakwater. There is no evidence from these very limited data that the population is threatened by existing fishery practices. The projected decrease in landings during 1999 may reflect the imposition of a minimum size limit.



Recreational Catch 1947-1999, California Sheephead
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

Management Considerations

See the Management Considerations Appendix A for further information.

John Stephens
Occidental College-retired

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Cabezon

History of the Fishery

Evidence exists for subsistence use of cabezon (*Scorpaenichthys marmoratus*) by prehistoric native Americans along the central California coast. Cabezon represented five percent of the fish remains taken from exposed rocky coastal archaeological sites.

As game fish, cabezon are prized by sport divers for edibility, size, and ease of capture. The recreational take aboard commercial passenger fishing vessels (CPFVs) does not comprise a large proportion of the catch, but those that are taken are usually of a good size, averaging around 3.5 pounds. In central California, cabezon generally account for less than one percent of observed annual CPFV catches. Recreational landings data are available from 1980 to 1999 for CPFV and private boat anglers as well as shore and pier anglers from the National Marine Fisheries Service Recreational Fisheries Information Network (RecFIN). RecFIN data from 1982 to 1999, for all four modes of recreational fishing showed a 40 percent decline in average annual landings between the 1982 through 1989 and 1993 through 1999 periods, from 122 to 74 tons. Data from RecFIN also suggest that cabezon are more common in catches north of Point Conception and more frequently caught by anglers fishing on private boats and from shore than on CPFVs.

Cabezon were taken incidentally in commercial catches by boats fishing for rockfish using hook-and-line or gillnets until 1992. From 1916 to 1992, commercial landings only exceeded 30,000 pounds in 1951 and again from 1979 to 1982, when reported landings reached 62,614 pounds. Development of the live/premium fishery in the late 1980s resulted in increasing commercial catches of many species occupying the nearshore environment in and around kelp beds. The commercial catch of cabezon started increasing in 1992 with the expansion of marketing live fish to markets and restaurants in California's Asian communities. Most of the initial increase in landings was from the Morro Bay area, but by 1995, landings in most central and northern California ports had increased dramatically. Sampled catches from the Morro Bay area from 1995 to 1998 suggested a large proportion of landings were immature fish.

Commercial landings continued to increase through 1998 with over 373,000 pounds reported, then declined slightly in 1999 but remained over 300,000 pounds. Live fish are taken primarily by trap and hook-and-line gear. About 90 percent of the catch is landed live. Markets demanded top quality live fish, and fishermen received premium prices for their catches evidenced by the increase in average price per pound from $0.85 in 1990 to $3.30 in 1998. The estimated value of reported landings in 1998 was $1,231,700.

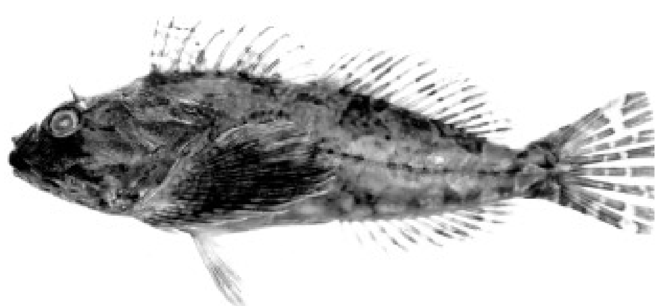
Concerns over the increased harvesting of nearshore species and potential impacts on fished populations led to passage of legislation known as the Marine Life Management Act of 1998 (MLMA) which was enacted in January of 1999. Within the MLMA, minimum commercial size limits were implemented for several nearshore species including a 14-inch size limit for cabezon. Implementation of the size limit may have been responsible for the decline in landings between 1998 and 1999.

Status of Biological Knowledge

The cabezon is the largest member of the cottid family. In Spanish, *cabezon* means bigheaded or stubborn and, proportionally, the massive head is definitely the largest feature of this fish. The specific name *marmoratus* refers to the marbled or mottled appearance of the body, which can be reddish, greenish, or bronze. Generally the belly is a pale turquoise or white, and there are no scales on the body.

Populations range along the eastern Pacific coast from Point Abreojos, Baja California to Sitka, Alaska. They are found on hard bottoms in shallow water from intertidal pools to depths of 250 feet. Fish frequent subtidal habitats in or around rocky reef areas and in kelp beds.

Cabezon may reach an age in excess of 20 years. The largest recorded size is 39 inches in length and over 25 pounds. Limited information available on age at sexual maturity in published literature suggests that in central California males begin to mature in their third year and all are mature by their fourth year. Average size of males in their fourth year is 17 inches. Some females begin to mature in their fourth year between 16 and 20 inches in length, and all females are sexually mature by the sixth year when they are 19 to 23 inches in length. These data collected from 1950-1951 suggest a size of female 50 percent maturity greater than 16 inches. Unpublished DFG data collected in the Morro Bay area from 1996 to 1999 indicates that half of females are mature at 14 inches.



Cabezon, *Scorpaenichthys marmoratus*
Credit: DFG

In California, spawning commences in late October, peaks in January and continues until March, whereas in Washington, the spawning season begins in November and extends to September with a peak in March and April. There is some evidence that females may spawn more than once in a season. Females spawn their eggs on subtidal, algae-free rocky surfaces, which can be horizontal or vertical in orientation. Up to 152,000 eggs can be expected from a large female (30 inches, 23 pounds). Masses of the pale green or reddish eggs are up to 18 inches in diameter and up to two to four inches thick. As the eggs develop they change to an olive green color.

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

Males fertilize the eggs after spawning by the female, and the male guards the nest. Apparently the same nest sites are used from year to year. Fish are very protective of the nests for the two to three weeks it takes the eggs to develop and hatch.

Pelagic juveniles are silvery when small, spending their first three to four months in the open ocean feeding on tiny crustaceans and other zooplankton. At a size of about 1.5 inches, juveniles leave the open water and assume a demersal existence. They appear in kelp canopies, tide pools, and other shallow rocky habitats such as breakwaters from April to June in California.

Cabezon can be aptly described as "lie-in-wait" predators. Their mottled coloration lets them blend in with the surroundings, as they lie motionless to wait for their next meal. With large, robust pectoral fins set low on the body and a powerful tail, they quickly lunge after unwary prey, engulfing it in their large mouth.

Their diet consists mainly of crustaceans, although large and small cabezon have different diets. Adult fish eat crabs, small lobsters, mollusks (abalone, squid, octopus), small fish (including rockfishes), and fish eggs. Small juveniles depend mainly on amphipods, shrimp, crabs, and other small crustaceans.

Juveniles are eaten by rockfishes and larger cabezon, as well as by lingcod and other sculpins. Large cabezon may be preyed upon by harbor seals or sea lions.

Cabezon normally occur nearshore, except as larvae. Usually solitary, juveniles and adults are common on rocky bottom areas with dense algal growth. They are often in the vicinity of kelp beds, jetties, isolated rocky reefs or pinnacles, and in shallow tide pools.

Most of their time is spent lying in holes, on reefs, in pools, or on kelp blades beneath the canopy. As fish get older and larger they tend to migrate to deeper water. In shallower water, they migrate in and out with the tide to feed. Their habit of lying motionless makes them an easy target for sport divers.

Status of the Population

Limited information is available on population biology or changes in biomass over time. Recent increases in commercial fishing pressure on cabezon have intensified efforts to learn more about their life history characteristics, population biology, and to assess stock size. Recreational landings have declined concurrent with the increase in commercial fishing efforts and reported commercial landings. As fishing effort increases, it is likely that populations living in heavily utilized areas will decline further.

Management Considerations

See the Management Considerations Appendix A for further information.

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California Department of Fish and Game

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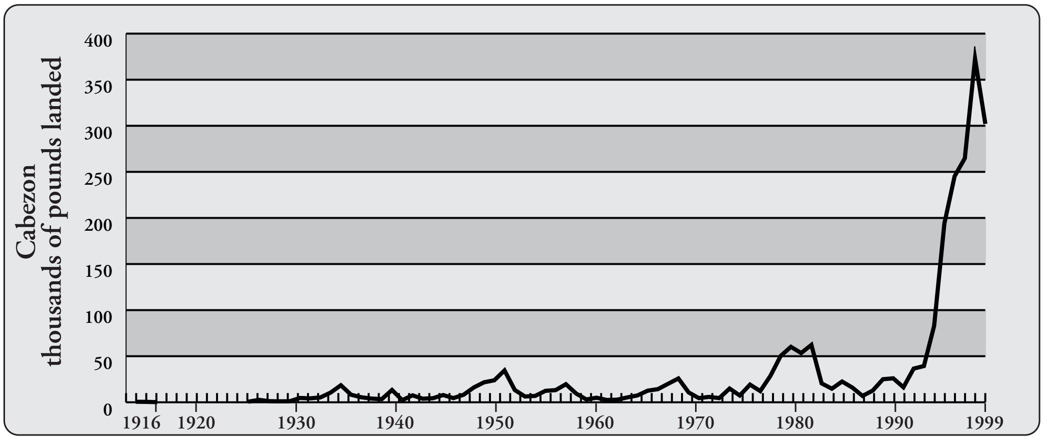
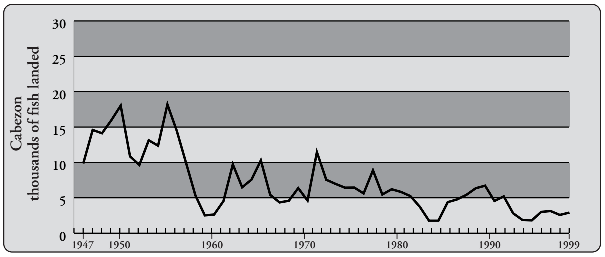


Commercial Landings 1916-1999, Cabezon
Data Source: DFG Catch Bulletins and commercial landing receipts.



Recreational Catch 1947-1999, Cabezon
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

California Scorpionfish

History of the Fishery

The California scorpionfish (*Scorpaena guttata*) is a valuable commercial fish in southern California. For many years, the fishery experienced a long decline, with peak catches of 223,000 pounds in 1925 and fluctuating catches thereafter. However, the rise of the live fish fishery in the 1990s led to the fishery's resurgence, as this species' bright red color and hardiness after capture has made it a favorite target. Today, about 85 percent of the commercial California scorpionfish catch goes to the live fish fishery. Catches in 1998 totaled about 75,000 pounds valued at $175,000. Most fish are taken in traps or by hook-and-line.

California scorpionfish are a moderately important part of the sport fishery in southern California. They are taken primarily from party boats and private vessels, and occasionally from piers and jetties, mostly from Point Mugu southward.

Status of Biological Knowledge

California scorpionfish are easily distinguished from most other California fishes. They are a relatively heavy-bodied species, with strong head and fin spines, ranging in color from red to brown, often with purple blotches and always covered with dark spots. They reach a length of 17 inches.

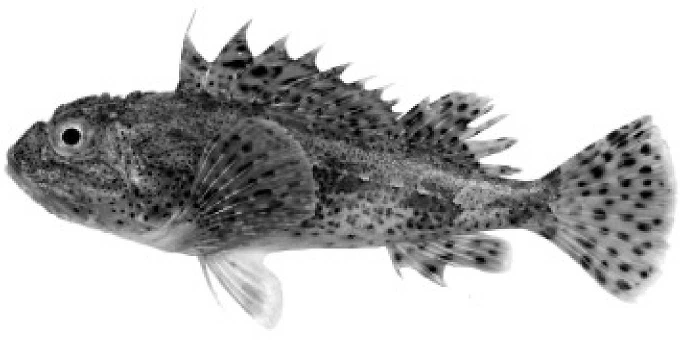
California scorpionfish live from tide-pool depths to about 600 feet (usually in about 20-450 feet) from Santa Cruz to southern Baja California, and in the northern part of the Gulf of California. Preferring warmer water, the species is common as far north as Santa Barbara. While they are most abundant on hard bottom (such as rocky reefs, sewer pipes and wrecks), they are also found on sand.

California scorpionfish grow to 17 inches and some live at least 21 years. After four years of age, females grow faster than males and reach a larger size. Although a few fish mature at six inches (one year), over 50 percent are mature by seven inches (two years) and all reproduce by nine inches (four years). Spawning occurs from April to August, peaking in June and July. Scorpionfish are oviparous, have external fertilization, and females produce eggs imbedded in the gelatinous walls of hollow, pear-shaped "egg-balloons." These paired structures, each five to 10 inches long, are joined at their small ends. The walls of these "balloons" are about 0.1 inch thick, transparent or greenish in color, and contain a single layer of eggs. Each egg is about .05 inch in diameter. The egg masses float near the surface and the eggs hatch within five days. Very young fish live in shallow water, hidden away in habitats with dense algae and bottom-encrusting organisms. Small crabs are probably the most important food of California scorpionfish, although other items, such as small fishes, octopuses, shrimps and even pebbles are sometimes eaten. These animals are primarily nocturnal and feed at night. Octopuses prey on small individuals. California scorpionfish make extensive spawning migrations in late spring and early summer, when most adults move to 12 to 360 foot depths, forming large spawning aggregations on or near the bottom. During spawning, these aggregations rise up off the bottom, sometimes approaching the surface. Spawning occurs in the same areas year after year, and it is likely that the same fish return repeatedly to the same spawning ground. When spawning ends, the aggregations disperse and many (though not all) of the fish move into shallower waters.

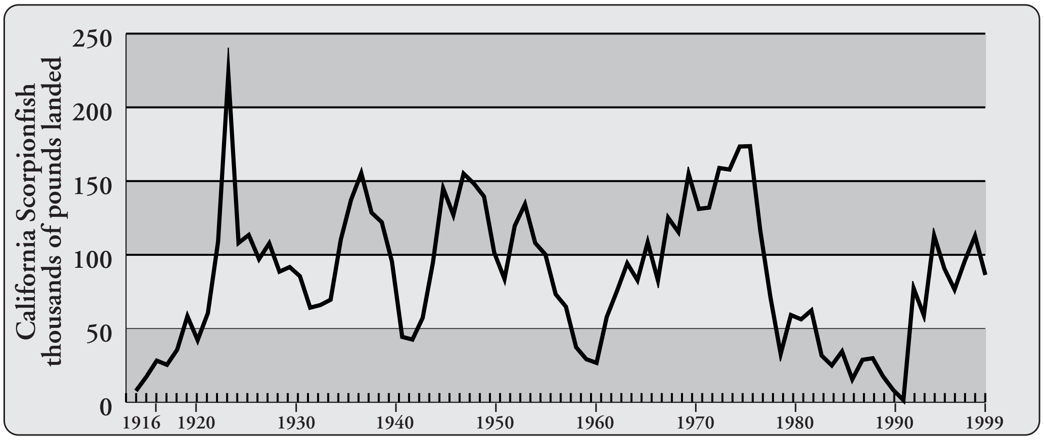
The sharp spines on the dorsal, anal and pelvic fins are poisonous. The toxin is produced in glands that lie at the base of each spine and run up to the tip through a groove. A wound, although painful, is seldom fatal, and bathing the wound in hot water can reduce the pain. The heat alters the toxin's structure making it harmless. One should be careful not to make the water so hot as to damage tissue.

Status of the Population

No population estimates exist for California scorpionfish. However, data from trawl studies conducted by the Los Angeles County Sanitation Districts, Southern California Coastal Water Research Project and the Orange County Sanitation District from 1974-1993 show that there are substantial short-term fluctuations in California scorpionfish abundance within the Southern California Bight.



California Scorpionfish, *Scorpaena guttata*
Credit: DFG



Commercial Landings 1916-1999, California Scorpionfish
Data Source: DFG Catch Bulletins and commercial landing receipts.

Management Considerations

See the Management Considerations Appendix A for further information.

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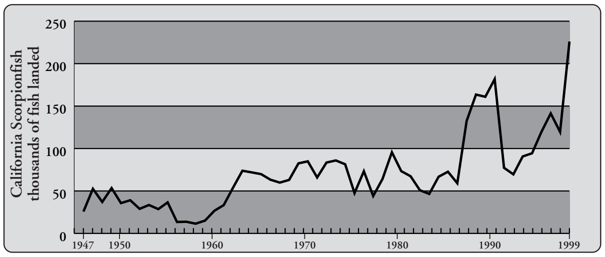

Recreational Catch 1947-1999, California Scorpionfish
CPFV = commercial passenger fishing vessel (Party Boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

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Black Rockfish

History of the Fishery

Black rockfish (*Sebastes melanops*), also known as black snapper and black bass, are a minor to moderate component of nearshore commercial and recreational fisheries, with increasing importance from the San Francisco area northward. The Eureka area accounts for 80 percent to 90 percent of all commercial landings in the "black rockfish" market category (which may contain other species, most commonly blue rockfish). Annual statewide landings in the 1990s ranged from 189,000 to 277,000 pounds, except in 1993 when only 86,000 pounds were landed. Landings from port areas south of San Francisco have never comprised more than 10 percent of total landings in the market category. In the San Francisco port area, "black rockfish" landings increased fifteen-fold from 1989 to 1992. The majority of black rockfish in commercial fisheries are landed dead but a small portion are now landed live in the recently expanded live fish fishery, primarily from Morro Bay north to Fort Bragg. They are also taken incidentally in the commercial salmon troll fishery. Black rockfish also comprise minor to significant proportions of other market categories, in particular "blue rockfish," "small rockfish," and "unspecified rockfish."

Black rockfish are an important recreational species, particularly in northern California. Long-term monitoring of the recreational skiff fishery in the Eureka/Crescent City area showed them as the most frequently taken species every year in the 1990s; in 1997, for example, black rockfish comprised 58 percent of the observed catch. During the period from 1981 through 1986, the Marine Recreational Fisheries Statistical Survey (MRFSS) showed that in Humboldt and Del Norte Counties (northern California), black rockfish comprised from 15 to 31 percent annually of the estimated total marine recreational catch for all fishing modes combined. South of the Eureka area, black rockfish gradually decrease in importance in the recreational catch and are infrequently observed south of Santa Cruz. They are often among the top 10 species observed annually in commercial passenger fishing vessel (CPFV) catches from Fort Bragg south to the San Francisco/Princeton area. Black rockfish also are important to divers. In a 1972 survey in northern and central California, black rockfish comprised approximately eight percent of all fish taken by divers, and were primarily taken in northern California.

Black Rockfish, *Sebastes melanops*
Credit: DFG

A six- to seven-fold increase in estimated annual landings of black rockfish in the recreational fishery occurred between 1957 through 1961 and 1979 through 1986, which reflects a substantial increase in fishing effort between the two periods. Since then, estimated total recreational catch has been variable and has not continued to increase steadily. During the 1990s, the annual estimated take of black rockfish in the recreational fishery was fairly similar to that of the commercial fishery.

In 1992, DFG initiated a voluntary catch-and-release program in recreational and commercial fisheries for black rockfish less than 14 inches in total length in response to concerns over the lack of larger fish in sampled recreational catches, particularly in the San Francisco/Half Moon Bay area. The program was unsuccessful in the primary target area (Bodega Bay to Santa Cruz) and was not continued due to two factors: 1) increased recruitment of sub-adult fish to the fishery (*i.e.,* recreational anglers were unwilling to return a substantial portion of their catch to the water); and 2) perceived competition for the same resource from non-cooperative fishermen.

Status of Biological Knowledge

Black rockfish range from Amchitka Island, Alaska to Santa Monica Bay in southern California, but are uncommon south of Santa Cruz. They frequently occur in loose schools ten to twenty feet above shallow (to 120 feet) rocky reefs, but may also be observed as individuals resting on rocky bottom, or schooling in midwater over deeper (to 240 feet) reefs. They may attain a maximum length of 25.5 inches in California, although individuals over 20 inches are rarely observed today. Average size observed in commercial and recreational fisheries now is 14 to 15 inches in northern California and 11 to 13 inches in central California.

Black rockfish have a relatively fast growth rate. First year growth is usually 3.5 to 4.0 inches. Most individuals become available to the fishery by the time they have reached three to four years of age and are approximately 10 to 11.5 inches. They are larger at equal age then blue rockfish; four-to-seven-year old black rockfish may average from 11.5 to 13.8 inches, while blue rockfish range from 10 to 12 inches within that age range. By age five, growth rate of female black rockfish surpasses that of males, and by age 15, female black rockfish may average 2.4 inches longer than males.

At six years, or about 14 inches, half of all males are sexually mature. At seven to eight years, or about 16 inches, half of all females are sexually mature.

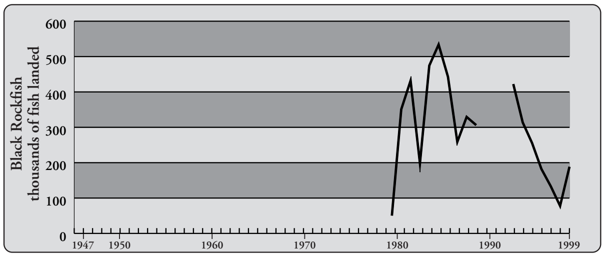
As with all members of the genus *Sebastes*, fertilization and development of embryos takes place within the female's body. Black rockfish mating generally occurs between September and November. Females store the sperm until their eggs mature in December or January, at which time the eggs are fertilized by the stored sperm. The larvae develop within thirty days, at which time black eyespots become visible to the naked eye. The eyed larvae are released into the water from late January to May, peaking in February off of California.

Larvae may remain in the ocean's surface waters for three to six months where they are dispersed by currents, advection, and upwelling. They begin to reappear as young-of-the-year (YOY) in shallow, nearshore waters by May, but the major recruitment event usually occurs from July to August. YOY black rockfish generally recruit to the shallower portions of kelp beds (15- to 40-foot depth) as well as semi-protected sandy areas of the coast. As newly settled YOY (approximately 1.5 inches) they most closely resemble yellowtail rockfish YOY. As they grow, YOY black rockfish more closely resemble YOY blue rockfish in pigmentation but lack the mottling on the sides, which are a uniform tan to light brown. As juveniles and adults, black rockfish are frequently mistaken for blue rockfish. The best characteristics that separate black from blue rockfish are a wide, unmottled, light blue-gray area along the lateral line, a relatively large mouth, the shape of the anal fin, and black speckling in the dorsal fin.

Although black rockfish may occur with blue rockfish, particularly in central and northern California, they are not considered to be competitors because their diets share little in common. Juvenile and adult black rockfish primarily consume crab megalopae, amphipods, isopods, and other fishes, including YOY rockfishes,.

Major predation occurs on all rockfishes from the moment of larval release throughout the first year by a variety of fishes and invertebrates, as well as marine birds. Larger black rockfish are preyed upon by lingcod and marine mammals such as sea lions.

Black rockfish are commonly associated with other nearshore fish species, particularly other rockfishes. A statistical technique, cluster analysis, was used to partition CPFV catch data from 1987 to 1992 in the Monterey area based on the frequency of occurrence of species in the sampled catch. Interestingly, no other schooling rockfish was closely associated statistically with black rockfish, but three benthic species (gopher, China, and brown rockfishes) showed an affinity to the same habitat and depth range as black rockfish. It is commonly known among fishermen that black rockfish in central California are characterized by localized areas of relatively high abundance in the nearshore area.



Recreational Catch 1947-1999, Black Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992

The DFG has conducted limited tagging studies on juvenile and adult black rockfishes. Between 1978 and 1985, 89 black rockfish were tagged in central California. Four tags were returned from fish which had been at liberty from 18 to 552 days; all fish were recaptured in the same areas where they were released.

Status of the Population

Although no fishery-independent population estimates have ever been made of black rockfish stocks in California, substantial information exists on relative abundance and length frequency from fishery-dependent surveys. Data from the 1981-1986 MRFSS survey showed a 23 percent decline in the average weight of black rockfish taken compared with fish harvested from 1958 through 1961.

Onboard observations from CPFVs in the San Francisco area documented a significant change in the length frequency of the sampled catch from 1989 to 1990. During that period, the occurrence of larger adult black rockfish (greater than 15 inches) declined precipitously. This occurred during a time when nearshore commercial hook-and-line fishing effort and landings were expanding, as mentioned previously. Mean length in the sampled catch from the San Francisco area declined from 14.3 inches in 1988-1989 to 12.1 inches in 1990-1991, and has ranged from 11.4 to 12.6 inches annually from 1993 to 1998. This is well below the average length at 50 percent sexual maturity. Since 1993, all other CPFV port areas from Fort Bragg south to Morro Bay have yielded similar low mean lengths.

Results from commercial fishery sampling are consistent with the above. For example, 296 black rockfish sampled from the Morro Bay area commercial nearshore fishery from 1993 to 1997 averaged 12.2 inches. Coincident with these observed declines in mean length were increased harvest rates (catch per angler hour) observed in the CPFV fishery in central California, particularly from 1994 to 1997. Thus, the observed decline in mean length is partially related to stronger recruitment, and, in spite of increased fishing effort on black rockfish in recent decades, localized populations of adults still must be present in California to provide this recruitment.

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Blue Rockfish

History of the Fishery

The blue rockfish (*Sebastes mystinus*), also known as bluefish, blue perch, blue bass, priestfish, and reef bass, is most commonly caught from the northern Channel Islands (in the Southern California Bight) to the Oregon border. Although only a small portion of blue rockfish landings is from the commercial fishery, those landings have increased in the past decade. During the 1987-1989 period, landings in the "blue rockfish" market category (which may include other morphologically similar rockfishes) averaged 25,670 pounds; in 1998 landings were approximately 92,000 pounds. Based on market sampling in the Morro Bay area, total landings of the species blue rockfish are significantly greater than those of the market category "blue rockfish." For example, in 1998 in this port area, estimated total landings for the species were 19,300 pounds, yet total reported landings for the market category were only 2,100 pounds. The former estimate is based on the percentage of blue rockfish in various sampled market categories and the total landed weight of all market categories. Blue rockfish are often landed as "unspecified rockfish" or "group small rockfish," both frequently used market categories.

Blue rockfish have become a minor component of the live fish fishery, which developed during the 1990s in California. For example, in the Morro Bay area during the 1996-1998 period, less than one percent of the live fish landings were blue rockfish, and about four times as many blue rockfish were landed dead than alive. In 1998, the ex-vessel value of all fish landed statewide in the "blue rockfish" market category was $57,700.

The blue rockfish is one of the most important recreational species in California. It is usually the most frequently caught rockfish north of Point Conception for anglers fishing from skiffs and Commercial Passenger Fishing Vessels (CPFVs). It is also an important species for skin and scuba divers using spears, and is occasionally caught by shore anglers fishing in rocky subtidal areas. In a 1981-1986 survey of sport fish taken between the southern boundary of San Luis Obispo County and Oregon, an estimated 800,000 blue rockfish were harvested annually - more than any other species. This represents a doubling of the estimated annual harvest from a similar survey conducted in 1957-1961.

In every complete year sampled by the department, from 1988 through 1998, blue rockfish has been among the three most frequently observed species caught on CPFVs in every major port area from Morro Bay to Fort Bragg. Based on the Department of Fish and Game's (DFG) onboard observations and log book summaries, estimated annual take of blue rockfish by CPFV anglers ranged from 199,000 to 546,000 fish for the period 1988 to 1995 and averaged 335,000 fish. This species truly has been the bread and butter of the nearshore recreational angler in northern and central California.

In a survey of divers conducted in 1972 in northern and central California, blue rockfish ranked second in importance to lingcod with 10.5 percent of all fish landed and was the most common rockfish taken, comprising 29.6 percent of all rockfishes. Preliminary data from a 1999 survey of Monterey Bay area divers revealed that blue rockfish was the fourth most abundant species harvested, after California halibut, kelp rockfish, and lingcod.

For more than 25 years, the recreational harvest of rockfish was limited to 15 fish per day, with 15 blue rockfish allowed within that limit. Effective January 1, 2000, the bag limit was reduced to 10 rockfish overall, with 10 blue rockfish allowed within that limit. The National Marine Fisheries Service considers the blue rockfish a "nearshore species." Effective January 1, 2000, very restrictive limits on the commercial harvest of nearshore rockfishes have been imposed by the National Marine Fisheries Service upon recommendation of the Pacific Fishery Management Council. In addition, the DFG now requires a special permit for the commercial harvest of nearshore fishes, and it is likely that a restricted access program will be developed for the nearshore commercial finfish fishery in California.

Status of Biological Knowledge

Blue rockfish range from the Bering Sea to Punta Baja, Baja California, and from surface waters to a maximum depth of 300 feet. They are less common south of the northern Channel Islands and north of Eureka, California. They are a medium-sized species among all rockfishes; the largest known specimen was 21 inches, although individuals exceeding 15 inches are uncommon in central and southern California. Average size in California recreational fisheries today is 11 to 13 inches. In central and southern California, larger blue rockfish are now common only in areas distant from fishing ports or in larger kelp beds which are practical to fish only from the edges.

Blue Rockfish, *Sebastes mystinus*
Credit: DFG

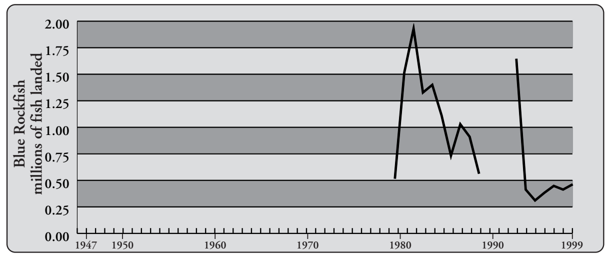
Rockfishes in general are considered to be slow-growing fishes. However, blue rockfish are among the faster growing rockfishes. First year growth may vary from 3.0 to 4.5 inches (central California average about 4.25 inches), and after two years blues may reach six inches. An occasional two- or three-year old blue rockfish may be caught by anglers, but most do not recruit to the sport and commercial fisheries until four to seven years of age when they range from eight to 10 inches. Females grow at a slightly faster rate than males. Maximum age is about 24 years.

Age at first spawning is protracted for both sexes. Only about 10 percent spawn for the first time at three years of age. At five years, or about 10 to 10.5 inches, half of all males are sexually mature. At six years, or about 11 inches, half of all females have spawned.

In males, the gonads increase in size from May to July, but in females the eggs begin maturing from July to October. Males transfer sperm to the females in October, but the embryos do not begin to develop until December when the eggs are fertilized by the stored sperm. Embryos develop within the female and hatch immediately upon being released into the water; larval release usually peaks in mid-January. Larvae live in the surface waters for four to five months, where they may be carried many miles by ocean currents. Young-of-the-year (YOY) blue rockfish begin to appear in the kelp canopy and shallow rocky areas by late April or early May when they are about 1.2 to 1.4 inches in length. However, they are not considered fully recruited each year until July due to the variability in the planktonic period. As YOY, they are mottled reddish-blue in color upon settlement and may appear in massive swarms in certain years in inshore areas, especially in kelp beds.

After more than two decades of estimating relative abundance of blue rockfish in central California, DFG biologists have shown a positive statistical correlation with blue rockfish recruitment and annual upwelling index. Continuing research is directed towards the mechanisms by which YOY rockfish recruit to nearshore areas, and the relationship between spawning areas and recruitment areas, as influenced by current patterns and oceanographic events.

Feeding habits vary considerably depending upon life history stage, depth, and locality. Larval and YOY blue rockfish consume primarily planktonic crustacea. Adult fishes in deeper water feed almost entirely on macroplankton consisting of tunicates (salps), scyphozoids (gonadal material of jellyfish), and crustaceans. In shallow areas and kelp beds, blue rockfish feed on the same types of macroplankton as those in deeper water, but they also feed on algae, small fishes, hydroids, and crustaceans, including amphipods and crab larvae.



Recreational Catch 1947-1999, Blue Rockfish
Data Source: RecFin data base for all gear types; data not available for 1990-1992

During their first few months on nearshore reefs, larval and YOY blue rockfish are preyed upon by most large piscivorous fishes. As adults, their predators include lingcod, harbor seals, sea lions, and, occasionally, larger rockfishes, especially bocaccio.

Adult blue rockfish are common in kelp beds, where food is plentiful and the kelp provides protection from predators, but they also occur on deeper rocky reefs between 100 and 300 feet deep. In kelp beds they form loose to compact aggregations. Under dense kelp canopies, they will sometimes form columns at least 30 wide and 80 feet deep and may be extremely compact. In deeper waters, they form aggregations that may extend from the surface to the bottom, but they are usually at or below mid-depth.

Blue rockfish are commonly associated with other nearshore fish species, particularly other rockfishes. A statistical technique, cluster analysis, was used to partition CPFV catch data from 1987 to 1992 in the Monterey area based on the frequency of occurrence of species in the sampled catch. In a broad area along the entire Monterey Peninsula extending out to 240 feet deep, blue rockfish were the predominant species and were in close association with olive, yellowtail, starry, and rosy rockfishes. This statistical relationship has been supported with observations using scuba and submersibles.

The DFG has conducted marking studies on all size ranges of blue rockfish from 1.8 to 18 inches. A population study using freeze branding as a marking technique resulted in more than 80,000 recently-settled blue rockfish being marked in a five-week period. These fish showed very little movement from an isolated reef 100 x 150 feet and, in fact, showed very little movement from one part of the reef to another.

Tagging studies of adult blue rockfish indicate they do not migrate laterally along the coast. Between 1978 and 1985, over 1500 blue rockfish were tagged and released in central California waters by DFG biologists. Eighteen tags were subsequently returned, with the fish being at liberty from 11 to 502 days; all were recaptured in the same locations where they were tagged. The longest recorded movement of a blue rockfish from any tagging study was 15 miles. While these studies show adult blue rockfish populations are more or less discrete at each fishing port, it is not known how much larval drift occurs between fishing areas.

Status of the Population

Although no fishery-independent population estimates have ever been made of blue rockfish stocks, it appears that they have withstood considerable fishing pressure over the last four decades and continue to be healthy, at least north of Point Conception. There is evidence of a decline in blue rockfish stocks off southern California since the 1970s. There is a well-documented difference in the population structure between northern and central California stocks. Northern stocks are generally characterized by a wider size range of adults, a higher proportion of adults greater than 15 inches and a correspondingly greater mean length, less variability in annual recruitment, and most likely a higher growth rate. These attributes are likely a result of a combination of greater fishing pressure and a greater influence of anomalous oceanic conditions such as El Niño events in central California. Greater variability in annual recruitment results in occasional strong year classes which cause strong length-frequency modes in the sampled catch; this occurred four times in recreational fishery samples obtained from 1959 to 1983 in central California. It is believed that the last exceptionally strong year class of blue rockfish in central California occurred in 1988, which is cause for concern. However, a relatively strong year class also was observed in 1999. In 1993, when the majority of the 1988 year class had become available to recreational anglers, mean lengths in the sampled catch declined substantially in central California. For example, mean length of blue rockfish sampled from Monterey area CPFVs declined from 11.9 inches in 1992 to 11.0 inches in 1993. In heavily fished and well-sampled populations of rockfishes, changes in annual mean length from one year to the next are commonly less than 0.5 inches.

The total number of blue rockfish caught in recreational fisheries increased substantially from the late 1950s to the mid-1980s, concurrent with increased effort. However in the past 15 years recreational fishing effort has been variable but has not shown a consistent increase; the recreational catch of blue rockfish has shown the same pattern. However, increased commercial fishing in the nearshore area during the same period has put additional stress on blue rockfish populations. Fishery managers have increased monitoring efforts for this keystone species of nearshore ecosystems.

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References

See black rockfish reference list.

Olive Rockfish

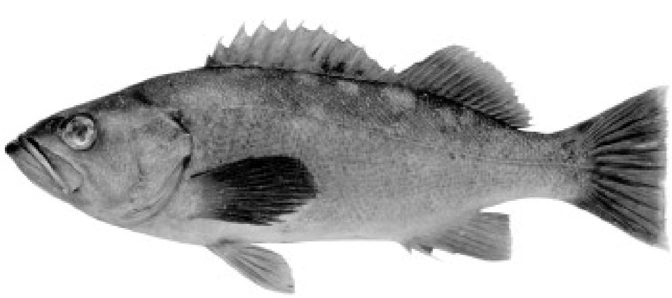
History of the Fishery

Olive rockfish (*Sebastes serranoides*) form a minor part of the commercial fishery in central and southern California, where they are primarily taken by hook-and-line. A relatively small number find their way into the live fish fishery. Historically, olive rockfish have been common in the recreational fishery as far north as Fort Bragg and were particularly important from central California to the northern Channel Islands. As late as the 1980s, olives were a very important recreational species throughout much of southern California. However, a combination of overfishing and poor juvenile survival brought about by changes in oceanographic conditions led to a steep decline (83 percent) in southern California party vessel catches between 1980 and 1996. In addition, while they were still commonly taken in the central California recreational catch, olive rockfish also declined there in the late 1990s.

Status of Biological Knowledge

Olive rockfish are streamlined fish with almost no head spines. Their body color is dark brown or dark green-brown on the back and light browns or green- brown on sides. There are a series of light blotches on the back. The fins range from olive to bright yellow, and olives are often mistaken for yellowtail rockfish. Olive rockfish are somewhat drabber in appearance, and yellowtail rockfish have red-brown flecking on the scales. They reach a maximum length of two feet.

Olive rockfish occur from southern Oregon to Islas San Benitos (central Baja California) from barely subtidal waters to 570 feet (the latter based on a trawl specimen collected by the Southern California Coastal Water Research Project). They are common from about Cape Mendocino to Santa Barbara and around the Northern Channel Islands from surface waters to about 396 feet. Olives appear to be uncommon off much of both southern California and Baja California.



Olive Rockfish, *Sebastes serranoides*
Credit: DFG

From April to September, young-of-the-year olive rockfish, around 1.2 to 1.6 inches long, settle out of the plankton to kelp beds, oil platforms, surfgrass and other structures at depths as shallow as 10 feet. During the day, young fish aggregate in the water column, occasionally with blue and black rockfish. They spend the night near or on the bottom, sheltering under algae or among rocks. Young olives also are found under drifting kelp mats. Olives about 2.5 inches long become more active at night, but it is not clear whether adult olives are nocturnal. They do feed commonly on octopuses, which are more available at night. Sub-adult and adult olives live over high relief reefs, as well as around the midwaters of oil platforms. In shallow waters, they are found throughout the water column and occasionally rest on the bottom. They form small to moderate-sized schools and a few often are mixed with blue rockfish schools. From tagging studies, most olive rockfish move relatively little; a maximum movement of 20 miles has been reported.

Olive rockfish live at least 25 years. Females grow larger, and, beginning at maturation, tend to be longer at a given age. Males reach maximum length earlier. Throughout California, males mature at a somewhat smaller size and a slightly greater age than females, however the difference is not large. Off central California, a few fish were mature at 10.6 to 11.2 inches (three years), 50 percent were mature at 12.9 to 13.7 inches (five years), and all were mature by 15.2 inches (eight years). Females release larvae once a year from December through March, peaking in January. Females produce between 30,000 to 490,000 eggs per season. Small juveniles are planktivorous, feeding on copepods, gammarid amphipods, cladocerans, euphausiids, other crustaceans and fish larvae. As they grow, their diet shifts to fishes, such as juvenile rockfishes, squids, octopuses, isopods, polychaete worms and krill.

Status of the Population

There has been no stock assessment of this species. However, there is clear evidence that olive rockfish have declined in abundance south of Pt. Conception.

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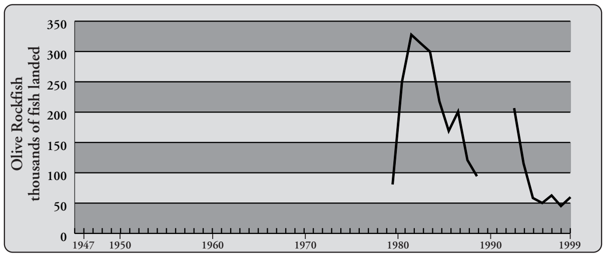

Recreational Catch 1947-1999, Olive Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992

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Brown Rockfish

History of the Fishery

Brown rockfish (*Sebastes auriculatus)*, commonly referred to as bolina by fishermen and markets, have long been an important component of the marine recreational fishery and a relatively minor but important component of the nearshore commercial fishery in California, especially north of Point Conception. In the commercial fishery freshly caught whole brown rockfish are sold either dead or alive in the fresh fish markets. Brown rockfish have not been reported separately from other rockfishes in catch statistics, but comprise the majority of the market grouping called bolina, which also includes other similar-looking rockfish species, such as copper or quillback rockfish, that are sold at the same price. In samples obtained from 1999 landings, brown rockfish comprised 70 percent by weight of the bolina category. Brown rockfish are also mixed into other market categories, such as the red rockfish group (19 percent by weight in 1999 landings).

Commercial catches were made in the past with hook-and-line gear and, to a lesser extent, gillnets until gillnets were excluded from state waters in 1991. Today, brown rockfish are primarily taken with hook-and-line gear, which includes mainly rod-and-reel and horizontal longline gear, along with some vertical longline (stick) and troll longline gear. In most port areas of the state, the majority of bolina group catch is made by rod-and-reel, although, in the San Francisco area, the longline fleet accounts for over 70 percent of bolina taken. The species is targeted directly in both nearshore and offshore ocean environments. In the San Francisco area, the brown rockfish was estimated to be the third most common rockfish species landed by weight in the hook-and-line commercial fishery through the 1990s. The 1999 and 2000 catch estimates suggest that they are now equal to line-caught landings of chilipepper and the two are the most common species in nearshore catches. Since the early 1990s, the brown rockfish has been the most common rockfish species sold live in San Francisco markets and comprised nearly 50 percent of the live rockfish catch in 1999.

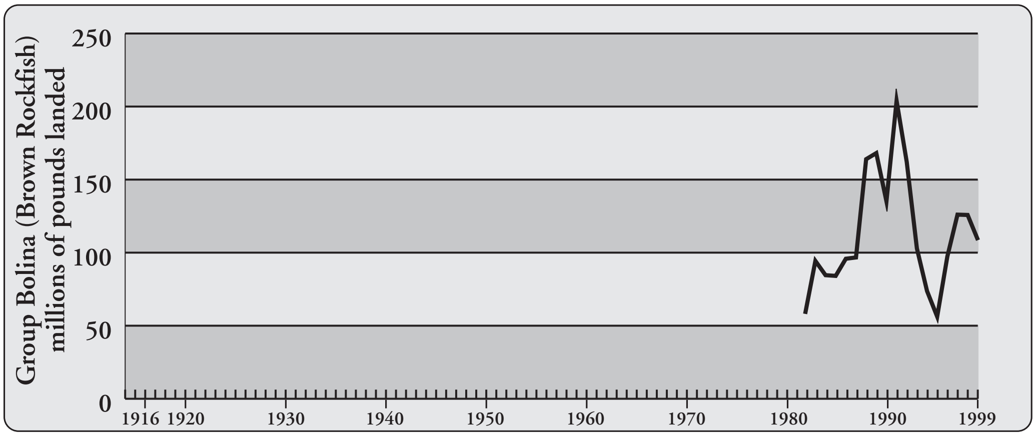
Brown Rockfish, *Sebastes auriculatus*
Credit: DFG

The number of vessels landing brown rockfish peaked in the early 1990s, when over 250 hook-and-line vessels made an average of over 1,300 landings per year statewide, usually ranging from 60 to just over 100 pounds per landing. Total landings of brown rockfish peaked in 1991, decreased through the mid-1990s, and increased again during the late 1990s coincident with an increasingly active nearshore premium and live fish fishery. Though landings have fluctuated over the last two decades, the value of the catch has continued to increase, particularly during the last decade, as rockfish quotas have been reduced and demand has continued to remain high. Markets in areas such as San Francisco (especially those in Chinatown) sell their brown rockfish whole and preferably live. Dead-landed fish obtain an ex-vessel price of $1 to $2 per pound, whereas live brown rockfish have demanded an ex-vessel price from $2 to $4 per pound. With the recent management-related reductions in supply, prices have increased to over $6 to $8 per pound at times in 1999 and 2000.

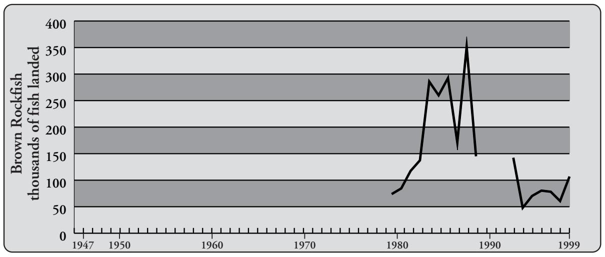
Sport anglers regularly catch brown rockfish with rod-and-reel either from the shore, commercial passenger fishing vessels (CPFVs), or private/rental boats (PRBs), especially in nearshore reef habitats (depths of less than 175 feet). Brown rockfish are most common in sport catches near San Francisco. In a sport fish survey conducted from 1980 through 1986, brown rockfish were among the top five species of rockfish caught and composed up to 6.6 percent of the estimated sport catch. Inside San Francisco Bay, they are the most common sport-caught rockfish species. Although catches south of Point Conception are lower, brown rockfish have comprised up to one percent of rockfish take and have remained among the top 15 species of rockfish caught during the last 20 years. These represent a seven-fold increase by number in statewide take relative to a 1958 to 1961 survey of recreational fishing. Substantial increases in take have occurred in all modes of fishing, especially by shore fishing, pier fishing, and PRBs.

Status of Biological Knowledge

Brown rockfish are found along the Pacific Coast of North America from the northern Gulf of Alaska to central Baja California. They live in shallow subtidal waters and bays, and have been found at depths of just over 400 feet, although they most commonly reside above 175 feet. Brown rockfish are typically found associated with sand-rock interfaces and rocky bottoms of artificial and natural reefs. In shallow waters, they may be found in small aggregations associated with rocky areas and kelp



Commercial Landings 1916-1999, Brown Rockfish
Group Bolina (Brown) rockfish landings were aggregated as rockfish prior to 1979. DFG market sampling indicates that 75 percent of the Group Bolina rockfish market category is made up of brown rockfish, the remaining 25 percent consists primarily of widow rockfish. Data Source: DFG Catch Bulletins and commercial landing receipts.



Recreational Catch 1947-1999, Brown Rockfish
Data Source: RecFin data base for all gear types; data not available for 1990-1992

beds, whereas they stay near the rocky bottom when in deeper waters. The sub-adults migrate into both high and low relief reefs and are strongly residential to their home sites.

Distinguishing characteristics of brown rockfish include orange-brown or dark brown mottling, especially on the back, and a prominent dark brown blotch on the gill cover. Little sexual dimorphism is evident between male and female brown rockfish in relation to growth or maturity rates. Recent studies found maturity as early as three years, and 100 percent maturity at six years, or roughly 12.2 inches total length (TL). Half of the population was mature at 3.9 and 4.2 years of age, measuring 9.8 and 10.4 inches TL in males and females, respectively. Brown rockfish grow to a maximum size of 22 inches, and live less than 25 years. This is a relatively short life span compared with most offshore rockfish species, though many nearshore rockfish species have a similar or shorter lifespan.

As with all members of the genus *Sebastes*, brown rockfish are ovoviviparous. A 12-inch TL female may produce approximately 42,500 eggs, while an 18-inch TL female may produce as many as 266,000 eggs. Peaks in larval release occur in the pelagic environment in both December-January and May-June. Larvae live in the upper zooplankton layer for approximately a month before metamorphosing into pelagic juveniles as part of the plankton and micronekton, and subsequently settling out into shallow nearshore waters. Although brown rockfish reproduce on the open coast, young-of-the-year fish commonly migrate into bays and estuaries for use as nursery habitat, which is an uncommon practice for rockfish species. They may remain in the bay around rubble, piers and other structures in areas of higher salinity for one to two years before returning to the open coast.

Brown rockfish feed on increasingly larger prey as they grow. They shift from small crustaceans, amphipods, and copepods as juveniles, to an adult diet of crabs and fish. Little is known about predation on brown rockfish, but it is thought to be similar to that of other nearshore rockfish species: Most predation on the brown rockfish presumably occurs during the larval and juvenile stages, with less predation occurring on the adults.

Status of the Population

While there have been studies of local abundance in certain coastal areas and within bays, the population size and structure of this species has not been comprehensively assessed. Evidence of stress on brown rockfish stocks in California exists, however, and some relative changes in the population have been identified. Commercial and recreational catches have steadily increased during the last 40 years, while the average length and weight of brown rockfish in landings have declined. When recreational statistics collected during the last 20 years were compared to results from a 1958 through 1961 recreational survey, brown rockfish showed a 49 percent decrease in average weight per fish over 30 years. Mean length of brown rockfish obtained from CPFVs and PRBs in northern California declined by 18 percent and 21 percent respectively over 40 years. In southern California, mean length in the CPFV catches declined by 31 percent during the same period. In relation to the length at which 50 percent of males and females are mature, recreational landings data indicate that from 1958 to 1961, most brown rockfish taken had reached sexual maturity. By the 1980s, however, few fish taken from shore or from the bays, and about half taken from PRBs were sexually mature. Lengths of brown rockfish sampled from commercial landings during the last decade also reflect that half of the fish were at or below the size at which 50 percent of the population is sexually mature, and few larger adult fish are being landed compared to historic values. The decline in size of fish in these fisheries does not seem to be associated with incoming year classes, but instead with a depletion of larger adults due to fishing pressure. Although nearly half of the fish landed statewide are adults that can replenish the population, there are now few large adults above the length of the median-sized fish recorded in the 1958 through 1961 survey. The brown rockfish has been identified as a species vulnerable to severe localized depletions in other geographic areas; in Washington state, the Puget Sound stock of brown rockfish was recommended for listing as a threatened species in 1999.

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Copper Rockfish

History of the Fishery

The copper rockfish (*Sebastes caurinus*) is a highly variable species in terms of coloration, and due to this characteristic it has been known by several names, depending to some degree upon locality. These include copper rockfish, whitebelly rockfish, gopher, white gopher, and bolina (this name is most commonly applied to the brown rockfish). Copper rockfish is most widely used and is the recommended vernacular name. Historically, copper rockfish was considered a common nearshore species.

Over the past 20 years, copper rockfish have become a less frequent component of the nearshore environment. Commercially, copper rockfish are landed in a number of market categories including copper rockfish as well as red, bolina, and gopher rockfish groups. It is sold as fillets by the market names rockfish or red rockfish and often whole as red rockcod; it is considered an excellent food fish. Copper rockfish is one of the species taken in the live-fish fishery. They have been an important component of the recreational catch in both skiff and commercial passenger fishing vessel fisheries, especially off central and northern California. Due to its relatively large size, known to reach 22.9 inches in length, copper rockfish has been considered one of the premium species in the recreational angler's catch and a prime target for the sport diver.

Status of Biological Knowledge

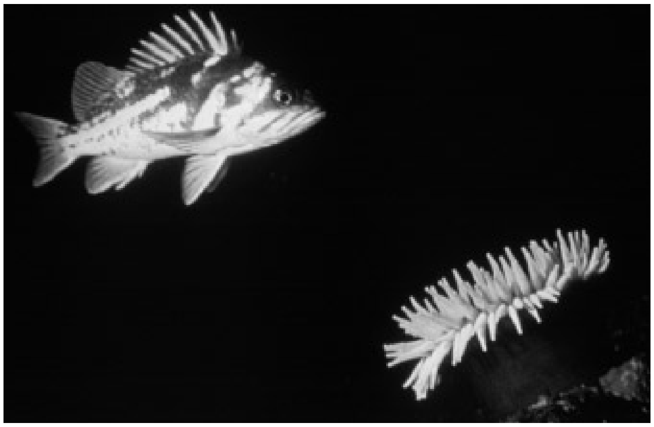
The copper rockfish was one of the first species of rockfishes to be described from the Pacific Coast, having been scientifically named in 1845 by John Richardson from Sitka, Alaska. For many years, the copper and whitebelly rockfish were considered as separate species but morphological and biochemical analyses in the 1980s have shown these two nominal forms to be conspecific, a highly variable-colored but genetically unique species. The copper rockfish is broadly distributed geographically, known from the Gulf of Alaska to off central Baja California, Mexico. It also has a broad bathymetric distribution, known to occur from the shallow subtidal to 600 feet.

As with all rockfishes, coppers are viviparous and highly fecund. A 13.4-inch female is capable of producing 215,000 ova and an 18.5-inch fish of producing 640,000 ova. The largest individuals may well produce over one million larvae. The larvae are released during winter months (Jan.-March). Young-of-the-year copper rockfish are pelagic and recruit into the nearshore environment at about 0.8 to 1.0 inch during April and May off central California. The newly recruited copper rockfish initially associate with canopy-forming kelps such as *Macrocystis*, *Cystoseira*, and *Nereocystis*. After several months, and at about 1.6 inches, the juveniles settle to the bottom on rocky reef as well as sandy areas and are referred to as benthic juveniles. Copper rockfish in the early juvenile stage are morphologically similar to two closely related species, gopher rockfish and black-and-yellow rockfish, and the three species at this life stage are extremely difficult to distinguish. Upon settling, color patterns and morphological characteristics develop and the three species become separable.

Copper rockfish are an important component of the nearshore rocky reef system and are frequently encountered by scuba divers in this environment. Submersible observations of the biotic community off the Big Sur coast revealed copper rockfish between depths of 70 and 325 feet. The majority of sightings were of individual (solitary) fish occurring over rocky reef or boulder fields and most frequently in areas of high relief. Occasionally, an individual was observed over sand. Coppers are considered epibenthic, normally occurring slightly above the substrate.

Tagging studies indicate that copper rockfish, for the most part, show little movement once they have settled to the bottom. Movement of up to one mile has been noted but the majority of tagged and recaptured copper rockfish are from the locality where they were originally taken. This life history characteristic makes species with high site fidelity susceptible to local depletion. In areas close to fishing ports and higher rates of utilization, fewer and smaller copper rockfish are caught.

Copper rockfish reach sexual maturity at about 11.6 inches total length (TL) for females and 14.6 inches TL for males. This is at about five years of age for females and seven years for males. Size and age for copper rockfish from off central California for the first five years are as follows: age zero, 3.6 inches TL; age one, 3.7 to 5.9 inches TL; age two, 4.2 to 9.4 inches TL; age three, 7.0 to 11.5 inches TL, and age four, 8.9 to 13.2 inches TL. There appears to be no significant difference in the growth rates between sexes.



Copper Rockfish, (*Sebastes caurinus*) and a sea anemone
Credit: CA Sea Grant Extension Program

Off central California, copper rockfish have been aged to 28 years for a 22.1-inch individual. Copper rockfish from Puget Sound have been aged to 34 years.

Copper rockfish feed on a wide variety of prey items. Crustaceans form a major part of their diet; these include *Cancer* crabs, kelp crabs, and shrimps. Squid of the genus *Loligo* and octopuses are also important food items. Fishes, which include young-of-the-year rockfishes, cusk-eels, eelpouts, and sculpins are important forage for larger individuals. Juvenile copper rockfish feed primarily on planktonic crustaceans.

Hybridization of copper rockfish with brown rockfish has been suspected in Puget Sound, but this has not been noted from anywhere else within their range.

Status of the Population

There has been no stock assessment of this species in California. However, there is compelling evidence that copper rockfish populations have severely declined in many areas and large individuals are noticeably less common than in past decades. Due to their solitary nature, high habitat specificity, and the size they can enter the fishery (as juveniles), the copper rockfish is a prime candidate for local depletion.

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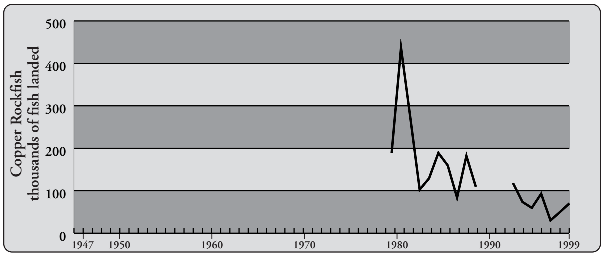

Recreational Catch 1947-1999, Copper Rockfish
Data Source: RecFin data base for all gear types; data not available for 1990-1992

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Canary Rockfish

History of the Fishery

Prior to 1944, the primary gear used for the capture of rockfish was the hook-and-line (primarily vertical long-line). Soon after World War II, the "balloon" trawl became the dominant gear used to capture rockfish. Canary rock-fish (*Sebastes pinniger*) became the largest component in the trawl fishery landings in northern California. From the 1940s to the late 1960s, rockfish landings began to increase steadily, due in part to Asian market demands. Estimated canary rockfish landings for this time period indicate annual catches of 550 to 2,200 tons, the majority being landed in northern California with trawl gear. The exact amounts harvested during this time period are not known since rockfish landings were not recorded sep-arately until 1981. During the 1970s, total landings of canary rockfish in California decreased slightly to between 440 and 990 tons. Trawl gear continued to dominate the total catch (60-70 percent), with recreational catches (15-30 percent) and commercial hook-and-line (5-15 per-cent) accounting for the rest.

In 1982, the trawl catch of canary rockfish in California accounted for 77 percent of the total canary rockfish catch (1,200 tons), with most of the fish being landed in Eureka and Fort Bragg. Recreational and commercial hook-and-line catches accounted for 21 percent and 2 percent of the total in 1982. During the 1980s, a new gear, the setnet or gillnet entered the fishery. Gillnet catches began to replace hook-and-line catches for a few years, but accounted for less landings compared to the recreational and trawl catches. The trawl remains the dominant gear type for harvesting canary rockfish to this day, but has experienced declines to levels nearly matching the hook-and-line catches. Since 1982, the total harvest of canary rockfish in California has declined dramatically to 250 tons in 1998. The trawl, commercial hook-and-line, recre-ational, and setnet catches account for 50 percent, 42 percent, 8 percent, and less than 1 percent of the total canary rockfish landings in 1998. Canary rockfish are cur-rently being managed through bi-monthly trip limits.

Canary rockfish is an important component of the com-mercial passenger fishing vessel (CPFV) recreational catch from central and northern California. This species was consistently one of the top ten species landed by CPFV anglers fishing in the San Francisco area north to the Eureka area. Average length of canary rockfish caught by CPFV anglers is small and usually involves immature fish (less than 50 percent maturity).

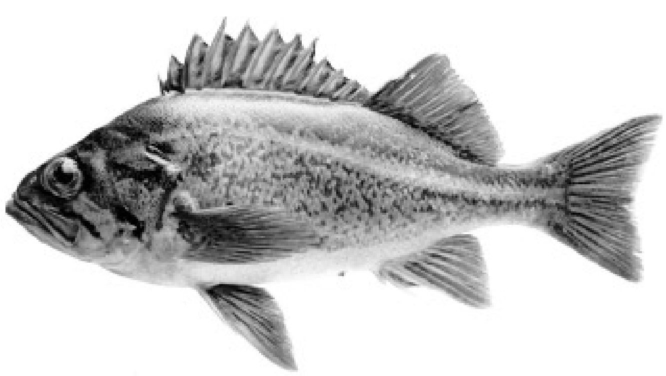
Status of Biological Knowledge

Canary rockfish, referred to as orange rockfish in older reports, occur from Baja California to southeast Alaska. Their center of distribution is the Washington-British Columbia area, and in California they have com-mercial importance only as far south as Bodega Bay. Elec-trophoretic differences indicate that canary rockfish may have two separate subpopulations: one north, the other south of central Oregon. A recent assessment of these two portions of the canary rockfish resource suggests the southern area may be receiving population enhancements from the northern spawned fish. Canary rockfish have been caught at depths below 1,000 feet, but are taken in abundance only to 500 feet.

Canary rockfish grow rapidly until they reach maturity at about 17 inches, then more slowly to a maximum age of 70 years and a maximum length of 24.5 inches for females and 21 inches for males. For example, at one year, females average 5.4 inches and males 4.3 inches; at four years both females and males average about 11.7 inches; by age 12, females average 20.2 inches and males 19.1 inches. By age 50 they have added little length (females, 24.4 inches; males, 20.9 inches). Most populations have few individuals older than 20 years.

Females begin to mature sexually at 10.6 inches, reaching 50 percent maturity at 17.3 inches, and 100 percent matu-rity at 21.2 inches. Males begin to mature at 11 inches, reaching 50 percent maturity at 15.7 inches, and 100 percent maturity at 17.7 inches. A 10.6-inch female carries about 69,000 eggs; a 17.3-inch female about 489,000 eggs; and a 21.2-inch female about 1,113,000 eggs.

Canary rockfish are viviparous, meaning that the females bear free-living young and contribute some energy to their young while they are inside the mother. Males fertilize the females around December, and the females hold their young until December to March. Pelagic juveniles occur in the upper 100 feet of the surface waters from April to June. It is assumed that the juveniles descend to



Canary Rockfish, *Sebastes pinniger*
Credit: DFG

benthic habitats after mid-June. Juvenile canary rockfish, like most rockfishes, tend to settle in the shallower depths of their range and move to deeper waters as they grow older.

Adult canary rockfish feed primarily on euphausiids. Next in importance as prey are fish, mainly myctophids and adult shortbelly rockfish which are most abundant in the fall and winter diet. Gelatinous zooplanktors and associated hyperiid amphipods are common prey but are a minor part of the diet. Pelagic juvenile canary rockfish feed on copepods and euphausiid eggs and larvae.

Predation on canary rockfish is most severe during the pelagic larval and juvenile stages. Juveniles (one to three inches) are commonly found in the stomach contents of chinook salmon. Undoubtedly, other predators of juvenile fish (other fishes, mammals and birds, including the common murre) prey on juvenile canary rockfish. After the juveniles descend to the benthos and become adults they are much less vulnerable to predators.

Status of the Population

The canary rockfish population has declined since the early 1970s, particularly in the waters north of California. The population size of age three and older canary rockfish for California was estimated to be approximately 4,700 tons in 1973 and had decreased nearly 60 percent to 1,900 tons in 1998. The mean length of canary rockfish has declined 13 percent since 1980 in the trawl fishery, indicating the removal of larger, older fish from the population. Off the coast of Washington and Oregon age two and older fish were estimated at 73,700 tons in 1967; in 1999 the estimate was 12,100 tons. The spawning population of canary rockfish has seen even more dramatic declines, with estimates of 1999 spawning population sizes of 6-23 percent of historically unfished levels. In 1999, the canary rockfish resource off the entire U.S. West Coast was declared overfished. Recent predictions of population trends indicate the population may take many decades to recover to fishable levels. Attempts to decrease fishing pressure on canary rockfish are resulting in severe restrictions for many other West Coast fisheries.

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Quillback Rockfish

History of the Fishery

Quillback rockfish (*Sebastes maliger*) are a minor component of the commercial passenger fishing vessel (CPFV) fishery and in general are only observed from the ports of Monterey northward. Only in the Eureka area does this species rank among the 10 most frequently observed benthic sport fishes caught by CPFV anglers. In the Fort Bragg area, quillback rockfish ranked between 13 and 17 among benthic sport fishes caught by CPFV anglers, and their importance in the fishery diminishes with decreasing latitude. A survey of all recreational sport fishing modes from 1981 to 1986 indicated an average annual harvest of approximately 9,000 fish.

Commercial landings of the "quillback rockfish" market category are significant only from the San Francisco area northward. However, historical landings are difficult to determine because of the low frequency of quillback rockfish and confused identification with other similar species. Statewide landings in this market category in 1999 comprised less than 0.3 percent of all rockfishes. Since 1992, this market category has not been used every year and when used, may have consisted of several different species.

Status of Biological Knowledge

The quillback rockfish was first described by Jordan and Gilbert in 1880. Also referred to as orange-spotted, yellow-back, or stickleback rockfish, it is part of central and northern California's nearshore benthic assemblage.

Quillback rockfish are relatively small, and are of "stout" morphology; a characteristic common among nearshore *Sebastes* found in close association with the bottom. They are usually orange-brown to black in color with a yellow or orange pale area between the eye and pectoral fin. This pale area is also present as a saddle on the first few dorsal spines and as speckling on the mid-dorsal surface. A characteristic that helps distinguish this species from similar species is its long dorsal spines and deeply notched forward dorsal fin membranes. Copper rockfish and other nearshore shallow dwelling rockfish also have deeply notched first dorsals but not so much as quillback.

Quillback rockfish are known from the Gulf of Alaska to Anacapa Passage in southern California, and are considered common between southeast Alaska and northern California. They are found from near the surface to a depth of 900 feet and can be common at depths of several hundred feet.

Like other *Sebastes* of shallow, benthic habit, individual quillback rockfish are not known to range far. Tagging studies in central California and Washington have shown quillback to be residential (no movement) or to show movement of less than six miles. They have also demonstrated homing ability and day-night movement patterns.

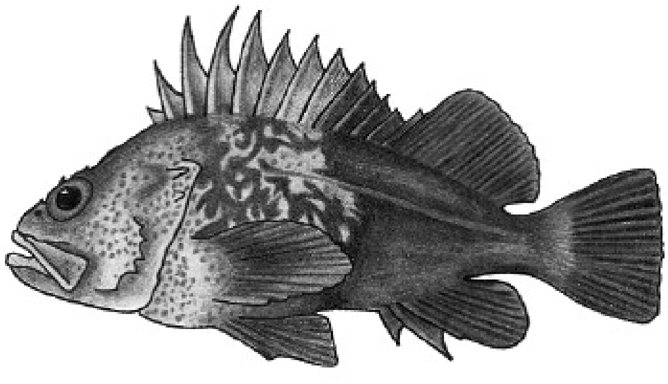
In California, quillback rockfish have been aged to 15 years, but are known to live longer, as they have been aged to 76 years in Canada. Quillback can grow to 24 inches, and growth rates differ along its range. In California, size for a 12-year-old quillback is approximately 7.1 inches. Size at first maturity for males is 8.7 inches (four years), and for females is 10.2 inches (six years). In California, size at 50 percent maturity for males and females was found to be the same as for first maturity.

As with all *Sebastes*, quillback have internal fertilization and produce live young. In California, mating takes place in the late winter and early spring, with birth occurring from April through July. After roughly one to two months in the plankton (0.7 to 2.8 inches), they begin to settle near shore.

As planktonic larvae and after they settle, quillback rockfish feed on other planktonic animals and eggs. As adults they feed on a variety of prey such as crustaceans, especially shrimps; small fish, including rockfishes and flatfishes; clams; marine worms; and fish eggs.

Quillback rockfish larvae are subject to predation by jellyfish and arrow worms. As juveniles, they are preyed upon by fishes, including larger rockfishes, lingcod, cabezon and salmon. Various marine birds and pinnipeds eat juvenile quillback as well. Adults are also subject to predation by larger fishes including some sharks, as well as sea lions, seals, and possibly, river otters.

Juveniles inhabit very nearshore bottom areas and are found over both low and high rocky substrate. They are sometimes found among sponges and algae that provide shelter. Adults are most often found in deeper water and are solitary reef-dwellers living in close association with the bottom. They are often seen perched on rocks or taking shelter in crevices and holes. Adults have also been noted to retreat to eelgrass beds at night. Quillback



Quillback Rockfish, *Sebastes maliger*
Credit: L. Sinclair Miller and Lea

are also associated with the rock-sand interface, but are rarely seen in the open away from suitable cover.

Status of the Population

While no stock assessment has been done for quillback rockfish in California, length-frequency data exist on their occurrence in the recreational fishery in northern and central California, as well as in the commercial fishery from the same region. Between the late 1980s and mid-1990s, quillback rockfish experienced increased take by the commercial fishery as the market demand for premium, live fish increased, yet no significant trend was noted in the average size of fish. Fishing pressure has relaxed somewhat in recent years because of restrictions placed on the fishery. Concern over sustainability of the commercial and recreational nearshore fishery has made this species of particular interest to managers.

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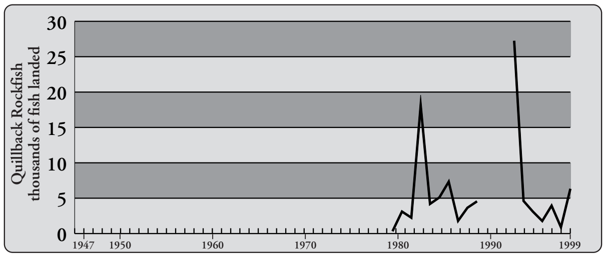

Recreational Catch 1947-1999, Quillback Rockfish
Data Source: RecFin data base for all gear types; data not available for 1990-1992

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Calico Rockfish

History of the Fishery

Calico rockfish (*Sebastes dalli*) are taken in the southern and central California sport fisheries for nearshore rockfishes. During the 1980s, the estimated annual calico rockfish sport catch averaged 8,900 fish with a high of 21,000 fish taken in 1985. An onboard study of the southern California commercial passenger fishing vessel (CPFV) or partyboat fishery from 1985 through 1987, ranked calico rockfish among the top 20 species taken during two of the three years surveyed. The same study also showed that CPFV anglers discarded large numbers of calico rockfish at sea each year in a practice commonly known as "high grading." In high grading, only the largest fish were retained by anglers as part of their bag limits, and the smaller fish were selectively discarded. For calico rockfish, the estimated number of discards on CPFVs exceeded the number of calico rockfish that were kept by anglers each year. This illegal practice has been widespread at times in the past and has been difficult to curtail. A more recent estimate of annual California sport catches of calico rockfish averaged 5,700 fish per year between 1993 and 1999, with a high of 8,000 calico rockfish caught in 1995 and in 1998.

Calico rockfish comprise a very minor portion of the state's commercial catch. Their small size and scattered distribution probably preclude them from being targeted. Calico rockfish, however, may be one of several small rockfish species, including squarespot, honeycomb, halfbanded and starry rockfishes, that are caught and subsequently discarded at sea as an unmarketable bycatch in nearshore hook-and-line, trap, or trawl fisheries. The quantity of calico rockfish bycatch in these fisheries is currently undetermined.

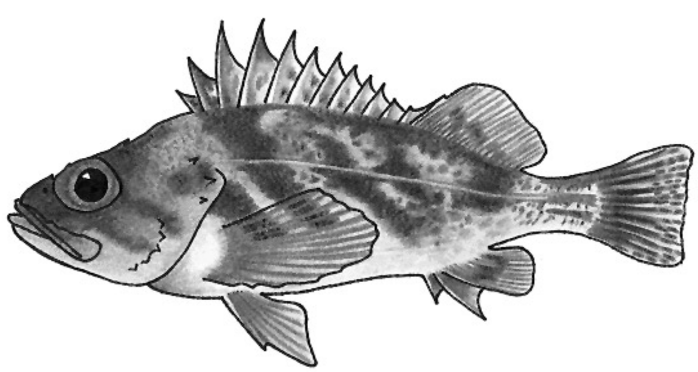
Status of Biological Knowledge

Calico rockfish range from Sebastian Viscaino Bay, Baja California to San Francisco within a depth range of 60 to 840 feet. They are small, colorful rockfish that inhabit nearshore areas of southern and central California. Calico rockfish are distinguished by having a greenish yellow background color overlaid with dark-brown oblique bars on the side, and a black spot on the edge of the gill cover. Juvenile calico rockfish are found in areas of soft sand-silt sediment, and on artificial reefs. Adults inhabit rocky shelf areas where there is a mud-rock or sand-mud interface with fine sediments. They are usually associated with structures that provide vertical relief and sheltered habitat, including artificial reefs. The main diet of calico rockfish is pelagic crustaceans, including calanoid copepods. They are preyed upon by larger rockfish species, lingcod, cabezon, and salmon. Sea birds, sharks, and dolphins have also been known to feed on juvenile and adult calico rockfish.

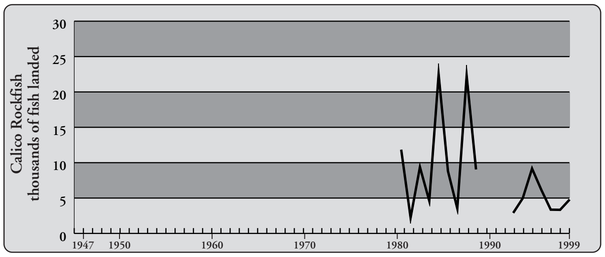
Calico rockfish up to 10 inches long and 1.25 pounds in weight have been measured. They have been aged to between 11 and 12 years. Male calico rockfish first become sexually mature at age seven and females reach sexual maturity at age nine. Spawning occurs in southern California between January and May, with peak spawning activity occurring in February. Fertilized eggs are present in November and December. The range of fecundity observed for calico rockfish was 1,700 to 18,000 eggs per female. The pelagic larval stage lasts from one to two months, and the post-larvae then settle out of the plankton between 0.08 and 0.1 inches in length.

Status of the Population

There are currently no estimates of abundance for calico rockfish in California. There were more calico rockfish landed annually by sport anglers in the 1980s than in the 1990s, which may have been a reflection of the abundance of that species during two strong El Niño events that occurred in the 1980s. Whether the reduced calico rockfish catch during the 1990s was a result of changing oceanic conditions or was due to actual depletion of calico rockfish stocks by sport and commercial fisheries is not known. Because of the relatively small size of adult calico rockfish, they are not usually targeted by either sport or commercial fishermen but are caught incidentally when other finfish species are targeted. Calico rockfish appear as bycatch in prawn trawls and other nearshore fisheries in southern California and are caught by sport anglers on CPFVs and private boats when they are fishing for other, larger benthic species.



Calico Rockfish, *Sebastes dalli*
Credit: L. Sinclair, Miller and Lea



Recreational Catch 1947-1999, Calico Rockfish
Data Source: RecFin data base for all gear types; data not available for 1980 & 1990-1992

Management Considerations

See the Management Considerations Appendix A for further information.

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Monkeyface Prickleback

History of the Fishery

The monkeyface prickleback (*Cebidichthys violaceus*) is a nearshore fish that is a minor component of the recreational and commercial catch. It is frequently referred to as monkeyface eel and blenny eel due to its eel-like appearance. However, it is more closely related to bass-like fishes (Perciformes) than to true eels. It is a member of the prickleback family, Stichaeidae, of which 17 species occur in California. Its elongate body shape is an adaptation for living in cracks, crevices, and under boulders, primarily in the intertidal zone. Monkeyface prickleback have been found in coastal Indian middens of California along with cabezon and rockfishes and were undoubtedly exploited as a food resource in historic and prehistoric times.

A specialized recreational fishery by shore anglers fishing in rocky intertidal and shallow subtidal habitat exists for this species. The most common fishing method is "poke poling," which normally consists of fishing with a long bamboo pole, a short piece of wire, and a baited hook. The bait is placed in front of or in holes or crevices in the rock. Skin and scuba divers also spear them.

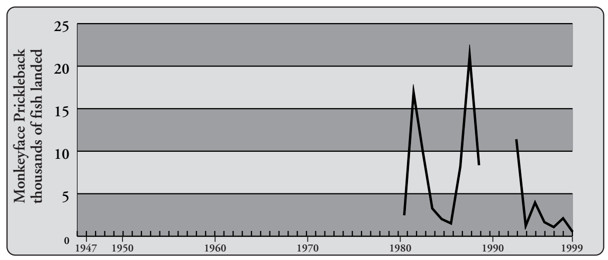
The monkeyface prickleback did not rank among the top fifteen species observed in either beach/bank or jetty/breakwater fishing categories in a 1980 through 1986 Marine Recreational Fisheries Statistics Survey (MRFSS) in California. The most recent (1999) MRFSS total catch estimate for northern California from all recreational fishing categories was 2,000 fish; however, the standard error of the estimate was much higher than the estimate.

Commercial landing records in California date from 1928. Catch since then can best be described as of minor significance. Since 1991, annual landings have ranged from 12 to 935 pounds, primarily from the port areas of San Francisco and Santa Barbara. However, catch statistics may include California moray, rock prickleback, wolf-eel, and other eel-like fishes or true eels.

Status of Biological Knowledge

The monkeyface prickleback ranges along the Pacific coast from San Quentin Bay, Baja California, Mexico to central Oregon. It is most common off central California from San Luis Obispo County to Sonoma County, and is uncommon south of Point Conception. They normally occur in the intertidal zone with a depth range extending from the high intertidal to a reported depth of 80 feet. Typical habitat for monkeyface prickleback includes rocky intertidal areas with ample crevices, boulders, and algal cover, including high and low tide pools, jetties and breakwaters, and shallow subtidal areas, particularly rocky reefs and kelp beds. Juveniles are particularly adapted for living in the high intertidal zone. The species is capable of living out of water under algae for extended periods and has air-breathing capacity. It is considered to be a residential species, moving short distances from crevices or under rocks to foraging sites. It appears to occupy a small home range of several meters and is primarily active during periods of a flooding tide.

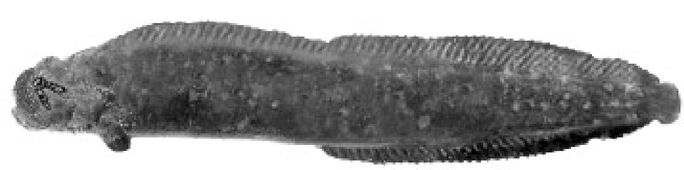
The coloration of the species is a uniform light brown to dark green, often with several rust-colored blotches on the sides of the body. Two dark stripes radiate behind the eye. Adults have a lumpy ridge on top of the head. The coloration of both sexes is similar.



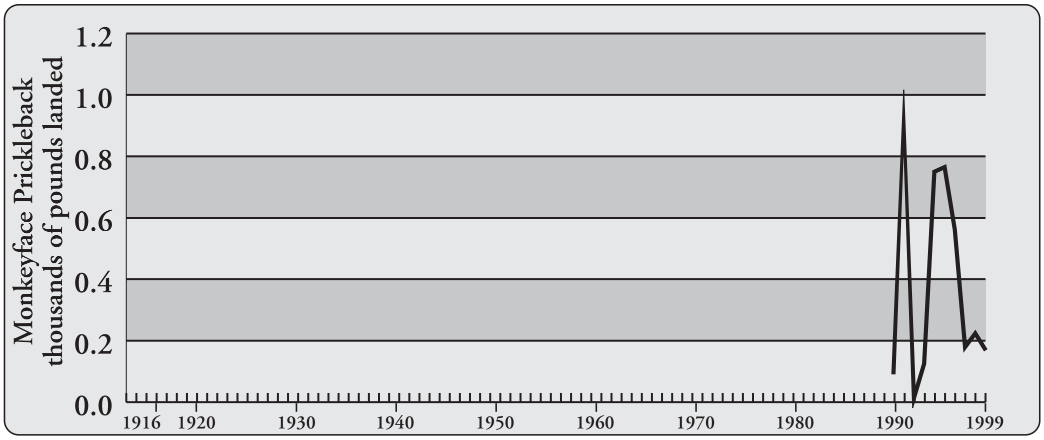
Recreational Catch 1947-1999, Monkeyface Prickleback
Data Source: RecFin data base for all gear types; data not available for 1990-1992

Monkeyface prickleback grow slowly, particularly after the first few years of life. A 12-inch fish is approximately three years old, while a 24-inch fish will be 15 to 17 years old. Monkeyface prickleback have been aged to 18 years using the otolith and opercular bone, but the largest specimens have not been aged. The maximum reported size is 30 inches in total length; 18 to 24 inch individuals are not uncommon.

Information available on age at sexual maturity suggests that both sexes begin to mature in their third or fourth year at a total length range of 11.0 to 14.2 inches, while 50 percent maturity occurs at approximately 15.4 inches at five years of age. Fertilization is internal and spawning activity occurs from January to May, with the peak spawning period from February to April. Females are oviparous, depositing their eggs on subtidal, rocky surfaces. Fecundity is known to range from 17,500 eggs for a 16-inch, seven-year old fish to 46,000 eggs for a 24-inch, 11-year-old fish, with smaller fish producing fewer eggs. Nest guarding behavior has been observed but it is unclear



Monkeyface Prickleback, *Cebidichthys violaceus*
Credit: PSMFC



Commercial Landings 1916-1999, Monkeyface Prickleback
No commercial landing are reported for monkeyface prickback prior to 1990. Data Source: DFG Catch Bulletins and commercial landing receipts.

if the female, male, or both sexes guard the egg mass. Larval length at hatching is unknown; larvae begin to settle out of the plankton at 0.7 to 0.9 inches.

The diet of monkeyface prickleback shifts from carnivorous to herbivorous with an increase in size. As early juveniles, up to 3.1 inches, prey items are predominantly zooplankton and include copepods, amphipods, isopods, mysids, and polychaetes. At approximately three inches, they then become almost exclusively herbivorous. Over sixty species of algae have been recorded as food items. Despite this wide array, they appear to feed selectively on eight to 10 species of red and green algae, mostly in the genera *Ulva, Porphyra, Mazzaella, Microcladia,* and *Mastocarpus*. Adults appear to prefer annual red and green algae to perennial red algae. This preference is determined to some degree by ocean season and availability.

Predators of monkeyface prickleback include piscivorous birds, such as great egrets and red-breasted mergansers, and fishes such as cabezon and grass rockfish. Predation is primarily on the earlier life stages of this species; large juveniles and adult fish most likely evade or outgrow these predators.

Other intertidal boulder and crevice-dwelling eel-like fishes, such as the rock and black pricklebacks and penpoint and rockweed gunnels, are possible competitors with monkeyface prickleback for space and food resources.

Status of the Population

No information is available on the status of stocks of monkeyface prickleback. The primary source of fishing mortality is from recreational poke polers and commercial anglers fishing from shore or the shallow subtidal, with a lesser number taken spearfishing by free and scuba divers. Historically, both recreational and commercial landings are considered to be low.

Management Considerations

See the Management Considerations Appendix A for further information.

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Kelp Greenling

History of the Fishery

Kelp greenling (*Hexagrammos decagrammus*) are fished primarily for sport. The commercial fishery has historically been based largely on catch incidental to the lingcod or nearshore rockfish fisheries, although their importance in the commercial catch has increased since 1997 with the emergence of a nearshore "live" fish fishery. Because of their abundance in nearshore rocky areas, they are frequently caught by people fishing from shore or small boats and are a common target for spear fishermen underwater. Sport fishing surveys made from 1958 to 1961 showed that kelp greenling were the most frequent catch of shore fishermen north of San Francisco, where in some areas they made up more than 30 percent of the total catch. In California, during those years, an average of 54,000 kelp greenling were caught by hook-and-line fishermen and another 2,000 by spear fishermen. In later surveys conducted from 1980 to 1999, the estimated sport catch averaged 106,650 fish per year, with 103,000 of those taken between Monterey County and the Oregon border. It should be noted that the two sport fishing surveys used different sampling designs, so results may not be comparable. By comparison, the commercial catch reported from 1981 to 1999 averaged about 8,500 fish per year. This average is somewhat exaggerated by exceptionally large numbers of fish landed commercially in recent years by the nearshore live fish fishery mentioned above. From 1981 to 1996 average commercial catch was only around 5,500 fish per year, while from 1997 to 1999 that average increased to 27,400 fish per year. Until recently most of these fish were sold in the fresh-fish market, although now many are sold live to restaurants. Though fillets from kelp greenling are not as large as those from their more popular relative, the lingcod, texture and taste are comparable.

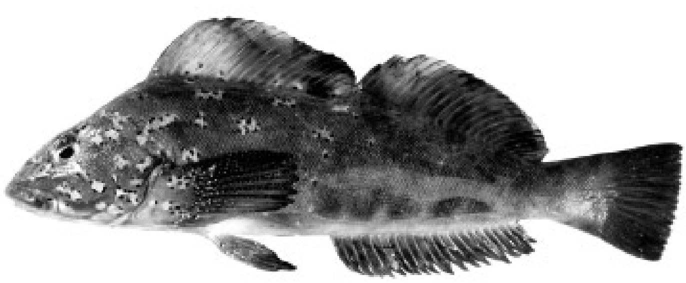
Status of Biological Knowledge

Kelp greenling range from San Diego to the Aleutian Islands, but are common only north of Morro Bay. Here they are one of the most conspicuous fishes in rocky nearshore habitats occurring often in and around kelp beds. The male and female look so different that they were first described as separate species. The body color is variable in both sexes, ranging from light gray to brown. Males, however, have large irregular blue patches anteriorly, while females are uniformly covered with smaller dark spots.

These solitary fish are common at depths between 10 and 60 feet, and range down to 150 feet. Sport catches indicate that larger fish live in deeper water. For example, fish caught at 80 to 100 feet range from 12 to 18 inches long while those caught at 20 to 40 feet tend to be eight to 13 inches long. Kelp greenling grow faster than most nearshore fishes during their first three years. After the third year, growth slows, especially in males (as it does in lingcod), so that by the fifth or sixth year males are smaller than females. The maximum reported age and size is 16 years and 21 inches. At age three, males average 10.6 inches and females 9.1 inches. By age five, the males average 12.6 inches while females are 14.7 inches. Ten-year-olds average 15.5 and 16.4 inches, respectively. These data are from Puget Sound, Washington.

The reproductive behavior of greenling is similar to that of the lingcod. Females are mature by their fourth year and spawn adhesive egg masses on the sea bed and encrusting biota within the territories of courting males. In Puget Sound, females deposit egg masses that range from golf-ball to tennis-ball size, with an average of about 4,000 eggs per cluster. Females are batch spawners, capable of producing multiple clutches of eggs per spawning season. Males fertilize the eggs and guard the nests until larvae about one third of an inch long emerge four to five weeks later. Often, males guard more than one egg mass at a time, each possibly produced by a different female. Studies done in British Columbia and California showed some nests did contain egg masses from multiple females. Hatching occurs from December through February in northern California and gets progressively earlier to the north, November through January in Puget Sound and August through September in Alaska. Larvae and early juveniles feed on small copepods and spend about one year in the pelagic environment before entering the nearshore benthic community.

After they settle in the nearshore environment, kelp greenling have flexible food habits. During most of the year, they consume a variety of prey that are consistently available in the habitat, including crabs, amphipods, polychaetes and ascidians. There are brief periods when organisms such as juvenile fishes or herring spawn become exceptionally abundant, and kelp greenling shift their food habits to take advantage of these opportunities.



Kelp Greenling, *Hexagrammos decagrammus*
Credit: DFG

The primary predators of adult greenling are lingcod and harbor seals. As juveniles they are probably prey to many nearshore predators.

Status of the Population

There are no estimates of abundance for kelp greenling in California. The yearly sport catch remained relatively constant during the first ten years (1980-1989) it was surveyed, but has declined steadily from 1993 to 1999. Since decline in catch is one symptom of overfishing, this may be an indication that current levels of fishing are having adverse effects on the population, although no population data are available at present to confirm this. Spear fishermen could overfish local populations, however, because they can select individual targets, and greenling are particularly vulnerable to spears when guarding their nests. Also, although commercial catch has been traditionally very low compared to recreational catch, the increased fishing pressure in recent years by the nearshore live fish fishery could have a much broader impact on the kelp greenling population in California.

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National Marine Fisheries Service

Revised by:
Kelly R. Silberberg
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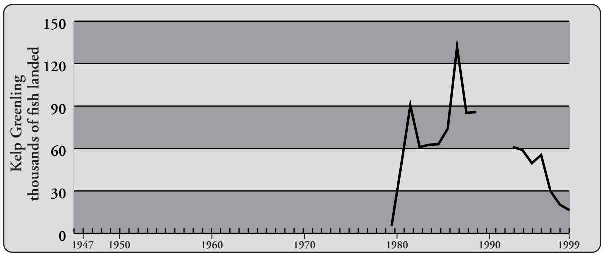

Recreational Catch 1947-1999, Kelp Greenling
Data Source: RecFin data base for all gear types; data not available for 1990-1992

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Other Nearshore Rockfishes

History of the Fishery

Historically, many of the nearshore rockfishes have been taken primarily by recreational anglers fishing from boats, the shore, or by diving. Kelp rockfish (*Sebastes atrovirens*), gopher rockfish (*Sebastes carnatus*), black-and-yellow rockfish (*Sebastes chrysomelas*), China rockfish (*Sebastes nebulosus*), grass rockfish *(Sebastes rastrelliger*), and treefish (*Sebastes serriceps*) have been minor components of recreational and commercial fisheries. Gopher rockfish is the only species of these six that comprised a significant proportion of recreational landings and was common enough in commercial landings to have a market category prior to 1994. Gopher rockfish have comprised up to 13 percent annually of commercial passenger fishing vessel (CPFV) observed landings from the Morro Bay area. A review of the marine recreational fishery statistics survey (MRFSS) catch data from 1980 to 1999 indicated recreational catches of grass rockfish, China rockfish, gopher rockfish and kelp rockfish have declined since the late 1980s and landings of treefish were higher from 1993 to 1999 than 1980 to 1989. While the MRFSS provides catch information for shore and vessel-based angling, divers are not represented. The "private/rental boat" method contributed the highest proportion of the gopher rockfish recreational catch for all of California. China rockfish have accounted for up to three percent of CPFV observed catches from San Francisco north. Both China rockfish and gopher rockfish are most frequently observed in CPFV and private boat catches. Grass rockfish, kelp rockfish, black-and-yellow rockfish and treefish are more frequently caught by anglers fishing from private boats than by anglers fishing from CPFVs or from shore.

Development of the live/premium fishery in the late 1980s resulted in increasing commercial catches of many species occupying the nearshore environment in and around kelp beds, including these six rockfishes. Live fish are taken primarily by line gear and pot and trap gear, but other gear types are used. The fishery serves mainly Asian American markets that demand top quality (live) fish. Fishermen receive premium prices for their catches ranging from $2 to $10 per pound, compared to $1.50 per pound or less previously. Grass rockfish command the highest prices up to $4.84 average price per pound in 1998. With the exception of treefish, these nearshore rockfish species are caught primarily north of Point Conception.

Historically, commercial landings have been recorded by both specific (gopher rockfish) or nonspecific (gopher group) market categories and until 1994 there were no specific market categories for any of these nearshore species except gopher rockfish. Annual total landings by species are difficult to determine due to the inexact nature of recording landings. Market categories are often comprised of multiple species; for example, sampled market categories from the Morro Bay area from 1993 to 1998 revealed a wide range of placement of the six species in both group and single species categories. Gopher and grass rockfish appeared most frequently in nine other market categories than their own. The most common classification error seemed to occur between gopher and black-and-yellow rockfishes with 34.4 percent of the black-and-yellow market category being made up of gopher rockfish. The gopher group contained up to 61 percent gopher rockfish. While species misidentification does occur, fish are often grouped by price rather than by species complicating specific landing estimates. Based on DFG CMASTER summaries of reported landings, landings of gopher and grass rockfishes and the gopher group peaked at 31,255 pounds ($35,740 value) in 1994, 109,003 pounds ($506,670) in 1995, and 221,018 pounds ($521,163) in 1996, respectively.

The live fish market demand is mainly for fish in the one to two pound size range, and up to four pounds for grass rockfish. For gopher, black-and-yellow, grass, and China rockfishes, this size range is above the size of sexual maturity, although in the development of the fishery all fish were kept regardless of size. Due to concerns over the harvest of immature fish, legislation passed in late 1998, the Marine Life Management Act, implemented minimum commercial size limits on grass, gopher, kelp, black-and-yellow, and China rockfishes. The new size limits are 12 inches for grass and China rockfishes, and 10 inches for gopher, kelp, and black-and-yellow rockfishes. The shallow, nearshore nature of this fishery renders it very weather dependent. Poor weather, combined with lower overall allowable catches, implementation of minimum size limits, and a lack of a market north of Bodega Bay resulted in reduced catches from 1997 to 1999.

Several of these species are also important in non-consumptive uses. Colorful, accessible, or both, treefish and

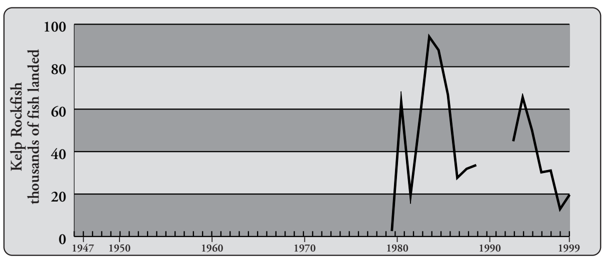
Gopher Rockfish, *Sebastes carnatus*
Credit: DFG

kelp, black-and-yellow, gopher, and China rockfishes are frequently observed and photographed by divers. In addition, individuals are taken for the aquarium trade.

Status of Biological Knowledge

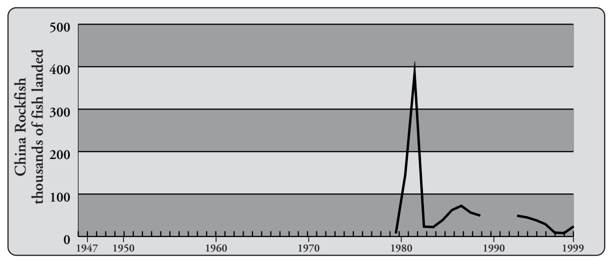
Kelp, black-and-yellow, gopher, and grass rockfishes are relatively well studied, while treefish and China rockfish are, to differing degrees, less well-known. Most of these species occupy restricted ranges of geography or habitat. The treefish is most common in depths of less than 100 feet or so on rocky reefs, and is restricted largely to the region south of Point Conception. Kelp, black-and-yellow, and gopher rockfishes are not abundant north of Sonoma County (or farther south, for kelp rockfish), and range south to the region of Point Eugenia, Baja California. Each has a restricted habitat, with kelp rockfish occurring almost exclusively in kelp forests, black-and-yellow rockfish occurring in high-relief rocky bottom at depths shallower than about 60 feet, and gopher rockfish occurring on rocky reefs from 40 feet to perhaps 150 feet. The geographical range of the grass rockfish extends throughout California and into southern Oregon, but its habitat is restricted to rocky areas shallower than about 20 feet.

The China rockfish is abundant into Washington, British Columbia, and southeastern Alaska, declining in abundance south into California. It is quite rare south of Point Conception, and seems to inhabit progressively deeper water in the southern part of its range. The ranges for some of these species have changed in the last 15 to



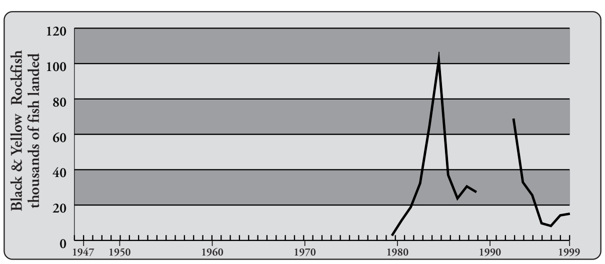
Recreational Catch 1947-1999, Kelp Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992



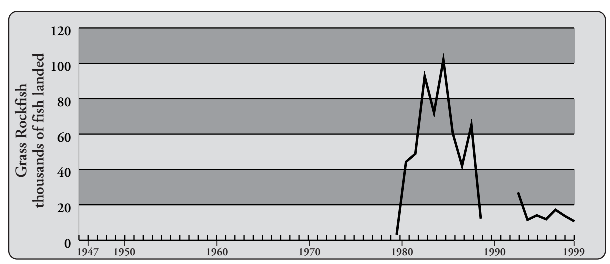
Recreational Catch 1947-1999, China Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992



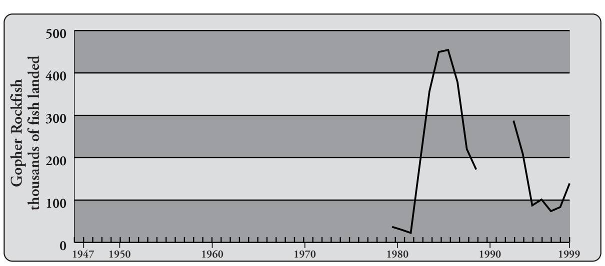
Recreational Catch 1947-1999, Black & Yellow Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992



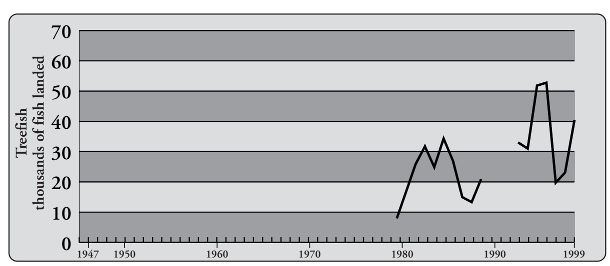
Recreational Catch 1947-1999, Grass Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992



Recreational Catch 1947-1999, Gopher Rockfish

Data Source: RecFin data base for all gear types; data not available for 1990-1992



Recreational Catch 1947-1999, Treefish

Data Source: RecFin data base for all gear types; data not available for 1990-1992

20 years. Black-and-yellow rockfish and kelp rockfish abundance have declined since the early 1970s in the northern Channel Islands, and probably throughout the Southern California Bight. Little has been documented on northward range expansion for these species, and nothing has been documented regarding changes in the ranges of gopher, China, and grass rockfishes. The treefish seems to be more abundant now in the Monterey area than in the 1980s. These changes in distribution seem to be related to ocean warming that began in 1977.

Five of the six species are relatively small for rockfish. The grass rockfish, at about 20-22 inches, reaches the largest size of the six species. The largest individuals of the other five species rarely exceed 15-17 inches; among the five, the China rockfish reaches slightly larger sizes than the others, followed in rough order by treefish, kelp rockfish, gopher, and black-and-yellow rockfishes. Treefish have not been aged, but at least one study of age and growth has been conducted on kelp, black-and-yellow, gopher, grass, and China rockfishes. The greatest ages recorded in each of these five species are between 20 and 26 years. However, because the largest individuals observed in each species have typically not been aged and because aging to date has been based largely on readings of whole otoliths, greater maximum ages may be possible. Different studies have produced different estimates of age at first maturity, perhaps because of differences in goals and methodology. In the five species that have been aged, many studies suggest that first maturity occurs in the range of three to four years, although one study indicates later maturity.

Treefish and kelp, black-and-yellow, gopher, and China rockfishes appear to reproduce once per breeding season. Grass rockfish may reproduce only once per season, but some contradictory data exist. There are no data on spawning seasonality in treefish, but the other five species appear to spawn in winter through spring. Grass rockfish seem to reproduce the earliest, giving birth primarily in December through February (except for an observation in August), China rockfish reproduce slightly later, black-and-yellow and gopher rockfishes slightly later still (spawning through early spring), and kelp rockfish the latest, spawning through May and June.

The adult movement of most of these species may be even more restricted than other rockfishes. Individual black-and-yellow, gopher, and kelp rockfishes have been shown to inhabit restricted home ranges, and it is likely grass rockfish, China rockfish, and treefish share this behavior. Aggressive behavior has been observed in all except grass rockfish (for which observations are limited), and gopher rockfish and black-and-yellow rockfish are definitely territorial. However, some evidence from artificial reefs suggests that typically sedentary individuals may occasionally wander indeterminate distances, on the order of tens of meters, from their home ranges.

Available data suggest that diets of juvenile fish of all six species include primarily crustacean zooplanktors such as barnacle cyprids. Overall adult diets are more varied. Crustaceans and small fish are common diet items for adult fish of all six species. Kelp rockfish also eat cephalopods, gastropods, polychaetes, and tunicates. Cephalopods and gastropods are consumed by gopher rockfish as well, along with ophiuroids (brittle stars) and polychaetes. Black-and-yellow rockfish and China rockfish also consume ophiuroids. A variety of mollusks are consumed by China rockfish including cephalopods, gastropods, chitons, and nudibranchs. Small fish consumed by these rockfishes include juvenile rockfish (mainly blue rockfish), sculpins, juvenile surfperch, kelpfishes, and plainfin midshipman. Information on diet of treefish is limited.

Status of the Populations

While there have been several studies of local abundance in some of these species (particularly black-and-yellow, gopher, and kelp rockfishes), there is no comprehensive assessment of their populations. Each species is probably subject to local depression in abundance and average size where diving, skiff fishing, party boat activity, or commercial fishing is concentrated. The low fecundity, restricted habitats, and limited movements of these species make them vulnerable to local fishing pressure. Statewide, the limited geographic ranges and restricted habitats of these species suggest that they have small populations in comparison to more widespread species that have traditionally been the targets of commercial fishing. These species have limited depth distributions so that all of the spawning population is vulnerable to fishing and few natural refugia probably exist. Because good recruitment years are infrequent there is the danger of removing too many spawners even with limited fishing pressure.

Management Considerations

See the Management Considerations Appendix A for further information.

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Vermilion Rockfish

History of the Fishery

Vermilion rockfish (*Sebastes miniatus*), though highly desirable because of their brilliant color and the flaky texture of their flesh when cooked, are only of moderate importance in California's commercial and sport fisheries.

It is difficult to accurately determine what percent of the commercial catch is comprised of vermilion rockfish, because individuals in reported landings are often misidentified or combined with other red and orange-colored rockfishes in the market category of "rockfish, Group Red." From 1991 to 1993, vermilion rockfish landings were less than 2,000 pounds annually, statewide. This may be in part because, prior to 1994, there was no printed market category for vermilion rockfish on landing receipts; thus, they were only designated by species when fishermen added the category. Since 1994, "Rockfish, vermilion" has been a printed market category on landing receipts. From 1994 to 1999, pounds landed for both market categories progressively declined. During this period annual landings quotas became more restrictive. Commercial landing in the San Francisco area in 1994 and 1995 accounted for 59 percent of statewide landings. From 1996 through 1998, this percentage declined to 44, 28, and 17, respectively. From 1996 through 1998, the Eureka area reported the highest landings within the state (54 percent average for the three-year period).

Vermilion rockfish comprised less than two percent of all landed fishes observed on commercial passenger fishing vessels (CPFV) from Fort Bragg to Monterey from 1992 through 1995. During this same period, they constituted between six and eight percent of all landed fishes observed on CPFVs from Port San Luis and Morro Bay and averaged 14 inches in length. Along lightly fished areas of the central coast, fish of comparable size comprised eight percent of the total CPFV catch. Fish taken north of Monterey by CPFV anglers were slightly larger on average. In a survey of southern California CPFVs from 1985 through 1987, vermilion rockfish ranked third in species composition and represented eight percent of the total observed rockfish catch. Between 1983 and 1988, they ranged from two to five percent of the observed commercial catch of rockfish landed south of Point Conception.

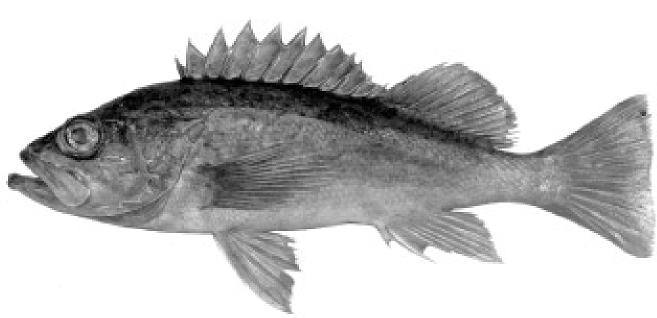
The average size of observed vermilion rockfish taken by recreational hook-and-line anglers fishing from Point Piños to Yankee Point in Monterey County, based on creel surveys at the Monterey Harbor, declined from 1981 to 1999. The average size was 18.8 inches in 1981, 16.1 inches in 1983, 15.5 inches in 1985, and 14.3 inches in 1987. In 1999, the average size rose to 15.5 inches.

Vermilion rockfish are marketed primarily in a fresh dressed form. Because the flesh has a short freezer life, it is rarely frozen. These rockfish are best when filleted, skinned, and deep-fried. They are also delicious when baked with vegetables in the oven or microwave. As with most other members of the family, the flesh is white, fine in texture, and mild in flavor.

Status of Biological Knowledge

Vermilion rockfish are found from the San Benito Islands, Baja California, to Prince William Sound, Alaska, and occur over rocky bottoms from the shallow subtidal to 1,400 feet. Large fish are more common at depths greater than 100 feet due to the combined fishing pressure in shallower waters from commercial and recreational fishermen. Vermilion rockfish generally remain on the same reef system on which they settle during their first year. Tagging studies have shown no movement of fish at liberty for one to three years. Vermilion rockfish are extremely long-lived. A 20-inch individual weighing 5.4 pounds was aged, using surface aging, at 25 years. Lengths up to 30 inches have been reported. Vermilion rockfish have lengthy juvenile life stages. Fifty percent of the population is mature at eight years and these fish average 14 inches. The slow growth and long juvenile period make vermilion rockfish very susceptible to overfishing. Once large individuals are removed from a reef system they are replaced only by larval settlement.

Peak spawning months are September in central and northern California and November in southern California. The number of developing eggs increases from 63,000 in a fish 12.5 inches long to about 1.6 million in a 21.5-inch fish. Females are fertilized internally by males. In October of 1997, while conducting population scuba surveys of subtidal fishes in Point Lobos Ecological Reserve, Monterey County, California, several vermilion rockfish courtship displays were observed and videotaped by divers from California Department of Fish and Game. The absence of previously published description of vermilion rockfish mating or courtship may be due to the scarcity of mature individuals in habitat shallow enough to allow routine observations. Newly released larvae are free swimming and lead a pelagic existence for three to four months,



Vermilion Rockfish, *Sebastes miniatus*
Credit: DFG

mers and tend to be very secretive, often taking refuge in dense algae.

The pelagic young of vermilion rockfish feed primarily upon crustaceans, while adults feed on octopus, squid, and small fishes such as anchovies and blue lanternfish. At times, macroplanktonic organisms such as euphausiids, pelagic red crabs, and pyrosomes (pelagic colonial tunicates) are found in their stomachs.

Status of the Population

In 1995, mean total length of observed vermilion rockfish taken during CPFV trips in central and northern California were consistently above the size of sexual maturation. Larger individuals and higher catch per-angler-hour were generally observed when fishing occurred in deep water and greater than 10 nautical miles from ports. Based on adjusted logbook data from San Simeon, Port San Luis, and Morro Bay, an estimated 23,000 vermilion rockfish were landed by CPFV anglers in 1995. This total is 2.7-fold higher than the combined estimate (8,530) from the remaining central and northern California ports.

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Lingcod

History of the Fishery

The lingcod (*Ophiodon elongatus*) has long been an important source of food for people living along the West Coast of North America, although current catches are low due to overexploitation of the stock. Archaeological studies of native American habitations along the central California coast indicate that between 6200 BC and AD 1830, large inshore species such as rockfishes, lingcod, and kelp greenling comprised more than half of the fishes caught on the open coast. American Indians used spears, nets, weirs, traps, and lures of wood with bone hooks to catch lingcod. Early Caucasian settlers caught lingcod as well. Fishing methods in the 1800s were similar to the hook-and-line techniques currently used to catch lingcod in the small boat jig fishery.

Catches of lingcod have been reported as a separate category since 1916 in California. Commercial landings from 1916 through 1929 ranged from 400,000 pounds to 1.2 million pounds. Landings in the first half of the century reached a peak in 1930 at 1.3 million pounds, and then declined to a low of 314,000 pounds in 1942. The California lingcod fishery grew again from 1943 through 1950, as landings ranged from 719,000 pounds to a high of 2.1 million pounds in 1948, due primarily to strong markets for liver oil and seafood. For the next two decades, landings averaged 1.2 million pounds per year, and then began to increase in the 1970s, due to the burgeoning west coast trawl fishery.

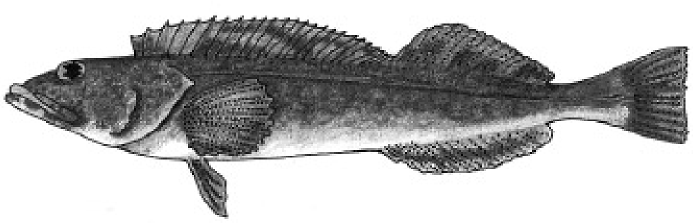
During this period of rapid fishery growth, lingcod landings in California almost tripled. From 1972 through 1982, commercial landings of lingcod averaged almost three million pounds per year. After a decline in the mid-1980s, landings rebounded to a high level again in 1989. Since then, however, commercial catches have rapidly declined, partly due to management restrictions enacted to rebuild depressed stocks. In 1999, commercial landings were only 313,000 pounds, valued at $283,000.

The character of lingcod fisheries has changed greatly in the past 30 years. In the 1970s, about 85 percent of the commercially landed lingcod were caught with trawls; however, hook-and-line gear now account for half of the commercial landings. In addition, the recently developed nearshore fishery that delivers live fish to markets and restaurants landed an average of more than 40,000 pounds per year in the 1990s. There has also been a shift in the lingcod fishery away from commercial and towards recreational catches. Recreational landings as a percentage of total lingcod landings increased from 20 percent in the 1970s to about 50 percent in the late 1990s. This was because recreational fishing effort in California increased by 65 percent between the time periods 1958 through 1961, and 1980 through 1986. Average annual landings in the California recreational fishery almost doubled during that period, from 510,000 pounds per year to 890,000 pounds per year. The increase was due largely to an increase in the private boat fishery. In 1961, 61 percent of the recreational landings came from commercial passenger fishing vessels. Now, 70 percent of the recreational landings come from the private boat fishery. In both the commercial and recreational fisheries, landings occur predominately in central and northern California.

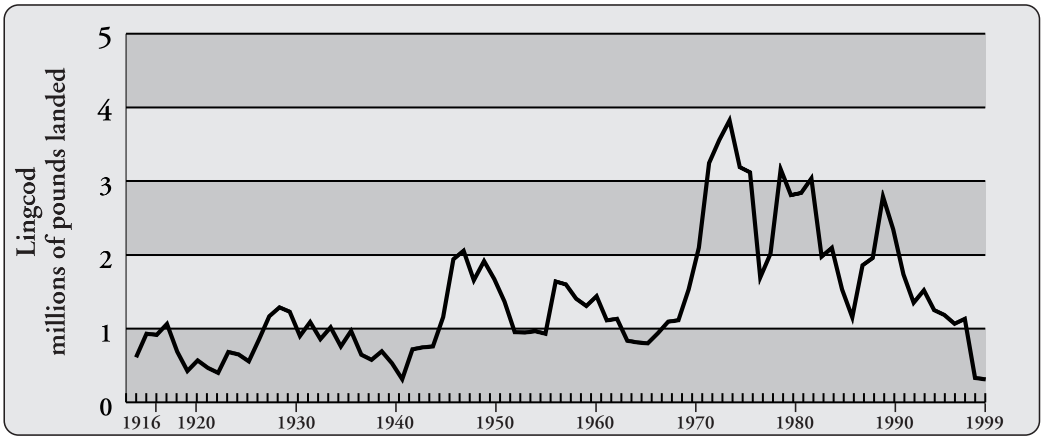
Stock assessments conducted by the Pacific Fishery Management Council (PFMC) have indicated large population declines for lingcod along its entire range. For the management areas that include California and Southern Oregon (the Eureka, Monterey, and Conception management areas), the current estimate of female spawning biomass is 13 percent of the unfished level. Consequently, fishery regulations have become more stringent, as fishery managers try to rebuild the stock.

With the implementation of the PMFC's Groundfish Plan in 1983, the combined Acceptable Biological Catch (ABC) for the Eureka, Monterey, and Conception management areas was 4.8 million pounds, or more than 1.5 million pounds higher than the commercial landings. In 1995, the combined quota for these areas was reduced by about 50 percent, and a 22-inch commercial size-limit was instituted. A monthly commercial boat-limit of 20,000 pounds per month was established along with a trawl trip-limit of 100 pounds under the 22-inch size-limit. By 2000, the combined ABC for the Eureka, Monterey, and Conception International North Pacific Fisheries Commission (INPFC) areas was reduced in half again to less than 1.2 million pounds. The monthly boat limit was reduced to 1,000 pounds and the commercial size-limit was increased to 24 inches.

Prior to 1980, there was a recreational catch limit of 10 lingcod per angler. This bag limit was reduced to five fish in 1980, and a 22-inch size-limit was introduced in 1981. In 1996, the bag-limit was reduced to three fish to conform to Oregon and Washington regulations, and the size-limit



Lingcod, *Ophiodon elongatus*
Credit: L. Sinclair, Miller and Lea



Commercial Landings 1916-1999, Lingcod
Data Source: DFG Catch Bulletins and commercial landing receipts.

was increased to 24 inches. In 1999, the bag-limit was reduced to two fish. In 2000, the size-limit was increased to 26 inches. Also, the lingcod fishery was closed south of Lopez Point, Monterey County during the months of January and February and from Lopez Point north to Cape Mendocino during March and April.

Status of Biological Knowledge

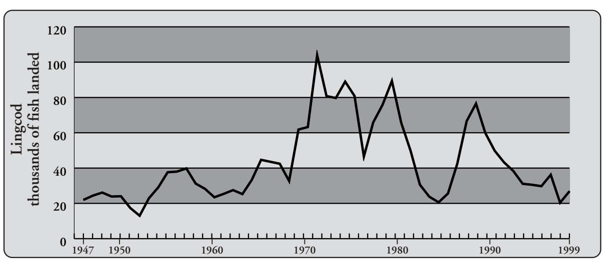
The lingcod is the largest member of the Hexagrammidae family. The scientific name *Ophiodo*n is a combination of two Greek words meaning snake and tooth, a reference to the lingcod's large teeth. The name *elongatus* is of Latin origin and refers to the elongated body. Lingcod are found only off the West Coast of North America. They are distributed in nearshore waters from northern Baja California to the Shumagin Islands along the Alaskan Peninsula. Their center of abundance is off British Columbia, and they become less common toward the southern end of their range.

Lingcod lack a swimbladder and thus will rest on the bottom or actively swim in the water column. They are found over a wide range of substrates at depths from 10 to 1,300 feet, but most occur in rocky areas from 30 to 330 feet. Typically, larger lingcod occupy rocky habitats; larger animals are found on deeper banks and reefs, whereas smaller animals live in shallower waters. Adult lingcod are strongly residential, tending to remain near the reefs or rocky areas where they live. Large-scale conventional tagging studies have found that the vast majority of mature lingcod are recaptured within six miles of where they were tagged, however acoustic tagging studies have indicated frequent short-term movements. Juveniles tend to disperse and travel over a wider range than adults.

Individuals grow to a maximum length of 39 inches for males and 59 inches for females. Maximum age is thought to be 25 years. Although there is large variation in length at age, the average one-year-old fish is 13 inches long, and a two-year-old is 17 inches long. After age two, females begin to grow faster than males. The average length of a four-year-old female is 24 inches, of an eight-year-old is 32 inches, and of a 12-year-old is 35 inches. The average length of a four-year-old male is 22 inches, of an eight-year-old is 29 inches, and of a 12-year-old is 32 inches. In California, the oldest lingcod on record is a 19-year-old, 45-inch female, and the longest is a 51-inch female.

Lingcod length and age at sexual maturity vary with latitude; lingcod in the northern part of their range are larger and mature later than fish in the southern part of the distribution. As with most fishes, fecundity increases with size of fish. In the northern end of the lingcod range, females can produce 50,000 eggs at a length of 24 inches, 124,000 eggs at a length of 32 inches, and 170,000 eggs at a length of 36 inches. This level of fecundity is low compared to many other marine species in the eastern Pacific, but high for a species that guards eggs.

Lingcod exhibit an interesting spawning behavior, which includes a spawning migration into nearshore habitats for



Recreational Catch 1947-1999, Lingcod
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

the deposition of eggs in gelatinous masses, termed nests, on rocky substrates. Males establish territory as early as a month before females lay eggs, and remain on guard at the nest until eggs are hatched. Preferred nest sites are rocky areas in shallow water where there are strong currents. Males move on to spawning grounds first, followed by large females, who spawn earlier than smaller females. After a female chooses a male and a spawning site, she swims over the site and deposits a layer of several eggs. The male then swims over the site and fertilizes the eggs. This process is repeated until spawning is completed, after which the female immediately leaves the spawning grounds. The eggs become firmly cemented to each other within the gelatinous mass in 24 to 48 hours. A relatively strong current is necessary to oxygenate the egg mass and prevent death of the embryos.

After spawning, males guard the nests from predation until the eggs hatch. On occasion, males have been found guarding two nests if they were close together, and sometimes if the male is removed, a new male will assume the guardian role. The nest guarding behavior of lingcod make them susceptible to targeted fishing during the spawning period. Males guarding nests are territorial and will aggressively strike at bait or lures that come close to the nest. Targeted fishing during the spawning season can thus directly increase lingcod mortality by increasing catch rates. It can also indirectly increase mortality by dislodging animals from the nest, resulting in increased egg mortality. Fish predators such as kelp greenling, striped seaperch, and small sculpins will eat lingcod eggs if a guardian male is removed from the nest. Invertebrates such as sea urchin, sunflower star, and snails also feed on lingcod eggs, but are not chased away by males guarding the nest. The eggs generally hatch about seven weeks after they are laid, but incubation can last from five to 11 weeks. Hatching may continue for 24 to 48 hours, after which the guardian male leaves.

Egg hatching is generally synchronous, with most eggs hatching within two to seven days of each other. Newly hatched larvae are 0.25-0.4 inches in length, and grow about 0.06 inches per day. The larvae are pelagic for about three months from early March to early June and settle to the bottom when they are about three inches long. Newly settled juveniles reside in shallow bays and on nearshore sand and mud bottoms from the beach to 333 feet in depth. Juveniles occur over a wide range of habitats including mud, sand, gravel, and eelgrass, but by age two occupy similar habitats as adults.

During the pelagic juvenile stage there is a gradual transition from a diet of small copepods to one of larger copepods, crab larvae, amphipods, euphausiids, and herring larvae. As small benthic juveniles, lingcod feed on herring, flatfishes, shiner perch, and other fishes. Even young lingcod have a very large mouth for their body size, allowing them to feed on prey much larger than other fish of their age and size. For large juvenile and adult lingcod, fish is the dominant prey, accounting for about 80 percent (by volume) of the stomach contents. In California waters, juvenile rockfishes are the most important prey.

Most predation on lingcod occurs during the egg stage, and predation becomes less common with age. On rare occasions, pelagic juvenile lingcod (1.5 to 2.6 inches) are found in the stomachs of chinook salmon. Other predators of juvenile fish, such as seabirds and marine mammals also prey on juvenile lingcod. Small benthic lingcod are probably eaten by adult lingcod and marine mammals, but have few other predators. Because of their large size, large juvenile and adult lingcod escape all but the occasional predator.

Status of the Population

Lingcod harvest has been higher than generally accepted population replacement rates for the last twenty years. Recent lingcod stock assessments have concluded that the lingcod stock is seriously depleted, and that California populations appear to be less than 25 percent of their pre-1970s level. By federal law, this level of stock depletion requires a management plan that rebuilds lingcod populations. The rebuilding plan is intended to restore the lingcod stock within 10 years. The substantial reduction in ABC after 1997 and resulting reduced fishery harvest was triggered by that rebuilding plan. Low levels of ABC and harvest will continue until lingcod populations show signs of rebounding. California lingcod appear to be highly productive, however, and there is good potential for rapid population increases given appropriate decreases in fishing effort.

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California Halibut

History of the Fishery

California halibut (*Paralichthys californicus*) is an important flatfish species in both the commercial and recreational fisheries of central and southern California. The highest recorded commercial landing of halibut was 4.7 million pounds in 1919, which was followed by an overall decline to a low of 950,000 pounds in 1932. Since 1932, the average annual catch has been 910,000 pounds, with five notable peaks in landings: 1936 (1.58 million pounds), 1946 (2.46 million pounds), 1964 (1.28 million pounds), 1981 (1.26 million pounds), and 1997 (1.25 million pounds).

The decline in commercial halibut landings after 1919 has been attributed to increased fishing pressure during World War I and to overfishing. Fishing restraints during World War II may have allowed halibut stocks to increase, resulting in peak landings in the late 1940s, followed by low catches in the 1950s. Increased landings in the mid-1960s followed warm water (El Niño) years in the late 1950s. The lowest landings occurred in the early 1970s, with the lowest recorded catch in 1970 of 257,000 pounds. Landings increased during the late 1970s to a peak again in 1981 and 1997. Since 1980, landings of California halibut have remained relatively constant, averaging more than one million pounds annually.

Historically, halibut have been commercially harvested by three principal gears: otter trawl, set gill and trammel net, and hook-and-line. The California halibut trawl fishery evolved late in the 19th century in the San Francisco Bay area. Since then, the boats used to tow this gear across the ocean bottom have gone from sail to steam to gasoline, and finally to diesel powered engines. Today, trawling is permitted in federal waters (three to 200 nautical miles offshore) using trawl nets with a minimum mesh size of 4.5 inches. Trawling is prohibited within state waters, except in the designated "California halibut trawl grounds," which encompass the area between Point Arguello and Point Mugu in waters greater than one nautical mile from shore. Bottom trawls used in this area must have a minimum mesh size of 7.5 inches, and trawling is closed from March 15 to June 15 to protect spawning adults.

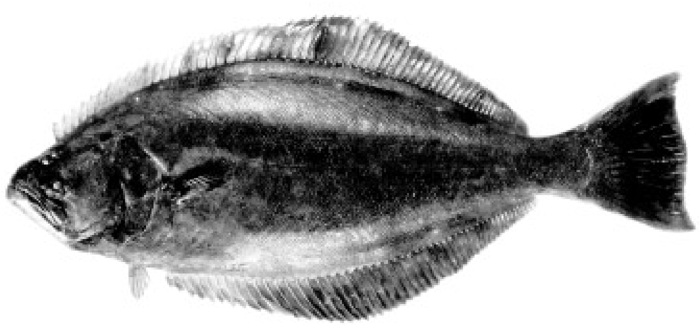
A decade after the introduction of the trawl fishery to San Francisco Bay, set gill and trammel nets were fished statewide along the coast. Historically, set nets have been the gear of choice for commercial halibut fishermen because of the restrictions on bottom trawl gear in state waters. In southern California, gill and trammel nets with 8.5-inch mesh and maximum length of 9,000 feet are the principal type of gear used. Today, gill and trammel net fishing is prohibited in Santa Monica Bay, shallow coastal waters north of Point Sal, and is subject to many other area, depth, and seasonal closures throughout the state. A Marine Resources Protection Zone (MRPZ) was established in 1990 extending three miles off the southern California mainland coast from Point Conception to the Mexican border and within one mile or 70 fathoms (whichever is less) around the Channel Islands. Gill and trammel nets have been prohibited in the MRPZ since Jan. 1, 1994.

Historically, commercial catches of halibut by hook-and-line gear have been insignificant when compared to the total pounds landed annually by the trawl and set gillnet fisheries. However, over the last decade, catches of California halibut by hook-and-line have ranged from 11 to 23 percent of the total pounds landed annually. A majority of those landings were made in the San Francisco Bay area by salmon fishermen mooching or trolling slowly over the ocean bottom.

Catches by commercial passenger fishing vessels (CPFV) displayed trends similar to the commercial landings from 1947 through 1974, with two peaks in 1948 (143,000 halibut) and 1964 (141,000 halibut). Following the 1948 peak, annual landings plummeted below 11,000 fish by 1957. The expansion of the CPFV fleet and no size limit restriction for the take of California halibut can be attributed to the 13-fold decrease in landings between 1948 and 1958. While the commercial catch increased in the late 1970s and steadied in the 1980s, the recreational catch remained low and variable with an average annual catch of 8,600 fish from 1971 to 1989. By 1995, CPFV landings surged to a 26-year high of 19,600 fish, declining to 14,200 fish in 1999. Since 1994, CPFVs operating in the San Francisco Bay area have landed a majority of the halibut statewide.

To assist with the restoration of the California halibut resource through the protection of sub-adult fish, a regulation was adopted in 1971 that set a minimum size limit of 22 inches for sport-caught California halibut. Commercial landings increased slowly after this legislation, whereas recreational landings remained low and did not recover to former catch levels.

Although California halibut range from the Quillayute River, Washington to Almejas Bay, Baja California, the



California Halibut, *Paralichthys californicus*
Credit: DFG

commercial fishery is concentrated from Bodega Bay in the north to San Diego in southern California, and across the international border with Mexico. The contribution to California landings of halibut captured in Mexican waters has varied but has generally been insignificant since 1966. Historically, the fishery was centered off southern California and Baja California, but over the past twenty years, the greatest landings have oscillated between ports in southern and central California. A majority of the halibut landings made in central California occurred in the San Francisco Bay area. A limited amount of fishing occurs around the Channel Islands of southern California, with a catch of substantially larger halibut (average length = 27 inches) than those caught in the nearshore mainland fishery (average length = 24 inches).

Commercial fishing laws prohibit the sale of California halibut less than 22 inches in total length, unless the weight is at least four pounds whole, 3.5 pounds dressed with the head on, or 3 pounds dressed with the head off. Four halibut less than the legal minimum size may be retained for personal use.

Recreational regulations also require a minimum size limit of 22 inches, in addition to a daily bag limit of five California halibut when fishing south of Point Sur, Monterey County, and only three halibut per day when fishing north of Point Sur. Halibut can be taken in recreational fisheries using hook-and-line, spear, or hand.

Status of Biological Knowledge

Adult California halibut inhabit soft bottom habitats in coastal waters generally less than 300 feet deep, with greatest abundance at depths of less than 100 feet. Adults spawn throughout the year with peak spawning in winter and spring. Pelagic eggs and larvae occur over the shelf, with greatest densities in water less than 250 feet deep and within four miles of shore. Halibut larvae appear to move inshore as they approach metamorphosis. Early larval stages (about 0.1 to 0.3 inches) occur in midwater more than one mile offshore, whereas transforming larvae occur within 0.6 mile of shore and occupy the neuston (surface zone) at night and the bottom during the day. California halibut have a relatively short pelagic larval stage (less than 30 days), transforming and settling to the bottom at a small size (0.35 to 0.5 inches). Newly settled and larger juvenile halibut are frequently taken in unvegetated shallow-water embayments and infrequently on the open coast, suggesting that embayments are the important nursery habitats. However, settlement either in bays or along the open coast varies yearly and may reflect variability in nearshore currents that influence the onshore transport of larvae. The advantages of bays as nursery areas are probably a decrease in the risk of mortality of newly-settled juveniles and an increase in the growth rate of larger juveniles that feed upon the abundant small fishes in the bays. Juveniles emigrate from the bays to the coast at about one year of age and 6.9 to 8.7 inches in length.

Tagging studies have indicated that California halibut do not tend to move extensively. Most sublegal halibut tagged and released from CPFVs in southern California were recovered within five miles from their tag sites; only 12 percent were found 10 miles or more from where they were tagged. Larger halibut appear to travel the greatest distances. One large tagged halibut (33 inches) was recovered 64 miles away 39 days after release.

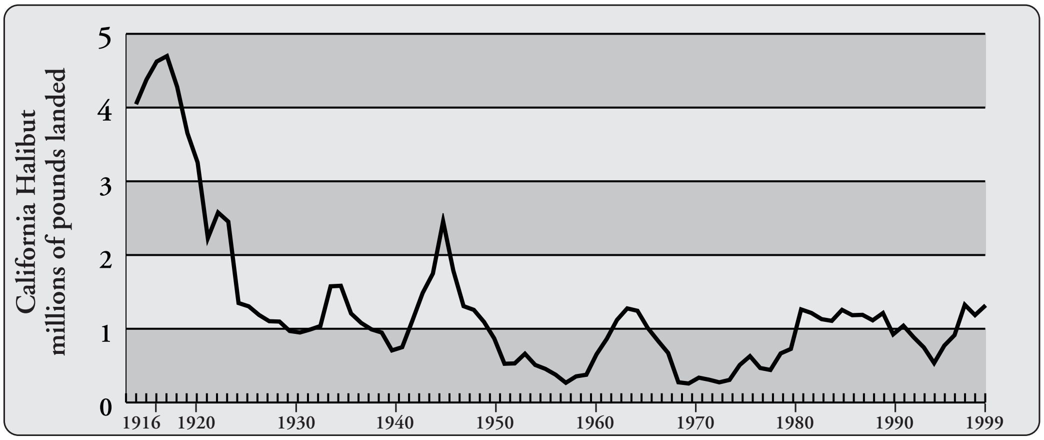
California halibut may live to 30 years and reach 60 inches in length. The maximum-recorded weight is 72 pounds. Male halibut mature at one to three years and eight to twelve inches, whereas females mature at four to five years and 15 to 17 inches. Female halibut attain larger sizes at age than males and represent a greater fraction of the commercial landings (60 to 80 percent). Female halibut reach legal size (22 inches) at five to six years of age, about a year before males.

California halibut are ambushing predators. Adults prey primarily upon Pacific sardine, northern anchovies, squid, and other nektonic nearshore fish species. Small juvenile halibut in bays primarily eat crustaceans, including copepods and amphipods, until they reach about 2.5 inches. They are then large enough to eat gobies that are found commonly in bays but not on the open coast. Juvenile halibut become increasingly piscivorous with size. On the coast, adult halibut feed primarily on Pacific sardine, anchovies, and white croaker.

Status of the Population

Abundance of larval California halibut in plankton surveys is correlated with commercial landings of halibut, suggesting that this species has a cycle of abundance approximately 20 years in length. However, the size of the halibut population may be limited by the amount of available nursery habitat, as juvenile halibut appear to be dependent on shallow water embayments as nursery areas. The overall decline in California halibut landings corresponds to a decline in shallow water habitats in southern California associated with dredging and filling of bays and wetlands.

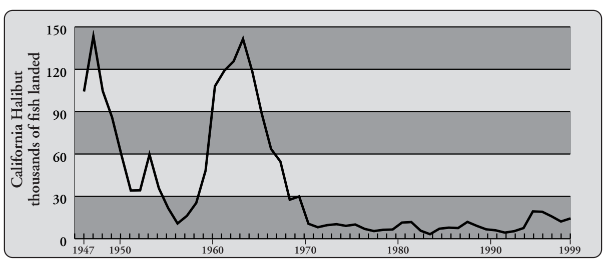
Recreational and commercial fishermen are in conflict over the California halibut resource in southern California. A differential minimum size limit of 22 inches for the recreational fishery and 26 inches for the commercial fishery was investigated as a possible management tool. This strategy would allow recreational anglers to harvest



Commercial Landings 1916-1999, California Halibut
Data Source: DFG Catch Bulletins and commercial landing receipts.

halibut between 22 and 26 inches in length before fish had grown large enough to recruit to the commercial fishery. Yield-per-recruit (Y/R) analysis indicated that: 1) differential size limits would provide an increased Y/R for the recreational fishery, whereas the commercial fishery would experience a loss; 2) overall fishing effort was about twice the optimum level; and 3) Y/R would probably increase with diminished fishing effort.

The total California biomass of the halibut resource obtained from virtual population analysis (VPA) estimates



Recreational Catch 1947-1999, California Halibut
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

in the late 1980s was 5.7 to 13.2 million pounds, with annual recruitment of fish at age one estimated to be between 0.45 and 1.0 million fish. The number of juvenile halibut emigrating from southern California bays to the open coast (age one) estimated from beam trawl surveys ranged between 250,000 and 400,000 in the late 1980s.

In the early 1990s, a swept-area trawl survey was conducted to better understand California halibut population dynamics. This fishery-independent survey produced a biomass and population estimate for halibut in southern and central California. The survey results indicated a halibut biomass of 6.9 million pounds for southern California and 2.3 million pounds for central California, while the population estimate was 3.9 million halibut for southern California, and 700,000 halibut for central California.

Management Considerations

See the Management Considerations Appendix A for further information.

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Starry Flounder

History of the Fishery

Prior to the late 1980s, the starry flounder (*Platichthys stellatus*) was a common species in both the commercial and recreational fisheries of northern and central California. Though seldom targeted, it was often taken by commercial fishers seeking more valuable species such as petrale sole or California halibut. Historically, most of the commercial catch was made by bottom trawl. During the 1980s, many starry flounders were also taken by gill and trammel nets in central California. During the late 1980s, commercial landings declined sharply and remained at relatively low levels through the 1990s. From 1992 through 1999, landings averaged only 62,225 pounds, ranging from a low of 25,353 pounds in 1995 to a high of 100,309 pounds in 1999. This is in contrast to annual landings of more than a million pounds during the 1970s and half a million pounds in the 1980s.

The recreational catch of starry flounders is from piers, boats, and shore, usually in estuarine and adjacent coastal waters. The estimated annual recreational catch for this species in California from 1981 to 1989 averaged 40,000 fish and ranged from less than 12,000 in 1985 to 63,000 fish in 1987. Estimated recreational catches, like commercial landings, declined dramatically during the 1990s. Catch estimates from 1993 through 1999 averaged 6,000 fish per year, and ranged from a high in 1998 of 15,000 fish to lows in 1994 and 1996 of 3,000 fish.

Status of Biological Knowledge

The starry flounder is probably the most easily recognizable of California's flatfishes. The dorsal and anal fins are prominently marked with alternating yellow or orange and dark bars. The body surface is rough owing to modified star-shaped scales that give rise to the names "starry" and "roughjacket," as this fish is often called by fishermen. It is very good at assuming the coloration of the substrate upon which it finds itself. Starry flounders in California are about equally divided between left-eyed and right-eyed fish, while those of Japan are nearly all left-eyed.

Starry flounders range from Korea and Japan, north to the Bering and Chukchi Seas and the Arctic coasts of Alaska and Canada, and southward down the coast of North America to southern California, although they are uncommon south of Point Conception. It is primarily a coastal species, living on sand and mud bottoms, and avoiding rocky areas. Though found to depths of 900 feet, they are much more common in shallower waters. They are frequently found in bays and estuaries, often one of commonest fishes in these settings. They are tolerant of brackish and even fresh water.

Tagging studies have not demonstrated extensive migrations, although there is some movement along the shore. There are also thought to be seasonal inshore-offshore movements of these fish, possibly related to spawning.

Most spawning occurs in shallow waters near the mouths of rivers and estuaries during the winter. In central California, December and January are the peak months of spawning. The number of eggs produced by each female depends upon her size. A 27-inch fish may produce about 11 million eggs. Fertilization is external.

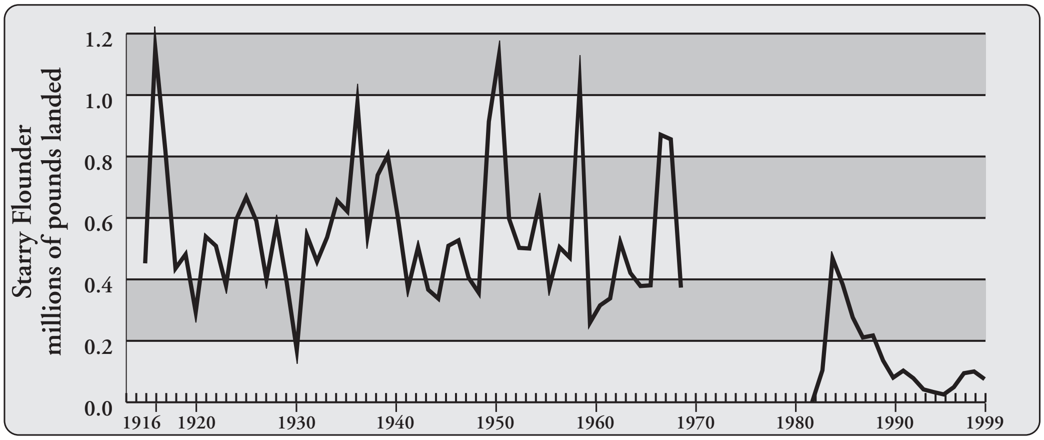
Eggs of the starry flounder are pelagic, floating near the ocean's surface. Under laboratory conditions, eggs held at 51° F hatched in 4.5 days, while those held at 54.5° F hatched in 2.8 days. Newly hatched larvae are less than one-tenth inch long. Metamorphosis occurs 39 to 75 days after hatching. Newly settled juveniles less than one-half inch long are common in low-salinity estuarine waters, although settling also occurs along the open coast.

Females grow faster and reach larger sizes than do males. In central California, most males are sexually mature at two years averaging 14.5 inches, most females at three years and 16 inches. The maximum size reported is 36 inches.

Larval starry flounders feed on planktonic organisms. Newly metamorphosed fish feed largely on copepods and amphipods. As they grow, their diet changes. Five-inch fish have developed jaws and teeth that allow them to crush small clams and pull worms from their burrows. At 10 to 12 inches, they tend to graze on tips of siphons of clams too large to be ingested whole. Crabs and polychaete worms are also taken. Sand dollars, brittle stars, and fish are included in the diets of larger starry flounders.

Wading and diving seabirds such as herons and cormorants, as well as marine mammals such as harbor seals, feed on juvenile starry flounders in estuaries. However, sea lions and harbor seals feeding on fish caught in gillnets will pass up a dozen starry flounders to eat a more

Starry Flounder, *Platichthys stellatus*
Credit: DFG



Commercial Landings 1916-1999, Starry Flounder
Starry flounder were aggregated under the landing classification "unspecified flounders" between 1970 and 1982. Data Source: DFG Catch Bulletins and commercial landing receipts.

valuable California halibut, much to the consternation of the fisherman.

On occasion, a fish is caught that displays physical characteristics intermediate between a starry flounder and an English sole and may be a hybrid of those species.

Status of the Population

No studies have been conducted to determine population size of the starry flounder; however, the commercial landing and the recreational catch trends suggest the California population is now at extremely low levels. The circumstance could arise from either a relocation of adult fish associated with the 1976-1977 oceanic regime shift or a rapid decline in the abundance of spawning adults due to fishing pressure. The large population decline suggested by fishery trends is substantiated by a fishery-independent trawl survey conducted by the California Department of Fish and Game within the San Francisco estuary from 1980 through 1995. Their results show age-zero and age-one-plus starry flounder abundance and catch-per-unit-effort dropping dramatically during the late 1980s and remaining at low levels through the 1990s.

There is very little or no yearly lag between the precipitous drop in the fishery harvest and the drop in abundance of age-zero fish in the San Francisco estuary survey, which suggests that adult fish were no longer present in the areas where fisheries normally operate, and were no longer spawning in areas that had previously resulted in higher levels of young-of-the-year within the San Francisco estuary. Recruitment is largely determined by survival of larval and juvenile fish. Given the importance of bays and estuaries to the young of this species, the continued environmental health of these areas may be the most important factor in maintaining healthy populations of starry flounder.

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Sanddabs

History of the Fishery

Although not as important to California fisheries as other flatfishes, sanddabs are nevertheless highly prized by the commercial industry and recreational anglers for their excellent edibility. Four species of sanddabs are found in California waters – Pacific sanddab (*Citharichthys sordidus*), longfin sanddab (*Citharichthys xanthostigma*), speckled sanddab (*Citharichthys stigmaeus*), and gulf sanddab (*Citharichthys fragilis*). Commercial sanddab landings and recreational catches consist predominantly of the two largest species, Pacific sanddab and longfin sanddab. Pacific sanddab is the most abundant and makes up the bulk of the landings in central and northern California waters, whereas Pacific sanddab and longfin sanddab are caught in southern California. Because of their smaller size, speckled and gulf sanddabs are not important to the fisheries.

Recorded sanddab landings were highest (2.6 million pounds) in 1917. In 1918, landings decreased to 1.8 million pounds, and from 1919 to 1921 they remained less than 0.8 million pounds. In 1922, annual landings increased, reaching approximately two million pounds in 1925. From 1930 to 1974, annual landings were below a million pounds. Since 1975, landings have fluctuated between 1.4 million pounds and 0.6 million pounds annually. During the last decade, landings have been above the historical annual average, except for 1983 and 1984, the period of a strong El Niño event. Landings rebounded in 1985 and have increased since then. Approximately 1.44 million pounds were landed in 1990, but landings crashed in 1992 (also an El Niño year) to 0.6 million pounds, and then rebounded to more than 2.0 million pounds in 1997 and 1999. In the 1990s, ex-vessel value ranged from $0.46 to $0.80 per pound (1990 and 1999, respectively). Value increased from $0.46 to $0.70 per pound from 1990 to 1993, dropped to $0.51 per pound in 1995 and 1996, and then increase to a high of $0.80 per pound in 1999.

Since 1970, most of the commercial sanddab landings have been in northern and central California, with the largest landings at Eureka and San Francisco Bay and less at Monterey Bay. The commercial catch of sanddabs is mainly by otter trawls and some by hook-and-line, especially in the Monterey Bay area.

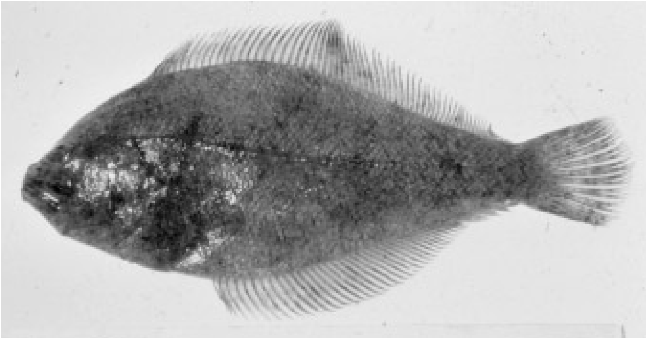
Many recreational anglers target them, mostly from small boats and commercial passenger fishing vessels (CPFVs). Sanddabs are one of a few fish groups for which there is no catch limit. Sanddab catches from CPFVs were small during the 1990s, with reported catches reaching 2,200 fish in 1990 and dropping to about 100 fish in 1998 (a strong El Niño year). About 70 percent of these were taken in southern California between Long Beach and Newport Beach. Sanddabs comprise an unknown, but probably large part of the unspecified flatfish catch, which has decreased from about 14,000 fish in 1990 to 4,000 fish in 1998.

As an El Niño event is more likely to have an immediate affect on the abundance of sanddab larvae than on harvestable adults, the immediate drop in sanddab catches during some El Niño years may be due in part to a shift in fishing effort to more desirable species.

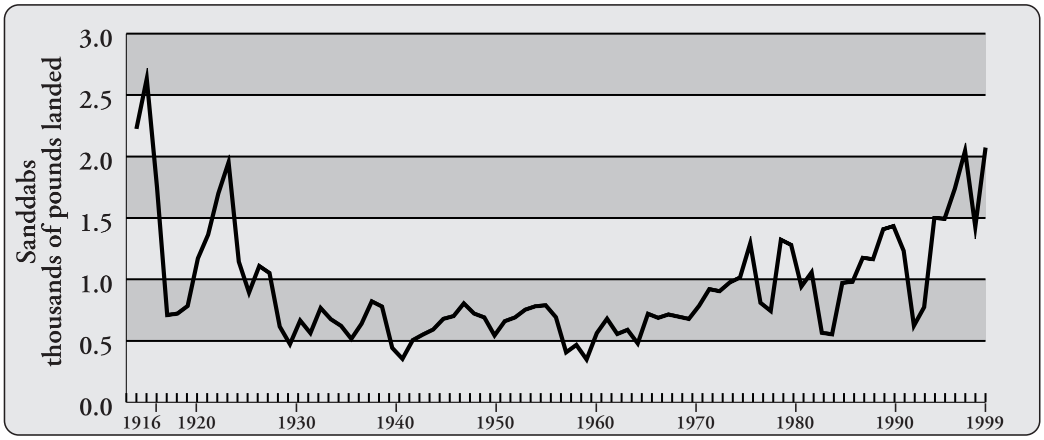
Status of Biological Knowledge

Sanddabs belong to the family Paralichthyidae (sometimes included as part of Bothidae - left-eye flounders). Biogeographically, Pacific sanddab and speckled sanddab are temperate species whereas longfin sanddab and gulf sanddab are warm-temperate to tropical species. Pacific sanddab ranges from the Bering Sea to Cape San Lucas, Baja California Sur, Mexico; speckled sanddab from Point Montague Island, Alaska to Magdalena Bay, Baja California Sur, Mexico; longfin sanddab from Monterey Bay to Costa Rica; and gulf sanddab from off Ventura, California to Cape San Lucas, Baja California Sur, and the Gulf of California. Speckled sanddab and Pacific sanddab occur throughout the state, with speckled sanddab occurring from the surface to a depth of 1,200 feet, and Pacific sanddab at 30 to 1,800 feet. Maximum depths of both species are suspect as the speckled sanddab seldom occurs deeper than 300 feet and Pacific sanddab seldom deeper than 600 feet. Longfin sanddab occurs at depths from seven to 660 feet, but usually less than 450 feet, and gulf sanddab from 59 to 1,140 feet. Most species are found on muddy to sandy mud bottoms but speckled sanddab occurs commonly on sandy bottoms.

Pacific sanddab is the largest species, reaching 16 inches, and up to two pounds. Most, however, are smaller than 10 inches and weigh, at most, 0.5 pound. The next largest species is longfin sanddab at 10 inches, followed by gulf sanddab at nine inches, and speckled sanddab at seven inches. Pacific sanddab live to a maximum of 10 years whereas speckled sanddab live to about 3.5 years. Pacific sanddabs mature at about three years, whereas the speck-



Pacific Sanddab, *Citharichthys sordidus*
Credit: DFG



Commercial Landings 1916-1999, Sanddabs
Data Source: DFG Catch Bulletins and commercial landing receipts.

led sanddab matures at one year. Spawning begins in July, peaks in August, and ends sometime in September for Pacific sanddab and extends from spring to fall for speckled sanddab. Females may spawn twice during a season. In contrast, most northern flatfish species spawn during late winter to early spring.

Sanddab larvae are pelagic and may be found near the surface and out to many miles offshore. Sanddab larvae transform and settle to the bottom at lengths of 0.6 to 1.6 inches. Juveniles and adults feed near or on the bottom on a variety of nektonic and benthic prey, including shrimp, crabs, marine worms, squid, octopus, eggs, and small fishes. Speckled sanddab feed largely on mysids and amphipods, but small Pacific sanddabs feed on copepods and polychaetes. Adults feed more on euphausiids and squid. Sanddabs, in turn, are preyed upon by larger fishes, diving birds, and marine mammals.

Status of the Population

Commercial landings indicate that sanddab populations are in good condition and currently are not being overharvested. The Pacific Fishery Management Council has not recommended a change in the minimal acceptable biological catch of incidentally caught "Other Flatfish" (which includes sanddabs) during the past decade, indicating a stable and likely reasonably utilized resource.

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Other Flatfishes

History of The Fishery

Several flatfish species are taken incidentally in commercial groundfish fisheries. These include the rock sole (*Pleuronectes bilineatus*), butter sole (*Pleuronectes isolepis*), fantail sole (*Xystreurys liolepis*), sand sole (*Psettichthys melanostictus*), slender sole (*Eopsetta exilis*), bigmouth sole (*Hippoglossina stomata*), California tonguefish (*Symphurus atricauda*), curlfin turbot (*Pleuronichthys decurrens*), hornyhead turbot (*Pleuronichthys verticalis*), spotted turbot (*Pleuronichthys ritteri*), C-O turbot (*Pleuronichthys coenosus*), diamond turbot *(Hypsopsetta guttulata*), arrowtooth flounder (*Atheresthes stomias*), and Pacific halibut *(Hippoglossus stenolepis*). Some of these, notably the Pacific halibut, diamond turbot, and rock sole, are taken by recreational anglers as well, but most are caught primarily by commercial boats. Arrowtooth flounder and Pacific halibut are considered as minor flatfishes in California flatfish fisheries because they are landed in relatively small quantities. However, both species are major components in the flatfish fisheries in northern waters from Oregon to Alaska.

Landings of most of these flatfishes are difficult to extract from landings data for the early years (beginning in 1916), because many were combined with other categories of flatfish. For example, prior to 1931 turbots were included with soles. Also, some species such as Pacific halibut are included in California landings, even though most were landed elsewhere and shipped to California ports. Starting in the early 1950s, some of these flatfish landings, primarily arrowtooth flounder (1950) and soles (1953), were listed separately in the catch data.

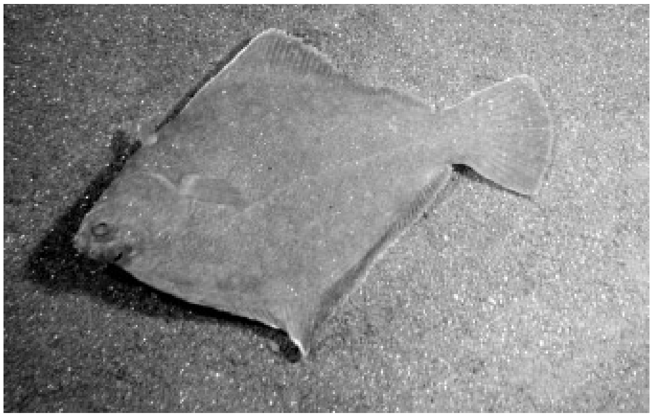
Generally, incidental flatfish catches have contributed only a small amount to the annual statewide commercial landings. From 1953 to 1999, these annual flatfish landings averaged about 0.1 percent of the total statewide landings. During this period, flounders (mostly arrowtooth flounder) comprised 49.2 percent of incidental flatfish landings, soles 41.2 percent, turbots 8.0 percent, and Pacific halibut 1.6 percent. Starting in the 1960s, commercial landings of minor flatfish, as a group, have declined, although not all species showed this trend.

Since 1950, arrowtooth flounder landings averaged 278,300 pounds per year with peak years occurring in 1956 (1,070,700 pounds), 1960 (1,007,700 pounds), and 1961 (1,100,900 pounds). These high landings were due, in part, to the less desirable fishes, such as arrowtooth flounder, finding a market with the animal food industry, primarily as mink food. Arrowtooth flounder no longer is used for mink food, but is processed for human consumption. Incidental sole landings since 1953 averaged about 244,000 pounds per year, with a peak in 1979 when 839,000 pounds were landed. After 1979, there was a general decline in the annual landings of sole. Turbot landings averaged about 47,000 pounds per year from 1953 to 1999, with a peak of 176,000 pounds in 1954, and another good year occurring in 1959 (129,000 pounds). Since 1964 there has been an overall general decline in commercial turbot landings. Landings in 1999 were approximately 8,000 pounds, the lowest since 1953. Pacific halibut contributed heavily to the minor flatfish fishery prior to the mid-1950s. The last good year for Pacific halibut landings was 1952, when 242,600 pounds were landed. Landings then began a rapid downward trend. From 1969 to 1988, no landings were recorded, except for three years: 1971, 1972, and 1986 (25, 235, and 34,500 pounds, respectively). From 1989 to 1999, landings did increase somewhat, averaging approximately 4,600 pounds per year.

Most of the incidental flatfish are taken by otter trawls. The exception is Pacific halibut, where set longline is the dominant gear used. Trammel nets are used to catch some flatfish in central and southern California waters, and many small-boat commercial fishermen use hook-and-line. Recreational anglers occasionally catch soles or turbots while fishing for sanddabs, starry flounder, or California halibut. Diamond turbots are sought by recreational anglers in quiet coastal waters, bays, and sloughs.

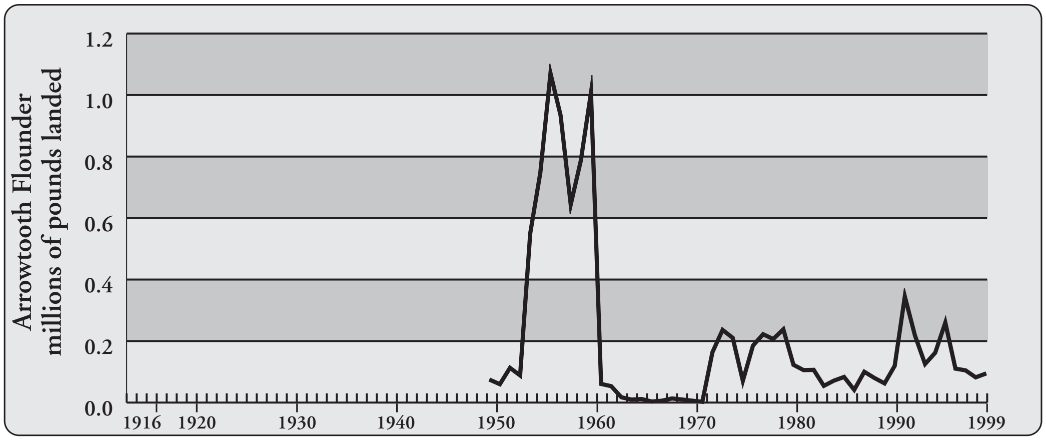
Status of Biological Knowledge

In general, flatfish spawn during late winter and early spring. Arrowtooth flounder, however, spawn as late as August in the southeast Bering Sea and Gulf of Alaska, where the greatest concentrations of this species are found. The larvae are pelagic and undergo metamorphosis to the adult form. After flatfish settle on the bottom, they eat small crustaceans, polychaetes, and mollusks. As they grow, they eat larger food forms of the same groups. Some, such as sand sole, arrowtooth flounder, and Pacific halibut, include fish in their diet.

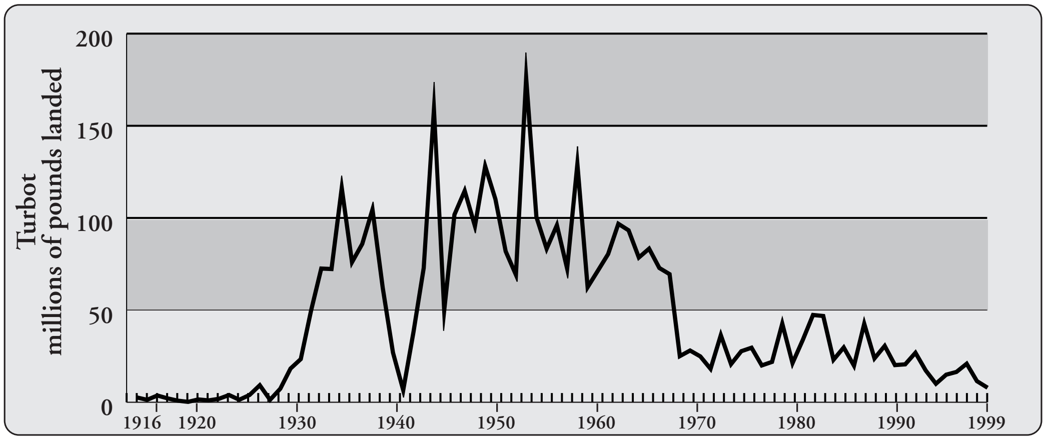


Diamond Turbot, *Hypsopsetta guttulata*
Credit: DFG

Commercial Landings 1916-1999, Arrowtooth Flounder
Arrowhead flounder were aggregated under the landing classification "unclassified sole" prior to 1950. Data Source: DFG Catch Bulletins and commercial landing receipts.



Commercial Landings 1916-1999, Turbot
Data Source: DFG Catch Bulletins and commercial landing receipts.



As a group, minor flatfish species range from the Gulf of California/Baja California to the Bering and Chukchi Seas off Alaska. Within this overall range some species are quite restricted while others are found throughout most of this range. They occur from shallow water to depths in excess of 3,000 feet (Pacific halibut).

Status of the Populations

Major fluctuations of commercial landings of flounder, soles, and turbot have occurred since 1950. Despite these fluctuations and declining commercial landings that started in the 1960s, market sampling and commercial landing records indicate that these populations remain in good condition and currently are not being over-harvested. Arrowtooth flounder stock assessment work conducted in 1993 by the Washington Department of Fisheries indicated that the status of the population, at that time, was in good condition because there was no decline in fishery catch-per-unit-effort (CPUE) between 1987 and 1992 and no trend in triennial bottom trawl survey CPUE from 1977 to 1992. Current catch levels remain well below the level of acceptable biological catch (ABC) established by the Pacific Fishery Management Council (PFMC). The densities of arrowtooth flounder are low south of Cape Blanco, Oregon. Pacific halibut landings in California have declined since the peak years during the 1930s; however, the species is considered uncommon in California waters. Pacific halibut are monitored extensively by the International Pacific Halibut Commission (IPHC) and recent stock assessment analysis indicates that while abundance in numbers is still quite high relative to the levels of 1975 or 1980, the prospect for a decline in the biomass in waters north of California is a possibility.

Management Considerations

See the Management Considerations Appendix A for further information.

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White Seabass

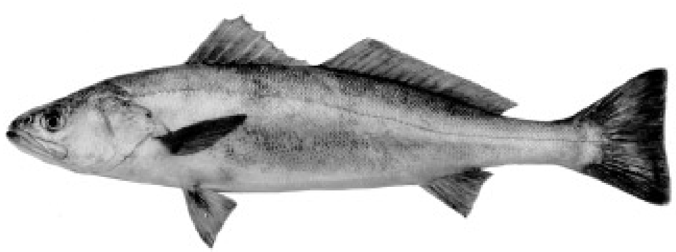
History of the Fishery

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

Commercial landings of white seabass have fluctuated widely over the nearly 85 years of record keeping. Almost three million pounds were reported in 1922, 599,000 in 1937, 3.5 million in 1959, and 58,000 in 1997. Since 1959 the trend has been one of decline, although landings have been over 100,000 pounds for the years 1984 through 1991 and 1998-1999. Although there was a commercial fishery in the San Francisco area from the late 1800s to the mid-1920s, landings of fish caught north of Point Conception rarely exceeded 20 percent of the total California catch.

Today, catches of white seabass are concentrated along the coast from Point Conception to San Diego and around the Channel Islands. The frequency of fish caught north of Point Conception has increased in the past few years, although the pounds landed still represent less than 20 percent of the total California catch. Before 1982, California commercial fishermen landed thousands of pounds of white seabass taken in Mexico. Often these landings comprised more than 80 percent of the annual catch. Since then, the Mexican government has denied access permits to U.S. fishermen, and the fishery is concentrated in California.

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



White Seabass, *Atractoscion nobilis*
Credit: DFG

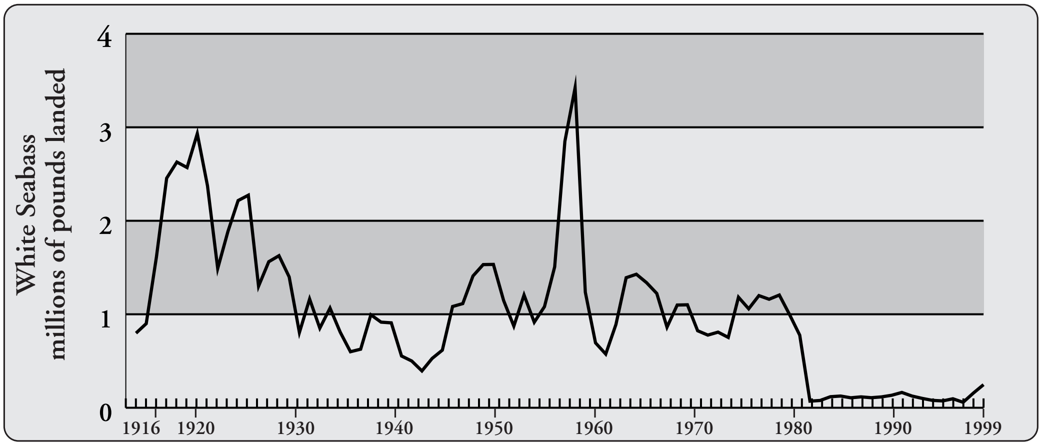
Although the legal size limit for white seabass is 28 inches (about seven pounds), the average commercially caught fish is nearly 40 inches (about 20 pounds). Because of consumer demand, seabass has always commanded relatively high prices. In 2000, commercial fishermen were typically paid $2.25 per pound for whole fish. At the retail level the fish are sold fresh, primarily as fillets and steaks.

Recreational fishing for white seabass began around the turn of the century. Because of their size and elusive nature, seabass are popular with anglers. Historical records show that anglers on commercial passenger fishing vessels (CPFVs), fishing in California waters, landed an average of 33,400 fish annually from 1947 through 1959. The catch steadily declined to an average of 10,400 fish in the 1960s, 3,400 fish in the 1970s, and 1,200 fish in the 1980s, but increased to 3,000 fish in the 1990s. In fact, the 1999 recreational catch of white seabass from California waters was greater than 11,000 fish and appears to be as high for 2000. Additional seabass are caught by anglers aboard private boats, but accurate catches by private boat anglers are difficult to estimate.

Today, sport anglers catch white seabass that are generally between seven and 25 pounds. This was not true in the past. While the 28-inch size limit also applies to recreational anglers, most of the catch prior to the 1990s (kept and released) was between 20 and 24 inches. In a survey of private boaters at launch ramp facilities from 1978 through 1982, biologists found that only six to 16 percent of the white seabass kept were of legal size. In a similar survey aboard CPFVs from 1985 through 1987, biologists reported that 16 to 25 percent of the seabass caught were legal. However, this has changed dramatically with the apparent increase in the abundance of legal-size white seabass. During the period from 1995 through 1999, data collected from private boat anglers revealed 77 percent of the fish were legal size while data from CPFV anglers showed 80 percent of the fish were legal size.

White seabass are more often caught with live bait than with dead bait or lures, but all are effective when the fish are actively feeding. Seabass can sometimes be brought to the surface by heavy chumming with live bait. Anglers fishing around Santa Catalina Island have reported consistently good catches using blacksmith and silversides as bait. However, when available, live squid and Pacific sardines are popular baits. Spearfishing for large seabass by free divers (without SCUBA) is successful in kelp beds.

Regulations covering white seabass have been in effect since 1931, and have included a minimum size limit, closed seasons, bag limits, and fishing gear restrictions. Such regulations are in effect today, with slight variations. A



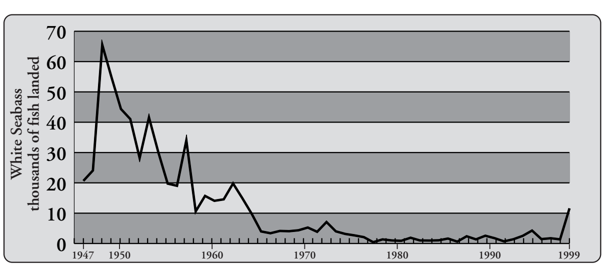
Commercial Landings 1916-1999, White Seabass
Data Source: DFG Catch Bulletins and commercial landing receipts.

fishery management plan for white seabass is presently being adopted and the need for additional regulations will be considered.

Status of Biological Knowledge

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

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



Recreational Catch 1947-1999, White Seabass
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

Spawning occurs from April to August, with a peak in the late spring to early summer. Fecundity (egg productivity) for this species has not been determined, but a maturity study in the late 1920s reported that females begin maturing when four years old (nearly 24 inches), and some males were sexually mature at three years (20 inches). All white seabass have probably spawned at least once by age six (nearly 32 inches).

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

Young-of-the-year white seabass, ranging in length from 0.25 inch to 2.25 inches, inhabit the open coast in waters 12 to 30 feet deep. They associate with bits and pieces of drifting algae in areas of sandy ocean bottom. Some time between the ages of one and three years old, they move into protected bays where they utilize eelgrass communities for cover and forage. Older juveniles are caught off piers and jetties and around beds of giant kelp. Adult seabass occupy a wide range of habitats including kelp beds, reefs, offshore banks, and the open ocean. Adult white seabass eat Pacific mackerel, Pacific sardines, squid, pelagic red crabs, and Pacific herring.

Laboratory spawning of white seabass was first induced in 1982. Beginning in 1983, the California Department of Fish and Game initiated the Ocean Resources Enhancement and Hatchery Program (OREHP) to test the feasibility of raising seabass for population enhancement. That goal was achieved in the first 10 years of the program and the goals of the program have been expanded to test the feasibility of enhancing marine fish populations through the stocking of cultured fish. By 1999, more than 375,000 juvenile white seabass had been released off southern California, and it is estimated that 17,500 of those may have survived to legal size or larger. Additionally, valuable life history information has been gathered during this program through ecological surveys, tagging, and genetic studies. However, more work is necessary to determine if artificial propagation is successful in enhancing the seabass population.

Status of the Population

The range of the white seabass population has contracted since the early part of this century, and few are found regularly north of Point Conception. Few data are available concerning the status of seabass in Mexico, and it is difficult to determine whether the decline in California waters indicates an overall population decline.

Population estimates have not been made. Fishery biologists have been concerned about the decline in landings since the late 1920s. Today, this concern still exists within the scientific community, commercial fishing industry, and with the angling public. Human-induced changes, such as pollution, overfishing, and habitat destruction have probably contributed to this long-term population decline. However, natural environmental changes can also influence the population. The large numbers of small seabass caught in recent years suggests that the warm water period beginning with the 1982-1983 El Niño helped to increase young fish survival. Young fish surveys conducted in southern California, as part of OREHP, showed a dramatic increase in the number of fish taken in research gillnet sets. During research work in 1997 over 600 juvenile fish were captured, in 1998 approximately 700 fish were taken, and in 1999 slightly over 1,300 juveniles were captured. Anecdotal evidence from commercial and sport fishers confirms this dramatic increase in juvenile white seabass. It is unknown whether this increase in juveniles will subsequently enhance the adult spawning population.

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California Department of Fish and Game

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Giant Sea Bass

History of the Fishery

Because giant sea bass (*Stereolepis gigas*) grow slowly and mature at a relatively old age, they are susceptible to overfishing. As a consequence, they have suffered a serious decline in numbers. Commercial landings from U.S. waters peaked in 1932 near 200,000 pounds before declining. Mexican waters were more productive (peaking at over 800,000 pounds in 1932) and did not permanently sink below 200,000 pounds until 1964. A few hook-and-line fishermen targeted giant sea bass, but they were also caught incidentally by gillnets set for halibut and white seabass.

Recreational landings, reported in numbers of fish rather than pounds, show a similar trend of peaking and permanently declining. The peak in California landings occurred in 1963 while Mexican landings peaked in 1973. That these recreational fisheries peaked after the commercial fishery is due to the later development of the recreational fishery rather than a reflection of the giant sea bass population. A few boats developed a special recreational fishery targeting spawning aggregations during the summer months. Trips made in July to certain reefs between Point Abreojos and Magdalena Bay, Baja California, consistently produced 70 to 100 giant sea bass. One trip produced 255 in three days. Once these aggregations were exploited the fishery disappeared with the fish.

In 1981, a law was passed that prohibited the take of giant sea bass for any purpose, with the exception that commercial fishermen could retain and sell two fish per trip if caught incidentally in a gillnet or trammel net. This law also limited the amount of giant sea bass that could be taken in Mexican waters and landed in California. A vessel could land up to 1,000 pounds of Mexican giant sea bass per trip but could not land more than 3,000 pounds in a calendar year. The law was amended in 1988, reducing the incidental take to one fish in California waters. Although this law may have prevented commercial fishermen from selling giant sea bass in California, it did not prohibit fishing over habitats occupied by this species and probably did little to reduce the incidental mortality of giant sea bass, as giant sea bass that were entangled in the nets were discarded at sea. The 1981 rule changes were more effective in protecting giant sea bass in Mexico, since large landings had been historically made by hook-and-line fishermen targeting grouper, cabrilla, and giant sea bass off the Pacific coast of Baja California. The banning of inshore gillnets displaced the California fishery from the majority of areas inhabited by giant sea bass; it is reasonable to assume that this closure significantly reduced the incidental mortality of giant sea bass in California.

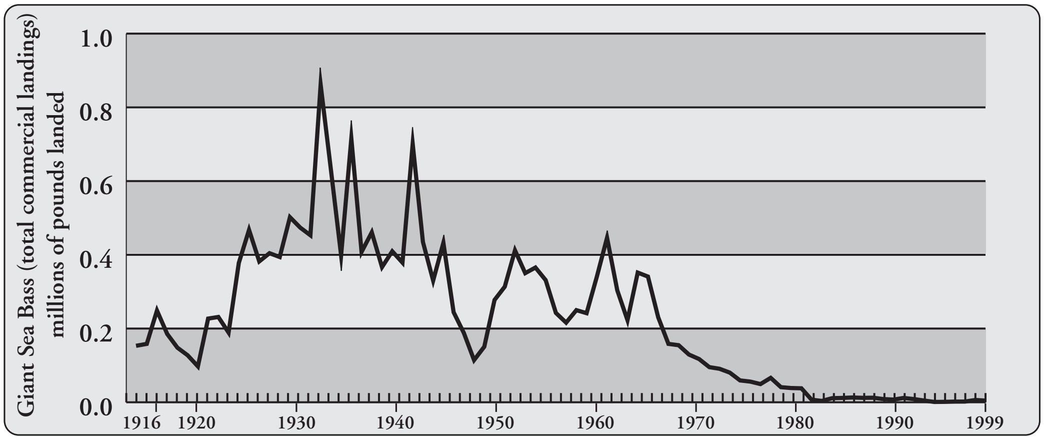
Status of Biological Knowledge

Although this species is most frequently referred to as black seabass in California, the American Fisheries Society has designated the common name as giant sea bass. Black seabass is an unrelated Atlantic coast species. Giant sea bass were originally assigned to the grouper family, Serranidae, but later placed in a new family, Percichthyidae. Although family placement has still not been resolved, similarities between larvae of wreckfishes and giant sea bass seem to support placement in the family Polyprionidae.

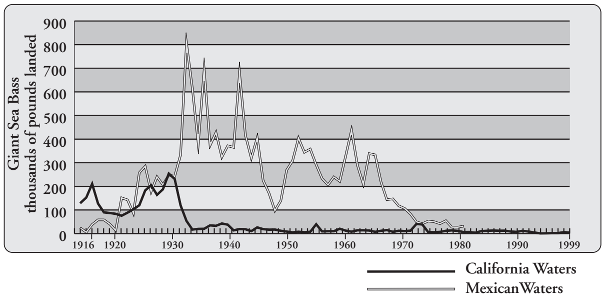
Small juveniles are bright orange with large black spots. As they grow they lose the orange coloration and take on a bronzy purple color. The spots slowly fade as the fish gets larger and darker, with large adults appearing solid black to gray with a white underside. Giant sea bass are capable of rapid and dramatic color changes. Large fish retain the ability to display large black spots, can take on a bicolor appearance (light below, dark above), white mottling, jet-black or light gray. As implied by the name, the most dramatic feature of giant sea bass is their large size. The International Game Fish Association world record for this species is 563.5 pounds, caught at Anacapa Island in 1968. Giant sea bass reach lengths in excess of seven feet, and are nearly as big around as they are long.

Despite the conspicuous size and protected status of giant sea bass, there are no published scientific studies to provide details of the biology and habits of this creature. In the eastern Pacific, giant sea bass range from Humboldt Bay to the tip of Baja California, and occur in the northern half of the Gulf of California. Some authors have stated that this species is also found along the coast of northern Japan and the Sea of Japan, but this may be a case of mistaken identity. Within California it is rarely found north of Point Conception. Adult giant sea bass seem to prefer the edges of nearshore rocky reefs. These reefs are relatively shallow (35 to 130 feet) and often support thriving kelp beds. Although the kelp may disappear due to a strong El Niño or overgrazing by sea urchins, giant sea bass remain at the reef. At certain times of the year,

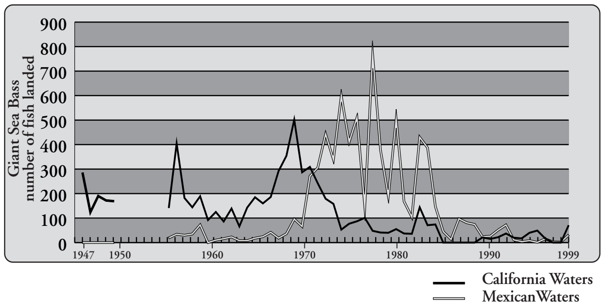
Giant Sea Bass, *Stereolepis gigas*
Credit: DFG



Commercial Landings 1916-1999, Giant Sea Bass
Data reflects catch from both California and Mexican waters landed in California. Data source: DFG Catch Bulletins and commercial landing receipts.



Commercial Landings by Location 1916-1999, Giant Sea Bass
Landings separated by location of catch. All landings were recorded at California ports. Data Source: DFG Catch Bulletins and commercial landing receipts.



Recreational Catch 1947-1999, Giant Seabass
Data derived from commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1936; no data available for 1941-1946; data separated by location of catch. Catch Data was not available for 1999.

adults can be found well away from the reef foraging for squid over a sandy bottom.

The orange juvenile phase has been reported among drifting kelp scattered over the bottom in 20 to 35 feet of water, over the soft muddy bottom outside of the Long Beach breakwater, and over flat sandy bottom in Santa Monica Bay. Larger juveniles up to 31 pounds have been found over flat sandy bottom and are sometimes caught over deep ridges (230-265 feet) off the coast of Del Mar by anglers targeting rockfish.

Given their depressed population and protected status, it is unlikely an aging study of giant sea bass will be completed in the near future. Although aging data are sparse, it is safe to say these fish grow slowly and live a long time. Estimated growth-rates are six years to reach 30 pounds, 10 years to reach 100 pounds, and 15 years to reach 150 pounds.

Spawning has never been observed in nature, but gonad examinations suggest that it occurs between July and September. Male fish have been observed to be mature at 40 pounds, and females at 50 to 60 pounds. Anecdotal information suggests that giant sea bass aggregate at specific locations and times to spawn. Because of the large size of this species, females are capable of producing enormous numbers of eggs. The ovaries of a 320-pound specimen contained an estimated 60 million eggs. Fertile, hydrated giant sea bass eggs are relatively large for a marine species, measuring about 0.06 inch in diameter. The eggs float to the surface and hatch in about 24 to 36 hours. The larvae drift and feed in the plankton for about a month before settling to the bottom and beginning their lives as juveniles. Giant sea bass have spawned in captivity several times, most recently at the Long Beach Aquarium of the Pacific where a single pair spawned in two successive years, nearly weekly beginning in June and ending in August or September.

Examinations of fish caught in Mexico indicate that the principal prey items are sting rays, skates, lobster, crabs, various flatfish, small sharks, mantis shrimp and an occasional kelpbass or barred sandbass. Earlier analyses found blacksmith, ocean whitefish, red crab, sargo, sheephead, octopus and squid. Giant sea bass are not built for speed, and the majority of their prey consists of organisms that live on the bottom. The vacuum produced when the huge mouth is rapidly opened draws such organisms into their mouth. Giant sea bass themselves are eaten by a variety of fishes and marine mammals when they are small. In addition to humans, large sharks prey on adults.

Except for the short period of time they spend as planktonic larvae, giant sea bass live in close association with the bottom. This way of life may become a problem for this species. The sediments along the coast of southern California carry high loads of toxins. In fact, an area off the Palos Verdes peninsula is thought to contain higher levels of DDE (a breakdown product of DDT) than anywhere else in the world's oceans. PCB is another pollutant that is prevalent along the coast of southern California. Many forms of invertebrates live in these sediments, ingesting the pollutants along with the organic material they feed on to survive. These organisms occupy very low trophic levels, and the toxins are passed up the food chain in increasing concentrations. Long-lived, top level predators accumulate the highest levels of toxins. Giant sea bass caught in southern California have been found to have high body burdens of DDE and PCB. Fish collected 200 miles south of the Mexican border were found to be free of toxins. Thus, California populations of giant sea bass may suffer from more than just overfishing. These two toxins have been found to affect reproduction in other species of fish, as well as in amphibians, reptiles, and birds.

It is presumed that giant sea bass migrate to specific sites to spawn. This was almost certainly the case prior to the exploitation of the spawning aggregations, but it is not known how far individuals traveled to participate in the aggregation, or whether these migrations take place today. The process of site selection for spawning aggregations is not well understood, but experimental manipulation of small aggregating reef species suggests that once a site is selected young fish learn its location from older fish. In this way, the same traditional spawning aggregation sites are used by subsequent generations of fish. Once the learning cycle has been broken it is not known how a new (or the same) spawning aggregation may form. The population may have to reach a particular density before the process of forming annual spawning aggregations becomes a possibility. Giant sea bass have been found in groups year round at a few locations in southern California. Although anglers that come across these areas and hook several giant sea bass in one day may be led to believe that this species is thriving, giant sea bass remain absent from the vast majority of our coast. It is likely that the fish are gregarious, and after heavy exploitation, the population has collapsed to a very few focal points where they can be found in healthy numbers.

Status of the Population

The California population of giant sea bass is well below historical highs. Anecdotal information suggests that numbers may be beginning to rebound under current measures. No hard data exist that provide actual or relative numbers of giant sea bass.

Management Considerations

See the Management Considerations Appendix A for further information.

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Yellowtail

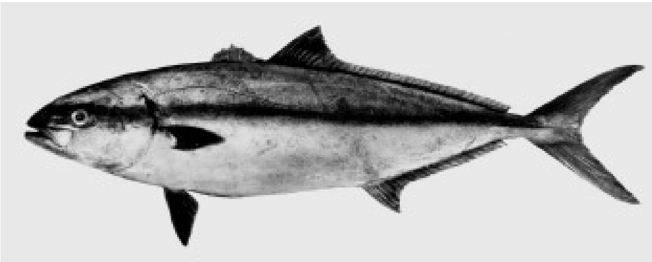
History of the Fishery

Sport and commercial fisheries for yellowtail (*Seriola lalandi*) have existed off California since the late 1800s. Commercial or subsistence fishing is the older of the two, with modern hook-and-line sport fishing getting its start in 1898 at Santa Catalina Island. Prior to 1898, sportsmen used handlines, a practice which faded with the advent of hickory rods, functional reels, and linen line. Both the sport and commercial fisheries in California are confined to the area south of Point Conception. The fishery usually occurs in nearshore areas, often adjacent to kelp beds. During the summer, fish may be found offshore under floating mats of kelp.

Commercial landings of yellowtail have fluctuated greatly in the past, ranging from a high of 11.5 million pounds in 1918 to a low of 9,769 pounds in 1995. Market conditions appear to dictate landings more than does the health of the resource. When market demand for fresh yellowtail was high or the canneries needed fish because tuna were unavailable, the price to the fisherman was great enough to encourage trips for the fish.

The commercial fishery for yellowtail was restricted to small live bait boats working off southern California or the Coronado Islands, Baja California, Mexico, until 1933. At that time, purse seiners began fishing in Mexican waters, as the supply of yellowtail off California had decreased and it was illegal to seine them north of the international border. Gillnet boats also started landing yellowtail taken incidentally to white seabass landed commercially in California. However, nearshore gillnet fishing was banned beginning in 1994. This greatly reduced the amount of fish landed by commercial fishers since only hook-and-line gear and gillnets fished outside three miles are legal methods of take.

Data from commercial passenger fishing vessel (CPFV) logs provide a general indication of the magnitude of the sport fishery for yellowtail in southern California. During years when the water was warm, CPFVs have landed over 450,000 fish. When the water was cold, yellowtail catches were sometimes less than 10,000 fish. Prior to the early 1950s, CPFVs were responsible for most of the sport catch. However, in the 1950s private boaters began taking a significant number of fish. During some years, private boaters land more yellowtail than do CPFV anglers. For instance, during 1997, private boat anglers fishing off California, landed 472,000 fish compared to 163,000 recorded by CPFV anglers. The increase in the number of private boat anglers may impact the yellowtail resource more than continued effort by CPFV anglers or commercial fishermen.



Yellowtail, *Seriola lalandi*
Credit: DFG

Major fishing areas for CPFV and private boat anglers include the Channel Islands, Santa Monica Bay, Dana Point to Oceanside, La Jolla, San Clemente Island, Santa Catalina Island, and the Coronado Islands. Long-range CPFVs fish primarily from Cedros Island south. They often concentrate on the offshore banks, especially in the Magdalena Bay area. The commercial fishery is conducted in the same areas as the sport fishery.

Status of Biological Knowledge

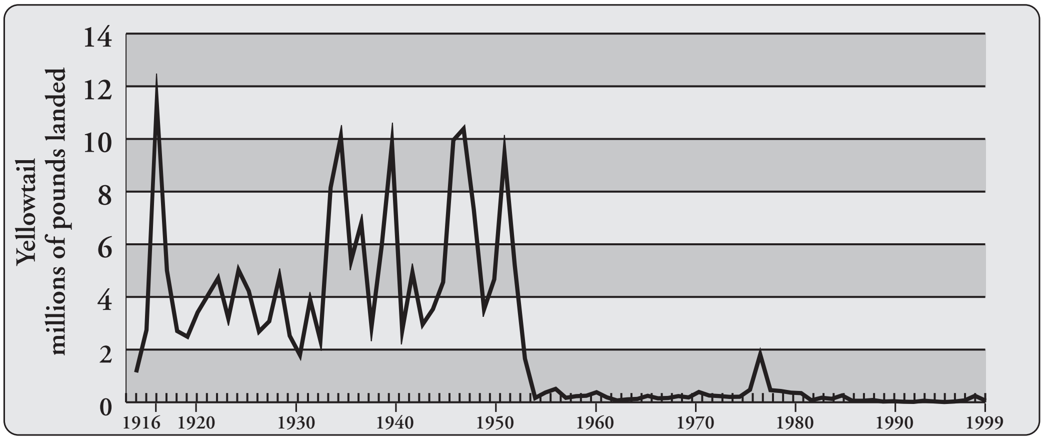
Yellowtail are found from British Columbia, Canada to Mazatlan, Mexico. They are present in the Gulf of California, occurring as far north as the Bay of Los Angeles.

Most yellowtail spawn during the summer months, June through September. During this period, adults move offshore and form spawning aggregations. Some two-year-old females may spawn, but all females over three years of age are capable of spawning. Young fish spawn only once during the season, while those seven years of age (20 pounds) and older are capable of multiple spawnings. A 20-pound fish is capable of producing 940,000 eggs during a single season.

Yellowtail are opportunistic daytime feeders. Off southern California, yellowtail stomachs contain sardines, anchovies, jack mackerel, Pacific mackerel, and squid. Fish taken off Mexico frequently are full of pelagic red crabs.

Age and growth studies conducted on yellowtail indicate the fish are relatively slow growing. They gain approximately three to four pounds a year during most of their lives, although very large individuals may gain only one to two pounds per year. Growth can vary considerably from year to year and also between and within geographical areas. The largest recorded individual weighed 80 pounds. The average sizes at selected ages are: age one, 20 inches and 3.8 pounds; age two, 25 inches and 7.4 pounds; age three, 28 inches and 9.9 pounds; age four, 31 inches and 13.2 pounds; age five, 33 inches and 15.9 pounds; age 10, 44 inches and 35 pounds.

Within southern California and at the Coronado Islands, sport anglers generally land yellowtail that weigh four to 12 pounds. Long-range CPFV anglers fishing off central Baja California usually catch 12 to 18 pound fish. Com-

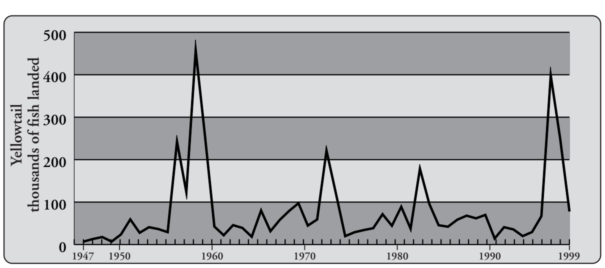


Commercial Landings 1916-1999, Yellowtail
Data Source: DFG Catch Bulletins and commercial landing receipts. Yellowtail landings include fish caught in waters south of the state but landed in California.

mercial gillnet fishermen generally land 10 to 20 pound yellowtail because of the selective nature of the nets. Commercial hook-and-line fishermen usually land four to 12 pound fish, although none can be less than 28 inches long, measured in fork length.

Results of a tagging study conducted by the California Department of Fish and Game indicate there are two stocks of yellowtail off Baja and southern California. One group occurs south of Cedros Island, Baja California, while the second group occupies the area from Cedros Island northward. There is some interchange of fish between the two groups around Cedros Island. Because of limited mixing between the two stocks, the southern California fishery is wholly dependent on fish recruited from the northern population.

The number of yellowtail available to southern California fishermen in any given year is dependent on whether warm water conditions exist off northern Baja California. Excellent yellowtail catches have occurred during years when water temperatures were at least three to five degrees F above normal in the spring. Conversely, periods of cool water produce low catches. When fish are available, they usually are found nearshore in the spring and fall but offshore during the summer months.



Recreational Catch 1947-1999, Yellowtail
Data Source: DFG, Commercial Passenger Fishing Vessel logbooks.

Status of Population

While no population estimate is available for the northern stock of yellowtail, the resource appears to be healthy. The stock is probably not as large as it was in the early 1950s, but it can support significant sport and commercial fisheries when oceanic conditions are favorable.

Data collected during the 1970s and early 1980s indicate that the northern population has undergone a shift in fish size. Two and three year olds now dominate the catch, whereas six to nine year olds made up the majority of the catch in the past. The shift in size could be an indicator of either population stress or good recruitment.

Because more of the northern stock is available to sport anglers during warm water conditions, CPFV catches during El Niño events provide an indication of the health of the resource. The El Niño event of 1997, which proved to be the strongest of many events beginning with 1983, pushed many young yellowtail north into southern California. The 1996 year class dominated the sport fishery during the summer of 1997 as one-year-old fish. The 1996 year class remained off southern California during the winter of 1998 and again dominated the fishery as two-year-olds. During 1998, the commercial fishery harvested almost a quarter million pounds of yellowtail since most of the 1996 year class fish reached legal size midway through the summer. This commercial catch represented a four-fold increase from 1997. With the cooling of ocean waters off southern California in 1999 and 2000, sport and commercial yellowtail catches dropped. However, the 1996 year class continued to dominate the sport fishery during both years. Based on data from the MRFSS, the 1996 year class was the strongest in recent history. Over 1.0 million yellowtail from the 1996 year class were landed by CPFV and private boat anglers between 1997 and 2000.

The department initiated a minimum size limit on sport caught yellowtail during 1998 in an effort to reduce the catch of one-year-old fish. The 10 fish limit was retained, but a 28-inch FL size limit was adopted with sport anglers allowed to retain five fish less than 28 inches FL.

Management Considerations

See the Management Considerations Appendix A for further information.

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Pacific Bonito

History of the Fishery

The Pacific bonito (*Sarda chiliensis*) is an economically important commercial species from Magdalena Bay in southern Baja California, Mexico to Point Conception, California, and in most years is ranked as one of the top 15 species sought by recreational fishermen in southern California.

As a result of the expansion of the commercial passenger fishing vessel (CPFV) industry after World War II, Pacific bonito catches by CPFVs increased from 36,500 in 1947 to over one million fish in 1960. Most of these fish were caught between Malibu Beach and the Coronado Islands. CPFV logbook landings of bonito remained high during the 1960s, with more than one million fish taken in 1964, 1968, and 1969. However, in the 1970s and 1980s, CPFV landings dropped and then stabilized with decadal averages for the 1970s and 1980s at 313,200 and 372,700 fish, respectively. In the 1990s, the number of fish taken by CPFVs dropped again. Logbook landings ranged between 2,880 and 263,000 fish with a decadal average of 101,700. The 1999 landings were the lowest annual catch on record and the decadal average the lowest since the 1940s.

During the 1980s, more then one-half of the bonito catch was made from private boats as this method of angling became increasingly popular. A similar trend was observed in the 1990s with private boats landing between 33 percent and 57 percent of the recreational catch. Private boat landings in the 1990s ranged between 1,200 and 128,400 fish with a decadal average of 49,600. This was significantly lower than the 1980s decadal average of 560,000 fish.

Recreational catches can be impacted by the availability of other desirable species. In the 1980s and 1990s, highly desirable species such as yellowfin tuna, bluefin tuna, and albacore occasionally were available in large numbers. The reductions in recreational landings of bonito can be attributed in part to a shift in targeted effort from bonito to these more desirable species.

Changes in regulations can also impact recreational catches. In 1982, a 24-inch size limit was imposed on bonito. Part of the reduction in sport landings after 1982 was probably due to this size restriction, but the impact of this regulation was probably limited because of a five fish tolerance for undersized bonito that was included with the size restriction.

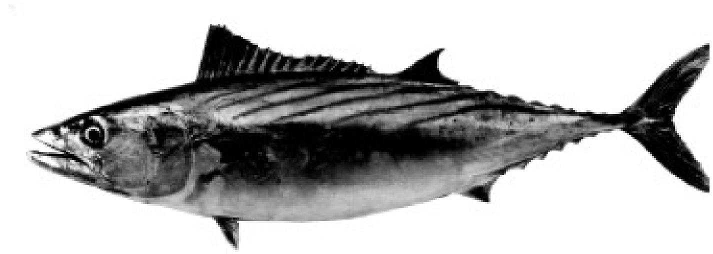
The bulk of the recreational catch consists of one-year bonito approximately 18 inches long. During fall and spring migrations, larger two-year fish become available to anglers. About five to 10 percent of the landings consist of fish larger then 24 inches.

Pacific bonito is well known for its fighting ability and quality as a food fish. Bonito can be caught recreationally with live anchovies and sardines or by casting or trolling with metal lures and feather jigs. Off California, recreational anglers typically catch bonito year round south of Point Conception with the highest catches in summer. North of Point Conception, recreational anglers usually take bonito during the fall months.

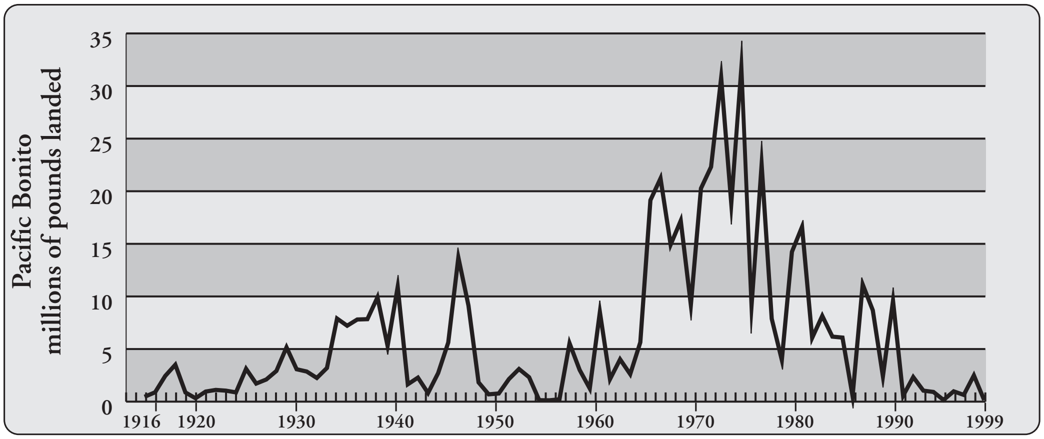
Bonito are taken commercially by troll gear, gillnets, and pole and line gear, but the landings of fish caught by these methods usually average less then two percent of the total catch. The primary commercial fishing gear for bonito is the purse seine. The purse seine fleet consists of two general groups: the local "wetfish" vessels with fish load capacities of 30 to 100 tons, and the larger tuna seiners capable of carrying 150 to 500 tons. Wetfish boats harvest mackerel and sardines, but seasonally target bonito, squid, and bluefin tuna. Nearly all of these wetfish seiners are based in San Pedro and fish in the Santa Barbara and San Pedro Channels. The large tuna seiners, now all but absent from California, operate primarily in the tropical waters off Mexico and Central and South America. Although the primary target for these seiners is yellowfin tuna, these vessels take bonito during their return trips to the United States to help compensate for small tuna catches.

Off California, commercial fishing for bonito occurs year round south of Point Conception with the largest catches in late summer and early fall. North of Point Conception, commercial fishing for bonito occurs primarily in the summer and fall.

Over the last 80 years, commercial landings of bonito have ranged between 127,600 pounds (1956) and 31.9 million pounds (1975). During the first half of the twentieth century, landings of bonito gradually increased from about 500,000 pounds in 1916 to around 10.9 million pounds in 1941. Landings briefly peaked again after World War II, but dropped during the 1950s and early 1960s. Landings then showed a major upward trend from the mid-1960s through the mid-1970s, increasing more than four-fold between 1965 and 1975. Starting in the late 1970s, this trend reversed with landings dropping in the 1980s to a decadal



Pacific Bonito, *Sarda chiliensis*
Credit: DFG



Commercial Landings 1916-1999, Pacific Bonito
Data Source: DFG Catch Bulletins and commercial landing receipts.

average of eight million pounds (compared to 9.7 million pounds for the 1960s and 17.7 million pounds for the 1970s). In the 1990s, landings for this fish ranged between 157,000 and 9.58 million pounds with a decadal average of 1.9 million pounds. This average was higher than that observed in the 1950s (1.8 million pounds) but lower than those from the previous three decades.

In the 1990s, bonito's ranking among the other commercial species also dropped. By total weight, bonito ranked among the top 20 species landed by California fisheries for most of the 1980s. In contrast, during the 1990s, this fish ranked among the top 20 species only in 1990 and 1998.

The amount of bonito landed is impacted by its availability, the availability of other desirable species, market demand, and price. Off of California, the availability of bonito can vary considerably between seasons and years. Some of this variation can be attributed to the migratory movements of these fish and some to oceanic changes. For instance, during El Niño events, more of the stock may move northward, becoming more available to California fisheries, while during La Niña events, fewer fish may move into California waters.

The availability of bonito also can be impacted by fishing restrictions. During the years from 1943 to 1958 and 1975 to 1978, at least 50 percent, and often more than 90 percent, of the landed bonito were taken off Baja California, Mexico. During the last two decades, Mexico has restricted access to foreign vessels fishing in its nearshore waters and California landings originating from Mexico have declined to less than 10 percent of the total landings.

In addition, the availability of bonito in California waters can be impacted by the amount of fish taken by the commercial fishery in Mexican waters. Mexican commercial landings of bonito over the last several decades show sharp periodic increases in the take of this fish. This pattern suggests that the Mexican commercial fishery for bonito is a pulse fishery. When bonito become more abundant, either from a gradual increase in the population or from the recruitment of a strong year class, then some of the commercial fishing effort in Mexican waters shifts to this species. The resource is harvested until the fish are no longer abundant. Effort then is redirected to other species until such time as the bonito resource becomes abundant again.

The availability of other desirable species can have a profound impact on the landings of bonito. Lower availability of other more desirable species due to environmental changes or management changes can increase the amount of bonito landed. For instance, bonito were targeted during seasonal yellowfin tuna closures in the 1970s because an incidental take of the more valuable yellowfin tuna was allowed while fishing for bonito. On the other hand, high availability of more desirable species can reduce the amount of bonito landed. This was likely the case in the 1980s and 1990s when a number of more desirable species including yellowfin tuna, skipjack tuna, albacore tuna, and bluefin tuna were at times quite abundant. In 1986, for example, high availability of bluefin tuna with a value of $1,550 per ton resulted in the wetfish seiners shifting their effort toward that species; as a result, bonito landings in 1986 dropped to a low of 533,000 pounds.

Market demand for bonito has been low over the last two decades. Commercial bonito landings are primarily purchased by canneries that process bonito for human consumption with the offal utilized for pet food or for reduction to fishmeal. Cannery orders for this fish in recent years have been limited. Higher demand exists for yellowfin tuna, skipjack tuna, albacore, and bluefin tuna for human consumption; for Pacific mackerel and jack mackerel as pet food; and for northern anchovy as fishmeal. Bonito also are sold fresh or frozen or are processed by curing or smoking. The market for this product is currently small, but is growing due to the changes in California's demographics.

Prices for bonito have generally showed an upward trend over time. Between the 1960s and early 1980s, the price of bonito increased from $50 to $90 per ton to $550 per ton. The price then declined to $200 to $300 per ton in the mid-1980s but increased again in the 1990s to an average of $990 per ton. While the 1990s average price is the highest reported for bonito, it is still lower than that paid for desirable fish such as bluefin tuna which usually sells for four to five times the price of bonito.

Status of Biological Knowledge

Pacific bonito is a rapidly growing piscivorous fish. In one year this fish can reach roughly 20 inches in fork length, and weigh about four pounds. At two years of age, bonito average roughly 25 inches in fork length and weigh about eight pounds. Their growth slows in the latter half of life with the fish reaching 32 to 35 inches and 17 to 22 pounds at six years. The California angling record is a 22-pound fish caught off Malibu Beach in 1978, but larger fish are occasionally reported.

Swimming is continuous to maintain orientation and respiration, and is powered by richly oxygenated red muscle tissues near the tail. As the fish grow, the proportion of red muscle tissue increases; hence, larger fish become relatively more powerful swimmers. At a continuous-maintenance swimming speed, aquarium-held fish averaging 22 inches in length swim as much as 43 miles daily.

Bonito is a temperate epipelagic schooling fish with a discontinuous distribution in the eastern Pacific Ocean. It ranges from Chile to the Gulf of Alaska, but is absent from the central coast of Mexico south to Panama. The northern population typically is centered between southern California and central Baja California, but this distribution can shift northward during warm-water years. This species migrates approximately 600 miles along the United States - Mexico coastline, moving southward from southern California in the winter and northward from Baja California in the summer. This migration probably is a response to changing sea temperatures since these fish appear to be impacted by local variations in sea temperature. Individuals tagged and released within warm-water discharges from electrical generating stations have been recaptured near their release site up to three years later. These tagging studies suggest that some bonito do not move southward in the winter and instead overwinter in the Southern California Bight.

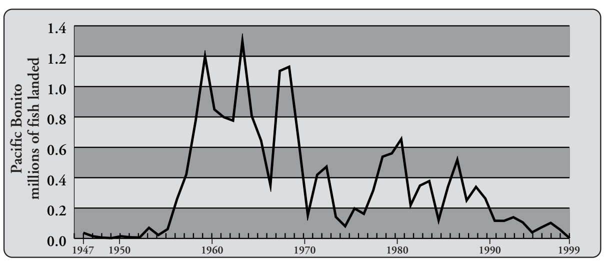
There is no external anatomical differences between the sexes. However, behavioral and visual cues can be used to distinguish males from females. During courtship of bonito observed in an aquarium, females swim with a wobble while males use color barring on their bodies to show their interest and aggressive nature. This aggressive vertical barring coloration in males has also been observed in aquarium-held bonito at feeding time. During courtship, males will follow directly behind the displaying female, jockeying for position. The successful male and female then pair and synchronize the release of gametes at the onset of a tight circle swim. Gametes are broadcast into the seawater where fertilization takes place.

Sexual maturity differs between males and females. Pacific bonito females begin to mature at two years of age and are fully mature at 24 inches. Males are more precocious. About 44 percent of the one-year males spawn, and all are mature at two years of age or 20 inches in length. Spawning begins in January and continues for a five-month period. Peak spawning occurs off central Baja California, but may take place in southern California late in the season or during El Niño episodes. Some localized spawning may also take place near warm-water discharges from electrical generating stations. Individuals may spawn more than once during a season. A 6.6-pound female releases an estimated 0.5 million eggs in one season.

Bonito consume prey equaling about six percent of their body weight per day. Northern anchovies are common prey, but market squid, highly vulnerable to predation while spawning, sometimes become a major part of the diet. Pacific sardines may also be a significant food source.

Status of the Population

Warm water conditions in the 1980s and 1990s may have provided good conditions for bonito survival, but large catches have been sporadic and the trends in both commercial and recreational landings continue downwards. This downward trend may be due in part to a shift in targeted effort from bonito to other more desirable species and to low market demand. It also may be due to changes in the distribution and migration of this northern population in response to oceanographic changes that have taken place over the last two decades. However,



Recreational Catch 1947-1999, Pacific Bonito

CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

this downward trend may well be due to a decline in stock abundance. If this is the case, then current fishing practices may make it difficult for this stock to rebuild.

Management Considerations

See the Management Considerations Appendix A for further information.

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Ken Miller and **Marija Vojkovich**
California Department of Fish and Game

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California Barracuda

History of the Fishery

The California barracuda (*Sphyraena argentea*), also known as the Pacific barracuda, has played a significant role in the growth and development of California's commercial and sport fishing industries. Taken primarily off southern California and northern Baja California, Mexico, barracuda figured prominently in the development of the purse seine fishery. Additionally, they have long been a major component of the southern California sport fish catch.

Annual records of commercial barracuda landings date back to 1889, but only nine years of intermittent records exist through 1915, and these are not specific as to catch areas. Commercial landings of barracuda in 1889 were 0.5 million pounds, and by 1915 they were up to 3.6 million pounds. Since 1916, landing records have differentiated barracuda caught in California waters (essentially off southern California) from those caught in waters south of the international border with Mexico (northern Baja California). By 1916, The southern California purse seine fleet consisted of at least seven vessels by 1916. Influenced by the economic impetus of World War I, the commercial barracuda fishery grew concurrently with the rapid development of the purse seine fleet.

Attempts to manage the barracuda fishery began in 1915 with a minimum size limit of 18 inches for hook-and-line caught barracuda. Since then, many commercial and sport regulations on gear, seasons, weight, size, and bag limits have been enacted, modified, or repealed. Today, most commercially caught barracuda are taken by gillnets with 3.5-inch mesh, although some are taken by hook-and-line. The minimum size limit is 28 inches. May and June are usually the peak months of commercial fishing activity for barracuda.

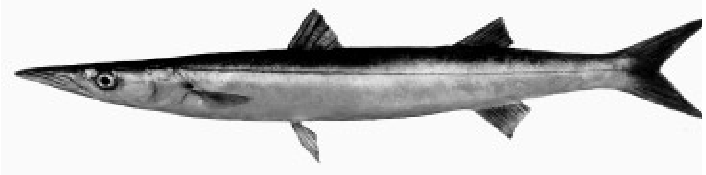
Between 1915 and 1970, commercial landings of barracuda harvested from California's nearshore waters averaged 2.1 million pounds annually, despite a gradual decline in landings since 1925. Landings have remained relatively low since 1970, averaging about 113,500 pounds annually. Prior to 1926, California barracuda harvested south of the international border exceeded those catches made in California. Barracuda harvest from Mexican waters remained an integral part of the California fishery until 1969, averaging over one million pounds annually. But over the past 30 years, landings have been insignificant, averaging only 600 pounds annually. The major cause for the decline was the imposition of increasingly restrictive commercial fishing regulations by Mexico which became increasingly restrictive to California fishermen over the years.

In general, commercial barracuda prices are a function of supply and demand. Historically, the price paid to fishermen has been low. In 1999, commercial fishermen received an average price of $0.70 per pound.

The popularity of California barracuda as a game fish goes back to at least the mid-1920s, as is evident from photographs and newspaper accounts. However, the California Department of Fish and Game (DFG) did not begin collecting records of commercial passenger fishing vessel (CPFV) sport fish landings until 1936. Records from 1936 through 1940 reveal that CPFV barracuda landings (in numbers of fish) exceeded those of other sport fishes, and that they often equaled or exceeded commercial landings (in weight) for barracuda taken in California waters. Annual landings for these five years averaged about 630,000 fish. Records were not kept from 1941 through 1946 due to fishing restraints during World War II. As interest in marine sport fishing grew in the post-World War II era, the sport take of barracuda greatly exceeded that of the commercial fleet in California waters. Between 1946 and 1971, CPFV barracuda landings ranged from 87,600 to 1.2 million fish, for an overall annual average of 447,000 fish. In 1971, the current 28-inch minimum size limit for all sport-caught barracuda became effective, causing an 86 percent decline in CPFV barracuda landings from the previous year. Since 1971, CPFV landings of barracuda have been increasing, ranging between 26,300 and 446,000 fish annually.

The Marine Recreational Fisheries Statistics Survey has shown that, on average, 54 percent of the total barracuda catch is from CPFVs, 45 percent is from private and rental boats, and one percent is from shore. In the late 1980s, a DFG study determined that roughly 60 percent of CPFV-caught barracuda are released (almost all of which are less than 28 inches). The study also indicated Los Angeles County accounted for 58 percent of the CPFV barracuda landings.

Sport anglers, especially aboard CPFVs, usually use live anchovies or sardines to fish for barracuda. Anchovies and sardines are also used to chum and hold barracuda schools close to the boat. Metal or plastic artificial lures in a variety of shapes and colors are also popular. Sport-caught barracuda are taken mainly near the surface. Most fishing activity occurs from May through September, when surface water temperatures range between 62° and 70°F.



California Barracuda, *Sphyraena argentea*
Credit: DFG

Status of Biological Knowledge

The California barracuda is a nearshore, epipelagic, schooling fish found from Cabo San Lucas, Baja California to Kodiak Island, Alaska. Catch origins indicate the population is centered between San Quentin, Baja California and Point Conception, California. During warm water oceanic events, such as El Niños, a portion of the population may shift northward into central California. Frequently seen at the surface, barracuda have been taken at depths of 120 feet.

Growth in length is most rapid during the first year of life. Barracuda reach a total length of 14 inches at one year. At two years, they have grown to 20 inches and weigh about one pound. However, the maximum growth by weight of nearly one pound per year is achieved by four- and five-year-old fish. The minimum size limit of 28 inches, approximately a three-pound fish, is near the average size for a four-year-old. At this age, females are about 0.75 inches larger than males, and the difference increases to about 2.5 inches in fish over six years old. The oldest fish aged was an 11-year-old measuring 41 inches and weighing about nine pounds. Larger and presumably older fish include the state angling record of 15 pounds 15 ounces and a 17-pound fish caught off Carpenteria in 1958 that measured 46.5 inches.

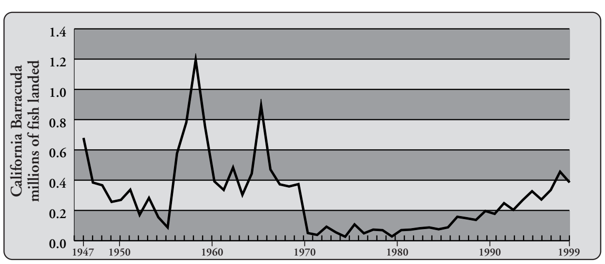
California barracuda produce pelagic eggs and larvae. Fertilization takes place externally as the sexes simultaneously release their gametes. At two years, almost all males and 75 percent of females are sexually mature. All are mature at three years of age. Full sexual maturity occurs in males at a length of 20 inches and in females at 22 inches. In a single spawning, a two-year-old female may produce 50,000 eggs, increasing to about 400,000 by age six. Individuals may spawn more than once during a spawning season. Off southern California, spawning takes place from April to September, peaking in June.

Feeding habits of California barracuda are not well documented, but some potential prey species can be mentioned. During pelagic schooling movements, barracuda may feed on other open water schooling fishes such as northern anchovy, Pacific sardine, Pacific mackerel, jack mackerel, and Pacific saury. In association with kelp beds or shallow water habitats, they may feed on topsmelt and California grunion. Opportunistic feeding on market squid made vulnerable during their spawning activity is likely.

Previous references to the predators that feed on California barracuda have listed sea lions, seals, porpoises, and giant sea bass. Analyses of the gut contents and scat from marine mammals have failed to discover barracuda remains. Observations of California sea lions and harbor seals opportunistically feeding on barracuda injured or entrapped by fishing gear are common, but these animals more typically feed on the same size prey as adult barracuda. Giant sea bass are more likely predators on juveniles and adult barracuda.

California barracuda have an inshore distribution during their early life history. Fish a few inches long are observed in protected bays and marinas. Larger young-of-the-year fish school below the canopy of semi-protected kelp-bed habitats. Older juveniles and adults form large schools that disperse widely in the open-water environment.

Movements of California barracuda have been studied by tagging. Fish tagged during May 1959 at locations off northern Baja California and off southern California were recovered at intermixed locations, indicating a single population. Movements of up to 100 miles north and south occurred during the summer, but a portion of the recoveries were at the release sites. However, a general migration pattern that was distinctly northward during the summer and less distinctly southward during the fall was indicated. Movements are presumably a response to sea temperature, and warm overwintering temperatures off southern California reduce the southward return. High catch success during spring and summer off southern California has been correlated with warm sea temperatures the preceding winter.

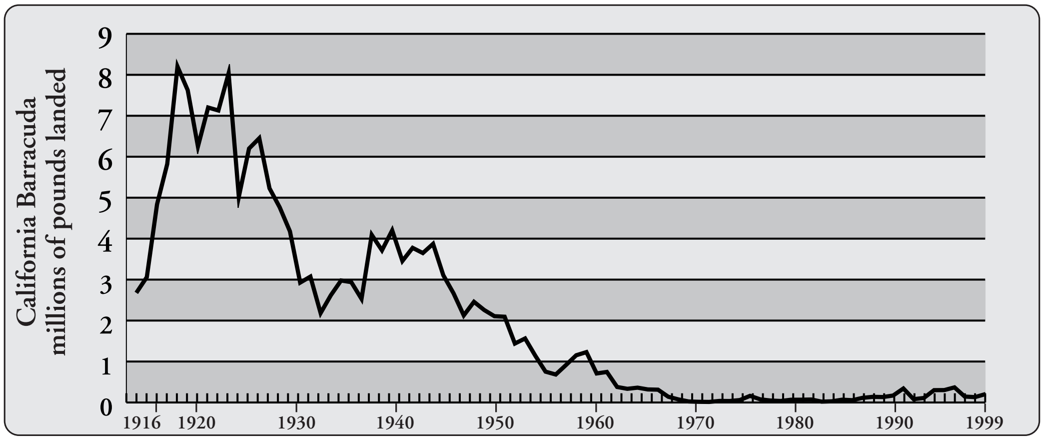


Recreational Catch 1947-1999, California Barracuda

CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

Status of the Population

The status of the California barracuda population is unknown, because data concerning catch, fishing effort, and age composition are scarce. Barracuda catches off California are variable for many reasons, one of which is that barracuda are migratory with a preference for warmer waters. During an El Niño event, when warmer than normal water masses move up the coast, barracuda are caught far north of their normal range and in greater than average numbers off southern California, suggesting a higher population level. This was apparent during the 1957-1959 El Niño event, one of the most intense on record. However, during the similarly intense 1982-1983 and 1997-1998 El Niño events, barracuda catches did not



Commercial Landings 1916-1999, California Barracuda
Data Source: DFG Catch Bulletins and commercial landing receipts.

increase appreciably. Assuming fishing effort and the percentage of the population migrating northward were similar, the difference suggests that the barracuda population was depressed during the latter El Niño periods. Since the late 1980s, catches have increased but remain well below those reported prior to 1970. This is due to the fact sport anglers may no longer keep short barracuda as they were allowed to do prior to 1971. Only during one three-year period, 1958 though 1960, has the number of barracuda off southern California been estimated by the DFG. Estimates ranged from 1.6 to 2.9 million fish.

Because of uncontrollable factors such as migration, water temperature, and Mexico's management policies, the DFG's management policies for this species probably have a limited effect on its population level. Nevertheless, the regulations are intended to reduce the likelihood of overfishing this valuable resource.

Management Considerations

See the Management Considerations Appendix A for further information.

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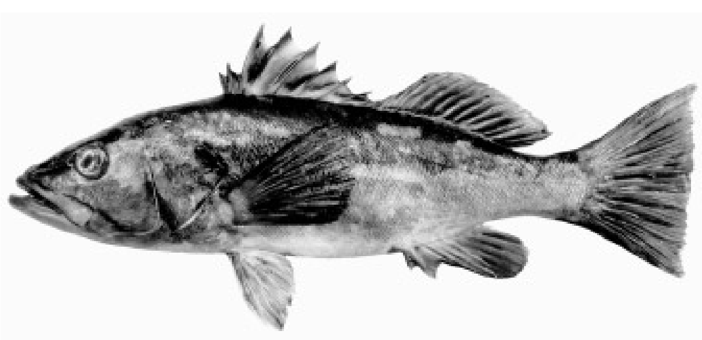
Kelp Bass

History of the Fishery

Kelp bass (*Paralabrax clathratus*) are popularly referred to as calico bass and represent one of the most important nearshore, recreational species in the waters off of southern California. This important species has been the target of southern California anglers and commercial fishermen since the early 1900s. In the early years of the fishery, catch statistics grouped kelp bass and the two other *Paralabrax* species, barred sand bass and spotted sand bass, into a single "rock bass" category. Based on recent information, it is very likely that kelp bass comprised most of this catch category early on. The largest commercial landings of rock bass occurred during the 1920s and 1930s; annual landings averaged 500,000 pounds. A sharp decline in fishing activity occurred during and after World War II and landings never exceeded 150,000 pounds from 1941 through 1953. The general decline of the rock bass resource prompted conservation measures, which in 1953 made commercial fishing for rock bass illegal in California waters. Legally sold fish imported from Mexico dwindled to insignificant levels since the late 1950s. Sport anglers using light hook-and-line tackle catch kelp bass while fishing from piers, beaches, private boats, and commercial passenger fishing vessels (CPFVs). Sport catch records for rock bass taken by CPFVs have been available since 1935, but only CPFV records since 1975 reliably differentiated kelp bass catches from the other rock bass. Early sport anglers considered the kelp bass a nuisance when attempting to catch more desirable gamefish. Only the largest "bull bass" were sought. In 1939, a limit on sport fish catches in California, 15 total fish in an aggregate of several species, was the first management attempt to prevent depletion of popular sport fish populations.

Intense fishing immediately after World War II may have caused a progressive decrease in the size of landed bass, and the popular kelp bass fishery was deteriorating. The California Department of Fish and Game (DFG) instituted comprehensive studies in 1950 that resulted in size and bag limits for sport caught kelp and sand bass combined. The new size limit began at 10.5 inches and was increased several times until the 12-inch limit was reached in 1959.



Kelp Bass, *Paralabrax clathratus*
Credit: DFG

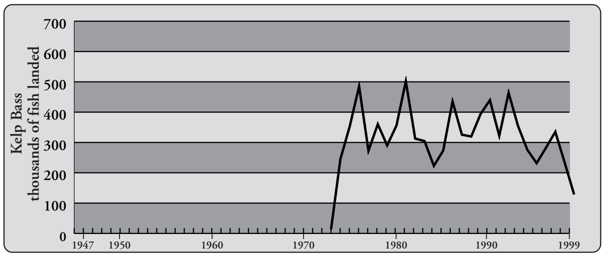
The kelp bass catch has fluctuated greatly since the 1960s. The largest CPFV catches occurred during the mid-1980s, estimated at over 1,000,000 fish annually. Since 1980, the CPFV kelp bass catch has ranged from 273,000 to 2,795,000 fish in 1988 and 1986, respectively, and averaged about 1,000,000 kelp bass per year. CPFV landings of kelp bass typically peak in the late spring and early fall. The recent Federal Marine Recreational Fishery Statistics Survey estimated that since 1990 the catch from shore, pier, and private boat anglers averages about 900,000 kelp bass per year which exceeds that of CPFV fishermen (about 800,000 fish per year). The CPFV landings of kelp bass steadily declined each year from 1993 to 1999.

The most productive fishing areas for kelp bass in recent years have been off the Coronado Islands, Baja California, Mexico; Point Loma and La Jolla in San Diego County; Dana Point and Huntington Beach in Orange County; Santa Catalina Island and Horseshoe Kelp in Los Angeles County; and around the Channel Islands in Santa Barbara and Ventura Counties.

Status of Biological Knowledge

Kelp bass have ranged historically as far north as the mouth of the Columbia River and south to Bahia Magdalena, Baja California, Mexico. However, they are rare north of Point Conception. They are abundant in southern California waters including the shores of all the Channel Islands. They are typically found in shallow water (surface to 150 feet) being closely associated with high relief structure, including kelp. Kelp bass range throughout the water column, but seem to concentrate between eight and 70 feet. In general, they live solitary lives but form assemblies to spawn and to feed on small schooling fish. Early tag and release studies showed little movement for the majority of kelp bass and concluded that if they move at all, it is to nearby rocky reefs or short distances to gather into breeding assemblages. More recently, tagging studies in the northern portion of the Southern California Bight from Point Conception south the northern Channel Islands indicated the kelp bass were quite mobile with some fish traveling as far as 50 miles.

Kelp bass have the broad diet of a generalized carnivore consisting of small fishes (including anchovies, sardines, surfperch, queenfish), squids, octopuses, crabs, shrimps, and amphipods. They forage primarily in the midwater, but occasionally feed on the bottom. Young kelp bass feed on small crabs, copepods, and plankton. They feed lightly in the winter and most heavily during May through September.



Recreational Catch 1947-1999, Kelp Bass
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks. Prior to 1973, Kelp Bass and Barred Sand Bass CPFV catch data were aggregated.

Kelp bass mature between seven and 10.5 inches in length and about three to five years and form breeding aggregations in deeper water off of kelp heads and rocky headlands, generally, in depths down to 150 feet. Several hundred ripe adults may aggregate in a small area during spawning. During spawning, high-contrast, black and white individuals with yellow-orange snouts are usually males, and fish with golden hues and yellow chins and jaws are usually females. Spawning occurs primarily around the full moon from April through November peaking in the summer months. Kelp bass produce pelagic eggs (0.04 inches in diameter) which enter the plankton in coastal waters. Larvae remain in the plankton for 28 to 30 days at which time they settle out in shallow water in attached, as well as drift algae including kelps. Young-of-year kelp bass grow to a length of about two inches in the first 90 days of life.

Kelp bass are known to grow to 28.5 inches and 14.5 pounds. The oldest known kelp bass was 34 years old and 25 inches long. Juvenile kelp bass can be five to six inches after one year and are about 12 inches (legal size) at five years. The average 10 year-old kelp bass is about 18 inches in total length. As with most fishes, growth is highly variable with the largest fish not necessarily being the oldest. The world record kelp bass (14.5 pounds) caught off Newport Beach in 1995 was 27 years old while a 9.5 pound fish caught at San Clemente Island in 1993 was 34 years old.

Status of the Population

In the 1970s and 1980s, the kelp bass was among the top three species taken by the average angler per hour of fishing (along with barred sand bass and Pacific mackerel). In 1986 and 1989, kelp bass were the most commonly taken species in the CPFV fleet. Throughout the 1980s, kelp bass have consistently ranked among the top five fishes caught by CPFV anglers. DFG surveys indicate the estimated total catches of kelp bass have increased since the mid-1970s. Low periods of kelp bass landings in the mid-1970s and early-1980s may be attributed to El Niño events that provide anglers with alternative species to catch. Peak landings have followed each El Niño event. DFG surveys of the CPFV industry in the 1970s and 1980s indicated a stable spawning population is being maintained because of the large number of age classes that are caught and kept by anglers. Approximately 85 percent of the kelp bass kept by CPFV anglers measure between 11.4 to 15.9 inches, representing up to seven age classes. However, the alarming decline of recreational catch from all sources that has occurred in the 1990s is a major cause for concern.

Management Considerations

See the Management Considerations Appendix A for further information.

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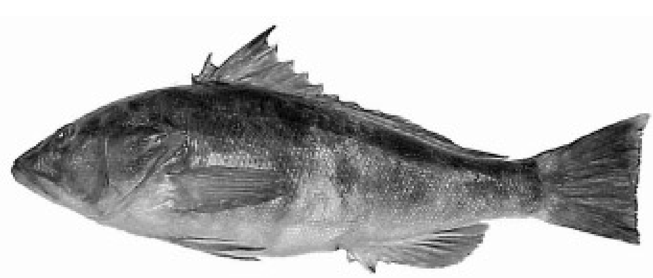
Barred Sand Bass

History of the Fishery

Barred sand bass (*Paralabrax nebulifer*) are commonly caught by anglers in California. Since the late 1970s, this species has consistently ranked among the top 10 species in the southern California marine sport fish catch. The major barred sand bass fishing sites include the Silver Strand, Del Mar, San Onofre, Huntington Flats area off Orange County, the inshore portion of northern Santa Monica Bay off Pacific Palisades and Santa Monica in Los Angeles County, and the Ventura Flats area off northern Ventura County. Barred sand bass are targeted exclusively by sport anglers; the commercial harvest of this species has been illegal since 1953. Throughout the 1930s and early 1940s, sand bass, as well as kelp bass, were not considered to be quality angling fare but gained tremendously in popularity as game fishes by the mid-1950s. At that time, concern about the resource by sport fishermen and fishery managers resulted in the initiation of life history studies and the formulation of conservation measures. By 1959, a 10-fish bag limit and a 12-inch minimum size limit had been imposed on all three kelp and sand bass species, measures designed to counteract the declining numbers, and shrinking size composition of the bass catches. The commercial passenger fishing vessel (CPFV) bass fishery responded positively to this management regime, and landings of kelp and sand bass increased substantially through the 1960s and early 1970s. From 1975 through 1989, the CPFV barred sand bass catch expanded threefold to a peak of 400,000 fish in 1988. Although lacking some of the sporting qualities of kelp bass, barred sand bass are much more susceptible to hook-and-line gear and are somewhat easier to catch. When CPFV skippers target barred sand bass aggregations, they can usually produce substantial catches for their passengers, even for novice anglers possessing minimal fishing skills. In 1985, 1987 and 1988, barred sand bass was the leading bass species in the CPFV catch exceeding kelp bass landings for the first time since 1961 when kelp bass and sand bass landings were first reported separately. Estimates of annual barred sand bass landings from all sport fishing activities (shore, pier, private boat, CPFVs, etc.) ranged as high as 1,940,000 in 1988. The CPFV landings of barred sand bass remained stable at around 600,000 fish from 1993 to 1996, but declined dramatically thereafter. On average, landings of barred sand bass in the 1990s were about 40 percent lower than those in the 1980s.



Barred Sand Bass, *Paralabrax nebulifer*
Credit: DFG

Status of Biological Knowledge

Barred sand bass range from Santa Cruz south to Bahia Magdalena, Baja California, Mexico. They are rare north of Point Conception. Sand bass chiefly inhabit the shallow waters near the southern California mainland, but have been captured at depths as great as 600 feet, but the greatest concentrations are found in depths less than 90 feet. Young sand bass are abundant in very shallow water (five to 30 feet). The name "sand bass" is somewhat unfortunate since they are usually closely associated with sand/rock interfaces of deep reefs and artificial structures and are rarely found out over sandy expanses.

Barred sand bass feed mainly on small fishes (including anchovies, sardines, midshipman), and invertebrates such as crabs, clams, and squid. The largest barred sand bass on record measured 26 inches in length, and the maximum-recorded weight was 11.1 pounds. Like their sympatric congener the kelp bass, barred sand bass are also relatively slow growing. A juvenile barred sand bass is approximately six inches long after one year, and reaches sexual maturity between seven and 10.5 inches in length and about three to five years. The oldest known barred sand bass was found to be 24 years old.

Barred sand bass form large breeding aggregations over sandy bottoms at depths of 60-120 feet in the summer months. Spawning occurs in these aggregations from April through November, usually peaking in July. During spawning, high-contrast, gray and white individuals with large golden-yellow crescents under their eyes are usually males. Sand bass produce a large number of small pelagic eggs that enter the plankton in coastal waters. Young-of-the-year sand bass begin appearing in shallow, nearshore waters in the early fall.

DFG tagging studies have revealed that barred sand bass are capable of movements of from five to 40 miles. In the early 1970s, evidence was presented that tumors, deformities, and other anomalies found in barred sand bass may have been linked to industrial and domestic wastes discharged into the nearshore environment. Reports of such abnormalities have decreased in the past two decades.

Status of the Population

The barred sand bass catch rose steadily in importance from 1975 to late 1989, to the point where sand bass are rivaled only by kelp bass in the nearshore recreational catch off southern California. From 1975 to 1978, barred sand bass ranked in the top ten in CPFV catch. By 1986 to 1989, barred sand bass consistently ranked in the top three species and was the top ranked species in CPFV catch in 1988. CPFVs and private boats take the majority of sand bass while fishing the summer spawning aggregations. Several factors seem to account for the upward trend. Most significantly, CPFVs, which account for the greatest portion of the barred sand bass catch, have begun to target them more frequently, especially during the summer spawning period. The fish are concentrated at that time, usually in well-defined areas along the coast. Also, new barred sand bass spawning sites have been discovered over the last 20 years and are now being exploited by CPFVs and private boats. As fishing effort targeting barred sand bass has increased, there has been concern that the stock may become over-exploited. Although, more information must be collected before the impacts of this intense fishing on barred sand bass populations can be determined, landings have recently begun to decline and there is cause for concern.

Management Considerations

See the Management Considerations Appendix A for further information.

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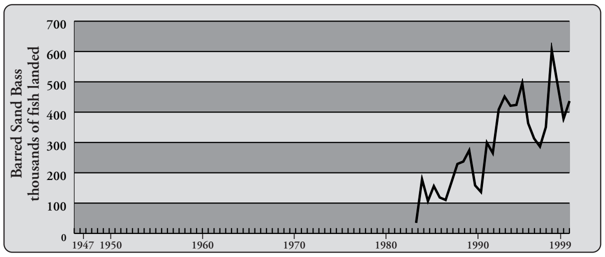

Recreational Catch 1947-1999, Barred Sand Bass

CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks. Prior to 1973, Barred Sand Bass abd Kelp Bass CPFV catch data were aggregated.

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Spotted Sand Bass

History of the Fishery

The spotted sand bass (*Paralabrax maculatofasciatus*) has quickly gained popularity with nearshore anglers for its aggressive behavior and fighting ability. Recreational angling for the spotted sand bass has seen a dramatic increase in the last 10 years, resulting in angling tournaments that target spotted sand bass exclusively.

Not considered quality-angling fare in the 1930s and the early 1940s, the spotted sand bass began to gain in popularity with shore and bay anglers in the mid-1950s. During that period, almost all landings were made from shore or by small skiff anglers fishing within the bays of southern California. Concern regarding the growing pressure on this little-known resource by sport anglers resulted in the formulation of conservation measures for the spotted sand bass. These measures include the restriction on commercial exploitation of the genus *Paralabrax* in 1953, and in 1959, the adoption of a 10-fish bag-limit and a 12-inch size-limit on kelp bass and barred sand bass, as well as the spotted sand bass. Unfortunately, early landing data of spotted sand bass were either lumped in with the other *Paralabrax* landings or not adequately reported. For these reasons, accurate landings numbers for this species are difficult to obtain and no substantial data were recorded until the mid-1970s.

Surveys conducted by the Department of Fish and Game on skiff fishing estimated that the annual catch of spotted sand bass in southern California waters ranged from 12,790 to 23,933 fish between 1976 and 1981. Additional estimates of sport catch, based on data from boat and shore fishing, indicated that between 53,000 and 170,000 spotted sand bass were taken per year from 1980 to 1989. No landing data were recorded from 1990 to 1993; however, from 1994 to 1999 between 37,000 to 347,000 spotted sand bass were landed either by shore or small skiff fishermen, a substantial increase from the landings numbers recorded in the 1980s. This rise in landings can be attributed to an increased interest in recreational fishing in shallow nearshore waters and consequential increase of angling pressure on the resource. Additionally, with the introduction of float-tube technology and the popularity of ocean kayaks, the accessibility to spotted sand bass habitat has opened up dramatically. This accessibility has generated interest in the spotted sand bass as a challenging recreational fishery.

Although the annual catch of spotted sand bass for the record keeping period has been considerably lower than the catches of the kelp bass and the barred sand bass, the increase in fishing pressure and landing numbers is cause for concern due to their restricted habitat in southern California waters. Early DFG shore surveys revealed that due to its restricted bay habitat and geographically localized populations (San Diego Bay, Mission Bay, Newport Bay, Anaheim Bay), the spotted sand bass fishery may have been viewed as a less important sport fishery by the public. However, recent increases in landing numbers, indicate that this view may be changing.

Spotted Sand Bass, *Paralabrax maculatofasciatus*
Credit: DFG

Status of Biological Knowledge

The spotted sand bass has an historic range from Mazatlan, Mexico to Monterey, California. However, this species is rarely seen north of Santa Monica Bay. Included within that range are substantial populations in the Gulf of California. Southern California populations are typically restricted to sandy or mud bottom habitat within shallow bays, harbors and coastal lagoons that contain eelgrass, surfgrass and rock relief. These areas act as warm-water refuges for this generally subtropical species.

Spotted sand bass grow rapidly during their first two years. Some specimens may reach as much as 8.8 inches at the end of their first year and there is no significant difference in growth rates between males and females.

Spotted sand bass spawn in the warm summer months, from late May to early September and the presence of multiple sized oocytes in gravid females indicates that this is a multiple spawning species.

During the spawning season, spotted sand bass form breeding aggregations at or near the entrances of bays in southern California. Observations on spawning in the wild have shown that females initiate the spawn by leaving the bottom and entering the water column to release eggs. At the time of release, multiple males may dart in to fertilize the eggs. The observed episode was extremely brief and once completed all participants return to the bottom.

The eggs and larvae are pelagic and enter the plankton in the coastal waters, settling out of the water column at 25 to 31 days. Juvenile spotted sand bass (greater than two inches) have several dark stripes running longitudinally along their sides, making them similar in appearance to juvenile barred sand bass. Juveniles of this species occupy eelgrass beds and can share these nursery environments with their sympatric juvenile relatives, the barred sand bass and the kelp bass. Adults usually occupy a depth of two to 30 feet, however specimens have been taken from waters as deep as 200 feet in the Gulf of California.

The spotted sand bass appears to have a complex mating system. Individual populations within southern California display varied patterns of reproduction. In San Diego Bay, protogynous hermaphroditism, where individuals start their lives as females and after a period of time change to males occurs. In Anaheim and Newport Bays, gonochorism, a pattern where the individuals do not change sex is found, resulting in an essentially equal distribution of males and females throughout the age and size class in the population. During the spawning season, male and female spotted sand bass exhibit a definite sexual color dimorphism. Males will display a whitish chin color and an overall high-contrast, body coloration, while females will display a yellow chin and a darker body. Male spotted sand bass mature at 7.8 inches and about 1.4 years and females mature at about 6.7 inches and about one year of age. The impact of potential sex change, if any, on these values is unknown.

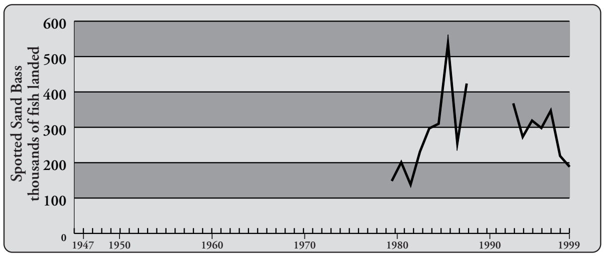
In California waters, adult spotted sand bass have a diet that consists primarily of crabs and clams, with fishes forming a relatively small component of their overall food compliment. The crab component consists of brachyuran crabs, and the dominant bivalve in the diet is the jack-knife clam.

While spotted sand bass can reach 14 years-of-age, most have a maximum life span of about 10 years. The current world record spotted sand bass is an individual caught in 1995, which measured 23 inches and weighed 6.7 pounds. This record fish was 10 years old.

Significant morphological and genetic differentiation has occurred among spotted sand bass populations throughout their geographic range. The Gulf of California populations appear to be distinct from those on the Pacific coast. Those populations in southern California also appear to be genetically distinct from those in the mid-Baja, Pacific coast. This subpopulation structure indicates that spotted sand bass exhibit limited dispersal from their restricted habitats.

Status of the Population

The spotted sand bass fishery has received a dramatic increase in angling pressure in the last 10 years, and it is unclear how the increased pressure will effect the limited, and genetically distinct, southern California populations. Studies indicate that most of the spotted sand bass caught by recreational anglers are released. The restrictive, limited environment inhabited by spotted sand bass tends to amplify the adverse effects of environmental changes and of recreational fishing pressure. Factor in



Recreational Catch 1947-1999, Spotted Sand Bass
Data Source: RecFin data base for all gear types; catch data not available for 1989-1992

sporadic recruitment by spotted sand bass, and the future of this fishery may depend on such a policy.

What effect ever-increasing development in the attractive bay communities will have on the spotted sand bass populations is unknown. Waterfront development may permanently alter nursery habitat, water quality and may negatively impact recruitment, resulting in a negative impact on certain populations.

Environmental conditions such as sea surface water temperatures may influence recruitment as well. Spotted sand bass have been shown to have a substantial increase in recruitment success during elevated sea surface temperatures occurring nearshore in southern California just after El Niño episodes. In other years, recruitment has been poor. This sporadic recruitment pattern may have an adverse effect on a population that is subjected to an increase in angling pressure.

Management Recommendations

See the Management Considerations Appendix A for further information.

Tim E. Hovey
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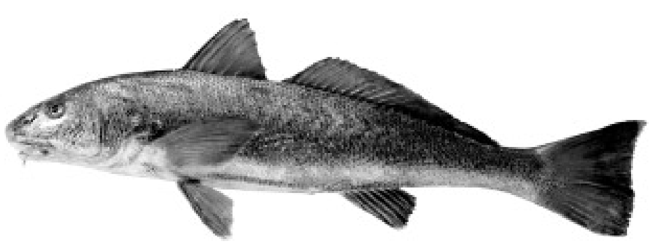
California Corbina

History of the Fishery

The California corbina (*Menticirrhus undulatus*) is a nearshore croaker that is reserved for the recreational fishery. It has been illegal to take corbina with nets since 1909, and illegal to buy or sell them since 1915. This wary species is a challenge to anglers. Sometimes corbina can be seen in small schools, swimming slowly along the bottom seeking food. While feeding in this manner, it seldom takes bait. The corbina is considered one of the most difficult fish to catch in southern California, although on occasion it takes an angler's bait without hesitation. Its temperamental behavior, fine fighting qualities, and tasty flesh make it a popular sport fish.

Corbina can be taken throughout the year, but fishing is best in summer and early fall. Most corbina are caught along sandy surf-swept beaches, but they are also taken from piers and jetties; anglers on private and rental boats, and commercial passenger fishing vessels seldom take them. A 1965-1966 survey estimated that 30,000 corbina were taken by southern California shore anglers along the open coast, making it the third most abundant species accounting for 13 percent of the surf-angler's creel. Anglers use conventional, spinning, and fly-fishing gear. The best baits are soft-shelled sand crabs, mussels, bloodworms, and clams.

The annual number of corbina caught by anglers has been quite variable. Marine Recreational Fishery Statistics Survey annual catch-estimates for 1980 through 1998 ranged between 17,000 and 75,000 fish; the average was 44,600. Annual catch estimates were much lower in the 1990s than during the 1980s; however, catches-per-unit-effort were similar.



California Corbina, *Menticirrhus undulatus*
Credit: DFG

Status of Biological Knowledge

The California corbina is a slender croaker with a gray to bluish back and a white flattened belly. It has a short, stiff chin barbel and may have wavy oblique lines on its sides. The corbina ranges from Point Conception, California to the Gulf of California. It is found along sandy beaches and shallow bays to depths of 45 feet, but is most common in about six feet of water. It is usually found in small groups of several individuals, with larger fish being more solitary.

Corbina can grow to 30 inches and weigh 8.5 pounds; a verified specimen measuring 28 inches and weighing seven pounds, four ounces was caught in 1955. Females grow faster than males, especially after two years, and reach a larger size. A three-year-old female is about 15 inches whereas a three-year-old male is about 13 inches. Apparently, corbina residing in bays grow much faster than those on the open coast. A 23-inch female corbina caught on the open coast was eleven years old, whereas similarly sized females from the bay were aged at six years. More than 50 percent of females are mature at 12 inches (two years) and all are mature at 15 inches (three years). Males mature at about 10 inches (two years). The spawning season is from May through September and is heaviest from June through August. Spawning apparently takes place offshore, since running-ripe fish are not often found in the surf zone; eggs are pelagic. Small (1.5 to 3 inches) corbina have been captured inside the surf zone to 30 feet of water.

The corbina feeds predominantly on benthic organisms. Individuals may be seen feeding in the surf, at times in water so shallow their backs are exposed. They scoop up mouthfuls of sand and separate out food by pumping sand through their gill openings. The diet of juveniles consists of clam siphons and small crustaceans. As they grow, they consume larger parts of clams and sand crabs.

Limited tagging studies indicate that the corbina does not move around much; it has no discernible migratory pattern. The greatest distance traveled was 51 miles.

Status of the Population

Population size, recruitment, and mortality of California corbina are unknown. Beach seine hauls along the open coast from 1994 through 1997 yielded slightly lower but similar numbers of corbina to those obtained during a similar study from 1953 through 1956. In addition, similar angler catch-per-unit efforts during the 1980s and 1990s indicate that the population is sustaining itself under present recreational harvest levels.

Management Considerations

See the Management Considerations Appendix A for further information.

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California Department of Fish and Game

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Spotfin Croaker

History of the Fishery

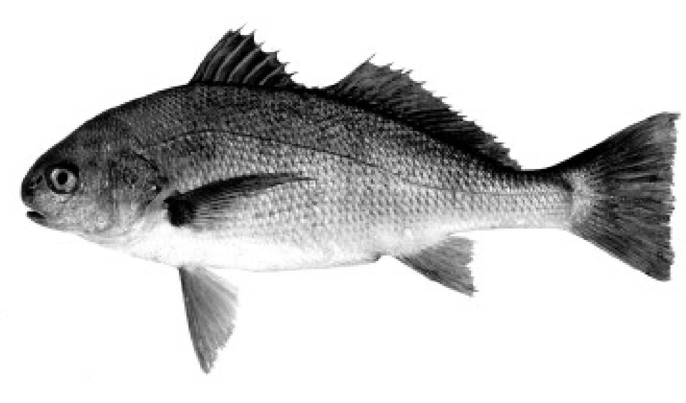
The spotfin croaker (*Roncador stearnsii*) is a nearshore croaker reserved for the recreational fishery. It has been illegal to take them with nets since 1909, and illegal to buy or sell them since 1915. Anglers can experience good fishing when there are croaker "runs" and when "croaker holes" are found. Most of the spotfin croaker catch consists of smaller fish (one to three pounds). Its fighting spirit and delicate taste make it a prized sport fish.

Spotfin croaker can be taken throughout the year, but fishing is best in late summer. Most spotfin croaker are caught from shore on piers and jetties along beaches and in bays; they are occasionally taken by private and rental boats but are rarely taken by commercial passenger fishing vessels. Anglers use conventional and spinning gear. The best baits are marine worms, clams, and mussels.

Annual landings of spotfin croaker have fluctuated greatly. Marine Recreational Fishery Statistics Survey (MRFSS) annual catch estimates for 1980 through 1998 ranged between 1,000 and 46,000 fish; the average was 14,900. Catch-per-unit effort has remained relatively low and stable since 1980, but started to increase in the late 1990s.

Status of Biological Knowledge

The spotfin croaker is a medium-bodied croaker with a bluish gray back, brassy sides, and a silver to white belly. It has a large, distinctive black spot at the base of its pectoral fin. The spotfin croaker ranges from Point Conception, California to Mazatlan, Mexico. In California, it is most common south of Los Angeles Harbor. It lives along beaches and in bays over sandy to muddy bottoms at depths from four to 50 feet. Most spotfin croaker are found in 30 feet of water or less, preferring depressions and holes near shore. These "croaker holes" are well known to surf anglers. Spotfin croaker aggregate in small groups or schools of usually fewer than 50 fish; however, schools containing several hundred fish are occasionally encountered.



Spotfin Croaker, *Roncador stearnsii*
Credit: DFG

Spotfin croaker can grow to 27 inches and weigh 14 pounds. A fish weighing 10.5 pounds was eight or nine years old, and a 26.5-inch long individual was at least 15 years of age. During the breeding season, females develop blackish streaks on their bellies, while larger males have golden pectoral and pelvic fins, and are commonly called golden croaker. Apparently, most males are mature at nine inches (two years), and most females are mature at 12.5 inches (three years); all are mature at 14.5 inches (four years). Spawning occurs from June to September. It probably occurs offshore, since few ripe fish have been captured in the surf zone. Small (two- to four-inch) spotfin croaker have been captured inside the surf zone to 30 feet of water.

The spotfin croaker is a bottom feeder. The diet of juveniles consists of small crustaceans and clam siphons. Larger individuals use their strong pharyngeal teeth to crush shells and consume whole clams, mussels, and polychaetes.

A limited tagging program showed that the spotfin croaker moves around considerably, especially from bay to bay, without a discernible pattern. Fish tagged in Los Angeles Harbor were later recaptured as far south as Oceanside.

Status of the Population

Southern California is on the northern fringe of the spotfin croaker population. Their population size, recruitment, and mortality are unknown. Modifications of bay and nearshore environments, including development, land fills, and dredging, have had an adverse effect on the habitats of this species. Beach seine hauls along the open coast from 1994 through 1997 yielded many fewer spotfin croaker than during a similar study from 1953 through 1956. However, catch-per-unit effort estimates from MRFSS data and gillnet sets inside bays and along the open coast indicate that spotfin croaker populations were increasing in the late 1990s.

Management Considerations

See the Management Considerations Appendix A for further information.

Charles F. Valle and **Malcolm S. Oliphant** (retired)
California Department of Fish and Game

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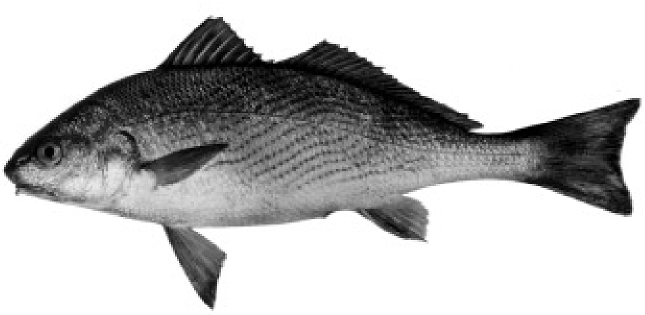
Yellowfin Croaker

History of the Fishery

The yellowfin croaker (*Umbrina roncador*) is a nearshore croaker that has been reserved for the recreational fishery since 1915. It is primarily caught by anglers fishing from sandy beaches, piers, jetties, harbors and bays from Santa Barbara south to the U.S.- Mexico border. This croaker is among the most common fish caught from many of southern California's piers and sandy beaches during summer months. It is important to many anglers because they can be readily caught from shore with minimal investment in fishing gear and time. Yellowfin croaker are typically caught with light spinning gear using a variety of popular baits, including live and dead anchovies, mussels, blood worms, and ghost shrimp. About 80 percent of the catch occurs from May-October. Anglers fishing from piers and breakwaters account for 35 percent of the total catch, whereas anglers fishing from private skiffs and beaches account for 35 percent and 25 percent, respectively. The commercial passenger fishing vessel (CPFV) fleet accounts for approximately five percent of the total catch. CPFV catches fluctuated from a high of over 8,000 fish in 1947 to less than 100 fish in 1958. Catches are relatively low because the CPFV fleet rarely targets shallow (< 25 feet) sandy areas where yellowfin croaker are most abundant.

Status of Biological Knowledge

Yellowfin croaker have a series of yellow-brown stripes on their back, mostly yellow fins, and a pronounced chin barbel. Yellowfin croaker range from Point Conception to the Gulf of California, but are most abundant south of the Palos Verdes Peninsula. They occur in small schools over soft bottom habitats from shore to 125 feet, but are most commonly found in waters less than 30 feet. Yellowfin croaker are also common in harbors and bays and occasionally frequent kelp beds.



Yellowfin Croaker, *Umbrina roncador*
Credit: DFG

Although very little is known about their basic life history, it appears that spawning occurs during summer months. Young-of-the-year have been found near the entrance of embayments during late fall and offshore in 30 feet of water during winter. They have been reported to reach 18 inches in length and weigh over five pounds, however fish over two pounds are uncommon. The current California state record is three pounds and 14 ounces. Preliminary ageing estimates indicate that a 10-inch fish is about 4 years old and a 15-inch fish is about 10 years old. Yellowfin croaker are opportunistic predators that feed during day and night. Their diet consists of a broad variety of prey, however California grunion eggs, mysids, and pelecypods are the most important components. Small fish feed primarily on mysids, whereas large fish concentrate on bivalves. Yellowfin croaker eggs, larvae, and small juveniles are preyed upon by many fishes; larger individuals are preyed upon by seals, sea lions, halibut and other large fishes.

Status of the Population

No population estimates exist for yellowfin croaker, and stock structure has not been examined. The population appears healthy despite potentially damaging impacts associated with recreational fishing, contaminants from urban run-off, and shoreline habitat modifications such as development, dredging, filling, and erosion control projects. In fact, the population may be increasing; catch-per-unit-effort data from the Marine Recreational Fishery Statistics Survey have increased during each of the past five years. In addition, a fishery independent study found a much greater abundance of yellowfin croaker in the mid-1990s than a similar study conducted during the mid-1950s. Increased sea surface temperatures caused by several El Niño events during the 1990s have probably benefited yellowfin croaker, since they are a warm temperate species whose center of abundance is in warmer waters off Baja California. However, without regular monitoring of catch and effort data it is difficult to accurately assess the status of the fishery.

Management Considerations

See the Management Considerations Appendix A for further information.

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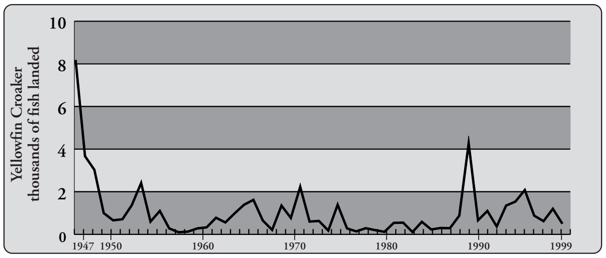
California Department of Fish and Game



Recreational Catch 1947-1999, Yellowfin Croaker

CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

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White Croaker

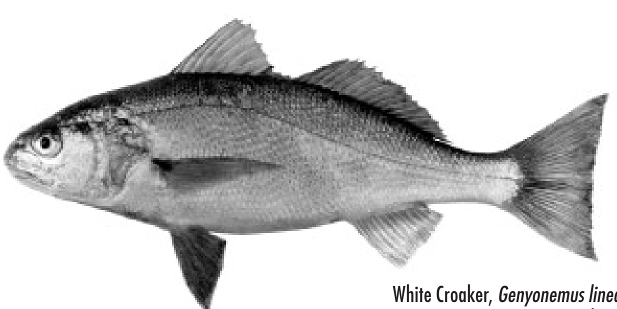
History of the Fishery

Although not a highly prized species, the white croaker (*Genyonemus lineatus*) has been an important constituent of commercial and sport fisheries in California. Before 1980, most of the catch was in southern California. However, since 1980, the majority of the catch has been in central California. The changes in fishing methodology and area of greatest landings since 1980 are due primarily to the entrance of Southeast Asian refugees (mainly Vietnamese) into this fishery. Many of these refugees who settled in California's coastal areas were gillnet fishermen in their homelands and sought to earn their living here by that method of fishing. The underutilized white croaker resource (especially in central California) and moderate start-up costs required for gillnetting (small to medium-size boats and moderate gear costs) offered many of them an opportunity to enter the commercial fishing business. In contrast, most of the sport catch is in southern California. Anglers fishing from piers, breakwaters, and private boats account for about 90 percent of the catch.

Prior to 1980, white croaker landings averaged 658,000 pounds annually and exceeded one million pounds in several years. Peak landings in 1952 (88 percent in southern California) were probably in response to the total collapse of the sardine fishery that year. From 1980 through 1991, total landings have averaged 1.1 million pounds and were above one million pounds in all but four years. Since 1991, landings have averaged 461,000 pounds and have steadily declined to an all time low of 142,500 pounds in 1998.

Before 1980, the commercial catch of white croakers was primarily by round haul net (mainly lampara), although some were taken by trawl, gillnet, and hook-and-line. After 1980, most white croakers have been taken by gillnet and hook-and-line. Most of the commercial catch is sold in the fresh fish market, although a small amount is used for live bait. "Kingfish" is the most common name seen in markets. Also, small quantities of another croaker, the queenfish, are included in the commercial landing records, mostly for southern California.

Landings of white croaker by recreational anglers aboard commercial passenger fishing vessels, were highest in the late 1940s and early 1950s, averaging about 70,000 fish per year. Since 1954, however, they have averaged well below 30,000 fish per year, with one exceptional peak in 1988 of about 120,000 fish. Landings from 1990 through 1998 have averaged about 12,000 fish per year, with approximately 96 percent of the landings from southern California.



White Croaker, *Genyonemus lineatus*
Credit: DFG

Status of Biological Knowledge

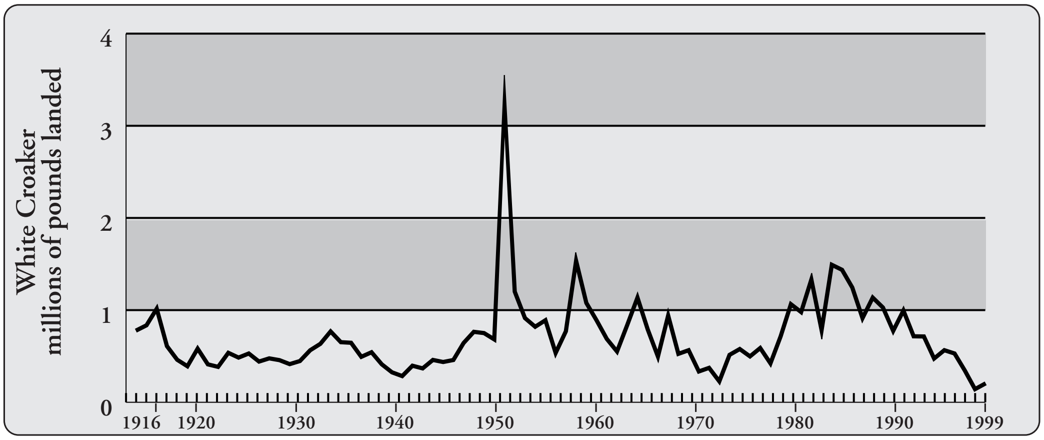
White croaker is one of eight species of drums, from the family Sciaenidae, recorded off of California. *Genyonemus* is a combination of two Greek words, *genys*, meaning lower jaw, and *nemus*, meaning barbell. The species name *lineatus* is a Latin word meaning striped. White croaker are often sold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

White croakers have subfusiform compressed bodies, inferior mouths with a subterminal lower jaw, falcate pectoral fins, thoracic pelvic fins, and a truncate caudal fin. They are typically silvery to brassy colored, with a small, but prominent black spot at the base of each pectoral fin and a cluster of minute barbells on the membranes underneath the lower jaw.

The white croaker is an abundant, nearshore species in California, usually found over soft, sandy-mud substrata. They range from Vancouver Island, British Columbia to Magdalena Bay, Baja California, but are not abundant north of Point Reyes, California. They usually swim in schools, and are found from the surf zone to depths as great as 780 feet and in shallow bays, sloughs, and lagoons. Most of the time, they occupy nearshore areas at depths of 10 to 100 feet, but sometimes are fairly abundant to a depth of 300 feet.

The maximum recorded length for white croaker is 16.3 inches; however, fish larger than about 12 inches rarely occur. Fish up to four pounds have been reported, but those weighing over two pounds are extremely rare. White croakers live to about 15 years and over 50 percent of both sexes are sexually mature by one year (about 5 1/2 inches for males, six inches for females). By three or four years and 7.5 inches, all white croakers are mature.

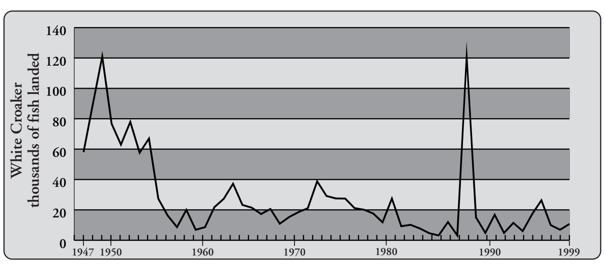
In southern California, white croakers spawn mainly from November through April, with peak months being January through March. In central California, they spawn all year and may have winter and summer spawning peaks (ovary weights were found to be highest in January and September and lowest in May). Females may spawn about once every five days and about 18 to 24 times each season, depending upon their size and age. Batches of eggs range from an estimated 800 eggs in a six-inch female to 37,200 in a 10-inch female. The fertilized eggs are pelagic and



Commercial Landings 1916-1999, White Croaker
Data Source: DFG Catch Bulletins and commercial landing receipts.

occur in depth ranges from about 25 to 120 feet. The larvae initially are pelagic and most abundant in ocean depth ranges from about 50 to 75 feet. As the larvae grow, they descend toward the bottom and migrate towards shore. Juveniles occur near the bottom where ocean depth is about 10 to 20 feet. As they mature, they migrate to somewhat deeper water.

White croaker are omnivores, their diet including a variety of worms, shrimps, crabs, squid, octopuses, clams, small fishes, and other items, living or dead. They feed primarily at night and on the bottom, although some midwater feeding occurs during the day. They are preyed upon by seals, sea lions, halibut, giant sea bass, bluefin tuna, and other fishes.



Recreational Catch 1947-1999, White Croaker
CPFV = commercial passenger fishing vessel (party boat); Recreational catch as reported by CPFV logbooks, logbooks not reported prior to 1947.

White croakers that live near marine waste discharges may concentrate toxic materials such as pesticides (DDT, DDE, etc.), polychlorinated biphenyls (PCB's), metals (zinc, selenium, mercury, etc.), and petroleum products in their bodies at levels that are considered hazardous for human consumption. Some white croakers in these areas are diseased and malformed and some show reproductive impairment. Current health guidelines advise against human consumption of white croakers from southern California waters in Santa Monica Bay, off the Palos Verdes Peninsula, and the Los Angeles-Long Beach Harbor area.

Status of the Population

The size of the white croaker population is not known. Although previous catch data indicated that the overall population was healthy and sustaining itself under fishing pressure, recent declines in commercial catches imply that future monitoring may be needed.

Management Considerations

See the Management Considerations Appendix A for further information.

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California Department of Fish and Game

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Surfperches

General

The surfperches, family Embiotocidae, are a small abundant assemblage of 23 species found predominantly in temperate eastern North Pacific waters, two which are found in the Sea of Japan. Nineteen of the 20 species found in California occur in inshore coastal waters. Tule-perch (*Hysterocarpus traski*) occupies freshwater and estuarine habitats. Collectively, the 19 marine species are found in a variety of habitats, including beaches, rocky substrate, intertidal and subtidal kelp beds. A few species inhabit several of the habitat types. Included in this group are the pile perch (*Rhacochilus vacca*), rubberlip surfperch (*Rhacochilus toxotes*), shiner perch (*Cymatogaster aggregata*), walleye surfperch (*Hyperprosopon argenteum*), and the white surfperch (*Phanerodon furcatus*). The majority of surfperches occupy only one type of habitat. Species most commonly found along beaches include the barred surfperch (*Amphistichus argenteus*), calico surfperch (*Amphistichus koelzi*), redtail surfperch (*Amphistichus rhodoterus*), silver surfperch (*Hyperprosopon ellipticum*), and the spotfin surfperch (*Hyperprosopon anale*). Black perch (*Embiotoca jacksoni*), dwarf perch (*Micrometrus minimus*), kelp perch (*Brachyistius frenatus*), rainbow perch (*Hypsurus caryi*), reef perch (*Micrometrus aurora*), sharpnose seaperch (*Phanerodon atripes*), and striped seaperch (*Embiotoca lateralis*) tend to be associated with rocky substrate and kelp beds. The pink seaperch (*Zalembius rosaceus*) inhabits deep water and is seldom taken in the sport catch.

The surfperch fishery in California includes both sport and commercial components. The sport fishery is enjoyed by anglers of all ages who fish for surfperch from piers, jetties, sandy beaches, and boats. The recreational catch of surfperch for 1999 totaled 489,000 fish, with the majority being caught in central and northern California. The average sport catch for 1993 through 1999 was 864,000 fish with a high of 1,119,000 fish in 1998.

Surfperch are easy to catch, which makes them highly sought. They can be caught using light gear and a variety of baits such as clams, tubeworms, or sand crabs. A spinning or casting outfit using 10 to 15 pound test monofilament line, and a standard two-hook surf leader with size six hooks, is ideal for shore based surfperch fishing.

Barred Surfperch, *Amphistichus argenteus*
Credit: DFG

Annual commercial landings of surfperches have also been highly variable. While the market for fresh "perch" fillets is relatively small, the total catch for the fishery was 49,000 pounds in 1999. The California Department of Fish and Game did not distinguish between species in their statistics until 1987, simply listing the category as surfperch. Currently, there is a large commercial fishery for various surfperches in the southern part of the state and a moderate fishery focusing on redtail surfperch in northern California.

Surfperches can be identified by their elliptical, compressed body form and forked tail. Most are marked with bars or stripes. They have a continuous dorsal fin with nine to 11 spines and 19-28 soft rays. The anal fin has three spines with 15-35 soft rays.

The diet of surfperches consists of isopods (*e.g.*, rock lice) of all sizes, and gastropod mollusks (*e.g.*, snails); various amphipods (*e.g.*, skeleton shrimp), polychaete worms, brittle stars, and small crabs, also are included. Surfperches are usually bottom grazers, but apparently will feed midwater when competitors are absent.

Surfperch reproduction is viviparous, their young being highly developed and free swimming at birth. Newborn males of a few species are reproductively mature.

Much information is lacking on this group. Although the taxonomy has been recently refined, life history and habitat requirements are areas in need of more research.

Barred Surfperch

History of the Fishery

The commercial fishery for barred surfperch is minor compared to the sport fishery. Its popularity as a sport fish stems from abundant numbers and accessibility. The average catch for the 1993-1999 period was 176,000 fish in southern California, and 202,000 fish in the remainder of the state. In the southern California sport fishery for barred surfperch, 99 percent were caught from beaches and jetties. Similarly, 99 percent of central and northern California's catch also came from shore. The best months for fishing are December, January, and February with the majority of large individuals being gravid females. Sand crabs are the best bait for barred surfperch, especially female sand crabs carrying orange colored eggs. Small jigs and spinners also work well. Although barred surfperch are excellent sport fish for the light tackle angler, they are sometimes considered a pest to anglers pursuing other fish such as California halibut or corbina.

Status of Biological Knowledge

Barred surfperch have eight to 10 rust-colored, irregular bars on their sides with spots in between. The background color is usually silver or white, and the back can take on a blue or grayish coloration. Similar species are the calico surfperch and the redtail surfperch, but the barred surfperch can be distinguished from the redtail and calico because it lacks red coloration in its fins.

Barred surfperch are found in small schools along sandy beaches and near jetties, piers, and other sources of food and cover. They range from Bodega Bay in northern California to north central Baja California. While the majority are found in the surf zone, some have been caught in water as deep as 240 feet. The largest individual ever taken was a female that weighed 4.5 pounds and was 17 inches in length. Most fish are in the one- to two-pound range and are highly prized by anglers.

Barred surfperch mate during the fall and winter months, and young are released during spring and summer. Males and females both darken considerably during courtship, and males make "figure-eights" around females before mating. A female can produce from four to 113 young, depending on her size. Females undergo a five-month gestation period, and juveniles are born at about 1.75 inches in length. Juveniles are miniature replicas of the parents and are independent at birth. The young usually live relatively close to where they were born.

Status of the Population

During the last seven years, the sport fishery in southern California has yielded up to 306,000 barred surfperch (1998), while central and northern California together produced upwards of 252,000 fish annually. No estimates have been made of the size or current status of the barred surfperch population.

Calico Surfperch

History of the Fishery

The calico surfperch is of moderate sport value along the California coast. Due to its striking similarity and frequent misidentification with the redtail surfperch, calico surfperch, until recently, have been considered of minor importance in the sport catch. The mean sport catch from 1993-1999 was 16,000 fish. There is no targeted commercial catch but small numbers are taken in the directed redtail surfperch fishery. The calico fishery has historically included fishing from piers, sandy beaches, and skiffs.

Status of Biological Knowledge

The calico surfperch can be identified by its silvery surface, which is covered by olive-green mottling and broken bars down each side. The calico reaches a length of 12 inches and rarely weighs more than one pound.

The range of the calico surfperch is from north central Washington to northern Baja California. The primary habitat of the calico is sandy beaches, although they can occasionally be found over rocky substrate. The vertical distribution of the calico includes depths from the surface down to 30 feet.

Calico Surfperch, *Amphistichus koelzi*
Credit: DFG

Status of the Population

At this time, little information is available on the population status of the calico surfperch.

Pile Perch

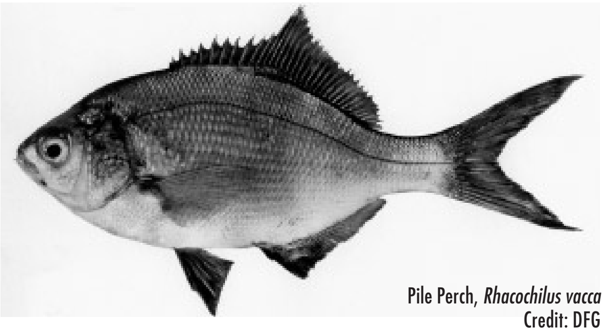
History of the Fishery

Pile perch sustain a limited commercial fishery in Del Mar, California, and Papalote Bay, Baja California, but do not contribute substantially to annual commercial landings in the state.

They are of interest as a sport fish throughout the state, with an average of 16,000 perch caught between 1993 and 1999. Many are caught from piers, jetties, beaches, or skiffs. Pile perch may be caught year-round on any number of popular baits, including clams, sand shrimps, and worms.

Status of Biological Knowledge

Pile perch can be identified by the silvery sides with a dark vertical bar about midbody, and a unique dorsal fin with the first few soft dorsal rays longer than any of the others, giving the fin a peaked appearance. They are equipped with strong, well-developed teeth, enabling them to feed on hard shelled mollusks, crabs, and other



Pile Perch, *Rhacochilus vacca*
Credit: DFG

crustaceans. Their specialized dentation differs enough from rubberlip surfperch to convince some ichthyologists to place them in their own genus (*Damalichthys*).

Pile perch are found between southeastern Alaska and northern Baja California, including Guadalupe Island. They usually live along rocky shores, from the surface down to 150 feet, and grow to around 17.5 inches in length.

Fecundity increases with age and size of the females. Average fecundity at first reproduction is 11.7 young, and sometimes exceeds 60 in older females. Adult longevity of pile surfperch is seven to 10 years.

Status of the Population

Because accurate landings data for pile perch are lacking, little can be concluded about the current population status in California.

Redtail Surfperch

History of the Fishery

Redtail surfperch sustain a sport fishery from central California to Vancouver Island, British Columbia. They support a commercial fishery only in northern California, especially in the inshore waters of the Eureka/Crescent City area where over 99 percent of the catch is taken. These fish are taken primarily from sandy beaches or the mouths of rivers and streams entering the sea, but also can be caught from jetties and piers inside harbors and bays. Humboldt and Del Norte counties in northern California are the primary locations of the winter redtail commercial fishery. Fishing is mostly from open beaches using hook-and-line gear. The best catches are in March and April when the fish are concentrated for spawning. Commercial fishing is closed from May 1 to July 15. The annual commercial harvest averaged 37,000 pounds over the last 10 years, with a high catch in 1990 in excess of 62,000 pounds and a low catch of around 27,000 pounds in 1998.

Sport fishing for redtails occurs in the same areas where they are commercially taken. They are taken year-round by hook-and-line, but are usually targeted during the spawning season. The sport catch since 1993 has ranged from a low of 10,000 fish in 1998, to a high of 56,000 in 1994.

Status of Biological Knowledge

Redtail surfperch are distinguished by the nine or ten vertical, orange-to-brassy bars alternating at the lateral line and the light red pelvic, anal, and caudal fins. The body is moderately deep and laterally compressed, with a light green back and silver sides and belly. During the 1990s, adult female redtail averaged 10.5 inches and weighed 1.1 pounds, while the males averaged 9.8 inches and weighed 0.8 pounds. The largest recorded California redtail was a female that was 16.5 inches long and weighed 3.7 pounds. The largest recorded individual was 16.5 inches long and weighed 3.7 pounds. Females produce eight to 45 young about one year after fertilization, sometime between May and August.

Redtail surfperch are found from Vancouver Island, Canada, to Monterey Bay, California, but the fishery is centered north of the San Francisco Bay area.

Status of the Population

There are no estimates of the size of the redtail surfperch stocks in California coastal waters. The commercial catch averaged 50,000 pounds during the 1970s, 48,000 pounds during the 1980s and 38,000 pounds during the 1990s, which suggests a decreasing population. Another indicator of problems with the population is the decrease in weight from an average per fish weight of 1.8 pounds during the late 1950s and early 1960s, to 0.9 pounds during the 1990s.

Redtail Surfperch, *Amphistichus rhodoterus*
Credit: DFG

Rubberlip Surfperch

History of the Fishery

The rubberlip surfperch is one of the many important surfperch sport fish along the California coast. It is caught along jetties and piers, and also taken by skiff anglers nearshore or in kelp beds. The sport catch over the last seven years ranged from 13,000 fish in 1993 to 44,000 fish in 1997 with an average of 19,000. The commercial fishery is very small with landings of less than 1,000 pounds annually from southern California.

Status of Biological Knowledge

The large, thick lips of the rubberlip distinguish it from other surfperches. Its coloration varies from olive-to brassy-brown on the sides, with one or two dusky bars on adult fish. The pectoral fins are yellow to orange, and the pelvic fins are usually black. The maximum length of rubberlip seaperch is 18.5 inches, making the rubberlip the largest of the surfperches.

Rubberlip surfperch are found from Russian Gulch State Beach (Mendocino County), California, to central Baja California, including Guadalupe Island. These fish range from inshore waters to depths of 150 feet.

Although no data have been collected on age at sexual maturity, gravid rubberlip surfperch have been caught from April to June. Time of birth is estimated to be midsummer.

Rubberlip Surfperch, *Rhacochilus toxotes*
Credit: DFG

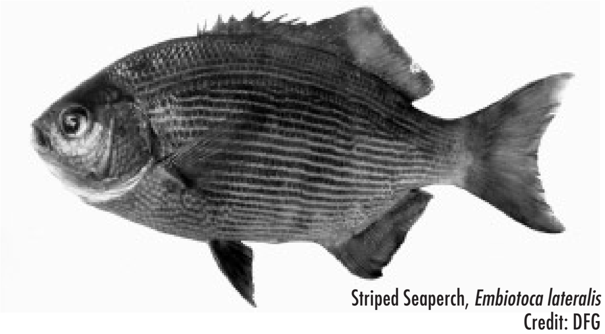
Status of the Population

No recent estimates have been made of the rubberlip perch population its size is unknown at this time.

Striped Seaperch

History of the Fishery

Striped seaperch is one of the eight to 10 species that make up the small commercial "perch" fishery. However, it is a minor component when compared to such species as the barred surfperch. Conversely, striped seaperch do comprise a substantial portion of the state's sport fishery. The mean take of striped seaperch for the last seven years was 65,000 fish, almost wholly from central and northern California. These perch are easily taken from piers, jetties, beaches, and skiffs, and are favorites of anglers due to their beautiful coloration.



Striped Seaperch, *Embiotoca lateralis*
Credit: DFG

Status of Biological Knowledge

Striped seaperch can be easily identified by the red, blue, and yellow lines that run laterally along the length of the body. Maximum length is 15 inches. These fish are sexually mature in their third year of life and produce about 18 young per female. At age seven, the average number of young produced per female is 32. The maximum life expectancy for this fish is approximately 10 years.

Striped seaperch are found from southeastern Alaska to northern Baja California.

Status of Population

Population estimates of striped seaperch have not been made, but recent landing figures indicate that this species should be able to sustain a healthy sport catch.

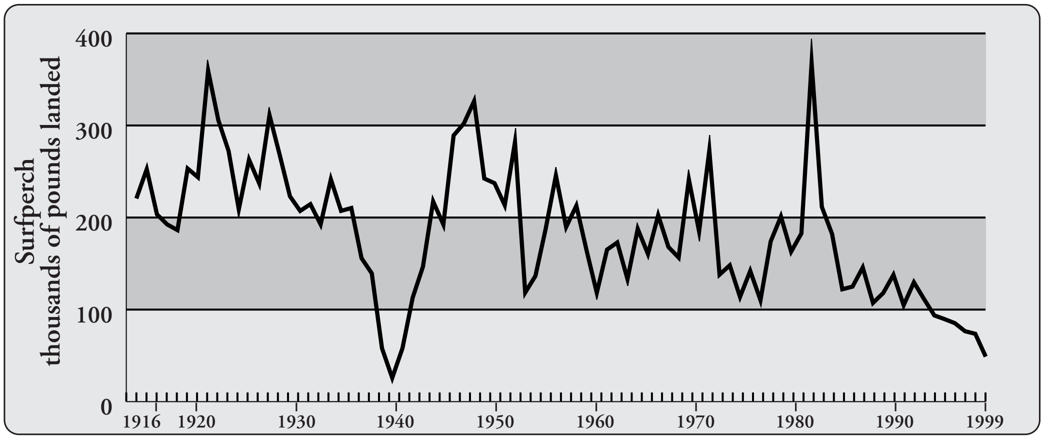
Walleye Surfperch

History of the Fishery

Sport anglers enjoy fishing for walleyes. In 1993, anglers caught 164,000 individuals, well over 90 percent being caught from shore, jetties, and piers. Walleyes can be taken on sand crabs and other invertebrates, as well as on small spinners and jigs. They are excellent to eat.

Status of Biological Knowledge

Walleye surfperch are silver to bluish above, with very faint pink bars that fade quickly after death. Most notable are the large eyes and black tipped pelvic fins. Similar species are the spotfin surfperch and the silver surfperch. However, the spotfin has black spots on its dorsal and anal fins, while the silver lacks any black coloration.



Commercial Landings 1916-1999, Surfperches
Data Source: DFG Catch Bulletins and commercial landing receipts.

Walleye surfperch are found in large schools along sandy beaches, jetties, kelp beds, and other habitats with rich invertebrate life. They range from Vancouver Island, British Columbia, to central Baja California, including Guadalupe Island. They reach a length of 12 inches and are found to depth of 60 feet.

Walleye surfperch mate from November to December and, after a five-month gestation period, give birth in mid-April. Males engage in an aggressive "swooping" courtship before mating. Females, depending on size, will have five to 12 young that are about 1.5 inches at birth. The young are miniature replicas of the parent and mature the fall or winter following their birth.

Status of the Population

The recent sport take has averaged 112,000 fish per year. However, the total stock size is unknown at this time.

Surfperch: Discussion

Surfperches are important both commercially and as sport fish. Most of the California coastal species are taken in the sport catch and the majority of the catch is taken when spawning aggregations are present. Female surfperches are intentionally targeted by sport anglers because they are larger than males. Sport anglers also grade their catch, which probably results in an even greater take of mature females with a resulting decline in the fishery. The redtail and barred surfperches are the most notable in the commercial catch and may be important to local economies. Total commercial surfperch landings have fluctuated over the years, but over the long-term have declined by 25 percent since the 1950s. Recent research has indicated that some of the decline is associated with the increases in water temperature.

Surfperch habitats have been, and will continue to be, areas of conflict. As humans develop the shoreline, areas inhabited by surfperches may become polluted or destroyed. Although surfperches may adapt to structures such as jetties and piers, it should not be assumed that they can continue to adapt to all the changes that are forced upon them.

Action is needed if surfperch populations are to be restored.

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Opaleye and Halfmoon

History of the Fishery

The commercial catch of opaleye (*Girella nigricans*) and halfmoon (*Medialuna californiensis*) has been small. Neither of these species is part of a designated fishery but both appear regularly as incidental catch in commercial and recreational fisheries.

During the 40 years prior to 1990, the average catch of halfmoon has been 16,714 pounds, with a high of 50,007 in 1956. Recently, catches have been well below this mean, with a peak in 1989 of 5,204 pounds. The mean catch of opaleye in the 43 recorded years prior to 1990 was 4,748 pounds with a high of 23,688 pounds in 1973. The mean catch for the last 10 years is 2,709, with very small catches recorded since 1995. Interestingly, a small number of halfmoon and opaleye are entering the live fish market. The 1999 landings of opaleye were largely live fish (616 pounds) and the price for the catch is now up to $1.37 per pound. Neither species was recorded in large numbers in the California Department of Fish and Game's gill and trammel net study, although the opaleye was at one time a bycatch of nearshore purse seiners.

CPFV landings of opaleye are low, averaging 679 fish per year since 1990. By contrast, CPFV catches of halfmoon have averaged over 50,000 fish per year. 1998 was an extremely poor year for catches of these species, yielding only eight percent and 16 percent of the average catch of opaleye and halfmoon respectively. In the last reported survey of pier and jetty fishing (1965-1966), both species were abundant and it is likely they remain an important part of that fishery today.

Status of Biological Knowledge

As herbivores, the members of the sea chub family, Kyphosidae, play an important role in kelp forest communities. They regulate kelp growth, and on occasion may overgraze, causing damage to newly transplanted or isolated kelp plants or small kelp beds. The opaleye reaches a length of 26 inches and a weight of 16 pounds, while the halfmoon reaches 19 inches and 5 pounds. Kyphosids have small mouths with a single prominent row of blade-like, incisor teeth that are used for cutting vegetation. The opaleye is olive green with two light spots under the mid-dorsal. The halfmoon is blue to blue-gray, sometimes with a lateral white stripe, and the spinous dorsal fin is much lower than the soft dorsal. Both species range from central California to Baja California. While the opaleye is more common north of Point Conception, the halfmoon extends its range to the south into the Gulf of California. Both reach a depth of a little over 100 feet.

Larvae of both species are pelagic and are followed by a pelagic juvenile schooling stage, which appears in the nearshore environment. Larval distributions mirror the adults latitudinally, with the larval stages distributed primarily in the neuston. CalCOFI data indicate that halfmoon larvae are occasionally taken well off shore, while most opaleye larvae are taken within 70 miles of the coast. Young opaleye leave the pelagic environment and enter the intertidal when they are about an inch long. They are found in relatively high tide pools preferring warm water (>75° F), and feed largely on small invertebrates. As they grow to a size of three to six inches, the young leave the pools and form small schools in the shallow subtidal, eventually changing their diet to include primarily algae. Adults browse in the kelp bed on kelp and other algae, often moving in medium sized schools. Young halfmoon stay in the shallow subtidal and kelp bed habitat occupying the same position as the adults. Juvenile opaleye have been reported to clean parasites from other fish on occasion.

Status of the Population

The abundance of opaleye and halfmoon, and their status as incidental catch rather than as targeted species, makes it unlikely that either the sport or commercial fisheries will have an effect on the populations. Data gathered in southern California since 1974 at Palos Verdes and King Harbor show no population trends and suggest both species are stable with regular recruitment.

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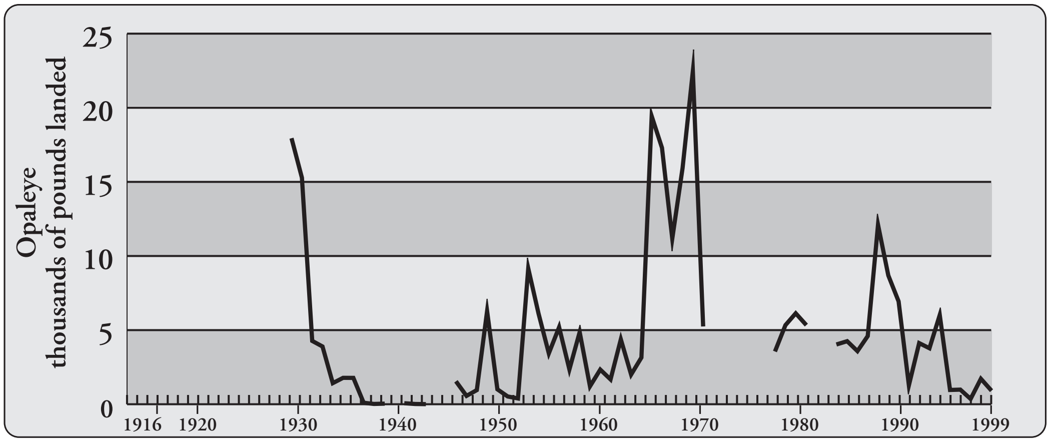
Opaleye, *Girella nigricans*
Credit: DFG

Commercial Landings 1916-1999, Opaleye
Landings data unavailable prior to 1930 and for 1941, 1945-1946, 1972, 176-1977, and 1982-1983. Data Source: DFG Catch Bulletins and commercial landing receipts.



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Silversides

There are three species of silversides (family Atherinopsidae) in California ocean waters, grunion, topsmelt (*Atherinops affinis*), and jacksmelt (*Atherinopsis californiensis*). Information on grunion is presented in a separate section. Even though "smelt" is included in the common names of these species, silversides differ in part from true smelts (family Osmeridae) in having two dorsal fins (one with spines), while the true smelts have one dorsal fin and an adipose fin near the tail.

History of the Fishery

Silversides are marketed fresh for human consumption or bait. The commercial fishery for silversides has been conducted with gillnets, lampara nets, and round haul nets. Historically, set lines have been used in San Francisco Bay for jacksmelt, and during the 1920s beach nets, pulled ashore by horses, were used at Newport Beach. Commercial catches of jacksmelt have varied sharply over the past 80 years. The high year for this fishery was 1945, when more than two million pounds were taken. During the 1990s, the catch varied between 40,765 pounds in 1997 and 2,530 pounds in 1998 and 1999, with most of the catch being landed in the Los Angeles area. This is an occasional or incidental fishery, and fluctuations observed in catch records reflect demand, not true abundance. Principal commercial fishing areas are usually in harbors and bays such as San Pedro, Monterey, San Francisco, Tomales, and Humboldt. Commercial catches of topsmelt are not as large as those of jacksmelt because of the smaller size and more scattered distribution of topsmelt. There are no commercial or sport bag and possession limits on these species.

Jacksmelt and topsmelt make up a significant portion of the pier and shore sport catch throughout California, and private boat anglers fishing nearshore catch them occasionally. From 1958 to 1961, these two species comprised about 10 percent of the total hook-and-line sport catch by numbers (272,000 jacksmelt and 43,000 topsmelt) in central and northern California. These are among the most abundant fishes available to pier and shore anglers and represent a very important recreational fishery, especially for children. When taken with light fishing gear, they are easy to catch and excellent fighters.

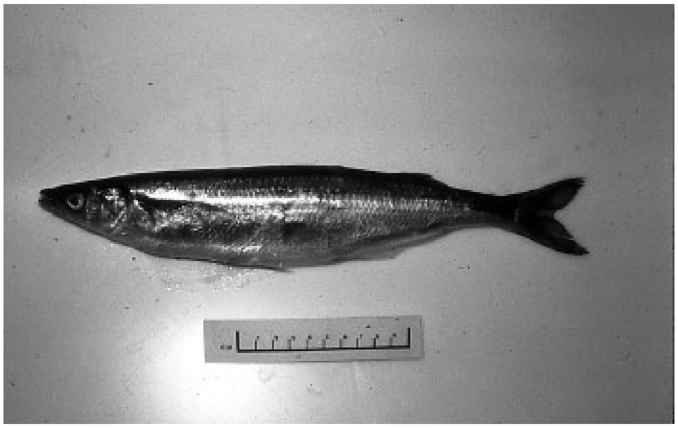
Jacksmelt are caught by a variety of sport fishing methods. A string of half-a-dozen bright red artificial flies or small hooks baited with shrimp or squid is the most successful terminal tackle used by pier anglers. Single baited hooks are also used from piers and by shore and skiff anglers. The larger jacksmelt is quite a game fish and will take a small spinner or lure cast out and retrieved with a series of quick jerks. Young jacksmelt and topsmelt are quickly attracted with breadcrumb chum thrown into the water. A rapid feeding activity takes place, making it easier to catch fish with hooks or hoop nets.

Status of Biological Knowledge

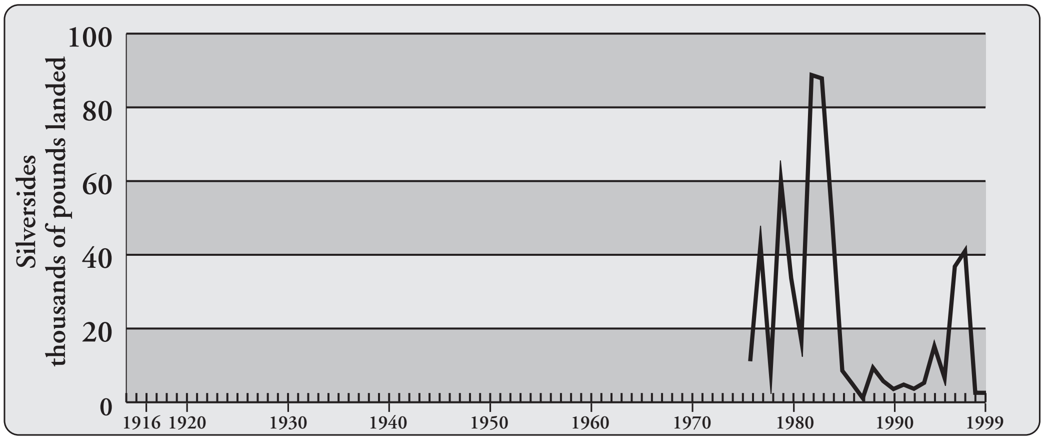
Topsmelt range from the Straits of Juan de Fuca, British Columbia, to the Gulf of California. They attain a total length of 14.5 inches, but individuals in sport catches are usually six to eight inches in length. There are seven subspecies of topsmelt, three of which are in California. These numerous subspecies demonstrate varied behavior and reflect the different environments occupied by this species: kelp beds, harbor areas, and sandy beach areas. They usually form loose schools but will congregate when feeding.

Topsmelt grow about 2.5 to four inches the first year, gain another two inches the next year, and grow proportionally less each year until they reach maximum size of about 14 inches. The largest topsmelt that has been aged was seven or eight years old. Some topsmelt spawn by their second year but most reach maturity during their third year. The spawning period is from April through October with a peak in May and June. This species attaches its eggs in a mass on eelgrass and low growing algae in harbors and bays, and possibly on kelp. The egg mass from each female is intertwined to the substrate by fine string-like filaments attached to each egg. Eggs may be deposited more than once in a spawning season. Topsmelt larvae are particularly abundant in tidal basins and the shallow edges of coastal bays. Juvenile topsmelt generally move into the open water of estuaries, bays, and coastal kelp beds.

The food of topsmelt consists primarily of plankton species including crustaceans. Intertidal inhabitants eat algae and fly larvae, as well as crustaceans. Bay forms have been observed working along muddy bottoms for food items. Topsmelt have the ability to withstand a wide range



Jacksmelt, *Atherinopsis californiensis*
Credit: DFG



Commercial Landings 1916-1999, Silversides
Data Source: DFG Catch Bulletins and commercial landing receipts. No commercial landing are reported for silversides prior to 1976.

of salinity concentrations. They are found in mesohaline waters and have been known to live in salt ponds with salinities as great as 72 parts per thousand – twice that of open ocean water.

Topsmelt are a very important species in bay and near-shore ecosystems in southern California. Collections of fishes by beach seine in bays are almost always numerically predominated by young topsmelt. Young-of-the-year topsmelt were found to contribute 85 percent of the total annual fish production in the shallow water areas of Upper Newport Bay. Topsmelt have been shown to be the most ubiquitous and numerically abundant fish species in submarine meadows of surfgrasses on the open coast. They are one of the five primary species brought to the breeding colonies of the least tern, an endangered seabird.

Jacksmelt form dense and larger schools than topsmelt and range over much of the inshore area of California. The geographic range is from Yaquina Bay, Oregon to Santa Maria Bay, Baja California. They are usually found in bays and within a few miles of shore in a salinity range from seawater to mesohaline. This species attains a length of 22 inches, with 17-inch fish commonly taken. Jacksmelt are relatively fast growing, reaching 4.5 to five inches in the first year and up to eight inches during the second year. Jacksmelt mature at two to three years or about eight inches. The oldest jacksmelt aged, a 16-inch male, was 11 years old. The spawning season is during winter, from October to April. Large masses of eggs, about the size of small BBs, are attached to eelgrass and algae by means of long filaments. Pinkish egg masses have been observed along with herring eggs during winter months in Elkhorn Slough and attached to eelgrass in Tomales Bay. Jacksmelt eggs have been observed to hatch in salinity as low as five parts per thousand. Jacksmelt can spawn several times during a spawning season.

The larvae and young are distributed near the surface in harbors, along sandy beaches, and in the kelp canopy, often mixed with the young of topsmelt. Their food habits are not well known, but it can be assumed that fish as fast as jacksmelt, that readily take a moving lure, are predatory animals. Small fish as well as crustaceans make up part of their diet.

The species is not desired by some sport anglers because of the presence of relatively large sized worms in the flesh. These are an intermediate stage of a spiny-head worm that is thought to be a parasite in sharks and pelicans. It probably is harmless to man, and definitely is harmless when the flesh is cooked.

Status of the Populations

Stock sizes of these two species have not been determined. At present, there are no indications that topsmelt or jacksmelt are being overfished in California. However, as these species occur in inshore waters, they are at risk of being affected by pollutants and loss of habitat through development.

Management Considerations

See the Management Considerations Appendix A for further information.

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California Department of Fish and Game

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Grunion

History of the Fishery

The commercial use of grunion (*Leuresthes tenuis*) is very limited, this species forming a minor portion of the commercial "smelt" catch. Grunion are taken incidentally in bait nets and other round haul nets, and limited quantities are used as live bait. In recent years, no commercial landings have been reported. However, since grunion usually are taken with other small fish and are not separated out, catch records would not show any landings.

The grunion's principal value is as the object of a unique recreational fishery. These fish are famous for their spawning habits, which are so remarkable as to arouse an "I don't believe it" response from a person hearing about them for the first time. They are the only species of fish in California to actually leave the water to spawn in wet sand on beaches. They are subjects of widespread popular interest, bringing thousands of people to beaches during night high tides in spring and summer months to catch the fish or just to observe them. Grunion hunting has become one of the famous sports of southern California. As the fish leave the water to deposit their eggs, they may be picked up while they are briefly stranded. Racing for fish spotted far down the beach and clutching for the small bits of slippery, wriggling energy provide an exhilarating time for young and old alike. The attraction provided by grunion can only be realized when one sees the numbers of people lining the more popular beaches in the Los Angeles area on the night of a predicted run. Often there seem to be more people than fish, but at other times, everyone catches fish.

In the 1920s, the recreational fishery was showing definite signs of depletion, and a regulation was passed in 1927 establishing a closed season of three months, April through June. The fishery improved, and in 1947, the closure was shortened to April through May. Grunion may be taken by sport fishermen using their hands only. No appliances of any kind may be used to catch grunion, and no holes may be dug in the beach to entrap them. Anglers sixteen years of age and older must posses a valid sport fishing license. Grunion may be taken June 1 through March 31. There is no bag limit for grunion.

Grunion, *Leuresthes tenuis*
Credit: Mike Brock

Status of Biological Knowledge

The grunion is now classified in the family of New World silversides, Atherinopsidae, along with the jacksmelt and topsmelt in California. They are small, slender fish with bluish green backs, silvery sides and bellies. Silversides differ from true smelts, family Osmeridae, in that they lack the trout-like adipose fin. They normally occur from Point Conception, California, to Point Abreojos, Baja California. They are rarely found from San Francisco on the north to San Juanico Bay, Baja California, on the south. They inhabit the nearshore waters from the surf to a depth of 60 feet. A description of their essential habitat would be the surf zone off sandy beaches. Marking experiments indicate that they are nonmigratory.

Young grunion grow very rapidly and are about five inches long by the time they are one year old and ready to spawn. Grunion adults normally range in size from five to six inches with a maximum size recorded at 7.5 inches. Average body lengths for males and females respectively are 4.5 and 5.0 inches at the end of one year, 5.5 and 5.8 inches at the end of two years, and 5.9 to 6.3 inches at the end of three years. The normal life span is two or three years, but individuals four years old have been found. The growth rate slows after the first spawning and stops completely during the spawning season. Consequently, adult fish grow only during the fall and winter. This growth rate variation causes annuli to form on the scales, which have been used for aging purposes.

Grunion spawn at night on the beach, from two to six nights after the full and new moon, beginning a little after high tide and continuing for several hours. As a wave breaks on the beach, the grunion swim as far up the slope as possible. The female arches her body, keeping her head up, and excavates the semi-fluid sand with her tail. As her tail sinks, the female twists her body and digs tail first until she is buried up to her pectoral fins. After the female is in the nest, up to eight males attempt to mate with her by curving around the female and releasing their milt as she deposits her eggs about four inches below the surface. After spawning, the males immediately retreat toward the ocean. The milt flows down the female's body until it reaches the eggs and fertilizes them. The female twists free and returns to the sea with the next wave. The whole event can happen in 30 seconds, but some fish remain on the beach for several minutes.

Spawning may continue from March through August, with possibly an occasional extension into February and September. However, peak spawning is from late March through early June. Once mature, an individual may spawn during successive spawning periods at about 15-day intervals. Most females spawn about six times during the season. Counts of maturing ova to be laid at one spawning ranged from about 1,600 to about 3,600, with the larger females producing more eggs.

The eggs incubate a few inches deep in the sand above the level of subsequent waves. They are not immersed in seawater, but are kept moist by the residual water in the sand. While incubating, they are subject to predation by shore birds and sand-dwelling invertebrates. Under normal conditions, they do not have an opportunity to hatch until the next tide series high enough to reach them, in 10 or more days. Grunion eggs can extend incubation and delay hatching if tides do not reach them, for an additional four weeks after this initial hatching time. Most of the eggs will hatch in 10 days if provided with the seawater and agitation of the rising surf. The mechanical action of the waves is the environmental trigger for hatching, and the rapidity of hatch, in less than one minute, indicates that it is probably not an enzymatic function of softening the chorion, as in some other fishes. One can witness the spectacle of grunion eggs hatching. If you gather a cluster of eggs after a grunion run, keep them in a loosely covered container of damp sand in a cool spot. After 10 to 15 days, place some in a jar of seawater shaken briefly, and they will hatch before your eyes in a few minutes.

Grunion food habits are not known. They have no teeth, and feed on very small organisms, such as plankton. In a laboratory setting, grunion eat live brine shrimp. Humans, larger fish, and other animals prey upon grunion. An isopod, two species of flies, sandworms, and a beetle have been found preying on the eggs. Some shorebirds such as egrets and herons prey on grunion when the fish are on shore during spawning. The reduction of spawning habitat, due to beach erosion, harbor construction, and pollution is probably the most critical problem facing the grunion resource.

Status of the Population

Despite local concentrations, the grunion is not an abundant species. While the population size is not known, all research points to a rather restricted resource that is adequately maintained at current harvest rates under existing regulations.

Management Considerations

See the Management Considerations Appendix A for further information.

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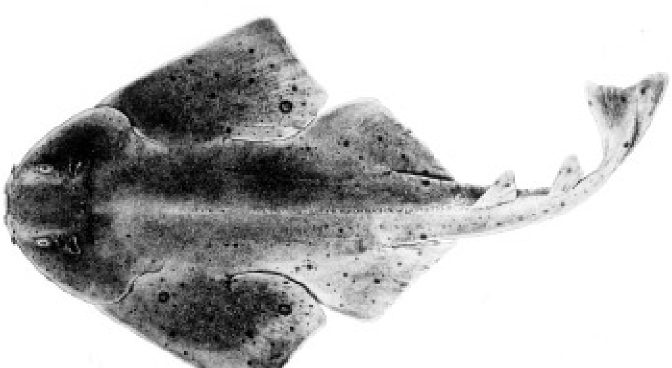
Pacific Angel Shark

History of the Fishery

Discarded as a nuisance species by halibut gillnet fishermen for several decades, the Pacific angel shark (*Squatina californica*) became one of the most sought after commercial shark species in the Santa Barbara Channel during the 1980s. Changes in consumer acceptance of sharks as high quality food fish and a concentrated marketing effort by an innovative processor working with local fishermen, stimulated development of the angel shark fishery in the Santa Barbara Channel area in 1976. Two key elements led to the rapid growth of this fishery: maintenance of quality and freshness of the shark by cleaning and dressing (removal of head and fins) at sea; and development of a method to fillet this irregularly shaped shark to satisfy retail distributors and consumers. Market development was linked to the popular but seasonal thresher shark, which is caught by the drift gillnet fleet in the summer and fall. As supplies of thresher shark diminished in the winter, angel shark was promoted as a viable substitute. Local demand grew rapidly as Santa Barbara and Ventura seafood retailers and restaurant owners found ready acceptance among consumers. Nearly every part of this shark, with the exception of skin, cartilage, and offal is utilized. The head and fins are sold as crab bait, large fillets are cut from the trunk, and portion-controlled pieces from the tail are used in fish and chips dishes. Small irregular-shaped pieces are used to make shark jerky. A yield of 50 percent of the dressed shark is generally expected.

The development of markets for angel shark was a significant benefit to halibut fishermen, providing them with a supplemental source of income. As demand increased for angel shark in the early 1980s, innovative fishermen developed nets to harvest them specifically. Because of their selectivity for market-sized angel shark, these nets caught only a few large California halibut. Nonetheless, 8.5-inch mesh monofilament gillnets designed for halibut continued to be used to take both species. After area closures were instituted in 1994, the directed gillnet fishery for these sharks ended and the smaller mesh halibut set gillnets again became the standard. Vessels used in the fishery are generally in the 25 to 40 foot range, suited for inshore coastal operations. Trawl vessels often caught a few angel sharks incidentally, but landings were insignificant compared to the set gillnet harvest. Trawl landings represented one percent of the total catch in 1990, rising to 17 percent in 1994.



Pacific Angel Shark, *Squatina californica*
Credit: DFG

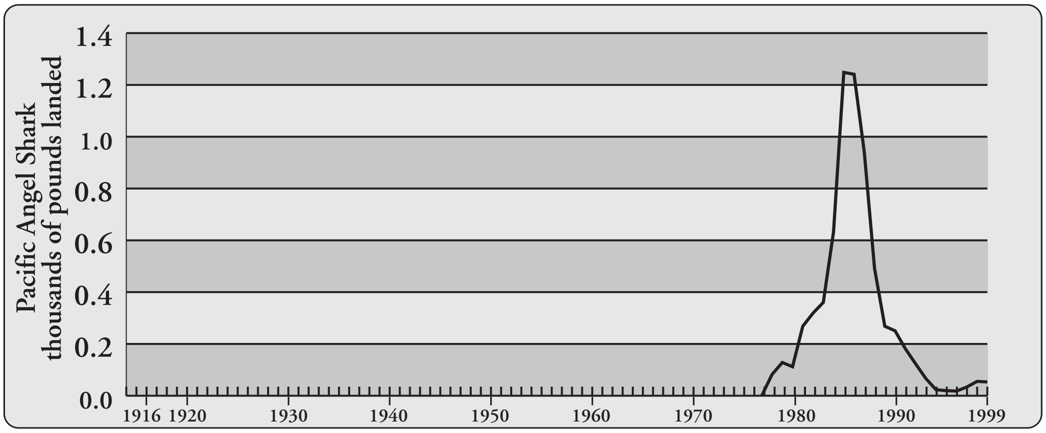
There has been little recreational interest in angel shark as nearshore anglers using hook-and-line catch relatively few compared to other more active sharks. One study logged only 12 angel sharks compared to over a thousand other sharks landed between 1997 and 2000. Nearly all of the angel sharks were caught at night.

In 1977, landings of dressed angel shark totaled 328 pounds. By 1981, landings rose to 258 thousand pounds, and by 1984, to 610 thousand pounds. Landings of angel shark exceeded one million pounds annually in 1985 and 1986, replacing the thresher shark as the number one species of shark taken for food in California.

Fishing effort throughout the early development and expansion phase was concentrated off Santa Barbara and Ventura counties and around the northern Channel Islands, especially Santa Cruz and Santa Rosa Islands. Landings began to decline in 1987, dropping to 940 thousand pounds with an ex-vessel value of $542,000 and further declining to 248 thousand pounds ($166,000) in 1990. A minimum size limit adopted by the DFG in 1986 contributed to a decrease in landings in the following years.

A second major decline in landings occurred in 1991 when a voter initiative was passed banning the use of gill and trammel nets within three miles of the southern California mainland coast and within one mile around the Channel Islands. Many gill-netters switched to other fisheries and a few dropped out entirely or retired. In 1990, a total of 144 vessels (including a few trawlers) landed angel shark and by 1994, the number was reduced 50 percent to 72. These boats landed 23 thousand pounds, a decline of 91 percent from the catch in 1990. Of the 72 vessels reporting landings, nine boats landed the major share (61 percent). The closures, in effect, established a large "no-take" reserve for angel shark in southern California, since gillnetting, considered to be the most viable fishing method for this species, was eliminated in the primary nearshore angel shark habitat.

Another factor affecting the fishery and contributing to the decline in landings was the sale of the primary angel shark processing plant in 1991 and its subsequent closure in 1992. This led California seafood wholesalers and retailers to search for alternative sources of angel shark, as the



Commercial Landings 1916-1999, Pacific Angel Shark
Data Source: DFG Catch Bulletins and commercial landings receipts. No commercial landing are reported for Pacific angel shark prior to 1977.

demand in California remained high, especially for use as fish and chips in seafood restaurants.

Prior to the 1994 fishing area closures, a gillnet fishery for angel sharks began in the upper reaches of the Gulf of California and a processing plant was established in Puerto Peñasco, Mexico. By 1993, imports of angel shark fillets were being used to meet the market demand in California. One buyer estimated imported fillets increased from 65 thousand pounds in 1994, to approximately 90 thousand pounds in 1999. Since 1997, a share of these sharks has been caught off Ensenada and Cedros Island near Guerrero Negro. The frozen and glazed imported fillets represent a weight of approximately one-quarter of the whole shark, so the actual landing figure was closer to 360 thousand pounds in 1999 from Mexican waters.

California landings dwindled to 19 thousand pounds in 1995 and 18 thousand pounds in 1996, but began to increase again between 1997 (33 thousand pounds) and 1999 (53 thousand pounds). Adding the Mexican imports (from two processing operations) to the California landings provides a better estimate of the California market demand and consumption of angel shark, which in 1999 totaled over 413 thousand pounds. Mexican imports now provide at least 87 percent of the total market share of the state.

The ex-vessel price for angel shark in 1977 was 15 cents per pound. The price rose to 35 cents per pound in 1982 ($1.60 to $1.70 per pound at retail markets) as demand increased for the firm, white-fleshed shark. With continued market demand and lower landings, ex-vessel prices in 1991 rose to 75 cents per pound dressed (head off) and in 1999 averaged 91 cents per pound. The standard ex-vessel price in 2000 is reported to be over $1 per pound. Retail prices have increased to between $4 and $6 per pound.

Cooperative fisheries research began in 1979 to obtain information on angel shark distributions, migrations, growth rates, and eventually, reproductive rates. Members of the commercial fishing industry helped initiate the investigations, which, with the participation and cooperation of university research and extension personnel, helped fisheries managers develop a management plan in 1986. Development of regulatory guidelines for this fishery is an example of a "co-management" approach involving a partnership of managers and resource users. The drop in landings after 1986 was partially attributed to a new size limit, though fisheries biologists and fishermen agree that management regulations were initiated too late to maintain a sustainable yield angel shark fishery with the harvest levels experienced in the mid-1980s.

Status of Biological Knowledge

The Pacific angel shark is reported to occur only in the eastern Pacific Ocean from southeastern Alaska to the Gulf of California and from Ecuador to Chile. A gap in distribution separating subpopulations of *S. californica* occurs between the equator and 20° North latitude. The southern population was earlier reported as a separate species, *S. armata*.

Angel sharks are relatively small, bottom-dwelling elasmobranchs, attaining maximum length of five feet and a weight of 60 pounds. In the Santa Barbara Channel, commercially caught specimens generally range in size between three and four feet, although minimum size limits now allow the take of females 42 inches and above and males 40 inches or more. Angel sharks range in depth from three to over 600 feet. Fishermen working the northern Channel Islands reported that most of their catches were between 30 and 240 feet. After the inshore area closures were set in 1994, fishing shifted to deeper waters between 100 and 300 feet.

Pacific angel shark are usually found lying partially buried on flat, sandy bottoms and in sand channels between rocky reefs during the day, but they may become active at night. Tagged specimens near Santa Catalina Island were found to move from a few feet to four nautical miles per night. However, individual sharks have been observed to remain in the same place with no apparent movement for up to 10 days.

Sonic tagging studies conducted at Santa Catalina Island indicated that 11 sharks with transmitter tags remained near the Island for up to 90 days, although movement around the island was extensive. Of 30 conventionally tagged fish all but one angel shark remained in the same general vicinity in which they were tagged. The lone exception was a shark tagged on the coast and captured three and a half years later at Santa Cruz Island. Without further evidence from tag and recovery data, resource managers assume that isolated stocks may exist near islands, separated from the mainland and other islands by deep water channels (including San Clemente, San Nicolas, Santa Barbara, and Santa Catalina Islands). A 1997 report on the genetic variability of angel sharks, from two of the northern Channel Islands (Santa Rosa and Santa Cruz Islands) and a more southern island (San Clemente Island) showed that there were significant allele frequency differences between sharks from the northern and southern areas. This electrophoretic study provides a strong indication that genetically isolated populations of angel sharks exist in California.

Several techniques have been utilized in an effort to age angel sharks, but to date aging this species has been unsuccessful. Researchers have observed that angel sharks are born with six to seven bands in their vertebral centra, but growth curves based on size and band counts were found to be atypical. Both centrum edge histology and size-frequency analyses have proven inconclusive. Sharks grown in the laboratory, along with field-tagged, tetracycline-injected returns, indicated no periodic basis for band deposition in the vertebrae, but indicated that calcified band deposition is more related to rapid somatic growth.

Sexual maturity in both males and females occurs between 35 and 39 inches total length. Embryos present per female range between one and 11, with a mean of six pups produced annually from March to June. A 10-month gestation period was estimated for this species.

Major prey items of angel shark include queenfish and blacksmith in the summer and market squid in the winter. Fishermen in the Santa Barbara Channel report that mackerel and Pacific sardines are found in angel shark stomachs during the fall and early winter, along with squid, which predominates during the winter and spring.

Status of the Population

The rapid increase in angel shark landings between 1983 and 1986 led to concern that stocks were being over-exploited. Over 79,000 individual angel sharks were reported taken during the 1985-1986 season. Considering the low fecundity and apparent lack of significant migrations of angel sharks, the need to develop a management plan became critical. A minimum retention size limit was proposed by DFG in 1987 and became law in 1989. Because these sharks are nearly always retrieved alive, limiting retention size is a viable regulation. However, landings had decreased before the inception of the regulation, indicating a declining population along the Santa Barbara-Ventura County coastline and around the northern Channel Islands. The minimum size restriction is believed to have been effective in decreasing the numbers of immature sharks harvested and also to have decreased harvest pressure on exploited stocks. The area closures had a much more severe effect on the fishing community and led to the unintended consequence of shifting the fishery to Mexico where, at present, no management of the species exists. Large numbers of gillnet "pangas" on both sides of the Baja Peninsula now fish angel sharks for Mexican markets and for export to California.

No population studies have been conducted on angel shark since the nearshore fishery ended in 1994. A comparative research survey of nearshore fish assemblages around Santa Catalina Island and along the mainland (Santa Barbara to Newport Beach) between 1996 and 1998 indicated that *Squatina* was a commonly caught species at many of the 10 sampling stations. The researchers reported that the survey showed a greater abundance and proportionately larger biomass for nearshore sharks than any other southern California study. Further, they note that gillnets are much more efficient for sampling mobile and elusive fishes than trawls and diver surveys. In terms of biomass, angel sharks ranked third at Santa Catalina Island and ninth at the mainland sites. There have been no recent studies of *Squatina* populations at the northern Channel Islands.

Management Considerations

See the Management Considerations Appendix A for further information.

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Leopard Shark

History of the Fishery

The leopard shark (*Triakis semifasciata*) is taken as both a food and game fish in California, and its distinctive markings and hardiness also make it desirable for public aquarium displays. Although some commercial landings may be lumped under a general "shark, unspecified" category, those reported as "leopard shark" have ranged from 9,270 pounds in 1958, to a high of 101,309 pounds in 1983. These landings, while not extensive, increased in the south and decreased in the north during the 1980s. Landings in southern California began increasing in 1981, and in 1985 surpassed landings in northern California for the first time since the collection of statistics began in the 1940s. Since 1991, landings have averaged about 31,000 pounds per year, with about 57 percent of the landings occurring south of Point Piedras Blancas. Legislative curtailment of inshore gillnetting in the San Francisco/Monterey Bay area undoubtedly contributed to much of the decline in northern California landings after 1986.

Judging from estimates made since 1980 by the National Marine Fisheries Service (NMFS) Marine Recreational Fisheries Statistics Survey, the recreational leopard shark catch appears to be greater than the commercial catch, although these estimates are subject to large sampling variability. According to the survey, sport catches in California between 1980 and 1988 averaged over 52,000 fish per year with a low of 33,000 fish taken in 1980 and a high of 59,000 fish taken in 1988. Since 1993, an estimated average of 45,000 leopard sharks have been taken by anglers, with a low of 34,000 taken in 1993 and again in 1994, and a high of 58,000 taken in 1997.

A variety of fishing methods and gear types are used in the fisheries for leopard sharks. Most of the recreational catch is taken angling with baited hooks with some spearfishing by divers. Analysis of tag-recaptures in the central California area in the 1980s suggests that most angler-caught leopard sharks are taken from private boats (55 percent), and from shore (41 percent), with a small percent landed by partyboats (four percent). The commercial catch, largely incidental in recent years, is taken mainly by set net (53 percent), hook-and-line (30 percent), and trawl (13 percent).

Leopard Shark, *Triakis semifasciata*
Credit: CA Sea Grant Extension Program

A 36-inch minimum size and a possession limit of three fish have been in effect for the sport fishery since 1991. This size limit was also extended to the commercial fishery in 1994, both for market and aquarium display. Additionally, the state has general restrictions on usage of certain types of commercial gear in the nearshore zone.

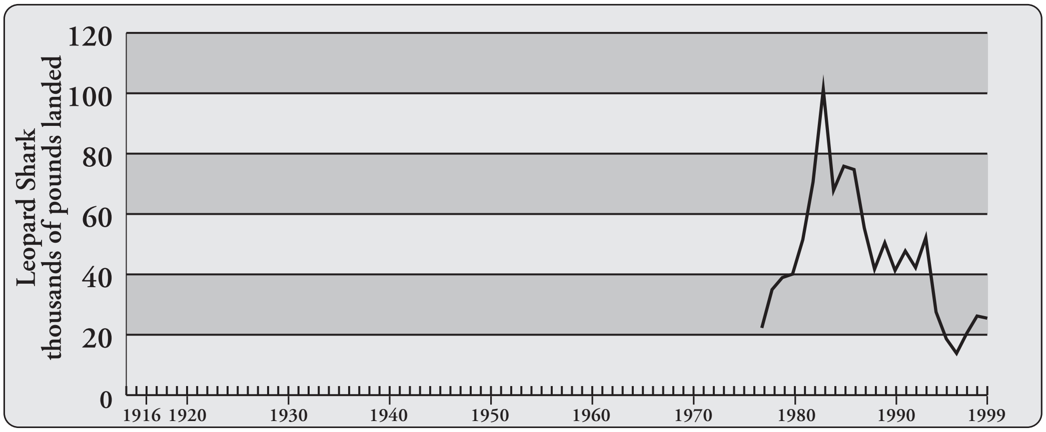
Status of Biological Knowledge

The leopard shark, also known as "tiger shark" and "cat shark," ranges from Mazatlan, Mexico, into the northern Gulf of California, and northward to Oregon. It is most common in shallow water from the intertidal down to 15 feet, less so down to 300 feet or deeper in ocean waters. Favoring muddy bays and sloughs, especially in northern California, it is known to move out and in with the tides to feed over shallow tidal mudflats. It also occurs along the open coast and around offshore islands off southern California, where it frequents kelp beds, sandy bottoms near rocky reefs, and the surf zone along sandy beaches.

The population structure throughout its range is not clearly understood, but is thought to consist of regional stocks among which there is relatively little exchange. Tagging studies in central California have shown there is at least some mixing between stocks in San Francisco Bay and those in central and southern California, but such exchange appears limited. The Gulf of California, Mexico, stock is presumed to be separate from the California stocks.

The maximum recorded and verified total length is about six feet long. The oldest validated age that has been determined by reading tetracycline-labeled rings on the vertebrae, is 26 years for a 49-inch female, an average of 1.8 inches per year. Size at birth is about eight to 10 inches in total length. Longevity is presumed to be around 30 years.

The live-bearing female leopard shark produces from seven to 36 offspring in an annual reproductive cycle. Males mature at seven years, and females at 10 years, when fish reach lengths between 40 and 42 inches total length. The gestation period is estimated at 10 to 12 months. Birth apparently takes place from March through July. The only known eye-witness account of leopard sharks giving birth in the wild is that of a fisherman who observed "pupping" activity at Santa Catalina Island in southern California in the 1940s. Dozens of large females,



Commercial Landings 1916-1999, Leopard Shark
Commercial landings for leopard shark were not reported prior to 1977. Data Source: DFG Catch Bulletins and commercial landing receipts.

with backs and dorsal fins breaking the surface of the water over a shallow mudflat in Catalina Harbor, were observed releasing their pups in the three to four-foot deep water; some of the pups were seen milling around in water only about a foot deep.

This shark is an opportunistic benthic feeder. Invertebrates taken include crabs, ghost shrimp, clam siphons and sometimes whole clam bodies, polychaete worms, fat innkeeper worms, and octopuses. Fishes in the diet include herring, anchovy, topsmelt, croakers, surfperches, gobies, rockfishes, midshipman, flatfishes, and small elasmobranchs such as smoothhounds, guitarfishes, and bat rays. Leopard sharks seasonally consume the eggs of herring, topsmelt, jacksmelt, and midshipman.

The leopard shark is preyed upon by the white shark and sevengill shark, and presumably other large sharks as well, which are known to enter bays. The phenomenon of young sharks being preyed on by larger sharks is not uncommon.

These nomadic sharks often occur in schools, sometimes with smoothhounds, which also belong to the houndshark family. Numbers of animals may suddenly appear in an area, then move on. Although generally timid and wary of divers, there is one record of an attack on a skin diver in 1955 in California.

Movements of this species have been studied in central California. Tagging in San Francisco Bay has revealed that this stock is mostly resident, although at least 10 percent of the population moves out of the bay into the ocean during fall and winter. One female at liberty for 20 years was recaptured in south San Francisco Bay less than five miles from where she was originally tagged. Of the longer distance migrants, one three-foot male tagged in San Francisco Bay was recaptured in Santa Monica Bay a decade later.

Status of the Population

The leopard shark is one of the many species considered, but not now actively regulated, under the Pacific Fishery Management Council's Groundfish Management Plan. Regulatory actions enacted by the State of California have contributed significantly toward protecting this species. Even though the commercial catch may be underestimated because of reporting problems, this species does not appear to be at risk, judging by the combined landings in relation to previously calculated estimates of fishing mortality and exploitation rates and current conservation measures which appear to have reduced these rates. The imposition of a sport and commercial fishing size limit and general curtailment of gillnetting within this species' nearshore range appear to have halted the increase if not reduced total fishing mortality over the past decade. Commercial sport fishing boat catches of leopard shark in California have dropped from an average of 6.8 fish per trip between 1980 and 1991 to an average of 4.0 fish after the size limit was imposed from 1992 to 1995, as more fish were released. Also encouraging is evidence that mortality from hooking injuries is quite low.

The size of the California leopard shark population has not been estimated, and the only information on relative changes in stock abundance is what can be inferred from catch statistics. Because of its rather limited geographical range with little exchange among regional stocks within this range, resident stocks near large population centers may be particularly vulnerable to heavy localized fishing pressure. A recent re-assessment of the leopard shark's intrinsic productivity and vulnerability to harvest revealed it to be even more susceptible to over-exploitation than previously reported. Its annual rate of increase under maximum sustainable yield exploitation has been calculated at only about two to three percent per year. And while the size limit protects juveniles, it does not protect mature adults in their prime reproductive years in feeding and near shore pupping areas. Nonetheless, it appears that current conservation measures, as long as they are in place, appear to provide adequate protection for the sustainability of the California stock of this species at the present time. Possible future fishing mortality increases within regulatory constraints could be a concern if mature females become an increasingly important component of the catch, or if inshore fisheries develop that are efficient at targeting this species.

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Soupfin Shark

History of the Fishery

The soupfin shark (*Galeorhinus galeus*) was the mainstay of the shark fishery boom for vitamin oils between 1936 and 1944 when over 24 million pounds were landed. Prior to that time, soupfins were mainly marketed within the local Asian communities up and down the Pacific coast. The meat sold anywhere from $0.10 to $0.20 per pound, but the fins, which are used for soup stock brought as much as $2.50 per pound prior to 1936. The fishery for this species began in earnest when it was discovered that their livers were rich in vitamin oil. The value of each shark species was based on its high potency vitamin oil and the soupfin was found to have the highest vitamin oil levels among California's shark species. Prior to the development of this fishery, cod liver oil was produced in Europe and exported to the United States. With the onset of World War II and the curtailment of cod liver oil production in Europe, these events set the stage for the expansion of this fishery. Shipping cod liver oil from Europe became so hazardous that its production and exportation eventually declined to nothing. The West Coast soupfin shark population represented a tremendous source of raw material. The market for shark liver oils to replace the non-available cod liver oil improved rapidly and in a relatively short time the huge potential of the Pacific coast soupfin supply had been tapped. The fishery finally collapsed in the mid-1940s from over-exploitation and the development of synthetic vitamins. This fishery decimated the soupfin population, particularly nursery areas in San Francisco and Tomales bays, which to this day have never fully recovered. In the mid-1970s, there was a renewed interest in shark fisheries, although this time for their meat as food for human consumption.

While the commercial fishery for soupfins has been widely recounted, less attention has been paid to its recreational exploitation. Soupfins were one of the more common species caught in San Francisco Bay during the late 1940s through the early 1960s by recreational anglers. This fishery declined somewhat until the *Jaws* phenomenon of the mid-1970s brought about a renewed awareness of sharks. Sport fishing boats in San Francisco Bay and southern California began targeting these, among other shark species. Unlike the commercial fishery, landings data for recreational caught soupfins are sketchy at best and are under-reported, if reported at all. Soupfins are prized by recreational anglers for their meat.

Status of Biological Knowledge

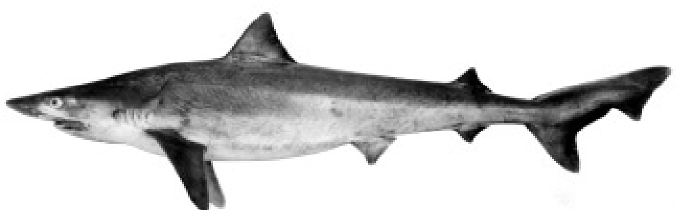
The soupfin shark is one of five species of houndsharks (Family Triakidae) found in California waters. Along the California coast, soupfin sharks generally inhabit continental shelf waters from close inshore, including shallow bays, often near the bottom, but also offshore waters up to 1,500 feet deep. In the eastern North Pacific they range from British Columbia to central Baja California.

Coast wide there is a preponderance of adult males in the northern part of the state and females to the south; in central California the sex ratio is about one to one. Adult males south of Point Conception tend to occur in deeper water (more than 65 feet) while females occur closer inshore (less than 45 feet). Soupfins often occur in small schools that segregate by size and sex.

Soupfins are highly migratory, moving to the north during the summer and south during the winter or into deeper waters. They are swift moving and can travel up to 35 miles per day and have been reported to travel at a sustained rate of 10 miles per day for up to 100 days. One soupfin tagged off Ventura was captured 26 months later off Vancouver Island, British Columbia. Another shark tagged in San Francisco Bay was recaptured 12 months later in the same location.

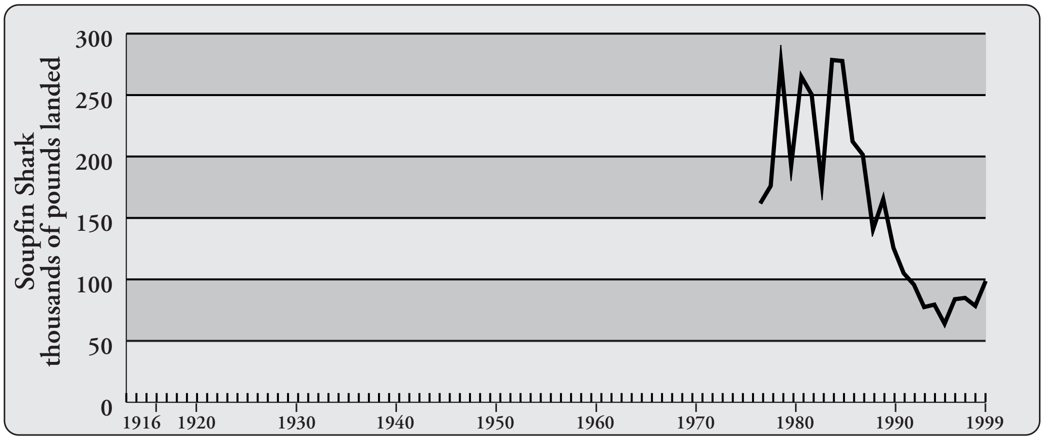
Soupfin sharks are ovoviviparous, with litters of between six and 52 young, the average being 35. The litter size increases in proportion to the female's size. Mating takes place during the spring with a gestation period of about 12 months. Southern California, south of Point Conception, is an important nursery ground. Adult females and newborn soupfins occur in considerable numbers in this area. Pups are born during the spring at a size of between 12 and 16 inches. Males mature between 53 and 60 inches, and grow to a maximum size of 70 inches. Females mature at about 24 inches, and grow to a maximum size of 77 inches. Males mature in eight to nine years and females in about 11 years. The maximum estimated age for these sharks is about 40 years.

Soupfins readily forage on both demersal and pelagic bony fish species, although larger individuals prefer cartilaginous fishes. Invertebrate prey includes cephalopods, crabs, shrimp, and lobster. Young sharks tend to feed more heavily on invertebrates than do adults. Natural predators on soupfins, particularly juveniles, include the white shark, sevengill shark, and possibly marine mammals.



Soupfin Shark, *Galeorhinus galeus*
Credit: DFG

Commercial Landings 1916-1999, Soupfin Shark
Data Source: DFG Catch Bulletins and commercial landing receipts. Commercial landings prior to 1977 were not available. All shark landings were aggregated until 1977.



Status of the Population

California's soupfin shark population has not been studied in over 50 years and its status is unknown. Since 1977, the fishery has averaged between 150,000 and 250,000 pounds dressed weight landed annually.

David Ebert
US Abalone

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Skates and Rays

History of the Fishery

Skates and rays are not specifically sought by commercial fishermen, but are taken incidentally, primarily by bottom trawlers in central and northern California waters. Of the species identified in the commercial catch the most common are the shovelnose guitarfish (*Rhinobatos productus*), bat ray (*Myliobatis californica*), big skate (*Raja binoculata*), and thornback (*Platyrhinoidis triseriata*). This does not represent the true catch composition, however, as 98 percent of the landings are listed as "unidentified skate." A few nearshore species, most commonly the bat ray and shovelnose guitarfish, are the target of small sport fisheries.

Only the wings of skates caught in the commercial fishery are marketed. The bodies are either discarded at sea or occasionally sold as bait for the rock crab fishery. Skate wings are sold fresh and frozen, predominantly in the Asian fresh fish markets in southern California. Wings are also dried or salted and dehydrated for the Asian markets. At times, skates have been processed for fishmeal, but most such enterprises experienced economic failure. Seafood restaurants and retail markets have been suspected of punching out rounds of skate wing to serve as cheap substitutes for scallops.

Historically, the economic value of the skate fishery compared to other seafood fisheries was relatively small. From 1958 to 1969 the ex-vessel price for skate wings ranged from $.01 to $.02 per pound. Prices increased from $.12 per pound in the 1970s to $.25 per pound in 1991. This increase has continued through the 1990s ranging as high as $1 or more and averaging around $.40. In 1999, the total ex-vessel value of skates and rays was approximately $340,000.

Central California (Monterey and San Francisco) shared the majority of the skate catch from 1948 through 1989, accounting for 41 to 100 percent of the annual landings and more than 70 percent of the total catch during the period. The northern California areas (Eureka, Crescent City, and Fort Bragg) have played an increasing role since about 1975. Over the period from 1989 through 1999, the northern California catch has increased dramatically, accounting for nearly 75 percent of the total catch. Areas south of Monterey remain relatively insignificant in terms of total landings.

From 1916 to 1990, skate landings, which ranged from 36,247 pounds (1916) to 631,240 pounds (1981), comprised two to 90 percent of the total elasmobranch catch (11.8 percent average). Like the shark fishery, which had peaks from 1937 to 1948, and more recently from 1976 to 1990, the skate catch has fluctuated widely during the last half century. In the past 10 years, however, skate and ray landings have increased nearly ten-fold in California, from around 228,566 pounds in 1989 to 1,912,695 pounds in 1999. This trend is most notable in the trawl fishery after 1994.

Some of the apparent increase may be due to increased landings of previously discarded catch. In 1994, the commercial groundfish fishery was divided into limited entry and open access components, each with new regulations and quotas. Groundfish quotas for both components were significantly reduced in the period from 1994 through 1999, leaving more space in the boats' holds for non-quota species. Trawl vessels have supplemented their groundfish landings with skate and ray bycatch. There is considerable uncertainty whether the total impact on the skate and ray resource has increased or if more of the catch is being retained and landed.

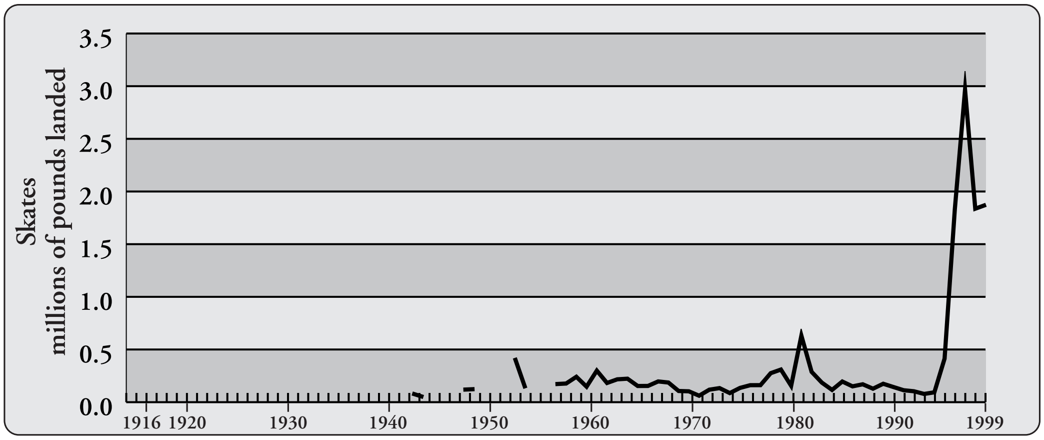
Status of Biological Knowledge

Skates and rays (batoids) can be distinguished from sharks by having pectoral fins which extend above and in front of the gills, attaching to the head and forming an expanded and flattened disc with gill slits located completely on the underside. They can be thought of as sharks flattened to accommodate a life spent on the sea floor. Twenty species of rays and skates have provisionally been recorded from California waters.

Rays and skates occur in all marine habitats, from protected bays and estuaries to open seas, ranging from the surface to 9,500 feet deep. While some species are common, others are known from only a few specimens. So far as is known, batoids follow the typical elasmobranch reproductive strategy in which sexual maturity is attained relatively late in life, brood size is relatively small, and fecundity is generally low. These characteristics make populations more susceptible to overfishing.

All batoids have internal fertilization, but two different modes of development exist. The skates are egg layers, or oviparous. Following fertilization, the yolk is enclosed in a

Longnose Skate, *Raja rhina*
Credit: DFG



Commercial Landings 1916-1999, Skates
Data Source: DFG Catch Bulletins and commercial landing receipts. Landings data are not available prior to 1943, 1945-1947, 1950, 1952, and 1955-1956.

tough, permeable egg case, which is deposited on the sea floor. The embryo develops within the egg case, feeding on nourishment stored in the attached yolk mass. Hatched egg cases (commonly known as "mermaid's purses") are washed ashore and frequently found by beachcombers. All other batoids are live bearing, or viviparous. The embryo is protected by, and develops within, a portion of the female's oviduct, which functions as a uterus. The gestation period for skates and rays varies widely; depending on the species it may range from two to 18 months.

Batoids feed on a variety of worms, mollusks, crustaceans, other invertebrates, and fishes. Some lie buried on the bottom to wait for prey, while others actively forage. As a group they have a large variety of feeding strategies, ranging from straining plankton (manta), to electric shock (electric ray), to excavation and suction (bat ray). In turn, marine mammals, sharks, and other large fishes prey upon batoids. An adult giant sea bass (*Stereolepis gigas*) was found to have three whole thornbacks in its stomach. Batoid predator avoidance adaptations include cryptic (camouflage) coloration and burying themselves in sand or mud. In some species, rows of sharp spines on the back and/or tail also serve as protection. Only a few of the batoid species are dangerous to humans. Electric rays are capable of producing a powerful shock, and stingrays can inflict serious wounds on unwary anglers and bathers.

The Skates and Softnose Skates - Families Rajidae and Arhynchobatidae

The skates are the largest group of batoid fishes. Nine species in three genera are presently known to occur in California waters. California's three commercially important skates are the California skate (*Raja inornata*), big skate (*R. binoculata*), and longnose skate (*R. rhina*).

The skates have a greatly flattened, usually rhomboidal shaped disc. Most species have enlarged thorns or sharp spines (denticles) on disc and tail. Adult males have rows of enlarged, hooked thorns along the front edge (malar thorns) and lateral edge (alar thorns) of the disc. The tail is slender, with two small dorsal fins located near the tip. The caudal fin is small or absent, and there are no stinging spines. Skates have paired electric organs along the sides of their tails, which generate weak, low-voltage electric currents believed to be used in intra-specific communication, possibly for mate recognition or to demonstrate aggression. These electric currents are not harmful to humans.

The California skate ranges from the Strait of Juan De Fuca to southern Baja California. It is common inshore in shallow bays at depths of 60 feet or less, but also occurs in deeper water to a depth of 2,200 feet. Females and males both reach sexual maturity at a total length of about 30 inches. They feed on shrimp and other invertebrates.

The big skate ranges from the Bering Sea to southern Baja California, but is relatively rare south of Point Conception. It occurs at depths from 10 to about 2,600 feet, being most common at moderate depths. It is the only known Californian skate with more than one embryo per egg case. The big skate grows to a length of up to eight feet, but usually does not exceed six feet and about 200 pounds. Females mature at 12 to 13 years and a length of 51 to 55 inches; males mature at seven to eight years and a length of 39 to 43 inches. It feeds on crustaceans and fishes.

The longnose skate also ranges from the Bering Sea to central Baja California, and is usually found on the bottom at depths from 80 to 2,250 feet. It attains a maximum length of about 4.5 feet. Females mature at eight years and a length of 28 inches; males mature at five years and a length of 24 inches.

Other skate species include the sandpaper skate (*Bathyraja interrupta*) and starry skate (*Raja stellulata*) occurring in moderate depths and the deep-sea skate (*B.*

abyssicola), roughtail skate (*B. tachura*), and white skate (*B. spinosissima*) occurring in deep water up to 9,500 feet (deep skate). One other species, the broad skate (*Amblyraja badia*) is very rare with only two records from California.

The Guitarfishes and Thornbacks - Families Rhinobatidae and Platyrhinidae

The guitarfishes derive their name from their similarity in shape to the musical instrument; head tapered or round, flattened, and somewhat broader than their sturdy, shark-like tail. Thornbacks share this general body shape, but have rows of spines down the dorsal surface. Guitarfishes and thornbacks are usually found on the bottom and close inshore. All are viviparous, the embryos being nourished by nutrients stored in their yolksac. They have small, blunt teeth used for crushing, and feed on invertebrates such as worms, crustaceans, and mollusks, as well as small fishes, and are generally harmless to humans. Three species are known from California waters.

The shovelnose guitarfish (*Rhinobatos productus*) has a sharply pointed snout and a tapered, somewhat shovel-shaped disc. It ranges from San Francisco to the Gulf of California, but is rare north of Monterey Bay. It is found in shallow coastal waters, bays, sloughs and estuaries over sandy or muddy bottoms to a depth of about 50 feet. Mating occurs during the summer months in southern California and the females give birth to live young the following spring or summer. Newborn guitarfish are six inches long, with up to 28 pups per litter. Females reach a length of 5.5 feet and a weight of about 40 pounds; males are smaller. The banded guitarfish (*Zapteryx exasperata*) has a more rounded snout and dark banding across the disc. It inhabits rocky reefs and gravel beds and occurs rarely in southern California.

The thornback (*Platyrhinoidis triseriata*) is identified by three parallel rows of large, curved spines running down the back and base of its tail to just past the first dorsal fin. Adults reach a length of 2.5 to three feet. Thornbacks occur in shallow water to depths of 150 feet resting on sandy bottoms partially or completely buried. Thornbacks are common in the southern part of the state and Baja California, becoming more rare to the north.

The Electric Rays - Family Torpedinidae

Electric rays are found worldwide in all tropical and warm-temperate seas. They have a greatly expanded sub-circular disc that is fleshy toward the margins, and specialized to accommodate the two kidney-shaped electric organs. These organs are modified muscles capable of producing a powerful electrical shock. Only one species is known from California waters.

The Pacific electric ray (*Torpedo californica*) ranges from northern British Columbia to central Baja California, at depths from 10 to 1,400 feet. Commonly found over sandy bottoms, it also occurs in rocky areas and kelp beds. Females reach a length of over 4.5 feet, while males may reach three feet. It feeds exclusively on fish, including anchovies, herring, kelp bass, mackerel, and halibut. One four-foot female ray was observed to consume a two-foot silver salmon. Unlike most predatory fish, however, it does not initially seize its prey with its mouth, but first immobilizes it with electric discharges. It then manipulates the prey toward its mouth, using its remarkably dexterous disc, before swallowing it.

Sometimes aggressive when approached or provoked by divers, it may swim toward them with pectoral fins curled downward in a challenging manner. While its electric shock may be quite powerful, reaching up to 60 volts in larger individuals, it does not extend a great distance from the ray's body. The shock is apparently not fatal to humans, but often snaps the backbone of prey fish.

The Myliobatidiform Rays (Stingrays) - Families Urolophidae, Myliobatidae, Dasyatidae, Gymnuridae, and Mobulidae

The stingrays are a large and rather diverse group, most of which have a greatly flattened disc and whiplike tail with one or more serrated stinging spines that are readily replaced when they become old or worn. This group includes both the smallest and largest batoids. Most are bottom-dwellers, occurring in shallow inshore waters, bays, estuaries and sloughs, but some are also found in deeper waters. At least one species of stingray and all mantas and mobulas are epipelagic, occurring in the upper water column of the open ocean.

The stingrays bear live young and are unique among the elasmobranchs in their method of nourishing the developing embryo. A nutritive fluid called uterine milk is secreted from hair like processes called trophonemata, which line the oviduct wall. Adults feed on soft benthic invertebrates, mollusks, crustaceans, and benthic, midwater, and schooling nektonic fishes.

Rays are usually popular when displayed in public aquaria; bat rays are especially suited for shallow petting tanks. Although used by cultures throughout the world for food, myliobatidiform rays are of little interest to California commercial fishermen, who mostly consider them a nuisance. Because most species have a stinging spine, care should be taken when handling them.

The round stingray (*Urolophus halleri*), our most common stingray, has a nearly round disc and short, stout tail with well-developed caudal fin and stinging spine. It ranges from northern California to Panama, but is most abundant south of Point Conception. A benthic species with restricted habitat requirements, this ray is limited to a relatively shallow coastal zone at depths from three to 100 feet, occurring primarily in water less than 50 feet deep. It can be found off beaches and in protected bays, sloughs, channels and inlets, where it inhabits loose sand or mud bottoms.

The round stingray's stinging spine is located far enough back on its tail to afford a powerful stinging reflex. When large numbers of round stingrays congregate off beaches, injuries to bathers can result. This danger can usually be avoided, however, by shuffling one's feet or pushing a stick along the bottom. Injuries from the spine may also result when rays are removed from nets or hooks. While the wounds do not appear to be fatal, they can be severely painful, and can cause vomiting, diarrhea, sweating, cramps, and difficulty breathing.

The bat ray (*Myliobatis californica*) is a common seasonal inhabitant of shallow inshore waters from Oregon to the Gulf of California. It occurs in muddy or sandy bays and sloughs as well as rocky areas and in kelp beds from near the surface to depths of 150 feet.

Gestation is estimated to take from nine to 12 months, with two to 12 young per litter. Size range at birth is 8.7 to 13.8 inches disc width (wingtip to wingtip). Onset of sexual maturity in males occurs at an age of two to three years and a disc width of 17.7 to 24.5 inches; maturity in females occurs at five to seven years and disc width of 35 to 40 inches.

Female bat rays reach a greater size than males, attaining a maximum disc width of 70.9 inches and weight of 210 pounds. The largest reported male is 40 inches wide at a weight of 37 pounds. Bat rays grow slowly, reach sexual maturity relatively late, have few young, and seem to be fairly long-lived. A 60-inch disc width female was estimated to be 24 years old.

Bat rays feed on clams, abalones, oysters, marine snails, worms, shrimps, and crabs. Bat ray predation on oysters is a major reason for the fencing seen around commercial oyster beds. Pieces of backbone (centra), tooth plates, and sting fragments have been identified from coastal shell-mounds, suggesting that bat rays were a regular diet item of early California natives.

The diamond stingray (*Dasyatis brevis*) is found in shallow waters to a depth of 55 feet. It ranges from southern California (with a possible record from British Columbia) to Peru inhabiting sand and mud bottoms, often around kelp beds. Maximum reported size is 38.5 inches disc width.

A truly open ocean species, the pelagic stingray (*Pteroplatytrygon violacea*) is commonly found swimming in open water well above the bottom. Found worldwide in warm-temperate and tropical waters the pelagic stingray reaches a maximum disc width of 32 inches. It is a frequent incidental catch of drift longline gear.

The California butterfly ray (*Gymnura marmorata*) inhabits shallow bays and sandy beaches. It has a very wide disc, reaching widths up to five feet. The butterfly ray is found from Point Conception to Peru, including the Gulf of California.

Found worldwide in tropical seas the Pacific manta (*Manta birostris*) is seen on rare occasions in southern California. The manta can reach a maximum width of 25 feet. Its close relative, the mobula (*Mobula japonica*), which occurs in temperate waters of the Pacific, is also rarely seen in southern California. Mobulas are smaller than mantas, reaching a maximum width of four to seven feet. Mantas and mobulas are unique among the batoids in being filter feeders. They pass huge volumes of water across complex filter plates at the gills, straining out small pelagic crustaceans and schooling fishes.

Status of the Populations

Based on existing data, little can be said about the current or past population levels of California's skates and rays. While landings are increasing dramatically, this may or may not reflect an actual threat to the resource. Fish that were discarded in the past, dead and alive, are now being retained and landed. The increase in landings, however, certainly warrants close monitoring. Although some skate species may have higher growth rates than other elasmobranchs, compared with bony fishes they have slow growth rates, late age at maturity, and low fecundity. Other regions have already witnessed decreases in skate and ray populations. In Japan and the Irish Sea, landings have decreased and overfishing has apparently occurred.

The impact of sport fisheries on skates and rays is relatively unknown. Data from 48 shark derbies in Elkhorn Slough from 1950 to 1990 show, however, that shovelnose guitarfish, which in the 1950s and 1960s were the second, and in some years the most abundantly caught elasmobranch, virtually disappeared from the catch in later years. In the 1990s, there was a two-thirds decrease in the catch-per-unit effort for bat rays compared to the 1950s catch rates in these derbies. Pacific States Marine Fisheries Commission recreational fisheries sampling, however, shows continued catches of bat rays, big skates, shovelnose guitarfish, and thornback. The total numbers caught are hard to determine from the numbers of sampled skates and rays, as sampled catch numbers vary widely from year to year.

Management Considerations

See the Management Considerations Appendix A for further information.

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Commercial Landings - Nearshore Finfish

Year	Cabezon Pounds	California Barracuda Pounds	Pacific Bonito Pounds	White Croaker [1] Pounds	Arrowtooth Flounder [2] Pounds	Starry Flounder [3] Pounds	California Halibut Pounds	Lingcod Pounds
1916	569	2,687,362	480,406	779,287	- - - -	453,916	4,052,173	617,236
1917	434	3,060,323	889,376	835,259	- - - -	1,151,876	4,379,312	930,519
1918	167	4,837,284	2,441,714	1,014,820	- - - -	818,835	4,624,218	915,836
1919	- - - -	5,824,957	3,509,098	609,175	- - - -	435,731	4,698,123	1,063,136
1920	- - - -	8,201,335	873,648	461,459	- - - -	481,581	4,279,582	687,954
1921	- - - -	7,625,162	324,737	391,085	- - - -	293,656	3,653,861	425,543
1922	- - - -	6,250,218	957,942	581,863	- - - -	539,220	3,254,505	568,481
1923	- - - -	7,200,575	1,115,247	411,564	- - - -	508,961	2,229,381	467,347
1924	- - - -	7,128,523	1,045,282	384,317	- - - -	379,770	2,576,882	400,432
1925	3,352	8,036,449	879,166	536,654	- - - -	594,420	2,452,551	683,130
1926	- - - -	5,022,464	3,121,604	484,921	- - - -	667,711	1,349,031	649,902
1927	752	6,199,739	1,718,008	529,267	- - - -	590,064	1,303,559	556,308
1928	2,628	6,452,456	2,107,089	441,758	- - - -	399,880	1,187,651	853,537
1929	1,196	5,228,610	2,918,544	476,497	- - - -	580,752	1,102,573	1,167,120
1930	1,046	4,763,766	5,164,260	457,167	- - - -	391,096	1,097,760	1,288,172
1931	1,115	4,177,538	3,079,673	414,034	- - - -	169,806	969,773	1,229,088
1932	4,678	2,926,775	2,862,286	447,531	- - - -	543,806	949,702	899,912
1933	4,265	3,072,962	2,252,199	564,274	- - - -	457,998	989,649	1,088,955
1934	5,265	2,182,822	3,202,694	634,345	- - - -	537,164	1,037,008	857,600
1935	10,537	2,617,824	7,896,484	768,676	- - - -	656,113	1,575,863	1,017,455
1936	18,468	2,977,842	7,215,916	652,134	- - - -	621,186	1,582,907	758,547
1937	8,189	2,938,490	7,808,070	645,759	- - - -	974,770	1,207,235	968,258
1938	5,425	2,529,812	7,839,993	493,209	- - - -	542,812	1,078,229	646,004
1939	4,023	4,092,054	9,918,875	542,901	- - - -	739,311	991,621	576,972
1940	3,392	3,714,832	5,291,140	412,228	- - - -	804,089	948,457	692,243
1941	13,346	4,201,928	10,907,602	325,155	- - - -	601,577	706,650	529,772
1942	2,312	3,454,537	1,650,689	284,225	- - - -	370,125	750,539	314,334
1943	7,532	3,775,338	2,282,299	396,633	- - - -	505,399	1,111,998	719,318
1944	3,906	3,648,308	818,871	367,701	- - - -	366,520	1,485,463	746,039
1945	4,417	3,873,257	2,714,181	459,515	- - - -	337,543	1,748,821	758,395
1946	7,860	3,107,024	5,625,648	437,023	- - - -	509,448	2,457,187	1,156,127
1947	4,526	2,665,745	13,697,183	458,686	- - - -	527,072	1,787,901	1,940,747
1948	8,202	2,125,737	9,135,126	643,123	- - - -	405,251	1,306,629	2,056,088
1949	16,073	2,457,684	1,829,541	764,429	- - - -	356,374	1,256,435	1,656,184
1950	21,679	2,258,415	695,614	750,722	74,309	913,765	1,092,748	1,915,905
1951	23,875	2,106,928	776,803	682,269	59,801	1,128,892	868,201	1,672,114
1952	34,556	2,094,206	2,142,517	3,273,702	112,913	597,477	525,402	1,366,279
1953	13,365	1,438,846	3,102,647	1,201,134	88,367	502526	530,315	952,103
1954	6,262	1,562,739	2,319,060	913,802	550,457	500,550	661,331	947,383
1955	6,944	1,140,959	136,990	819,488	748,249	650,180	509,742	964,926
1956	12,415	752,527	127,614	889,870	1,070,597	375,400	455,659	931,311
1957	13,206	682,666	219,149	535,362	933,715	504,461	376,815	1,639,654
1958	19,612	915,259	5,546,806	770,534	643,880	471,202	267,446	1,599,515
1959	9,508	1,152,601	3,011,616	1,534,382	787,254	1,046,926	354,242	1,406,297
1960	3,067	1,229,668	1,250,544	1,078,119	1,007,679	259,038	376,263	1,307,129
1961	4,952	709,379	8,512,972	889,164	60,659	315,337	654,554	1,439,943
1962	2,474	746,476	2,134,902	687,633	53,326	338,192	863,086	1,112,204
1963	2,811	378,714	4,022,522	551,059	17,345	521,310	1,120,369	1,133,008
1964	5,281	334,140	2,612,269	838,584	9,735	420,986	1,276,105	836,377
1965	7,438	362,058	5,638,340	1,135,566	11,595	378,389	1,243,718	812,690
1966	12,599	319,116	19,148,494	790,997	3,503	380,628	1,011,412	800,303
1967	14,284	313,184	21,219,431	496,378	6,041	870,707	838,058	938,655
1968	20,106	140,500	14,921,929	941,304	13,400	856,157	671,654	1,094,054
1969	25,837	74,593	17,201,847	525,514	9,986	374,840	274,277	1,113,508
1970	10,698	24,588	9,192,304	564,871	6,120	- - - -	257,444	1,531,399
1971	4,518	17,264	20,268,984	334,395	2,661	- - - -	336,871	2,097,949
1972	5,853	13,915	22,312,627	373,410	163,947	- - - -	309,245	3,246,186
1973	4,554	37,605	30,787,731	227,096	236,244	- - - -	273,526	3,559,621
1974	14,901	36,498	18,817,766	514,317	210,510	- - - -	306,479	3,824,107
1975	7,332	58,597	31,873,688	577,785	70,714	- - - -	508,913	3,190,195
1976	19,166	162,091	8,896,859	497,961	185,228	- - - -	628,400	3,120,220
1977	12,150	77,119	22,547,605	588,551	222,300	- - - -	467,862	1,694,539
1978	28,781	48,437	7,882,396	422,288	206,603	- - - -	441,440	2,015,460
1979	50,327	37,327	3,960,071	716,315	238,203	- - - -	665,546	3,161,120

Commercial Landings - Nearshore Finfish, cont'd

Year	Cabezon Pounds	California Barracuda Pounds	Pacific Bonito Pounds	White Croaker [1] Pounds	Arrowtooth Flounder [2] Pounds	Starry Flounder [3] Pounds	California Halibut Pounds	Lingcod Pounds
1980	60,146	66,553	14,242,114	1,064,141	122,820	- - - -	726,852	2,810,797
1981	53,460	67,594	16,615,051	978,734	105,550	- - - -	1,262,265	2,839,852
1982	62,214	73,394	6,062,617	1,331,801	106,414	2,551	1,214,375	3,036,923
1983	20,515	21,256	8,154,181	783,153	54,405	104,066	1,130,581	1,976,790
1984	14,741	28,660	6,179,690	1,491,487	71,409	468,753	1,107,332	2,095,429
1985	22,506	68,025	6,089,254	1,437,132	83,297	383,797	1,256,375	1,531,569
1986	16,000	56,143	532,778	1,245,317	41,452	276,110	1,184,090	1,153,820
1987	6,884	113,258	11,140,031	912,963	100,182	210,976	1,188,881	1,858,678
1988	12,746	138,067	8,682,920	1,135,763	79,997	217,402	1,114,559	1,958,700
1989	25,012	133,262	2,406,757	1,027,804	62,465	135,945	1,213,193	2,790,853
1990	25,996	169,931	9,577,955	774,869	119,468	80,397	924,448	2,345,841
1991	16,293	341,646	562,060	995,435	345,090	102,938	1,041,167	1,735,834
1992	36,535	81,210	2,337,818	715,950	218,173	78,185	885,346	1,351,434
1993	39,312	109,812	1,047,606	714,249	125,347	41,897	746,559	1,519,828
1994	82,924	300,832	921,160	474,552	161,936	33,244	534,723	1,251,353
1995	193,814	302,790	157,439	565,144	259,994	25,580	771,628	1,185,394
1996	245,230	369,134	980,576	529,272	110,415	49,286	914,236	1,066,023
1997	264,754	145,377	641,598	345,034	104,739	94,591	1,325,175	1,132,160
1998	372,760	131,131	2,495,167	142,441	82,096	100,303	1,185,177	331,705
1999	302,563	202,726	191,269	203,061	94,301	76,462	1,313,150	312,445

- - - - Landings data not available.
[1] Landings for White Croaker for 1916-1969 include Queen Fish,
[2] Arrowtooth flounder were aggregated under unclassified sole prior to 1950. The drop in landings following 1959 reflects the elimination of recording catch utilized.
[3] Starry Founder were aggregated under unspecified flounders from 1970 until 1982.
[4] Yellowtail landings include fish caught south of the State but landed in California.

Commercial Landings - Nearshore Finfish, cont'd

Year	Monkeyface Prickleback Pounds	Opaleye Pounds	Sanddab Pounds	California Scorpionfish Pounds	Giant Sea Bass Pounds	California Sheephead Pounds	Silversides Pounds
1916	- - - -	- - - -	2,228,734	8,014	153,440	3,549	- - - -
1917	- - - -	- - - -	2,631,862	17,425	158,380	5,906	- - - -
1918	- - - -	- - - -	1,751,609	28,237	248,795	22,978	- - - -
1919	- - - -	- - - -	709,738	25,432	185,270	17,972	- - - -
1920	- - - -	- - - -	721,810	35,674	148,037	14,567	- - - -
1921	- - - -	- - - -	784,011	58,380	127,431	23,925	- - - -
1922	- - - -	- - - -	1,170,979	42,121	97,354	18,205	- - - -
1923	- - - -	- - - -	1,363,911	60,466	226,995	31,628	- - - -
1924	- - - -	- - - -	1,699,832	109,070	231,404	24,267	- - - -
1925	- - - -	- - - -	1,952,847	223,104	189,072	48,811	- - - -
1926	- - - -	- - - -	1,143,935	108,068	377,934	138,927	- - - -
1927	- - - -	- - - -	892,718	113,457	467,595	159,397	- - - -
1928	- - - -	- - - -	1,108,764	97,083	382,115	372,677	- - - -
1929	- - - -	- - - -	1,051,868	107,797	404,386	288,422	- - - -
1930	- - - -	- - - -	616,349	88,610	394,009	243,689	- - - -
1931	- - - -	17,913	472,805	91,688	502,064	198,347	- - - -
1932	- - - -	15,279	665,345	85,503	473,846	89,591	- - - -
1933	- - - -	4,272	562,994	64,160	453,023	58,609	- - - -
1934	- - - -	3,896	767,025	65,939	861,498	143,552	- - - -
1935	- - - -	1,424	675,597	69,549	631,759	188,022	- - - -
1936	- - - -	1,781	621,675	110,417	398,595	128,577	- - - -
1937	- - - -	1,778	516,195	137,312	715,584	81,466	- - - -
1938	- - - -	100	639,328	155,386	407,826	72,031	- - - -
1939	- - - -	20	821,204	128,628	460,943	71,361	- - - -
1940	- - - -	39	779,078	122,133	366,683	62,352	- - - -
1941	- - - -	- - - -	442,487	95,287	409,537	49,119	- - - -
1942	- - - -	66	353,540	44,332	378,780	50,258	- - - -
1943	- - - -	17	505,338	42,550	700,855	151,048	- - - -
1944	- - - -	7	551,269	57,270	434,880	168,653	- - - -
1945	- - - -	- - - -	592,062	94,656	330,168	249,584	- - - -
1946	- - - -	- - - -	679,072	145,129	432,561	267,125	- - - -
1947	- - - -	1,519	701,413	127,048	244,304	193,489	- - - -
1948	- - - -	564	804,695	155,076	188,011	100,227	- - - -
1949	- - - -	954	722,183	148,367	114,401	63,524	- - - -
1950	- - - -	6,278	690,621	139,523	150,796	66,209	- - - -
1951	- - - -	1,006	543,821	101,437	277,484	61,410	- - - -
1952	- - - -	525	659,874	83,610	313,494	36,231	- - - -
1953	- - - -	392	690,443	119,628	411,979	35,426	- - - -
1954	- - - -	9,164	753,471	134,310	350,276	29,184	- - - -
1955	- - - -	6,117	781,564	108,056	365,487	13,152	- - - -
1956	- - - -	3,433	789,280	100,232	331,318	6,575	- - - -
1957	- - - -	5,198	692,083	73,268	242,353	11,033	- - - -
1958	- - - -	2,351	406,438	64,872	216,027	11,366	- - - -
1959	- - - -	4,866	466,684	37,342	249,909	10,233	- - - -
1960	- - - -	1,208	348,373	29,203	241,690	4,740	- - - -
1961	- - - -	2,337	562,964	26,718	340,363	12,602	- - - -
1962	- - - -	1,674	679,911	57,951	446,209	20,327	- - - -
1963	- - - -	4,378	555,783	75,521	303,579	28,011	- - - -
1964	- - - -	2,001	589,526	94,225	222,715	17,934	- - - -
1965	- - - -	3,149	479,041	82,736	351,750	12,153	- - - -
1966	- - - -	19,432	720,101	108,499	340,967	15,984	- - - -
1967	- - - -	17,298	687,168	82,656	230,604	19,628	- - - -
1968	- - - -	11,173	714,622	125,175	158,421	12,750	- - - -
1969	- - - -	15,929	696,482	115,471	154,761	13,285	- - - -
1970	- - - -	22,452	678,505	154,961	129,541	3,805	- - - -
1971	- - - -	5,281	785,401	131,144	117,258	8,854	- - - -
1972	- - - -	- - - -	920,822	132,016	95,313	7,084	- - - -
1973	- - - -	23,688	904,001	158,860	90,837	3,072	- - - -
1974	- - - -	- - - -	975,276	157,833	80,439	3,721	- - - -
1975	- - - -	2,654	1,015,557	173,452	59,291	6,031	- - - -
1976	- - - -	- - - -	1,293,872	173,675	56,128	8,325	11,256
1977	- - - -	- - - -	809,615	116,734	49,363	6,409	42,766
1978	- - - -	3,591	743,206	71,209	66,227	11,144	8,686
1979	- - - -	5,335	1,322,739	32,745	40,942	8,819	60,121

Commercial Landings - Nearshore Finfish, cont'd

Year	Monkeyface Prickleback Pounds	Opaleye Pounds	Sanddab Pounds	California Scorpionfish Pounds	Giant Sea Bass Pounds	California Sheephead Pounds	Silversides Pounds
1980	- - - -	6,134	1,280,474	59,168	38,623	9,105	33,685
1981	- - - -	5,362	942,163	56,284	37,903	12,910	16,683
1982	- - - -	- - - -	1,057,614	62,264	6,999	11,776	88,770
1983	- - - -	- - - -	565,839	31,719	3,740	12,634	87,864
1984	- - - -	4,041	553,068	24,984	11,118	25,098	49,881
1985	- - - -	4,253	971,417	34,501	11,809	28,500	8,563
1986	- - - -	3,583	981,297	15,544	12,953	29,252	4,902
1987	- - - -	4,599	1,175,880	28,823	12,037	33,711	1,115
1988	- - - -	12,104	1,164,144	29,869	12,337	29,345	9,358
1989	- - - -	8,690	1,408,187	17,639	8,760	33,039	5,751
1990	92	6,939	1,433,861	8,407	7,259	123,526	3,590
1991	934	1,278	1,232,085	1,452	11,741	191,774	4,786
1992	13	4,124	623,219	77,323	- - - -	258,502	3,660
1993	125	3,777	773,906	58,877	- - - -	314,151	5,279
1994	750	6,017	1,499,812	113,123	- - - -	259,099	15,188
1995	765	963	1,493,536	90,740	- - - -	253,827	6,591
1996	561	986	1,738,110	76,444	- - - -	252,266	36,824
1997	179	358	2,046,029	95,880	- - - -	366,440	41,029
1998	224	1,717	1,428,411	112,822	- - - -	261,498	2,571
1999	170	939	2,069,189	86,675	- - - -	129,585	2,562

- - - - Landings data not available.

[1] Landings for White Croaker for 1916-1969 include Queen Fish,

[2] Arrowtooth flounder were aggregated under unclassified sole prior to 1950. The drop in landings following 1959 reflects the elimination of recording catch utilized.

[3] Starry Founder were aggregated under unspecified flounders from 1970 until 1982.

[4] Yellowtail landings include fish caught south of the State but landed in California.

Commercial Landings - Nearshore Finfish, cont'd

Year	White Seabass Pounds	Surfperch Pounds	Pacific Angel Shark Pounds	Leopard Shark Pounds	Soupfin Shark Pounds	Skates Pounds	Turbot Pounds	Yellowtail [4] Pounds
1916	798,115	221,186	- - - -	- - - -	- - - -	- - - -	2,608	1153394
1917	899,997	252,503	- - - -	- - - -	- - - -	- - - -	1,327	2745995
1918	1,613,520	203,420	- - - -	- - - -	- - - -	- - - -	3,664	11515372
1919	2,455,367	192,481	- - - -	- - - -	- - - -	- - - -	2,115	5005265
1920	2,628,108	186,381	- - - -	- - - -	- - - -	- - - -	855	2704937
1921	2,569,489	253,199	- - - -	- - - -	- - - -	- - - -	219	2490796
1922	2,932,051	243,776	- - - -	- - - -	- - - -	- - - -	1,534	3414423
1923	2,373,847	359,682	- - - -	- - - -	- - - -	- - - -	1,011	4062608
1924	1,489,589	305,726	- - - -	- - - -	- - - -	- - - -	1,868	4714149
1925	1,885,109	272,351	- - - -	- - - -	- - - -	- - - -	3,926	3179891
1926	2,216,402	208,910	- - - -	- - - -	- - - -	- - - -	1,365	5023114
1927	2,273,407	262,893	- - - -	- - - -	- - - -	- - - -	3,950	4224853
1928	1,300,214	236,974	- - - -	- - - -	- - - -	- - - -	9,234	2683514
1929	1,562,232	311,194	- - - -	- - - -	- - - -	- - - -	1,323	3075264
1930	1,626,422	267,972	- - - -	- - - -	- - - -	- - - -	7,345	4770756
1931	1,399,413	223,092	- - - -	- - - -	- - - -	- - - -	18,284	2525853
1932	804,796	207,222	- - - -	- - - -	- - - -	- - - -	23,422	1796364
1933	1,163,079	214,511	- - - -	- - - -	- - - -	- - - -	49,615	3898888
1934	851,197	192,596	- - - -	- - - -	- - - -	- - - -	72,548	2347161
1935	1,066,419	241,525	- - - -	- - - -	- - - -	- - - -	72,287	8148718
1936	808,093	207,280	- - - -	- - - -	- - - -	- - - -	116,275	10092470
1937	599,419	210,309	- - - -	- - - -	- - - -	- - - -	75,990	5371475
1938	626,647	155,815	- - - -	- - - -	- - - -	- - - -	85,896	6812318
1939	994,396	139,394	- - - -	- - - -	- - - -	- - - -	104,585	2866288
1940	915,716	57,977	- - - -	- - - -	- - - -	- - - -	62,124	5956804
1941	908,296	25,832	- - - -	- - - -	- - - -	- - - -	26,940	9830690
1942	553,855	58,018	- - - -	- - - -	- - - -	- - - -	6,571	2726269
1943	500,183	113,018	- - - -	- - - -	- - - -	81,109	38,047	4934879
1944	393,988	146,546	- - - -	- - - -	- - - -	50419	72,825	2957171
1945	527,730	217,486	- - - -	- - - -	- - - -	- - - -	159,870	3534052
1946	616,476	192,430	- - - -	- - - -	- - - -	- - - -	49,847	4561583
1947	1,083,023	289,182	- - - -	- - - -	- - - -	- - - -	101,784	9952854
1948	1,114,290	302,087	- - - -	- - - -	- - - -	119101	114,701	10384694
1949	1,409,599	326,336	- - - -	- - - -	- - - -	123464	95,605	7317740
1950	1,531,374	242,354	- - - -	- - - -	- - - -	- - - -	128,080	3529901
1951	1,533,255	237,331	- - - -	- - - -	- - - -	84634	110,164	4669736
1952	1,147,103	213,357	- - - -	- - - -	- - - -	- - - -	81,895	9446979
1953	873,293	281,998	- - - -	- - - -	- - - -	415669	69,158	5212383
1954	1,206,111	118,499	- - - -	- - - -	- - - -	136221	175,918	1656778
1955	914,865	136,554	- - - -	- - - -	- - - -	- - - -	100,498	164322
1956	1,081,223	187,681	- - - -	- - - -	- - - -	- - - -	83,294	370887
1957	1,507,095	245,699	- - - -	- - - -	- - - -	171678	96,055	508951
1958	2,849,763	189,679	- - - -	- - - -	- - - -	176896	72,533	169630
1959	3,423,353	212,853	- - - -	- - - -	- - - -	240801	129,225	231284
1960	1,236,198	164,273	- - - -	- - - -	- - - -	146934	62,438	248633
1961	694,224	118,245	- - - -	- - - -	- - - -	299317	71,367	380769
1962	574,408	165,115	- - - -	- - - -	- - - -	182178	80,383	188421
1963	891,220	172,884	- - - -	- - - -	- - - -	216825	96,819	69726
1964	1,391,081	133,115	- - - -	- - - -	- - - -	222705	93,280	110099
1965	1,428,145	187,736	- - - -	- - - -	- - - -	153475	78,531	127805
1966	1,337,850	160,381	- - - -	- - - -	- - - -	154014	83,327	245207
1967	1,222,759	202,513	- - - -	- - - -	- - - -	196751	72,853	150668
1968	861,880	168,040	- - - -	- - - -	- - - -	186350	69,504	163177
1969	1,098,708	156,528	- - - -	- - - -	- - - -	106068	25,033	234155
1970	1,101,445	241,409	- - - -	- - - -	- - - -	102,982	28,067	184223
1971	823,884	184,938	- - - -	- - - -	- - - -	61,233	24,882	390520
1972	777,388	272,913	- - - -	- - - -	- - - -	118,386	18,123	258071
1973	808,905	138,000	- - - -	- - - -	- - - -	133,433	36,400	235622
1974	752,496	148,086	- - - -	- - - -	- - - -	86,158	20,681	204957
1975	1,182,410	113,757	- - - -	- - - -	- - - -	135,291	27,697	210411
1976	1,058,673	142,037	- - - -	- - - -	- - - -	161,137	29,590	475931
1977	1,199,644	110,233	366	22,267	162,166	161,426	19,985	1814650
1978	1,160,755	174,064	82,383	34,956	176,070	275,057	21,902	460782
1979	1,205,666	201,160	128,295	38,939	276,428	309,521	42,657	427612

Commercial Landings - Nearshore Finfish, cont'd

Year	White Seabass Pounds	Surfperch Pounds	Pacific Angel Shark Pounds	Leopard Shark Pounds	Soupfin Shark Pounds	Skates Pounds	Turbot Pounds	Yellowtail [4] Pounds
1980	997,412	162,952	112,051	40,085	192,336	155,216	21,238	365176
1981	776,033	182,675	268,640	51,506	264,938	631,420	33,776	347297
1982	70,795	367,704	318,960	70,610	250,504	287,808	47,358	75109
1983	77,964	211,556	360,323	101,309	177,770	185,690	46,803	171956
1984	118,099	182,120	633,273	67,855	278,541	116,293	23,053	132165
1985	125,380	122,078	1,248,487	75,838	277,740	195,837	29,729	259759
1986	106,671	124,983	1,241,130	74,741	212,279	150,125	19,847	57746
1987	116,490	145,751	940,187	55,371	201,489	169,712	42,582	56866
1988	107,619	107,284	491,348	41,737	140,566	127,861	23,810	85131
1989	116,023	118,010	268,252	50,459	165,324	174,659	30,574	28329
1990	133,692	137,745	250,850	41,295	125,726	143,754	20,164	40267
1991	163,803	104,778	181,765	47,742	105,010	113,222	20,574	21560
1992	125,149	129,662	123,554	42,242	95,779	103,468	26,855	15281
1993	100,060	111,261	66,654	52,150	77,452	78,070	17,262	59066
1994	78,932	93,672	23,230	27,559	79,455	93,391	10,055	31992
1995	73,293	89,643	19,711	18,660	63,911	413,278	14,961	9789
1996	96,162	85,279	17,995	13,849	83,868	1,830,094	16,450	29680
1997	58,554	76,512	33,673	20,508	84,933	2,965,344	20,905	73428
1998	156,734	73,731	55,342	26,206	78,446	1,836,803	11,473	244858
1999	247,188	49,396	53,375	25,484	98,326	1,872,076	8,020	66175

---- Catch data not available

1 No. of Fish - All data presented in number of fish.

2 Recreational catch as reported by CPFV logbooks for the years shown

3 Data source RecFin Data base for all fishing modes, corrected to reflect actual DFG CPFV logbook catch for 1991-1999

4 Data source RecFin Data base for all fishing modes, data not availbale for 1990-1992

5 Kelp and Barred Sand Bass CPFV logbook data combined prior to 1972. The combined Kelp and Barred Sand Bass data after 1972 includes catches reported for Kelp Bass, Barred Sand Bass, and combined catches.

6 White Croaker catch data set includes queenfish.

Recreational Catch - Nearshore Finfish

Year	California Barracuda No. of Fish[1, 2]	Barred Sand Bass No. of Fish[1, 3]	Kelp Bass No. of Fish[1, 3]	Kelp and Barred Sand Bass No. of Fish[1, 2, 5]	Spotted Sand Bass No. of Fish[1, 4]	Giant Sea Bass No. of Fish[1, 2]	Pacific Bonito No. of Fish[1, 2]	Cabezon No. of Fish[1, 2]
1947	677,449	- - - -	- - - -	682,789	- - - -	160	36,496	9,886
1948	384,056	- - - -	- - - -	630,223	- - - -	439	14,519	14,590
1949	366,423	- - - -	- - - -	796,959	- - - -	212	5,372	14,125
1950	256,367	- - - -	- - - -	619,397	- - - -	179	2,359	15,971
1951	269,545	- - - -	- - - -	781,609	- - - -	261	14,475	18,029
1952	336,862	- - - -	- - - -	536,075	- - - -	92	7,649	10,847
1953	170,550	- - - -	- - - -	711,395	- - - -	135	6,321	9,650
1954	282,552	- - - -	- - - -	876,667	- - - -	102	70,078	13,132
1955	154,962	- - - -	- - - -	497,343	- - - -	162	22,409	12,366
1956	87,603	- - - -	- - - -	470,362	- - - -	74	61,404	18,195
1957	577,184	- - - -	- - - -	609,071	- - - -	151	258,555	14,479
1958	782,723	- - - -	- - - -	653,671	- - - -	203	422,568	9,909
1959	1,195,585	- - - -	- - - -	428,426	- - - -	184	776,386	5,329
1960	755,408	- - - -	- - - -	478,656	- - - -	228	1,199,919	2,516
1961	391,884	- - - -	- - - -	613,604	- - - -	310	849,426	2,639
1962	335,507	- - - -	- - - -	789,149	- - - -	390	798,725	4,538
1963	483,699	- - - -	- - - -	1,219,344	- - - -	598	775,719	9,726
1964	303,070	- - - -	- - - -	1,103,394	- - - -	353	1,298,804	6,491
1965	443,304	- - - -	- - - -	1,230,313	- - - -	580	806,322	7,575
1966	892,697	- - - -	- - - -	1,278,939	- - - -	548	644,415	10,293
1967	470,480	- - - -	- - - -	1,003,914	- - - -	622	349,952	5,419
1968	372,246	- - - -	- - - -	1,317,963	- - - -	496	1,102,936	4,349
1969	358,518	- - - -	- - - -	1,246,175	- - - -	653	1,130,241	4,583
1970	373,801	- - - -	- - - -	922,260	- - - -	487	651,898	6,372
1971	50,474	- - - -	- - - -	948,121	- - - -	598	152,795	4,611
1972	38,243	- - - -	- - - -	842,681	- - - -	244	418,984	11,452
1973	92,483	35,698	14,609	656,186	- - - -	816	472,451	7,551
1974	55,284	178,534	245,683	618,026	- - - -	419	141,619	6,964
1975	26,289	106,804	353,463	499,679	- - - -	228	80,438	6,433
1976	107,557	156,056	485,280	655,810	- - - -	561	197,382	6,445
1977	48,701	118,545	272,705	398,089	- - - -	205	161,962	5,620
1978	73,174	110,377	360,277	476,982	- - - -	140	315,643	8,887
1979	69,434	169,337	290,448	462,980	- - - -	574	538,476	5,469
1980	27,909	229,107	355,950	585,432	149,000	653	560,508	6,208
1981	69,924	237,084	501,927	739,562	201,000	221	654,051	5,830
1982	73,135	273,828	312,891	587,349	138,000	45	218,478	5,247
1983	81,989	158,353	304,645	463,270	231,000	13	348,050	3,758
1984	87,414	136,612	222,771	359,913	297,000	97	377,678	1,759
1985	75,448	299,152	273,299	572,620	310,000	81	120,139	1,760
1986	88,118	265,014	435,516	700,602	537,000	74	340,480	4,386
1987	157,913	408,635	325,685	734,323	255,000	41	517,523	4,773
1988	148,058	451,125	319,629	770,780	423,000	41	250,495	5,418
1989	137,222	421,110	393,892	815,065	- - - -	73	339,382	6,353
1990	196,030	423,885	439,701	863,586	- - - -	109	263,007	6,713
1991	177,390	495,784	321,926	817,714	- - - -	16	116,451	4,555
1992	248,055	363,304	463,673	827,130	- - - -	20	115,866	5,199
1993	203,693	313,390	355,088	668,563	367,000	48	139,567	2,812
1994	268,219	286,444	276,087	562,531	273,000	50	106,280	1,866
1995	326,868	350,540	231,687	582,227	319,000	32	39,995	1,810
1996	271,859	604,132	282,673	886,805	298,000	3	72,665	3,003
1997	334,704	490,048	335,127	825,175	347,000	2	102,474	3,133
1998	455,803	377,890	233,591	611,481	219,000	12	57,655	2,579
1999	386,318	435,778	129,475	742,081	189,000	12	2,810	2,905

---- Catch data not available

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4 Data source RecFin Data base for all fishing modes, data not availbale for 1990-1992

5 Kelp and Barred Sand Bass CPFV logbook data combined prior to 1972. The combined Kelp and Barred Sand Bass data after 1972 includes catches reported for Kelp Bass, Barred Sand Bass, and combined catches.

6 White Croaker catch data set includes queenfish.

Recreational Catch - Nearshore Finfish, cont'd

Year	White Croaker No. of Fish[1, 2, 6]	Yellowfin Croaker No. of Fish[1, 2]	Kelp Greenling No. of Fish[1, 4]	Other Greenlings No. of Fish[1, 4]	California Halibut No. of Fish[1, 2]	Lingcod No. of Fish[1, 2]	Monkeyface Prickleback No. of Fish[1, 4]	Blk & Yellow Rockfish No. of Fish[1, 4]
1947	58,034	8,166	----	----	104,436	22,011	----	----
1948	89,825	3,667	----	----	143,462	24,406	----	----
1949	121,053	3,032	----	----	104,639	26,131	----	----
1950	76,765	999	----	----	85,935	23,868	----	----
1951	62,945	663	----	----	59,295	24,052	----	----
1952	77,948	708	----	----	34,158	17,389	----	----
1953	57,606	1,367	----	----	34,292	13,011	----	----
1954	66,964	2,411	----	----	59,674	22,940	----	----
1955	27,349	595	----	----	35,802	29,113	----	----
1956	16,289	1,099	----	----	21,661	37,649	----	----
1957	8,648	275	----	----	10,795	38,012	----	----
1958	20,000	95	----	----	16,192	39,801	----	----
1959	6,895	132	----	----	25,365	31,206	----	----
1960	8,633	275	----	----	48,310	28,232	----	----
1961	21,782	325	----	----	108,011	23,466	----	----
1962	27,256	778	----	----	118,966	25,399	----	----
1963	37,225	562	----	----	125,669	27,513	----	----
1964	23,269	993	----	----	141,465	25,263	----	----
1965	21,448	1,386	----	----	118,213	33,260	----	----
1966	17,285	1,619	----	----	88,726	44,676	----	----
1967	20,590	645	----	----	63,582	43,559	----	----
1968	10,906	211	----	----	54,663	42,449	----	----
1969	15,273	1,351	----	----	27,634	32,693	----	----
1970	18,519	770	----	----	29,968	61,833	----	----
1971	21,112	2,230	----	----	10,598	63,239	----	----
1972	38,811	597	----	----	8,140	103,965	----	----
1973	29,158	627	----	----	9,622	80,778	----	----
1974	27,521	176	----	----	10,292	79,685	----	----
1975	27,456	1,390	----	----	9,118	88,976	----	----
1976	21,165	278	----	----	10,075	80,863	----	----
1977	20,122	139	----	----	6,982	46,521	----	----
1978	17,630	285	----	----	5,409	65,869	----	----
1979	11,834	199	----	----	6,329	75,826	----	----
1980	27,461	123	5,535	582	6,517	89,349	----	2,873
1981	9,228	537	47,183	30,739	11,440	65,604	2,503	11,165
1982	10,162	549	90,545	19,275	11,804	49,791	16,910	18,827
1983	7,738	112	61,001	23,777	5,682	30,543	9,874	32,282
1984	4,649	587	62,615	18,653	3,209	23,797	3,269	64,747
1985	3,166	234	63,019	29,649	7,090	20,603	2,026	101,962
1986	11,981	295	74,065	28,783	7,848	25,585	1,516	37,024
1987	3,225	289	131,689	30,861	7,560	42,504	8,179	23,780
1988	121,478	875	85,196	26,413	11,926	66,597	21,244	30,550
1989	15,062	4,274	85,736	19,306	9,116	76,517	8,388	27,415
1990	4,861	661	----	----	6,658	59,845	----	----
1991	16,768	1,098	----	----	5,984	49,824	----	----
1992	4,824	371	----	----	4,341	43,251	----	----
1993	11,449	1,354	61,044	10,585	5,335	38,323	11,375	68,742
1994	6,042	1,544	58,892	21,567	7,549	31,091	1,227	32,901
1995	17,084	2,084	49,636	23,615	19,345	30,542	3,953	25,612
1996	26,323	880	55,389	35,751	19,092	29,734	1,656	9,704
1997	9,960	616	29,901	21,822	15,846	36,218	1,079	8,201
1998	6,917	1,204	20,346	47,183	12,191	20,386	2,110	14,178
1999	10,744	506	16,504	4,080	14,339	26,847	551	15,078

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6 White Croaker catch data set includes queenfish.

Recreational Catch - Nearshore Finfish, cont'd

Year	Black Rockfish No. of Fish[1, 4]	Blue Rockfish No. of Fish[1, 4]	Brown Rockfish No. of Fish[1, 4]	Calico Rockfish No. of Fish[1, 4]	China Rockfish No. of Fish[1, 4]	Copper Rockfish No. of Fish[1, 4]	Gopher Rockfish No. of Fish[1, 4]	Grass Rockfish No. of Fish[1, 4]
1947	----	----	----	----	----	----	----	----
1948	----	----	----	----	----	----	----	----
1949	----	----	----	----	----	----	----	----
1950	----	----	----	----	----	----	----	----
1951	----	----	----	----	----	----	----	----
1952	----	----	----	----	----	----	----	----
1953	----	----	----	----	----	----	----	----
1954	----	----	----	----	----	----	----	----
1955	----	----	----	----	----	----	----	----
1956	----	----	----	----	----	----	----	----
1957	----	----	----	----	----	----	----	----
1958	----	----	----	----	----	----	----	----
1959	----	----	----	----	----	----	----	----
1960	----	----	----	----	----	----	----	----
1961	----	----	----	----	----	----	----	----
1962	----	----	----	----	----	----	----	----
1963	----	----	----	----	----	----	----	----
1964	----	----	----	----	----	----	----	----
1965	----	----	----	----	----	----	----	----
1966	----	----	----	----	----	----	----	----
1967	----	----	----	----	----	----	----	----
1968	----	----	----	----	----	----	----	----
1969	----	----	----	----	----	----	----	----
1970	----	----	----	----	----	----	----	----
1971	----	----	----	----	----	----	----	----
1972	----	----	----	----	----	----	----	----
1973	----	----	----	----	----	----	----	----
1974	----	----	----	----	----	----	----	----
1975	----	----	----	----	----	----	----	----
1976	----	----	----	----	----	----	----	----
1977	----	----	----	----	----	----	----	----
1978	----	----	----	----	----	----	----	----
1979	----	----	----	----	----	----	----	----
1980	50,951	517,610	74,064	----	7,770	189,428	36,771	3,264
1981	350,763	1,514,280	84,474	11,798	14,512	437,077	29,999	44,284
1982	431,844	1,929,444	117,438	2,224	38,413	271,800	22,427	48,854
1983	198,192	1,327,726	137,383	9,384	23,290	102,643	190,248	92,726
1984	474,352	1,400,043	285,695	4,594	22,229	129,170	356,589	72,028
1985	533,936	1,111,013	259,985	22,492	38,656	189,013	449,470	102,049
1986	442,879	733,148	292,393	8,802	62,273	159,723	454,368	60,549
1987	258,788	1,029,206	171,218	3,523	72,216	83,868	378,773	42,010
1988	329,358	911,028	351,357	22,281	56,307	182,081	220,296	65,149
1989	306,667	564,761	145,565	9,084	49,499	109,824	172,187	12,338
1990	----	----	----	----	----	----	----	----
1991	----	----	----	----	----	----	----	----
1992	----	----	----	----	----	----	----	----
1993	421,554	1,643,812	141,836	2,932	48,831	117,518	287,503	26,865
1994	313,817	413,219	47,965	4,958	45,130	73,600	208,224	11,522
1995	255,659	310,691	70,253	9,166	38,337	59,617	87,390	14,047
1996	182,263	383,204	80,335	6,137	29,078	92,907	101,182	11,848
1997	133,483	447,897	78,202	3,360	9,091	30,026	73,816	17,188
1998	77,780	413,373	60,707	3,333	7,985	49,632	83,305	13,697
1999	187,786	461,444	106,390	4,758	23,473	69,736	139,289	10,724

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6 White Croaker catch data set includes queenfish.

Recreational Catch - Nearshore Finfish, cont'd

Year	Kelp Rockfish No. of Fish[1, 4]	Olive Rockfish No. of Fish[1, 4]	Quillback Rockfish No. of Fish[1, 4]	California Scorpionfish No. of Fish[1, 2]	White Seabass No. of Fish[1, 2]	California Sheephead No. of Fish[1, 2]	Treefish No. of Fish[1, 4]	Yellowtail No. of Fish[1, 2]
1947	----	----	----	26,062	20,724	13,004	----	6,948
1948	----	----	----	52,554	24,078	17,261	----	13,028
1949	----	----	----	37,030	65,545	15,440	----	17,710
1950	----	----	----	53,419	54,718	14,281	----	6,971
1951	----	----	----	35,721	44,367	20,416	----	23,721
1952	----	----	----	39,068	41,043	16,481	----	59,263
1953	----	----	----	28,952	28,182	17,349	----	27,702
1954	----	----	----	33,462	41,588	21,499	----	40,872
1955	----	----	----	28,613	30,103	14,102	----	36,468
1956	----	----	----	36,558	19,755	14,789	----	29,198
1957	----	----	----	13,473	19,030	15,105	----	242,686
1958	----	----	----	13,743	34,039	18,120	----	123,384
1959	----	----	----	11,477	10,593	17,146	----	457,350
1960	----	----	----	15,111	15,697	11,541	----	254,969
1961	----	----	----	26,672	14,082	15,210	----	42,367
1962	----	----	----	33,314	14,564	13,488	----	21,826
1963	----	----	----	53,896	19,800	18,443	----	45,705
1964	----	----	----	73,844	14,901	26,822	----	39,104
1965	----	----	----	71,888	9,775	41,651	----	18,367
1966	----	----	----	69,851	3,972	52,967	----	80,163
1967	----	----	----	63,280	3,385	42,676	----	31,392
1968	----	----	----	59,863	4,138	33,075	----	58,049
1969	----	----	----	63,011	4,056	49,626	----	79,202
1970	----	----	----	82,522	4,359	39,464	----	97,376
1971	----	----	----	84,913	5,265	38,300	----	44,608
1972	----	----	----	65,886	3,858	33,541	----	59,031
1973	----	----	----	83,475	7,083	46,234	----	221,287
1974	----	----	----	85,956	4,003	30,379	----	121,149
1975	----	----	----	81,438	3,158	30,496	----	19,742
1976	----	----	----	47,524	2,671	32,926	----	28,962
1977	----	----	----	73,214	2,096	28,512	----	34,141
1978	----	----	----	44,114	433	34,409	----	38,528
1979	----	----	----	64,226	1,352	31,995	----	71,483
1980	2,690	81,231	361	95,615	1,002	34,368	8,033	44,246
1981	63,346	249,843	3,109	73,362	887	46,479	16,911	88,911
1982	19,380	327,679	2,245	67,339	1,899	37,242	25,849	37,308
1983	55,608	313,474	18,117	50,834	1,003	68,972	31,712	178,688
1984	94,097	299,704	4,190	46,538	973	38,522	24,886	96,018
1985	87,811	217,905	5,106	66,762	1,045	35,934	34,310	45,509
1986	66,766	168,991	7,326	72,675	1,634	36,707	26,974	42,005
1987	27,662	200,751	1,798	59,125	616	21,072	14,954	58,537
1988	31,884	120,961	3,647	132,520	2,383	31,701	13,319	68,020
1989	33,603	94,760	4,531	163,552	1,365	23,612	20,835	61,746
1990	----	----	----	160,948	2,563	34,374	----	69,805
1991	----	----	----	181,755	1,743	43,150	----	14,195
1992	----	----	----	77,290	698	25,778	----	40,834
1993	45,015	206,164	27,216	69,570	1,403	26,910	32,982	35,681
1994	65,578	115,519	4,609	90,665	2,519	19,955	31,000	19,882
1995	50,034	58,382	3,102	94,398	4,266	23,737	51,834	29,445
1996	30,248	50,194	1,777	119,492	1,452	23,455	52,777	66,763
1997	31,058	62,620	3,940	141,354	1,730	25,788	19,745	398,345
1998	12,915	45,207	889	119,620	1,365	18,363	23,101	250,857
1999	19,554	59,489	6,295	225,726	11,517	23,089	40,339	78,466

---- Catch data not available
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6 White Croaker catch data set includes queenfish.

Nearshore Marine Plant Resources: Overview

A bounty of marine algae flourishes along the coast of California, providing habitats and food for invertebrates, fishes and marine mammals in nearshore communities rivaling the richness and diversity of coral reefs. Our state's marine flora includes over 700 species and varieties of seaweeds: filamentous and fleshy red algae, as well as animal-like corallines; brown algae, including the distinctive, leathery kelps; delicate green algae and a few sea grasses. The undersea vegetation is sustained by our nutrient-rich coastal waters. The diversity of undersea life is enhanced by the variety of living conditions, and the range of wave exposures and substrates available from protected, muddy inlets to granitic outcrops exposed to crashing, open ocean waves.

California seaweeds have been collected from the wild since the mid-19th century when they were dried and shipped to San Francisco and China. In some cases, intertidal rocks were charred with gasoline torches or burning wood to clear off herbivores and less desirable seaweeds and allow better recruitment and growth of edible red algae, such as nori (*Porphyra*). A variety of species has been collected on a small scale for commercial sale or home use: wakame (*Alaria*), kombu (*Laminaria*), sea palm (*Postelsia*), bladderwrack (*Fucus*), bull kelp (*Nereocystis*), and the green sea lettuce (*Ulva.*) The giant kelp, *Macrocystis pyrifera*, an important source of the gelling compound alginate for industrial uses, has been harvested mechanically by commercial harvesting ships. The giant kelp has also been hand-harvested for aquacultural use as abalone food. As pharmaceutical research for new medicines targeted marine organisms for testing, several varieties of seaweeds were collected for screening as sources of antibiotic and anticancer compounds.

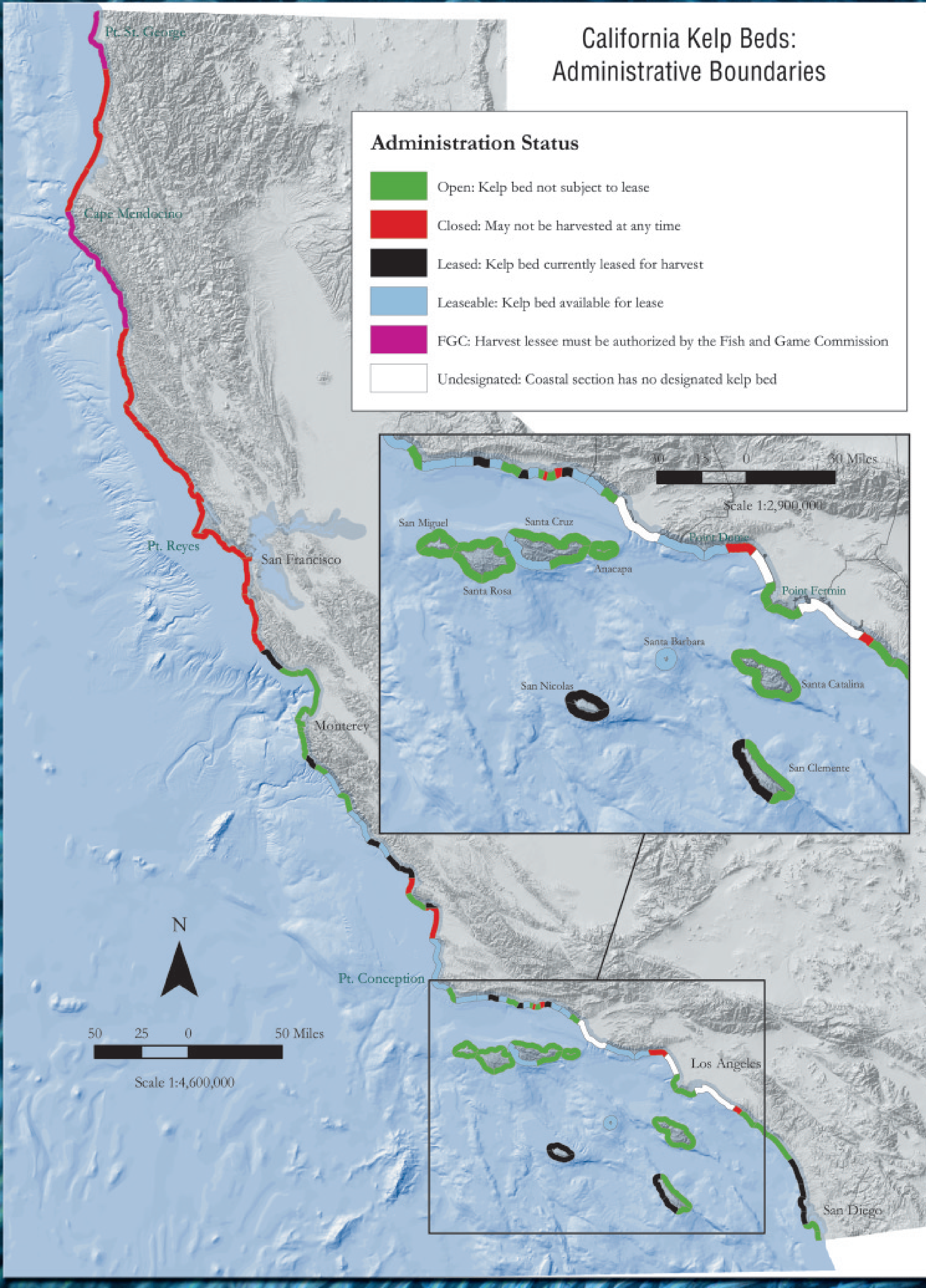
The value of nearshore seaweeds in recreational settings has more recently gained public attention as a consequence, in part, of increased participation in ocean sports and underwater photography, as well as the successful cultivation and display of seaweeds in public aquariums. Popular books, magazine articles and television programs on marine topics reinforced the heightened awareness. And, as coastal residents and visitors have come to appreciate seaweeds aesthetically and for their role of providing food and habitats for invertebrates and fishes, conflicts have developed over the perceived environmental and aesthetic impacts of harvesting and appropriate uses of these resources.

Plans for protection of our seaweeds and nearshore habitats are complicated by the very diversity of California's marine flora. Never a case of one-size-fits-all, effective management of these resources requires consideration of each species' cycle of life in each habitat. Is the species an annual (such as the sea palm, *Postelsia*) or perennial (such as the giant kelp, *Macrocystis*)? How abundant is the species? When and where does it grow best? What parts of the seaweed and how much could be harvested and still sustain a healthy wild population? Where does new growth occur: is it restricted to meristems at the tips or is cell division diffuse along the length of the whole structure? How fast can it recover from being trimmed? Should specific reproductive structures (such as the sea palm's topknot of blades) be restricted from harvesters? The seasonal weather patterns and seasonal cycles of growth and reproduction affect plants in the sea, just as they do on farmlands. But, as with crops on land, it is rarely one sole factor that sets the stage.

Biological interactions (such as diseases or over-grazing by sea urchins), pollution, catastrophic storms, and oceanographic conditions, such as El Niño and La Niña cause changes in the distribution and abundance of seaweeds. Warmer, nutrient-stressed El Niño conditions can deter growth of giant kelp and the full development of its canopy. With less canopy on the sea surface, more sunlight penetrates to the understory kelps (such as the winged kelp *Pterygophora*) which may grow and persist in spite of lower nutrients. In contrast, the cold, nutrient-rich La Niña conditions can lead to exceptional growth of giant kelp and an extensive, shady canopy that can inhibit some of the understory seaweeds.

There is some evidence that people, even nature lovers, can have negative effects on seaweed and animal communities. Researchers found that intertidal rocks in less accessible coastal sites near Santa Cruz had greater diversity and abundance than sites with more human visitors. And the state continues to attract additional human visitors and residents, with a population increase of 571,000 in 1999 alone. Our three largest cities (Los Angeles, San Diego and San Jose) collectively gained 98,000 additional residents that year. As California's population continues to increase, the state will harbor an estimated 41 million residents by 2010. If tourism and coastal recreational activities (such as tidepooling, kayaking, and surfing) also increase, the incidence of intertidal trampling and casual collecting in popular beach locations will heighten. The undersea vegetation that attracts so much recreational, educational and commercial interest warrants thoughtful management to ensure its continued richness and abundance along the coast of California.

Judith L. Connor
Monterey Bay Aquarium Research Institute


California Kelp Beds:
Administrative Boundaries
Administration Status
Open: Kelp bed not subject to lease
Closed: May not be harvested at any time
Leased: Kelp bed currently leased for harvest
Leaseable: Kelp bed available for lease
FGC: Harvest lessee must be authorized by the Fish and Game Commission
Undesignated: Coastal section has no designated kelp bed
Pt. St. George
Cape Mendocino
Pt. Reyes
San Francisco
Monterey
Pt. Conception
Los Angeles
San Diego
N
50 25 0 50 Miles
Scale 1:4,600,000
30 15 0 30 Miles
Scale 1:2,900,000
San Miguel
Santa Cruz
Santa Rosa
Anacapa
Point Dume
Point Fermin
Santa Barbara
San Nicolas
Santa Catalina
San Clemente

Giant Kelp

History of the Use and Harvest

Various species of kelp, including giant kelp (*Macrocystis pyrifera*) have been used for hundreds of years in many parts of the world as food for humans and animals. Kelp has also been used for many years in Asia and Europe as a fertilizer and as a component of gunpowder. Algin, found in the cell walls of kelp, is valuable as an efficient thickening, stabilizing, suspending, and gelling agent. Algin is used in a wide range of food and industrial applications including desserts, gels, milk shake mixes, dairy products, and canned foods. It is also used in salad dressings to emulsify and stabilize them, in bakery products to improve texture and retain moisture, in frozen foods to assure smooth texture and uniform thawing, and in beer to stabilize the foam. In industrial applications, it is used for paper coating and sizing, textile printing, and welding-rod coatings. In pharmaceutical and cosmetic applications, it is used to make tablets, dental impressions, antacid formulations, and facial creams and lotions. Giant kelp is harvested in California to supply food to several aquaculture companies for rearing abalones. It is also used for the herring-roe-on-kelp fishery in San Francisco Bay.

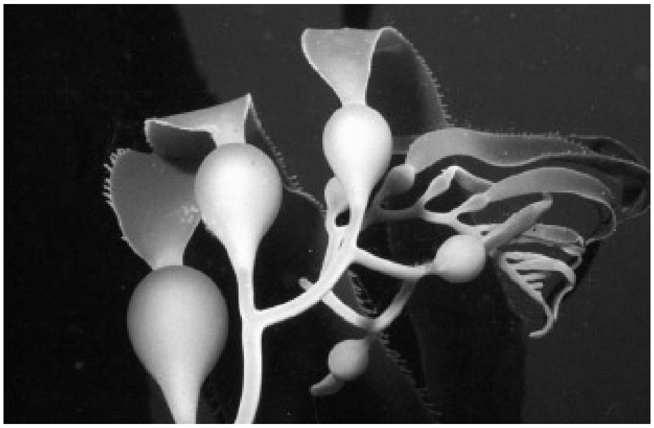
Giant kelp was first harvested along the California coast during the early 1900s. Many harvesting companies operated from San Diego to Santa Barbara beginning in 1911. Those companies primarily extracted potash and acetone from kelp for use in manufacturing explosives during World War I.

In the early 1920s, having lost the war demand, kelp harvesting virtually stopped. In the late 1920s, giant kelp was again harvested off California. Philip R. Park, Inc., of San Pedro began harvesting kelp in 1928 to provide ingredients for livestock and poultry food. The following year, Kelco Company of San Diego (now ISP Alginates, Inc.) began harvesting and processing giant kelp.

Since 1917, kelp harvesting has been managed by the California Department of Fish and Game (DFG) under regulations of the Fish and Game Commission. Although the surface canopy can be harvested several times each year without damage to the kelp bed, regulations state that kelp may be cut no deeper than four feet beneath the surface. There are 74 designated kelp beds and each is numbered; a kelp harvesting permit is required. Specific beds can be leased for 20 years; however, no more than 25 square miles or 50 percent of the total kelp bed area (whichever is greater) can be exclusively leased by a company holding a harvesting permit. In addition to leased beds, there are "open" beds that can be harvested by any company holding a permit. Permit holders pay an additional royalty of $1.71 to $1.91 per wet-ton of kelp harvested, depending on the international market price.

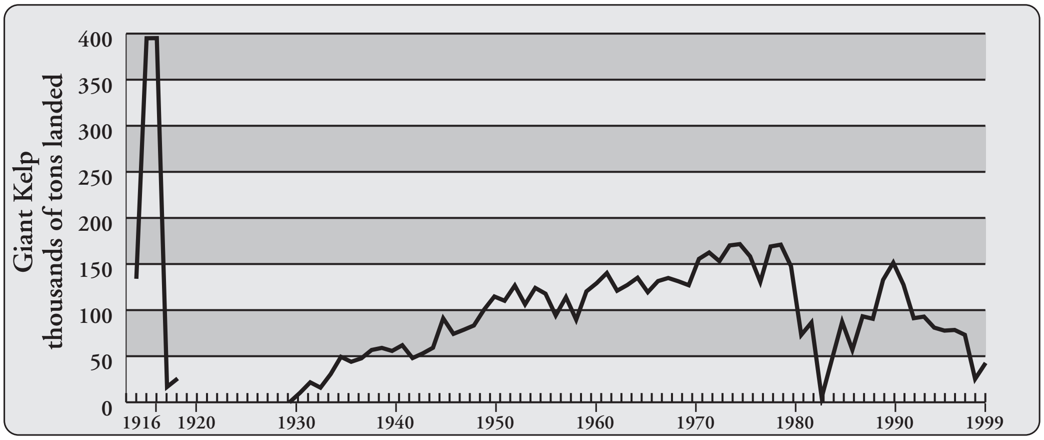
Today, giant kelp is harvested on kelp beds from Imperial Beach, near the U.S.-Mexico border, to Monterey Bay, California. Mexican harvesters in Ensenada provide another source of kelp from beds off Baja California. Giant kelp is one of California's most valuable living marine resources and in the mid-1980s supported an industry valued at more than $40 million a year. The annual harvest has varied from a high of 395,000 tons in 1918 to a low of less than 1,000 tons in the late 1920s. Such fluctuations are primarily due to climate and natural growth cycles, as well as market supply and demand. During the 10-year period 1970 to 1979, the harvest averaged nearly 157,000 tons, while from 1980 to 1989 the average harvest was only 80,400 tons. The harvest was low in the 1980s because the kelp forests were devastated by the 1982-1984 El Niño and accompanying storms, and by the 200-year storm that occurred in January 1988. In most areas, the beds of giant kelp recovered quickly, with the return of cooler, nutrient rich waters. Harvests in California increased to more than 130,000 tons in 1989 and to more than 150,000 tons in 1990. During the 1990s, increasing international competition from Japan for the "low end," or less purified end of the sodium alginate market caused ISP Alginates to reduce harvests by about 50 percent. ISP Alginates anticipates California's harvest in this decade will be approximately 80,000 tons annually.

Methods of harvesting are used to suit the harvesters' purposes and needs. The ISP Alginates Company uses specially designed vessels that have a cutting mechanism on the stern and a system to convey the kelp into the harvester bin. A propeller on the bow slowly pushes the harvester stern-first through the kelp bed, and the reciprocating blades mounted at the base of the conveyor are lowered to a depth of three feet into the kelp as harvesting begins. The cut kelp is gathered on the conveyor and deposited in the bin. These vessels can each collect up to 600 tons of kelp in one day and to facilitate its harvesting operations, the company conduct regular aerial surveys. The survey



Giant Kelp, *Macrocystis pyrifera*
Credit: DFG

Commercial Landings 1916-1999, Giant Kelp
Data Source: commercial landing receipts.
Kelp landings consist primarily of giant kelp; commercial kelp harvest data is not available for 1921 through 1930.



information is used to direct harvesting vessels to mature areas of kelp canopy with sufficient density for harvesting.

The Pacific Kelp Company uses a modified U.S. Navy landing craft with a cutting device and conveyor system mounted on the bow to harvest giant kelp off central California. The Pacific Kelp Company vessel holds approximately 25 tons of kelp. In contrast, for the herring-roe-on-kelp fishery, kelp is harvested by hand from small skiffs or other small boats and then transported by truck to San Francisco Bay.

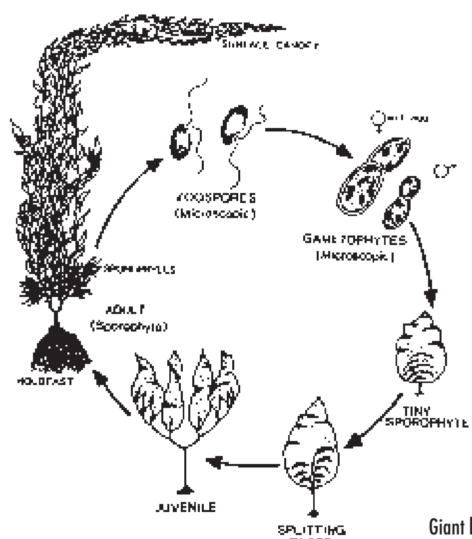
Status of Biological Knowledge

Forests of giant kelp occur in the temperate oceans of the world. These forests are especially well developed along the West Coast of North America from Punta Abreojos, about midway down Baja California, Mexico, to San Mateo County. They create a unique habitat that provides food, shelter, substrate, and nursery areas for nearly 800 animal and plant species. Many of these animals and some plants are of importance to sport and commercial fisheries.

Typically, giant kelp flourishes in wave-exposed areas of nutrient-rich, cool water that is 20 to 120 feet deep. By means of a root-like structure called a holdfast, the kelp attaches to rocky substrate. Along the protected shoreline of Santa Barbara County, however, giant kelp also grows on sand substrate. Here, it attaches to exposed worm tubes or the remains of old holdfasts. Kelp fronds originate from the holdfast, and eventually grow to the surface. A frond is composed of a stem-like stipe and numerous leaf-like blades. A gas-filled bladder (pneumatocyst) at the base of the each blade helps buoy the frond in the water column.

Giant kelp absorbs nutrients from the water through all its surfaces. Under optimal conditions of high nutrient levels and low ocean temperatures (50˚ to 60˚ F), fronds can elongate up to 24 inches a day. Fronds can reach a length of more than 150 feet, and large plants can have more than 100 fronds. The fronds eventually mature, die, and break away (slough) naturally, giving way to young fronds. Although giant kelp plants can live up to eight years, individual fronds survive for only about six to nine months, and individual blades about four months.

Giant kelp reproduction involves two very different growth forms, the large canopy-forming sporophyte and the microscopic gametophyte. Specialized reproductive blades (sporophylls), located just above the holdfast on an adult sporophyte, liberate trillions of microscopic zoospores each year. The zoospores then settle on the bottom and develop into microscopic male and female gametophyte plants. Fertilization of the female gametophyte produces an embryonic sporophyte. This tiny plant will develop into a canopy-forming adult within seven to 14 months if it survives competition with other plants and avoids being eaten by grazers or being destroyed by undesirable environmental factors.



Giant kelp life cycle.

Status of the Beds

The density and abundance of a kelp canopy varies by location, year, and season. In central California, sloughing and deterioration occur in late summer and early fall. Canopies virtually disappear during the late fall and winter, when storms cause frond and plant loss. Canopies usually begin forming again in the spring, becoming dense in the summer. Off southern California, kelp canopies frequently grow throughout the year in the mild weather conditions. Dense canopies often develop during the winter, when there are virtually no canopies in central California.

During the last 30 years, the size, distribution, and location of the kelp canopy throughout California has fluctuated considerably. Fluctuations can be viewed as seasonal events and as long-term changes. Decreases in canopy area were due to both natural and man-induced disturbances. Increases were due to natural growth and in some instances may have benefited from restoration efforts. An aerial survey conducted in 1967 showed a total of 70 square miles of kelp canopy along the entire California coast. Of that, 53.9 square miles was recorded for southern California. The southern California portion showed that 33 square miles occurred along the mainland coast and 20.9 square miles around the Channel Islands. A similar survey conducted in 1989 reported 40.7 square miles along the entire coast. Of this, 17.5 was recorded for southern California. The Channel Islands accounted for 9.8 square miles, while the mainland coast of southern California totaled 7.7 square miles. During the most recent statewide kelp forest survey, conducted in 1999, a total of 17.8 square miles of giant kelp was charted along the California coast, 11.4 square miles of that recorded off southern California, including the offshore islands. The 1999 survey shows only 3.7 square miles of the 17.8 total along the mainland coast, while 7.7 square miles was recorded in the Channel Islands.

The methodology used to conduct aerial surveys is subject to a high degree of error. The photographic method utilizes infrared film to highlight temperature differences between kelp canopy at the water's surface and the background water temperature. Kelp immediately below the surface is invisible to this method. So the results can vary due to wind waves and local currents. These errors could be greatly reduced by more frequent surveys.

This being said, it is still evident that a declining trend is occurring, particularly in southern California. This can be at least partly explained by the warming trend of the past twenty years and the frequency of severe El Niños.

However, when the distribution of kelp canopy in southern California between the Channel Islands and the mainland coast is examined, the warming trend should be factored out, since both areas are likely to experience the same oceanographic conditions in any year. So the change in relative abundance of kelp between these two areas is of greater concern. It suggests that factors other than the warming trend is responsible for the declines along the mainland coast.

The health and long term survival of the kelp forests are influenced by a variety of factors, including storms and climactic events, grazing, competition, sedimentation, pollution, and disease. These can be divided into natural and human induced causes. Because water of the Southern California Bight is warmer than the rest of the state, fluctuations in water temperature may have a more profound affect on kelp survival there compared to central and northern parts of the state. Human-induced impacts, pollution, and coastal development also tend to be greater in southern California where there are more people.

The southern California kelp beds, in particular, provide examples of both. Waters south of Point Arguello, referred to as the Southern California Bight, are considerably warmer than the rest of the state. Accordingly, fluctuations in water temperature tend to have a more profound affect on kelp survival than in the central and northern parts of the state. Human induced causes also tend to be greater in southern California due to the concentration of the state's population within this region, with its associated pollution and coastal development.

Excessive wave action from storms and surge can break kelp fronds and dislodge entire plants. Dislodged plants increase kelp loss by entangling nearby kelp, pulling them from their attachment. During the 1980s and 1990s, at least three major oceanographic events affected kelp beds: 1) the 1982-1984 El Niño and a devastating storm; 2) the 1992-1994 El Niño and subsequent storms; and 3) the 1997-1998 El Niño, which was the warmest of the three. The warm water and storms associated with the El Niño destroyed plants, inhibited kelp growth, and resulted in minimal canopy development throughout southern California. During the 18 year-period from 1981 to 1998, sea surface temperatures exceeded the previous 60-year mean in all but a single year (1988). In 1967, there were approximately 18 square miles of kelp canopy near Santa Barbara, compared to only six square miles remaining in 1989. The giant kelp forests on sand substrate near Santa Barbara had still not returned in 2000.

Fishes such as opaleye and halfmoon regularly graze upon kelp. Large numbers of these fishes can damage the kelp forests, especially when conditions are unfavorable for kelp growth. Crustaceans, such as amphipods, isopods and crabs, can also graze and damage kelp. The historical removal of the southern sea otter from southern California certainly changed the balance of the predator/prey relationship in the kelp bed community. But finally, the intensive fishing for the remaining sea urchin predators such as sheephead and spiny lobster, and for sea urchin competitors such as abalone, tremendously altered the sea urchin population dynamics in the forest. As a result, sea urchin populations increased exponentially in some areas and overgrazed the kelp, creating areas referred to as "urchin barrens."

Human-caused disturbances include sedimentation of the rocky bottom, which can retard kelp growth and even bury young plants, preventing development and reproduction. Pollution can affect kelp forests in a variety of ways. Industrial and domestic wastewater discharges carrying toxins, including pesticides and heavy metals, are released into coastal waters where they can accumulate in the sediments. Such chemicals alter the physical and chemical environment near the discharge and may decrease growth and survival of the kelp forests. Thermal outfalls from power plants also have localized effects on kelp forests. Wastewater and thermal discharges can increase turbidity and redistribute sediments into nearby kelp forests, affecting kelp growth and survival. A variety of pathogens are known to affect kelp but their broad impacts on kelp forests have not been studied. While tumors, galls, and lesions have been observed on kelp, only occasionally have they caused severe damage.

Short and long-term declines, or in one case a complete disappearance of southern California kelp beds, associated with human activity have been documented. Prior to the 1920s, an extensive kelp bed, known as Horseshoe Kelp existed off the coast of what is now Los Angeles Harbor. It was reported to have measured a quarter- to a half-mile wide and two miles long. A department Information Bulletin reported interviews with "old time fishermen" who recalled the kelp bed beginning to decline during the 1920s and 1930s coinciding with the widening of the main channel and west basin of Los Angeles Harbor, which included the dredging removal of an entire island, (Deadman's Island). Some recalled that the Whites Point Sewer Outfall, which began discharging in 1934, was associated with the disappearance of the last remnants of this bed. The Horseshoe Kelp Bed grew in a water depth of 80 to 90 feet. While kelp at this depth is still common in the Channel Islands, no kelp grows along the southern California mainland coast at this depth today.

Several years' declines to kelp beds near Salt Creek in Orange County and Barn Kelp near Las Pulgas Canyon off Camp Pendleton Marine Base in San Diego County were associated with extensive grading of land around drainages adjacent to these beds.

The most thoroughly documented human induced decline was associated with the start-up of the San Onofre Nuclear Generating Station in northern San Diego County. The discharge of heated and turbid cooling water caused the loss of approximately 150 acres of kelp. This single event was the only time when the damage was so well documented that mitigation could be required as compensation for the loss.

In the 1950s and 1960s, once-productive kelp forests off Point Loma and La Jolla in San Diego County and along the Palos Verdes Peninsula in Los Angeles County began to deteriorate. This too was attributed to biological and physical factors related primarily to human activities. Currently, there are several areas where the status of kelp is of concern, including the entire Santa Barbara/Ventura coastline, the Malibu coast, portions of the Palos Verdes Peninsula, the coast between Newport and Laguna Beach, San Onofre, south Carlsbad and Point Loma. Other kelp losses have undoubtedly occurred as a direct result of human activities along the southern California coastline, but the lack of strong baseline data prevents resource agencies from proving damages and seeking compensation. The development of computerized Geographic Information Systems may provide effective tools to document and analyze such damages in the future.

Kelp Restoration

In 1963, Scripps Institution of Oceanography and Kelco began a cooperative project to develop techniques to protect and restore kelp forests off San Diego. Work involved sea urchin control, including the use of lime and crushing of individual urchins and kelp transplanting. Later experimentation between 1991 and 1992 involved feeding urchins along a front to discourage feeding on attached plants and to increase urchin reproduction, so that commercial harvesting might be encouraged. This work appears to have succeeded in restoring kelp to these beds. However, this is a labor intensive effort, and there are indications that when the work ceases, the urchin fronts redevelop, calling into question the long term benefits of any one-time restoration effort, as well as the economic feasibility of conducting such work as a long term solution and over a broader area.

Between 1967 and 1980, kelp restoration was conducted along the Palos Verdes Penensula (PVP) by the Institute of Marine Resources and the department. This work also combined sea urchin control and kelp transplanting. The objective was to establish several small stands of kelp, which would provide seed stock for new and expanding beds. In 1974, the first naturally expanding kelp stand in 20 years was observed off PVP. By 1980, when restoration work was discontinued, nearly 600 acres of kelp had become established. By 1989, aerial surveys revealed over 1,100 acres of kelp off PVP. Two subsequent El Niño events have severely decreased the size of these beds.

Kelp restoration work has also been conducted in storm damaged areas off Santa Barbara and along the Orange County coast. Shortly after the 1982-1984 El Niño, Kelco began developing techniques for restoring kelp beds in Santa Barbara County. In 1987, under contract with the department, Kelco implemented operations for anchoring giant kelp in the sandy habitat near Santa Barbara. Several kelp forest nuclei were established; however, sea urchin grazing and unfavorable water conditions impeded progress. By the early 1990s, it became evident that this restoration attempt had failed.

Loss of Orange County kelp forests from Newport Harbor to San Mateo Point was caused by heavy rainfall and siltation in 1980, the 1982-1984 El Niño, and the effects of urchin grazing. Under contract with the department, MBC Applied Environmental Sciences company established kelp forest nuclei between Newport Harbor and Laguna Beach. This was done by transplanting adult and juvenile giant kelp and controlling sea urchins. Those kelp forests south of Laguna Beach recovered naturally after a few years. Those beds north of Laguna Beach, where restoration efforts took place, have not recovered.

In 1992, the department Artificial Reef Program built a 10-acre, low relief (three feet or less in height) reef outside the harbor entrance channel to Mission Bay, San Diego County. The reef was constructed from broken slabs of concrete provided by the demolition of a nearby roadway. By 1993, a kelp bed had naturally established itself on this reef. This bed has persisted through the spring of 2000.

During the fall of 1999, the Southern California Edison Company built a 22-acre experimental reef off the city of San Clemente, aimed at mitigating the damage to kelp from the San Onofre Nuclear Power Station. It is still too early to evaluate the success of this project, although based on a great deal of research, and the success of the Mission Beach reef, there is great optimism that it will succeed. If it does succeed in providing substrate for a persistent kelp bed, the reef will be expanded to a minimum of 150 acres in five years.

It appears now that the creation of new reef substrate, rather than other techniques, may provide a valuable mechanism for increasing the capacity for kelp bed expansion throughout southern California in future years.

A kelp cutter operating near Santa Barbara
Credit: DFG

Management Considerations

See the Management Considerations Appendix A for further information.

Dennis Bedford
California Department of Fish and Game

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Bull Kelp

History of the Use and Harvest

Until the late 1980s, there was little targeted harvest of bull kelp (*Nereocystis luetkeana*) in California, except as a small component of the localized edible seaweed industry. In central California, *Nereocystis* and *Macrocystis* often form mixed beds and it is likely bull kelp would have been incidentally taken during harvest of those beds, but not recorded separately on harvest records. Department records indicate about 19 tons of kelp, probably a mixture of *Macrocystis* and *Nereocystis*, were harvested from what is presently bed 302 off the Bodega Bay–Tomales Bay area between 1993 and 1999. All of this kelp was used by local abalone culturists. Other uses of bull kelp include pickling the stipe and marketing it as a specialty food product, and using the dried parts for arts and crafts. In southern Oregon, bull kelp was harvested from Orford Reef in the mid-1990s as an ingredient in liquid fertilizer. The Oregon Division of State Lands has since discontinued permitting that harvest.

Currently, there is only one mariculture firm harvesting significant quantities of bull kelp for abalone food. This business is located in Crescent City, Del Norte County, and has been harvesting bull kelp from Point Saint George to Crescent City harbor since 1988. Because bull kelp declines in the winter months, they often augment their supply with giant kelp from central California. From 1990 to 1994, the company and the department worked together to determine the possible effects of small scale harvesting on *Nereocystis* populations. The company kept detailed records of harvest amount, location, bed condition, and effort in hours. Though not required by regulation, they hand-harvest to a depth of about 2.5 feet below the surface, which allows the take of the upper portion of the stipe, the pnuematocyst and all the fronds, resulting in the loss of the entire plant. During this experimental period annual harvest ranged from six to 149 tons, and impact to the local beds was considered to be minimal. In 1996, the Fish and Game Commission developed designation numbers (300 series) for all the kelp beds north of San Francisco and established beds that could be exclusively leased by interested parties, a program similar to the one in use for giant kelp harvest. Prior to this, there were no official designations in this area, so any northern kelp bed could be harvested for commercial purposes.

The Crescent City firm applied for and received exclusive lease privileges for bed 312 in 1997. In accordance with department regulations, they were required to produce a kelp bed biomass estimate prior to harvest. They estimated 205 acres of kelp beds in the approximately five miles of coastal area between Pt. St. George and Whaler Island within bed 312 (an area representing only a fraction of the entire geographic area of bed 312). The November 1996 survey yielded a point estimate of 5,475 tons of bull kelp within those 205 acres, at 27 tons per acre. Based on that survey, their annual harvest would be limited to 15 percent of that estimate, equivalent to 821 tons. While their harvest up to that time was only 132 tons (in 1996), or 16 percent of their allowance, their bid application projected steady harvest increases through 2001, peaking at a 500-ton projected harvest. Through 1999, their highest harvest in any year has been 149 tons.

Bull Kelp, *Nereocystis luetkeana*
Credit: CA Sea Grant Extension Program

Status of Biological Knowledge

Bull kelp is primarily found adjacent to exposed shorelines along the Pacific coast of North America, ranging from Unalaska Island, Alaska to Point Conception, California. Along the central California coast, *Macrocystis* and *Nereocystis* occur together, forming extensive kelp forests in this region. However, from the Monterey Bay area northward to Alaska, *Nereocystis* becomes the dominant canopy kelp species in coastal waters. Within the nearshore environment, bull kelp, like giant kelp, is associated with hard substrates at depths of approximately 10 to 70 feet, where it provides habitat and food for hundreds of species, many of them commercially and recreationally valuable.

Distribution of marine algae is not only restricted geographically but also limited by a number of other factors within the nearshore environment, including water movement, light, temperature, nutrients, pollution, competition, and predation. The complex trophic interaction among sea otters, macro-herbivores and kelps has been documented by a number of researchers. Generally, the occurrence of sea otters in a kelp forest community greatly limits the population of invertebrate kelp grazers, thereby increasing kelp productivity. In northern California, absent the sea otter, commercial and sport fishermen have acted to significantly reduce populations of sea urchins and abalone, two major kelp grazers. While kelp populations have increased, the competition among seaweeds for space and light rules out any generalizations regarding specific impacts on bull kelp due to the reduction of these grazer populations.

The morphology of bull kelp is quite different from that of giant kelp. The most notable difference is the possession by bull kelp of only one pneumatocyst, situated on the end of the hollow stipe for flotation. Giant kelp has many gas bladders running its entire length. While bull kelp is also attached to the substrate by a holdfast, the size of the holdfast is much smaller than that of giant kelp. The holdfast resembles a small disk with many finger-like haptera. Much like giant kelp, the stipe of a bull kelp sporophyte is long, reaching lengths of up to 130 feet. The bull kelp stipe does not have the same tensile strength as giant kelp but is more elastic under stress. Bull kelp is able to stretch more than 38 percent of its length before breaking. The pneumatocyst gives rise to short dichotomous branches from which up to 64 blades are borne. The bull kelp canopy provides most of the photosynthetic and nutrient absorbing surface for energy production. Blade lengths of more than 13 feet have been reported for mature plants, but it is typical to find a range of blade sizes (two to 11 feet) on most plants. The reproductive structures (sporangia) are located on the blades in aggregations called sori, with mature sori located in patches near the blade tips and immature regions near the base of the blades.

Reproduction in bull kelp undergoes a cyclic alternation of generations similar to that of giant kelp and other laminarians. The large plant commonly referred to as bull kelp represents the sporophytic phase while the gametophytic phase is microscopic. During its sporophytic phase, spore production usually begins several weeks after the blades reach the surface. Biflagellate spores are formed within the sporangia on the blades. As the spores reach maturation during the summer and fall, the sori are abscised from the blades and the spores released. Upon settlement, germination begins, and over the course of several weeks, somatic growth gives rise to the gametophyte. After about 11 weeks, motile sperm are released and fertilization of the eggs takes place. The resulting zygotes grow as sporophytes. Once at the surface, stipe and blade elongation rates decrease while the plant increases in biomass.

As an annual plant, bull kelp has evolved an optimal reproductive strategy that involves accelerated stipe growth to reach the ocean surface where it can initiate spore production and release. Plants initiated in late March sometimes have developing sori prior to reaching the surface in May and spore release via abscission of the sorus begins as early as June. Maximum bull kelp growth rates occur under optimal environmental conditions of high light, nutrient and water clarity levels. Bull kelp stipe elongation can reach five inches per day, while blade growth accelerates to about 3.5 inches per day just prior to the plant reaching the surface. At maturity the growth rate of the holdfast can average about 0.2 inches per day.

Water temperature plays an important role in the growth of *Nereocystis*. Mean sea surface temperatures over the distributional range of *Nereocystis* vary from 55° F to 59° F at the southern end to 39° F to 50° F off the Aleutian Islands. The population of bull kelp in Diablo Cove has been adversely affected by the warm water discharge from the Diablo Canyon power plant which began in 1985. Plants in contact with the discharge experienced deterioration of blade tissue, which resulted in early death. This observation helps to explain the decline of *Nereocystis* that occurs during El Niño events.

Nereocystis is an opportunistic colonizer that takes advantage of substrate clearing caused by storms, sand scouring, or other disturbances. While bull kelp can rapidly recruit to a newly cleared location, its longevity as the dominant canopy-forming species depends on environmental conditions being conducive for its survival and detrimental for its major competitors. The biggest factor in growth of *Nereocystis* is the availability and quantity of light. Light levels below the surface canopy have been shown to decrease by almost 100 percent and below the secondary canopy, well below the minimum level necessary for growth. Thus, in established kelp communities there can be insufficient light and hard substrate for recruitment and growth of bull kelp.

Status of the Beds

The kelp resources of the eastern Pacific coast were first mapped in 1912. The survey extended from the Gulf of Alaska to Cedros Island, Baja California. Along the central coast of California between Point Montara, San Mateo county and Point Conception, subsequent coastwide surveys have not differentiated between *Nereocystis* and *Macrocystis*. Since the first survey in 1912, little work has been done along the north coast of California, primarily due to the absence of the commercially valuable *Macrocystis pyrifera* in this region. Current knowledge of the population levels of *Nereocystis* off the north coast is based on 1989 and 1999 surveys of the California coast, and information provided by a kelp harvester about the resource in the Crescent City area. Population abundance estimates resulting from these surveys are usually expressed in terms of square miles of surface area.

Despite the year-to-year variability in bull kelp coverage, both the 1912 and the 1989 surveys yielded similar results for the northcoast and about 6.5 square miles of canopy.

The 1999 survey, however, indicates about a 42 percent decline in kelp coverage in the Point Montara, San Mateo county to Shelter Cove, Humboldt county area. This decline is contrary to anecdotal observations along the Mendocino county coast in 1999, which indicated one of the most extensive kelp canopies in the last decade. The apparent decline may be due in part to the timing of the 1999 survey, which was conducted after a major storm had passed through the region, destroying portions of the kelp beds. Another factor to be considered is the improved method used to interpret aerial photographs in 1999, which resulted in a more accurate representation of kelp beds. This would seem to indicate that previous surveys may have overestimated the true extent of the beds. And finally, kelp beds are subject to high variability in coverage and density from year to year.

The 1912 survey estimated that about 32 percent of the 17.55 square mile kelp canopy in central California was bull kelp. However, since that survey there has not been an effort to estimate the proportion of bull kelp in the area. In this region, bull kelp is generally restricted to areas unsuitable for giant kelp and the outer edges of giant kelp beds and inshore of *Macrocystis* within the surge zone. However, following winter storms with heavy wave disturbance, bull kelp can become more abundant, sometimes replacing giant kelp removed by the storms.

Changes in kelp abundance over time and location are evident. For example, during the period from 1975 to 1982, biomass at Diablo Cove in San Luis Obispo County declined from 200 tons per acre to 4.8 tons per acre. At Van Damme Bay in Mendocino County, a density of six tons per acre was calculated in July 1990. Peak abundances in the Crescent City area ranged from 24 to 28 tons per acre during the period from 1994 to 1996.

Researchers reported that the Fort Bragg, Mendocino County area kelp beds appeared to increase in size and density between 1985 and 1988 based on aerial photographic surveys of the area. The *Nereocystis* beds were thought to have reached maximum potential during this period. The increase was coincident with the removal of over 32,500 tons of red sea urchins from Mendocino and Sonoma Counties by commercial divers. In 1992, the same beds showed delayed and reduced kelp recruitment and growth. The causes of the poor recruitment in 1992 may have been associated with the El Niño event of that year. These examples illustrate the kind of fluctuations that occur in the recruitment of bull kelp along the north coast and the factors that may play a role in the variability of this resource.

Management Considerations

See the Management Considerations Appendix A for further information.

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Sea Palm

Status of Biological Knowledge

The sea palm, *Postelsia palmaeformis,* is a brown alga first described by Franz Joseph Ruprecht in 1852 from specimens collected near Bodega Bay, California. It is locally abundant in the upper to mid-tidal zones from Vancouver Island, British Columbia to Morro Bay, California but is restricted to rocks exposed to heavy surf. Although it is illegal to harvest this attractive kelp, some people collect it for souvenirs or to eat its tender blades.

Postelsia is an annual kelp, thriving in dense aggregations where its dispersal and recruitment are local and influenced by seasonal disturbance. Several studies have documented sea palm's relationship to its unique habitat — its tolerance of and dependence on heavy surf and its common association with the California mussel.

Status of the Beds

Although individuals can regenerate blades, they cannot survive if they are cut near the base of the stipe. All of these characteristics (restricted habitat, short life span, local dispersal, and limited powers of regeneration) signify a species that cannot tolerate heavy harvesting pressure. Although many stands of *Postelsia* are difficult to access, others are in or adjacent to recreational areas where they are at risk from human disturbance. Education of the public is the best defense for the conservation of this charismatic and ecologically interesting alga.

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Sea Palm, *Postelsia palmaeformis* Credit: CA Sea Grant Extension

Agarophytes and Carrageenophytes

History of Use and Harvest

Agar is a Malay word for the gel, (which is now known to be a carrageenan) that is part of the cell wall of seaweeds in red algal genus Eucheuma. Its discovery is preserved in a folk legend that originated about 1660. A Japanese emperor and his Royal Party were lost in the mountains during a snowstorm and arriving at a small inn they were ceremoniously treated by the innkeeper, who offered them a seaweed-jelly dish with their dinner. Perhaps the innkeeper prepared too much jelly or the taste was not attractive; in any case, some jelly was thrown away. It froze during the night and, after thawing and draining, was reduced to a thin, papery substance. The innkeeper took the residue and, to his surprise, found that by boiling it up with more water, the jelly could be reconstituted.

In 1881, the German microbiologist Dr. Robert Koch, first established the use of agar in preparing solid culture media for bacteriological research. By 1903, there were 500 factories manufacturing agar in Japan. The California agar industry was developed initially by Dr. Matsuoka in 1921 with U.S. patents for extraction and processing. Horace Selby (the founder of American Agar and Chemical) and C.K. Tseng refined methods prior to and during World War II, when agar was not available from Japan.

Carrageenan, another gel, was originally derived from the red alga, *Chondrus crispus* (Irish Moss), and has a 600 year folk history in Ireland that includes milk puddings thickened by boiling sweetened milk with dried *Chondrus*. The word carrageenan is derived from the colloquial Irish name for this seaweed, carrageen, or *carraigín*; "little rock" (from the Irish place name, probably Carrigeen Head in County Donegal). Since the 1940s, the best-known use of carrageenan has been in products such as chocolate milk and ice cream, but they are also important in other industrial applications.

About 10,000 tons of agar, valued at $200 million, are produced worldwide from species in the red algal families Gelidiaceae and Gracilariaceae. There is currently a shortage of exploitable populations of agar-producing seaweeds; consequently, agar is an expensive product. The best quality agar is extracted from species in the genera *Pterocladia* and *Gelidium*, which are harvested by hand from natural stands in Spain, Portugal, Morocco, the Azores, Mexico, New Zealand, South Africa, India, Chile, Korea and Japan. For *Pterocladia* species, agar quality is low in the colder months and high in the summer. Agars of lesser quality are extracted from *Gracilaria* and *Hypnea* species.

The lower quality, and less expensive, types of agar are used for their gelling and water barrier properties in food products (frozen foods, bakery icings, meringues, dessert gels, candies and fruit juices). As a gelling agent in foods, agar is used at greater than one per cent concentration. For viscosity control and stabilization, lower levels (0.2-0.8 percent) are used. Agar is not assimilated by the human digestive system and, in fact, serves as a laxative. Industrial applications are paper sizing/coating, adhesives, textile printing/dyeing, castings, impressions, etc. The mid-quality agars are used as the gel substrate in biological culture media. Most agar media are made at a 1.0-1.5 percent concentration in water, melt above 185°F and gel at 105°F. They are also important in medical/pharmaceutical fields as bulking agents, laxatives, suppositories, capsules, tablets and anticoagulants. The most highly purified and upper market types (the neutral fractions called agarose) are used in molecular biology for separation sciences (electrophoresis, immunodiffusion and gel chromatography).

Carrageenans are extracted from members of the red algal families Hypneaceae, Phyllophoraceae, Solieriaceae, and Gigartinaceae. *Chondrus crispus* used to be the sole source of carrageenan, but species of *Gymnogongrus, Eucheuma, Ahnfeltia* and *Iridaea* are now used. The market for carrageenan has grown by at least five percent per year for the last 25 years. About 25,000 tons of carrageenan, valued at $200 million, are produced worldwide. *Eucheuma* and *Kappaphycus* are important carrageenan weeds in Hawaii, the Philippines, Indonesia, Malaysia, China and Thailand. In 1996, the Philippines exported $94 million worth of carrageenan from farm raised and natural stands of *Eucheuma cottonii* and *Eucheuma spinosum*. Another principal source is natural populations of *Chondrus crispus* in the Maritime Provinces of Canada, where about 50,000 wet tons are harvested each year.

Carrageenans are far more widely used than agar as emulsifiers/stabilizers in numerous foods, especially milk-based products. It is estimated that the average human consumption of carrageenans in the United States is 250 milligrams (0.01 ounce) a day. Kappa, iota and lambda carrageenans differ in gelling and milk reactivity and are the three most widely used types in commercial products. Kappa carrageenan (extracted chiefly from *Chondrus crispus* and *Eucheuma cottonii*) forms a firm, brittle gel and iota (extracted chiefly from *Eucheuma spinosum*) yields a flexible and dry gel. Lambda carrageenan (extracted chiefly from *Chondrus crispus* and *Gigartina* species) does not gel. Blending of these in different ratios produces different products. Kappa and iota carrageenans are especially important for use in milk products such as chocolate milk, ice cream, evaporated milk, infant formulas, puddings, whipped cream toppings and eggnog, because of their thickening and suspension properties. For these uses, concentrations range from about 0.01 to 0.2 percent. For water-based food products (jellies, jams, salad dressings, syrups, dessert gels, meat products and pet foods), carrageenan concentrations are somewhat higher (0.2-0.5 percent). Industrial products incorporating carrageenans are air freshener gels, cleaners, etc. Pharmaceutical and medical applications are similar to those of agar.

Status of Biological Knowledge

Agar and carrageenan are phycocolloids derived from galactan polysaccharides, the major polysaccharide constituents of the cell walls of most marine red algae. The types and quantity vary from species to species; this is an important character in biosystematics. The amount present also varies with ecological factors such as light, nutrients, wave exposure, and temperature. Polysaccharides have an important role in the biology of these algae, including protection from wave action, physical support of cells, ion exchange, water binding for protection from desiccation. The galactans have a common backbone which consists of galactose units linked alternately by ∂(1-3) and ß(1-4). The alpha (∂) unit is linked to either D- or L-galactose whereas the beta (ß) unit is always linked to D-galactose. In agar the ∂-linkages are all with L-galactose and in carrageenan they are all with D-galactose. (For pictures of these structures, see www.rrz.uni-hamburg.de/biologie/b_online/e26/26d.htm) The chemistry of these polymers is complex.

Status of the Beds

There are many genera of red algae in California that yield agars and carrageenans. The most common and abundant agar weeds in California are species in the genera *Gelidium* and *Pterocladia* (family Gelidiaceae) and *Gracilaria* and *Gracilariopsis* (family Gracilariaceae). Of the six species of *Gelidium* in California, only *G. robustum* is available in sufficient wild stocks to warrant limited harvest for agar production. Before and during World War II and until American Agar and Chemical Company in San Diego closed in about 1986, *G. robustum* was collected by divers along the southern California coast. Resource management of wild stock of *G. robustum* was investigated carefully to establish control of season, amount and method of harvesting, but it proved difficult to enforce regulations. Today, there is no harvest of wild stocks for commercial agar production in California, but wild stocks are still harvested in Baja California, Mexico, by local fisherman for processing in Ensenada and a subsequent export of refined agar. *Gelidium robustum* is very slow growing in nature and even slower in mariculture, thus making it unlikely as a major resource. Several other species, including *G. coulteri*, show much faster growth in nature and in tank culture, providing an acceptable quality agar. Unfortunately, the cost of these culture systems in California is too high for competition with either wild stock harvest or cultivation in other countries. *Gracilaria* and *Gracilariopsis* species in California and elsewhere offer considerable potential, because of their fast growth and yield of agar. Several species are extensively cultivated in Chile, China and Thailand, for example, contributing 50 percent of worldwide agar production; several countries (e.g., South Africa and New Zealand) are studying the possibility of mariculture. The best candidate for large-scale culture in California is *Gracilariopsis lemaneformis.* Although extensively cultivated in open bays of other countries, it is unlikely that such cultivation could occur in California, because of government restrictions.

The carrageenan weeds common in California are members of the genera *Mazzaella, Mastocarpus, Rhodoglossum* and *Sarcodiotheca.* Several California species can be grown successfully in mariculture, but the low value of carrageenan makes both wild harvest and culture economically unrealistic. Compared to agars, carrageenans generally are more plentiful and less costly, because the carrageenan weeds are widely available from harvest of wild stocks and extensive cultivated stocks in Canada and the tropics. Genetic manipulation and cell culture of *Chondrus crispus* are being explored to produce novel carrageenans to stimulate the possibility of mariculture on the East Coast of the United States.

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Commercial Landings - Nearshore Plants

Year	Kelp[1] Tons
1916	134,537
1917	394,974
1918	395,098
1919	16,673
1920	25,464
1921	- - - -
1922	- - - -
1923	- - - -
1924	- - - -
1925	- - - -
1926	- - - -
1927	- - - -
1928	- - - -
1929	- - - -
1930	- - - -
1931	260
1932	10,315
1933	21,622
1934	15,880
1935	30,602
1936	49,317
1937	43,954
1938	47,697
1939	56,736
1940	59,004
1941	55,717
1942	61,898
1943	47,958
1944	53,030
1945	59,181
1946	91,069
1947	74,237
1948	78,641
1949	83,346
1950	100,602
1951	114,760
1952	110,158
1953	126,649
1954	106,215
1955	124,063
1956	117,815
1957	94,207
1958	114,062
1959	89,599
1960	120,300
1961	129,256
1962	140,233
1963	121,032
1964	127,254
1965	135,129
1966	119,464
1967	131,495
1968	134,853
1969	131,239
1970	127,039
1971	155,559
1972	162,511
1973	153,080
1974	170,181
1975	171,597
1976	158,371
1977	130,597
1978	169,029
1979	171,020

Year	Kelp[1] Tons
1980	147,636
1981	73,064
1982	86,503
1983	5,271
1984	46,479
1985	87,300
1986	56,832
1987	93,264
1988	90,615
1989	132,761
1990	151,439
1991	127,505
1992	91,247
1993	92,940
1994	81,006
1995	77,753
1996	78,461
1997	73,165
1998	25,313
1999	42,211

- - - - Landings data not available

[1] Kelp landings consist primarily of giant kelp.

California's Offshore Ecosystem

California's Offshore Ecosystem

Far from the coast, California's offshore ecosystem consists of the open ocean environments over the deeper parts of the continental shelf, the continental slope, and ocean basins. This ecosystem is most often characterized by a deep luminous blue color, due to scattered light encountering fewer particles and dissolved substances than are found in rich coastal waters, where suspended sediment, marine organisms, and other material can absorb light and cause greenish or brownish colors.

California's offshore waters are dominated by the California Current, a relatively shallow, broad (approximately 300 km), and slow moving current. This current generally moves from north to south along the West Coast of North America, transporting cooler water toward the equator. Along our state, the California Current hugs the coast north of Point Conception during most of the year, except in winter when southeast winds force it farther offshore, producing the Davidson Current that flows north near the coast. In some years, this counter current is stronger than normal and is forced as far north as British Columbia, Canada. South of Point Conception, in the Southern California Bight, the coast bends sharply to the east. There the California Current breaks away from the coast and flows offshore along the continental edge until it swings back toward the mainland south of San Diego. In the Southern California Bight, the usual surface flow, called the California Countercurrent, moves north along the coast resulting in a counterclockwise gyre that mixes offshore and nearshore surface waters off southern California.

Off California, prevailing winds, most often from the north or northwest, blow surface waters away from the coast and nutrient laden subsurface waters are drawn up to replace them in a process called upwelling. California is in one of the major coastal upwelling regions of the world, with the most intense upwelling occurring during the summer near Cape Medocino in northern California. Productivity of marine plants is high along coasts with these features, and some of the largest fish populations are associated with productive coastal upwelling systems.

Although the offshore environment is generally less variable than nearshore and estuarine ecosystems, the California Current is a dynamic system with considerable inter-annual variation. Relatively short-term, dramatic events like El Niño (warmer water) and La Niña (cooler water) cause larger temperature changes, variation in productivity, and occurrences of organisms beyond their usual ranges. Long-term temperature regimes, periods of slightly warmer or cooler conditions that persist for decades, can affect reproduction and recruitment of marine species like sardines and rockfish for several generations and result in substantial changes in abundance over time.

The offshore ecosystem is home to groundfish species (shelf and slope rockfish, flatfish, sablefish, and Pacific whiting); coastal pelagic species (sardines, anchovy, mackerel, and squid); salmon during the ocean phase of their life-cycle; highly migratory species (tuna, billfishes, and pelagic sharks); marine mammals (such as whales and dolphins), pelagic seabirds (including albatross and shearwaters); phytoplankton; and zooplankton (including euphausids, copepods, salps, and occasionally red crabs). These species respond to the environmental variability in the California Current in different ways. The abundance and landings of coastal pelagic fish stocks such as sardines vary considerably due to environmental fluctuations, particularly temperature. Such highly fecund and fast growing species undertake extensive migrations as far north as British Columbia, when their population is large, to feed in upwelling areas and they tend to concentrate spawning in areas like the Southern California Bight, perhaps to help retain larvae in coastal habitats where they are less likely to be swept offshore by the strong offshore transport conditions of major upwelling centers. Highly migratory species like albacore make long trans-Pacific migrations and actively seek productive areas and avoid unfavorable conditions. Long-lived, slow growing and moderately fecund species such as rockfish persist by maintaining many reproductive age classes through periods of unfavorable environmental conditions.

The most significant challenge to effective management of fisheries for these species is the lack of understanding of the interactions among environmental variability, recruitment fluctuations, and fishing pressure. The current management strategy for sardines, a species that has recovered over the last 20 years from extraordinarily low levels in the 1950s through the 1970s, now takes temperature into account because of its effect on sardine productivity. In the last two years, seven species of groundfish have been designated as overfished and will require many years and special management efforts to recover. In retrospect, this occurred primarily as a result of our poor understanding of the relatively low productivity of these species, particularly low recruitment for many of these species over the last three decades, and resulting harvest levels that were inadvertently set too high.

Populations of many fish species in the offshore ecosystem extend along the entire or a major portion of the west coast, and so their fisheries cross state and sometimes national boundaries. To ensure coordination and more effective coast-wide management, coastal pelagic species, groundfish, highly migratory species, and ocean salmon are regulated by the Pacific Fishery Management

Council, a regional body of states (California, Oregon, Washington, and Idaho), tribal representatives, and federal agencies that has authority for West Coast fisheries in offshore waters. For those species we share with Mexico (coastal pelagic species and some highly migratory species), no formal bilateral management agreement exists.

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Coastal Pelagic Species: Overview

Coastal pelagic resources are small to medium sized, schooling species, that migrate in coastal waters often near the ocean surface. California's major coastal pelagic species include Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), northern anchovy (*Engraulis mordax*), and market squid (*Loligo opalescens*). Coastal pelagic species (CPS) collectively comprise one of the largest marine fisheries in California with respect to biomass, landed volume, and revenue. Historically, commercial utilization of each species in this group has, for varying periods of time, been primarily canning for human consumption. Much of the CPS catch is now frozen for bait or export, but some is still canned for human consumption.

One characteristic common to coastal pelagic species is the highly dynamic nature of their populations with respect to movement, biomass, and availability to the fishery. "Boom or bust" population cycles of coastal pelagic stocks have been attributed to a number of key factors, including relatively short life-cycles, variable recruitment, and annual and longer-cycle variation in optimal habitats for spawning, larval survival, recruitment, and feeding. Large natural fluctuations in coastal pelagic species abundance have been accentuated in the past by human influence, as exemplified by the Pacific sardine during the 1940s and 1950s. Although there are many similarities in the life histories of these fish species, there also are differences. They are all open-ocean, relatively near-shore, schooling fish for most of their life-cycles, but jack mackerel occur as far as 600 miles offshore, and sardine spawn as far as 300 miles offshore. Each fish species matures at a relatively young age of one to three years; and while jack mackerel live to be 35 years old, relatively few individuals of the other species attain half this age. Market squid live up to only 10 months and are an average of only six months old when captured during spawning activities. The eggs and larvae of all the species are common in coastal areas, but beyond 200 miles offshore only jack mackerel eggs and larvae are commonly encountered in scientific collections. Anchovy, Pacific mackerel, and sardine are known to migrate seasonally along the coast. Jack mackerel migrate away from nearshore banks and islands at a relatively young age (four to six years) and, while they range from at least off Baja California, Mexico to the Gulf of Alaska, little is known about their migratory habits as older adults. Estimates of biomass date back to the 1930s for sardines and Pacific mackerel, and to the late-1940s for anchovy. While there are no time series estimates of jack mackerel biomass, age and length composition data are available since the late 1940s. Biomass estimates for market squid are difficult, if not impossible, to obtain using normal assessment methods, and future management of the squid resource will likely depend upon real-time estimates of spawning escapement.

CPS management has varied widely and prior to the 1970s, management was minimal. When sardine and Pacific mackerel biomasses were declining (in the mid-1960s), the commercial fishing industry proposed an anchovy reduction fishery. By the late 1960s, this reduction fishery was authorized by the California Fish and Game Commission, complete with quota, season, area, and size restrictions. Legislation followed in the early 1970s that established moratoria on the commercial take of Pacific mackerel and sardines. The resurgence of Pacific mackerel, and the transition to federal management (Pacific Fishery Management Council) for anchovy in 1978, were accompanied by strict management regimes that included requirements for annual quotas and assessments of anchovy biomass.

Pacific sardine showed early signs of an abundance resurgence in the early 1980s, and by the mid-1980s the State of California managed this species as required by Fish and Game Code with biomass assessments and annual quotas. In 1998, the sardine population was declared fully recovered, with fish once again extending from British Columbia to the Gulf of California, Mexico. With the coast-wide sardine expansion, the State of California recognized that it no longer had sufficient resources to effectively manage the sardine resource alone and petitioned the Pacific Fishery Management Council to consider federal management of CPS. In 1998, the Council approved Amendment 8 to the Northern Anchovy Fishery Management Plan, to place Pacific sardine, Pacific mackerel, jack mackerel, and market squid in the management unit with northern anchovy. Amendment 8 was approved by the Secretary of Commerce and modified the anchovy plan to conform to the recently revised Magnuson-Stevens Fishery Conservation and Management Act and changed the name to the Coastal Pelagic Species Fishery Management Plan. Implemented in January 2000, Amendment 8 requires a limited entry permit to commercially harvest coastal pelagic finfish species south of Point Arena, California, with open fishing access north of this latitude. Species managed under authority of the plan are divided into two categories, actively managed (initially Pacific sardine and Pacific mackerel) and monitored (initially northern anchovy, jack mackerel, and squid). Actively managed species require annual determination of harvest limits based on current biomass estimates. Harvest strategies for actively managed species account for all west-coast CPS catches including Mexico, natural variability in the stocks, and the importance of CPS as forage for other fish, marine mammals, and birds. Monitored species are not subject to mandated harvest limits based on current biomass estimates, although other management measures such as area closures may be employed. The State of California is developing its own management plan for market squid, and has already implemented interim measures which prohibit fishing on weekends, restrict the design and intensity of lights used as attracting devices, and place a three-year moratorium on new vessels entering the fishery.

The outlook for CPS and their fisheries will depend upon the forces of nature, economics, and the combined wisdom of resource users and managers. Environmental factors have inherent cycles that can affect each resource in short and long time scales. Fishery scientists are just beginning to understand the mechanisms that determine success or failure of coastal pelagic populations. Hopefully, resource managers will continue to use the growing knowledge base of how these species respond to the environment, implementing harvest policies accounting for this uncertainty. Future utilization of the west coast CPS will depend not only on resource health and availability, but also upon basic economics and events in world export markets. The anchovy fishery's largest historical commercial utilizations were the reduction fisheries in California and Baja California. These fisheries have ceased to exist, primarily for economic reasons, and yet anchovy abundance remains high enough to allow continued use as live bait for the recreational fishing industry and as a fresh-frozen product for human consumption. Pacific mackerel catches sustained the southern California purse seine fleet throughout the 1980s, with record average landings; however, recent biomass assessments indicate that the large population increase documented in the late 1970s has not been followed by further highly successful recruitment pulses. The decline in availability to the fishery of Pacific and jack mackerel through the 1980s lead to rapid expansion of the market squid and sardine fisheries in southern California during the 1990s. Fish processors freeze significant portions of the squid and sardine catch for export to Europe, Asia, and Australia where it is utilized for human consumption, bait, or aquaculture feed.

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California Market Squid

History of the Fishery

Distinguished by its volatility, success of the California market squid (*Loligo opalescens*) fishery fluctuates as a consequence of El Niño conditions and rapid changes in the export market. With significant expansion of fishing activity in southern California waters during the 1980s and 1990s, the market squid fishery has emerged as one of the most important in the state. During the 1990s, squid ranked as the largest California commercial fishery by volume in six years of the decade and ranked three times as the state's most valuable fishery resource in value of the catch. Among U.S. exports of edible fishery products in 1999, market squid ranked sixth by volume and sixteenth in value, higher than any other California commercial fishery.

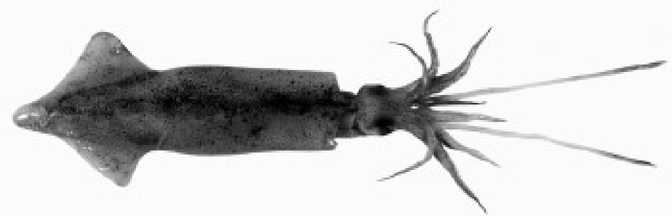
The vast majority of squid is frozen for human consumption. Much of this is exported to China, Japan and Europe. Other uses include fresh and canned squid for human consumption, and fresh or frozen squid for bait. The role of international buyers in the temporal success of the California market squid fishery is substantial. After decades of generally low catches, volume increased during the 1990s because of new (primarily Asian and European) markets and higher prices paid for California squid. However, landings and ex-vessel revenue declined during the 1997-1998 El Niño when squid became harder to catch and as overseas markets collapsed due to poor economic conditions in Asia. Currently, there has been some recovery of the Asian market, although demand is affected greatly by performance of other worldwide fisheries, particularly the Falklands *Loligo* fishery. In 1999 and 2000, California squid processors generally limited the daily catch from individual vessels to 30 tons per load, as supply of California squid could have exceeded international demand.

Although the volume of squid produced by California markets is dependent on the international market, the price paid to fishermen can influence both effort exerted toward fishing operations and overall volume of catch. Additionally, price paid to fishermen for their catch depends not only on market demand but availability of the resource. When volume of catch is low, the price paid per ton is high, exceeding $500 per ton during some months of the 1997-1998 El Niño when squid were scarce. When volume is high, as in the year 2000, the price is driven down and has been recorded at $100 per ton paid to some vessels bringing in full loads. Price paid for squid taken by brail and for squid purchased in low volumes by smaller local dealers tends to be significantly higher. Often times, the price of fish will start high at the beginning of the southern California season in November and decline as frozen product begins to accumulate in cold storage facilities. Consequently, there is often less incentive for fishermen to fish later in the season, and as a result, declines in landings for springtime months may not just reflect a reduction in the availability of squid, but also a lack of effort to fish for it. Additionally, many vessels participating in summer salmon fisheries will return to other ports during spring months.

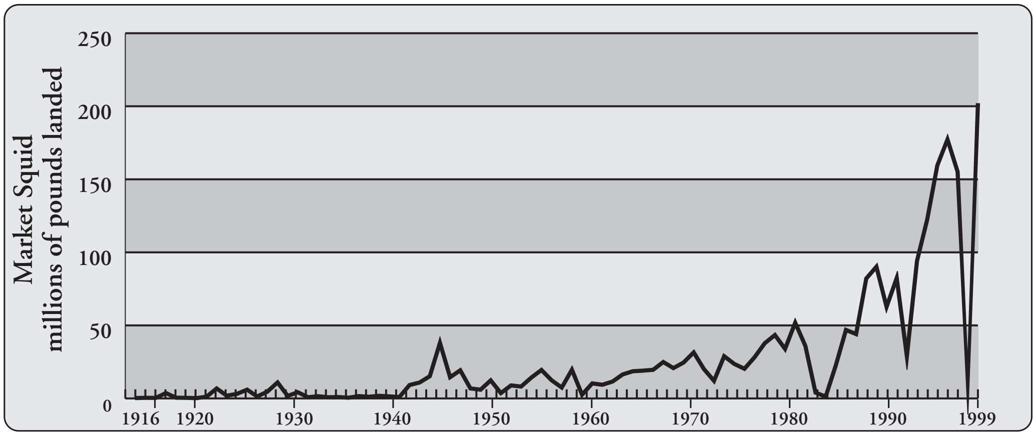
California markets also play a role in determining the composition of the market squid fleet. Although there are many California vessels which have historically participated in the fishery that are still active, there is an increasing proportion of fishery participants from Alaska, Washington and Oregon, reflecting a willingness of the markets to employ these vessels. During peak seasons, approximately 75 round haul vessels have produced about 95 percent of the California squid catch

Since 1961, the California squid fishery has experienced a major change. Prior to 1961, the fishery had been centered mainly in the Monterey Bay area, while a much smaller fishery existed off southern California. Central and southern California have distinctly different fisheries for market squid. Starting in 1961, the southern California squid fishery began to expand with a dramatic rise in landings in Santa Barbara area ports. Since 1985, the southern California fishery has dominated statewide landings while fishing areas have expanded, particularly in the Channel Islands. In recent years 90 percent of landings have occurred south of Point Conception, in sandy nearshore areas, when spawning activity is predominantly during winter months. Conversely, squid taken in the central California fishery, still centered in Monterey Bay, tend to aggregate and spawn during summer months.

Vessels fishing squid target schools that are aggregated in shallow water areas (from 50 to 150 feet deep) to spawn. Unlike other squid fisheries worldwide, the California fleet utilizes two vessels in fishing operations; a light vessel is used to locate and concentrate a school of squid using strong lights to attract squid to the surface. There they are caught using round haul nets deployed by a second vessel. A small fraction of squid sold commercially is caught by light vessels using brail gear. Additionally, a small volume of squid is taken by the live bait industry



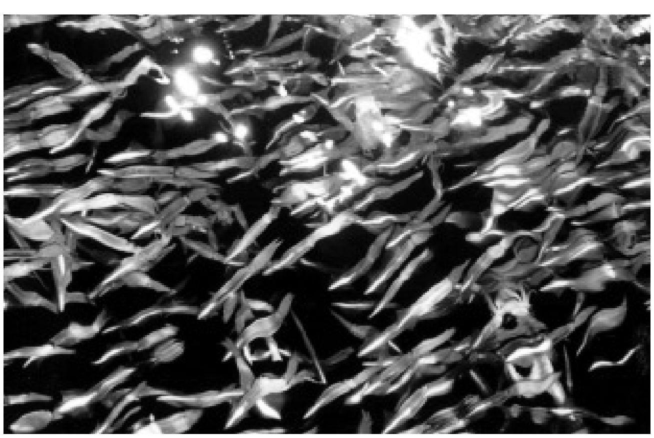
California Market Squid, *Loligo opalescens*
Credit: DFG



Commercial Landings 1916-1999, Market Squid
Data Source: DFG Catch Bulletins and commercial landing receipts.

While attracting lights have been used in the southern California fishery for many years, in the central California fishery a regulation was enacted which prohibited their use between 1959 and 1988. Fishermen sponsored the ban for protection from dealers who used lights in conjunction with dip nets on their piers and on floating unloading platforms. In this manner, they had effectively eliminated the need for many fishing boats. Some fishermen also believed that attracting lights disrupted squid spawning activity, but no studies to date have addressed that issue. In 1988, fishermen were allowed to use attracting lights in the Monterey Bay area, except in the southern portion of the bay. The following year, attracting lights were permitted throughout the area.

In 1999, the National Park Service brought to the attention of the Department of Fish and Game an apparent increase in nest abandonment and chick predation among shorebirds at the Channel Islands. The park service questioned whether the abundance of vessels lighting for squid near these islands during the nesting season in 1999 could be responsible. As an interim measure, the California Fish and Game Commission placed a statewide wattage restriction on vessels fishing commercially for squid, limiting both light boats and round haul vessels fishing squid to a maximum of 30,000 watts. Additionally, the Commission required these vessels to shield their lights to prevent emission of light onto shore.



Squid under lights
Credit: Jim Hardwick, DFG

Starting in 1989, fishermen were allowed to use all types of round haul gear (purse seine, drum seine, etc.) in the southern bight of Monterey Bay, which previously had been restricted to lampara nets for squid. By the end of 1990, nearly the entire fleet had switched over to purse seine or drum seine gear and the use of lampara nets had virtually ceased in Monterey Bay.

The market squid fishery was an unregulated, open access fishery prior to April 1, 1998. In order to assure sustainability of the resource, new legislation placed a three-year moratorium on the number of vessels in the fishery. This legislation required the purchase of a $2,500 per year permit for three years to land more than two short tons per trip or to attract squid by light for commercial harvest. In addition, participants must have purchased a permit the previous year. For the 2000-2001 squid fishing season (April 1 to March 31), 197 market squid vessel permits and 50 light boat permits were sold, down from originally 248 vessel permits and 54 light boat permits sold during the first season of the moratorium. The sale of market squid permits provided funds for scientific research and biological assessments of the resource for development of recommendations for a market squid conservation and management plan.

The same legislation provides for two committees, the Squid Fishery Advisory Committee and the Squid Research and Scientific Committee, established in 1998. These advisory groups serve to provide recommendations to the Director on squid research and monitoring, as well as to provide management recommendations for the fishery. In addition to the lighting restrictions, management measures recommended by either of the committees and approved by the Fish and Game Commission during 1999 included mandatory logbooks for squid vessels and light boats and statewide weekend closures for the fishery to allow for uninterrupted spawning activity.

Status of Biological Knowledge

The California market squid (*Loligo opalescens*) ranges from southeastern Alaska to Bahia Asunción, Baja California, Mexico. This pelagic mollusk attains a length of 12 inches, including its eight arms and two feeding tentacles. Several other squid species occur off the California coast, but these are normally associated with deeper offshore waters.

Spawning market squid tend to congregate in semi-protected bays, usually over a sand bottom with rocky outcroppings. Mass spawning starts around April in central California waters and ends about November. In southern California waters, mass spawning starts around October and ends about April or May. During some years, however, squid spawning, and landings, may occur throughout most of the year.

During spawning activity, the male transfers a bundle of spermatophores with a specialized left ventral arm into the female's mantle cavity near the oviduct. The eggs are laid within elongated, cigar-shaped capsules, each of which may contain as many as 300 eggs embedded in a gelatinous matrix. Each female produces from 20 to 30 egg capsules, attaching one end of each capsule to the sea floor or other suitable site. Females are visually stimulated to lay their eggs by the presence of other egg masses, resulting in egg capsule clusters covering vast areas, appearing to carpet the sandy substrate. Small red polychaete worms have been observed boring in the capsules' gelatinous substance, but apparently do not feed on the developing embryos. Bat stars and sea urchins, however, prey upon the eggs.

Depending on the ambient water temperature, squid eggs hatch in two to five weeks, with newly hatched paralarvae already resembling miniature adults. Squid feed predominantly on euphausiids and copepods, as well as other small crustaceans, gastropods, polychaete worms, small fishes and smaller squid. Squid are an important prey item for many fishes, birds and marine mammals, and studies indicate the market squid plays an important role in the food web of many organisms along California's coast.

Since 1998, research objectives being conducted by the department for market squid include: 1) collecting fishery and biological data through port sampling efforts; 2) conducting fishery independent surveys (i) utilizing a remotely operated vehicle (ROV) to characterize spawning habitats and measure egg density and (ii) midwater trawl surveys for relative abundance estimates; 3) culturing eggs and paralarvae to determine lowest viable temperature to resolve spawning range constraints; and 4) analysis of satellite data to track growth of the market squid fishery since 1992. Preliminary port sample data indicate that the average squid taken in the commercial fishery has a length of 5.2 inches and is approximately 185 days old.

Status of the Population

Little is known about the present size, structure or status of the population, but historical evidence from research cruises, as well as recent catch data, indicate the biomass is large. The California fleet fishes only spawning populations and in limited geographic areas, mostly in central and southern California. Other fishable concentrations of squid have been found occasionally along the coast from central California to British Columbia and southeastern Alaska, and short-term fisheries sometimes have developed in these areas.

Historically, the squid resource was considered by some to be underutilized; recently demand has sometimes exceeded the catch. Until more objective estimates of abundance are available, the true status of the population will remain unknown. Past work, and work elsewhere, has included acoustic surveys and various collection techniques. Acoustical assessment of squid has been attempted off the central Oregon coast. However, with the scientific research program initiated in 1998, efforts to model the population began which may eventually give rise to thorough and detailed stock assessments similar to those undertaken for other coastal pelagic species. It is hoped the preliminary modeling work, fishery-independent surveys and information from scientific research will allow for development of an effective management strategy for the resource by the year 2002.

Hauling a lampara net in Monterey Bay
Credit: Jim Hardwick, DFG

The market squid fishery is often subject to extreme fluctuations in availability due to El Niño events or other environmental conditions, and demand is largely dependent on international market forces. However, as typically seen in short-lived, highly fecund animals, the squid population seems to have the ability to recover fully in a relatively short period of time. Consequently, squid can probably be more intensively harvested than longer-lived marine fish.

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Packing squid in the Monterey Bay area
Credit: Jim Hardwick, DFG

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Pacific Sardine

History of the Fishery

A sustained fishery for Pacific sardines (*Sardinops sagax*) first developed in response to the demand for food during World War I. Demand grew, and fishing effort and landings increased from 1916 to 1936, when the catch peaked at over 700,000 tons. Pacific sardine supported the largest fishery in the Western Hemisphere during the 1930s and 1940s, with landings occurring in British Columbia, Washington, Oregon, and California. The fishery collapsed beginning in the late 1940s and declined, with short-term reversals, to less than 1,000 tons-per-year in the late 1960s. There was a southward shift in the catch as the fishery decreased, with landings ceasing in the northwest in the 1947-1948 season and in San Francisco in 1951-1952. Through the 1945-1946 season, most California landings were at Monterey and San Francisco, but San Pedro accounted for most subsequent landings.

Sardines were used primarily for reduction to fishmeal and oil, and canned for human consumption, with small quantities taken for live bait. Although most fish landed north of California were reduced, California processors began as canners, and expanded to reduction as a lucrative supplement. Reduction was often more profitable, and for many years reduction tonnage exceeded tonnage canned. An extremely lucrative dead bait market for sardines developed in central California in the 1960s, and was primarily responsible for continued fishing on the depleted resource.

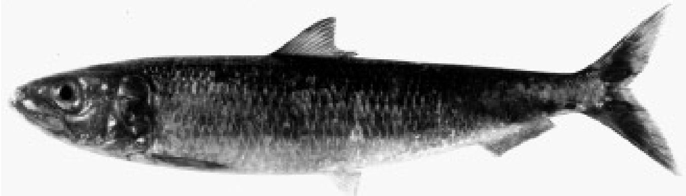
Prior to 1967, management of the sardine resource in California was mostly limited to: 1) control of tonnage of whole fish used for reduction; 2) case pack requirements (specified number of cases of canned fish per ton of whole fish); and 3) restriction of the fishing season. The first two controls were intended to lower the quantity of sardines used for reduction, since this was regarded as a less desirable use and demand for reduction products was high. The third control was designed to limit canning to periods when sardines were in prime condition and to improve the market for canned products. The total catch, however, was not regulated. From 1967 to 1973, California landings of sardines were limited to an incidental take of 15 percent sardines by weight mixed with other fish. Liberal provisions for use of incidental catch, and later a 250-ton dead bait quota still supplied the demand for bait. In 1974, a moratorium on fishing sardines was established, which restricted landings to the 15 percent incidental limit and eliminated the use of sardines for dead bait. This legislation also established the state's intent to rehabilitate the resource. Through 1981, sardine landings were less than 50 tons per year.

In the early 1980s, sardines were taken incidentally in the southern California Pacific and jack mackerel fishery. Most sardines from this source were canned for pet food, with a lesser amount canned for human consumption. A small directed fishery for sardines limited to 1,000 tons per year was permitted annually 1986 through 1990. The quota (excluding bait fisheries) was increased to 8,150 tons in 1991.

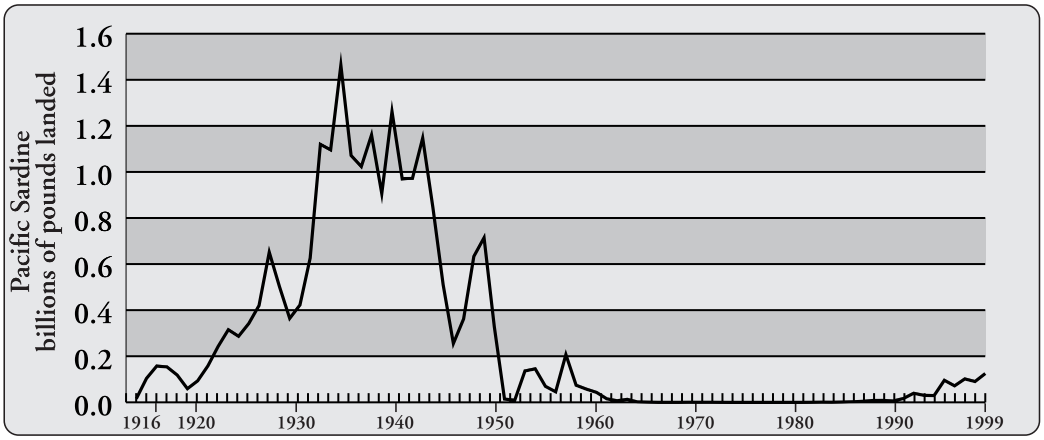
At the present time, sardines landed in the directed fisheries in southern and central California are primarily processed for human consumption (fresh or canned), pet food, or export. The majority of frozen exports are used as animal feed in Australian bluefin tuna aquaculture facilities. Small quantities are harvested for dead bait and live bait. With the exception of 1,217 tons reported in the PacFIN database for 1996, no reduction of sardines, other than waste produced from other processing operations, is taking place in California. Total annual landings of sardines have increased, from less than 100 tons in the 1970s, to an average of 13,400 tons per year through the 1980s, and 30,400 tons per year through the 1990s. Total sardine landings in California in 1999 were 62,600 tons.

Landings of sardines in Mexico increased from an annual average of 1,600 tons during the 1980s, to an average of nearly 42,000 tons per year through the 1990s. The total and average annual harvests by Mexico exceeded those for California over the period 1980 through 1999. Mexican landings of Pacific sardines, mackerels and herrings, are primarily used for reduction into fishmeal, with approximately 20 percent used for human consumption.

A federal fishery management plan (FMP) for coastal pelagic species in U.S. waters off the West Coast, including sardines, was implemented by the Pacific Fishery Management Council (PFMC) in January 2000, which transferred management authority from the California Department of Fish and Game (DFG) to the National Marine Fisheries Service (NMFS) through the PFMC. To calculate the 2000 harvest guideline, a formula selected by the PFMC in the federal management plan was used. Based on the 1999 estimate of total biomass, the 2000 sardine fishery opened January 1, with a harvest guideline of 205,902



Pacific Sardine, *Sardinops sagax*
Credit: DFG



Commercial Landings 1916-1999, Pacific Sardine Data Source: DFG Catch Bulletins and commercial landing receipts. Data includes sardines caught for reduction fishery between 1916 and 1969.

tons for the California fishery, a 65 percent increase over the 1999 DFG quota.

The price of sardines landed incidentally with mackerel decreased from about $190 per ton in the mid-1980s to about $150 per ton in 1991. The price for sardines landed in the directed fishery and canned for human consumption ranged from $80 to $100 per ton in the late 1990s. Only limited markets exist for canned products currently being produced. It remains to be seen whether new markets will develop to utilize the fully recovered population of Pacific sardines.

Status of Biological Knowledge

Sardines are small pelagic fish and members of the herring family, Clupeidae. The genus *Sardinops* occupies the coastal areas of warm temperate zones of nearly all ocean basins. The genus is considered monotypic, and *Sardinops sagax* is the correct scientific name for sardine populations in the Alguhas, Benquela, California, Kuroshio, and Peru currents, and for populations off New Zealand and Australia. In the northeast Pacific Ocean, as in most other areas, the Pacific sardine occurs with anchovy, hake, and mackerel. It is generally accepted that the Pacific sardine population consists of three subpopulations or stocks: a Gulf of California subpopulation, a southern subpopulation off Baja California, and the principal northern subpopulation ranging from northern Baja California to Alaska. These stocks were distinguished on the basis of serological techniques. A fourth, far northern subpopulation was also postulated. Recent electrophoretic studies and examination of morphological variation showed no genetic variation among sardines from central and southern California, the Pacific coast of Baja California and the Gulf of California.

Historically, the northern subpopulation of sardines made extensive migrations, moving north as far as British Columbia in the summer months and returning south to southern California and northern Baja California in the fall. Northward movement was greater with increased age. The migration was complex, and the timing and extent of movement were affected to some degree by oceanographic conditions. At present, the population is currently expanding, found primarily off central and southern California and Baja California, but extends as far north as Vancouver, British Columbia. Contraction and expansion of range and spawning area has been associated with changes in sardine population size around the world.

Estimates of sardine abundance from AD 280 to 1970 have been derived from the deposition of fish scales in sediment cores from the Santa Barbara basin. Significant sardine populations existed throughout the time period and varied widely in size, typically over periods of roughly 60 years. Population declines and recoveries averaged about 36 and 30 years, respectively. Scale data indicate that sardine populations were much more variable than anchovy populations. Studies of deposits of otoliths have shown that, while the anchovy has been present for a million years or more, no trace of sardines has been found that is more than seven thousand years old. The tendency for tremendous variations in sardine biomass may be a characteristic of a species that has only recently occupied its habitat.

Pacific sardines reach about 16 inches and live as long as 13 years but are usually less than 12 inches and eight years old. Most sardines in the historical and recent commercial catch were five years and younger. There is a good deal of regional variation in growth rate, with average size attained at a given age increasing from south to north. Sardine size and age at maturity may decline with a decrease in sardine biomass, although latitudinal and temperature effects may also play a part. At low biomass levels, sardines appear to be fully mature at age two, while at high biomass levels, only some of the two-year-olds are mature.

Sardines age three and older were nearly fully vulnerable to the historical fishery until 1953, but two and three year old fish became less available as the population declined and fewer southern fish moved northward. Recent catch data indicate sardines begin to become available to the fishery at age zero, and are fully vulnerable by age three. Sardines probably become vulnerable to the live bait fishery, which is located close to shore, at a younger age.

Spawning occurs in loosely aggregated schools in the upper 165 feet of the water column, probably year-round, with peaks from April to August from Point Conception to Magdalena Bay, and from January to April in the Gulf of California. The main spawning area for the northern subpopulation is between San Francisco and San Diego, out to about 150 miles offshore, with evidence of spawning as far as 350 miles offshore. Sporadic occurrences of spawning have been observed off Oregon and British Columbia in recent years.

Most spawning occurs between 55° and 63° F, with an apparent optimum between 59° and 61° F, and a minimum threshold temperature of 55° F. The spatial and temporal distribution of spawning is influenced by temperature; the center of sardine spawning shifts northward and continues over a longer period of time during warm water conditions. Pacific sardines are serial spawners and spawn several times each season, although the number of spawnings is not known. Eggs and larvae are found near the surface. The eggs are spheroid, have a distinct, large perivitelline space, and require about three days to hatch at 59° F.

Recruitment of Pacific sardines is highly variable. Analyses of the stock-recruitment relationship have been inconclusive and controversial, with some studies showing a density-dependent relationship and others finding no relationship whatsoever. From 1932 to 1965, mean recruitment only slightly exceeded potential replacement of spawners at all levels of abundance, indicating little resilience to fishing. Recruitment occurs in strings, with several years of successful recruitment followed by similar periods of poor recruitment. The timing and duration of these strings has a large effect on population growth.

A significant relationship exists among sardine reproductive success, spawning biomass and average sea surface temperature (SST). Recruitment, as well as predicted equilibrium biomass and maximum sustainable yield (MSY) are lower when temperatures are cooler.

Sardines are filter feeders and prey on crustaceans, mostly copepods, and other plankton, including fish larvae and phytoplankton. Larval sardines feed extensively on the eggs, larvae, and juvenile stages of copepods, as well as other zooplankton and phytoplankton.

Through all life stages, sardines are eaten by a variety of predators. Eggs and larvae are consumed by an assortment of invertebrate and vertebrate planktivores. Although it has not been demonstrated in the field, anchovy predation on sardine eggs and larvae has been postulated as a possible mechanism for increased larval sardine mortality during the 1950s and 1960s. Juvenile and adult sardines are consumed by other fish, including yellowtail, barracuda, bonito, tunas, marlin, mackerel, hake, and sharks; sea birds, such as pelicans, gulls, and cormorants; and marine mammals, including sea lions, seals, porpoises, and whales. It is likely that sardines will become more important as prey for numerous species, including species such as the state and federally listed California brown pelican, as the sardine resource continues to increase.

The Pacific sardine and other closely related species undergo similar interannual changes in abundance in several other temperate coastal regions of the world. Scientists in several countries have conducted joint studies of recruitment and biomass of these coastal pelagic stocks under the Sardine-Anchovy Recruitment Program. Knowledge of the population dynamics and variability of these clupeoid fishes may eventually contribute to the detection of the oceanographic effects of global climate change.

Status of the Population

Spawning biomass of the Pacific sardine averaged 3,881,000 tons from 1932 to 1934, and fluctuated from 3,136,000 to 1,324,000 tons from 1935 to 1944. The population then declined steeply over the next two decades, with some short reversals following periods of particularly successful recruitment, to less than 100,000 tons in the early 1960s. During the 1970s, spawning biomass levels were thought to be as low as 5,000 tons. Since the early 1980s, the sardine population has increased, and the total age-one-plus biomass was estimated to be greater than 1.7 million tons in 1998 and 1999.

Maximum sustained yield of Pacific sardine in the historical northern subpopulation was estimated to be 250,000 tons or about 22 percent per year, far less than the catch of sardines during the height of the fishery. Although combined landings in the U.S. and Mexico are still well below this level, landings have increased substantially in recent years. In the absence of a bilateral management agreement between the U.S. and Mexico, combined U.S. and Mexican catches of Pacific sardine have the potential for accelerating the next population decline.

Disagreement over whether the decrease in the sardine population was due to overfishing or to natural changes in the environment has persisted for many years. It is now apparent that both factors are important. Following the cessation of fishing and with the development of favorable environmental conditions, the sardine resource is now recovered.

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Northern Anchovy

History of the Fishery

Three separate fisheries in both California and Mexico exploit northern anchovy (*Engraulis mordax*). Anchovy landed by the reduction fishery are converted to meal, oil, and soluble protein. These products are sold mainly as protein supplements for poultry food, and also as feed for farmed fish and other animals. Meal obtained from anchovy is about 65 percent protein compared to about 50-55 percent for meal from other fishes.

Anchovy harvested by the live bait fishery are not landed but kept alive for sale to anglers as bait. Transactions between buyers and sellers of live bait take place at sea or at bait wells tied up at docks. Live bait dealers generally supply bait to commercial passenger fishing vessels (CPFVs) on a contract basis and receive a percentage of the fees paid by passengers. Bait is also sold by the "scoop" to anglers in private vessels. Anchovy landed by the non-reduction (other than live bait) fishery are used as dead frozen bait, fresh fish for human consumption, canned fish for human consumption, animal food, and anchovy paste.

Reliable records of California landings of northern anchovy date from 1916. Landings were small until the scarcity of Pacific sardines caused processors to begin canning anchovies in quantity during 1947, when landings increased to 9,464 tons in 1947 from 960 tons in 1946. To limit the quantity of anchovies being reduced to fishmeal, the California Fish and Game Commission required each processor to can a large proportion of the harvest (40-60 percent depending on can size). Anchovy landings declined with the temporary resurgence of sardine landings around 1951. Following the collapse of the sardine fishery in 1952, anchovy landings increased to nearly 43,000 tons in 1953, but subsequently declined due to low consumer demand for canned anchovy and increased sardine landings. Landings remained low through 1964. During the early years (1916 through 1964), anchovy were harvested almost exclusively by California fishermen. Mexico did not begin harvesting anchovy until 1962.

Beginning in 1965, the California Fish and Game Commission managed anchovy on the basis of a reduction quota. This quota had been taken by a fleet of approximately 40 small purse seine vessels operating off southern California known collectively as the "wetfish" fleet, which fishes for other species in addition to anchovy. In 1965, only 171 tons of anchovy were landed for reduction, which increased to an average of over 64,000 tons per year between 1965 and 1982. After 1982, reduction landings decreased dramatically to an average of only 923 tons per year from 1983 to 1991, and fell to zero in 1992 through 1994. During the period 1995 to 1999, only four tons were reported as reduction landings. Although Section 147 of Title 14, California Code of Regulations, currently provides a process for the California Department of Fish and Game (DFG) to issue permits for reduction fishing, decreased prices of fishmeal and the low prices offered to fishermen have deterred any significant reduction fishing in recent years.

The non-reduction live-bait fleet in recent years has consisted of about 18 boats that are distributed mostly along the southern California coast to serve the principal sport fishing markets. Live bait boats fish for a variety of species, but anchovies comprised approximately 85 percent of the catch prior to 1991. Pacific sardines became available to the live bait fishery again in 1992, and the composition of live bait catches shifted from primarily anchovy to primarily sardine. From 1996 through 1999, sardines constituted approximately 72 percent of the live bait catch. Historically, the anchovy live bait catch ranged from 4,000 to 8,000 tons per year and averaged approximately 4,500 tons annually between 1974 and 1991. This average dropped to slightly over 2,500 tons between 1992 and 1994. Current estimates of the live bait catch are available from the DFG Pelagic Fisheries Assessment Unit in La Jolla, California. Non-reduction (other than for live bait) landings averaged slightly over 2,200 tons per year from 1965 to 1994, and increased to an average of about 4,122 tons per year between 1995 and 1999.

Anchovy landed in Mexico, other than a small amount used for bait, have been used primarily for reduction. Mexico's harvesting and processing capacity increased significantly in the late 1970s when several large seiners were added to the fishing fleet and a large reduction plant was constructed in Ensenada. Mexican anchovy landings averaged approximately 85,500 tons from 1962 to 1989, with a high of over 285,000 tons in 1981. Northern anchovy catch decreased sharply in 1990, and despite landing 19,600 tons in 1995, average annual Mexican landings from 1990 to 1999 were only 3.600 tons.

The U.S. northern anchovy central subpopulation fisheries have been managed by the Pacific Fishery Management Council since 1978, and the central and northern subpopu-

Northern Anchovy, *Engraulis mordax*
Credit: DFG

amended to include all four species of finfish collectively known as coastal pelagic species (CPS); Pacific sardine, Pacific mackerel, jack mackerel, in addition to northern anchovy, and has been renamed as the Coastal Pelagic Species Fishery Management Plan. Regulations described in the fishery management plan designate the northern anchovy fishery as not actively managed due to low fishery demand and high stock size. If conditions change, and active management is required, then provisions in the fishery management plan require calculation of an Allowable Biological Catch (ABC) for northern anchovy fisheries in U.S. waters. As of May 31, 2000, there were 63 vessels licensed to fish CPS finfish under the NMFS limited entry program, which is in effect south of 39° N. latitude (Pt. Arena, California). North of this area, there is open access to the fishery.

Maximum Sustainable Yield (MSY) for northern anchovy in the central subpopulation is estimated to be 135,600 tons per year at a total biomass level of about 808,000 tons. At present, northern anchovy are not actively managed, but a recommended default MSY control rule gives an ABC for the entire stock equal to 25 percent of the MSY catch, or just over 34,000 tons. An estimated 82 percent of the stock is resident in U.S. waters. ABC in U.S. waters is, therefor, 82 percent of 34,000 tons or 27,600 tons. Under federal management, there is no longer a separate quota for reduction landings of anchovy. Although fisheries in Mexican as well as U.S. waters harvest the northern anchovy, there is no bilateral management agreement with Mexico. The Mexican fishery is managed independently and is not restricted by a quota.

Economics explain a great deal about the current dynamics of anchovy fisheries in California, because the fisheries are more limited by prices and markets than by biological constraints. The price paid to fisherman for anchovy landed as live bait in southern California was about $440 per ton in 1999, slightly less than the $480 per ton paid for sardines as live bait. Although prices and revenues for live bait tend to be surprisingly high, annual catches have been modest due to market limitations.

During 1981 to 1999, the price paid for anchovy landed for non-reduction purposes other than live bait averaged about $330 per ton. As with live bait, market limitations have resulted in modest annual catches despite relatively high prices paid to fishermen.

The average price for anchovy landed by the U.S. reduction fishery during 1981 to 1999 was about $80 per ton, but the price paid during 1997 was only $40 per ton. Low prices, as well as market problems have prevented a significant U.S. reduction fishery in recent years.

Status of Biological Knowledge

Northern anchovy are distributed from the Queen Charlotte Islands, British Columbia to Magdalena Bay, Baja California. The population is divided into northern, central, and southern subpopulations or stocks. The central subpopulation ranges from approximately San Francisco, California to Punta Baja, Baja California, with the bulk being located in the Southern California Bight.

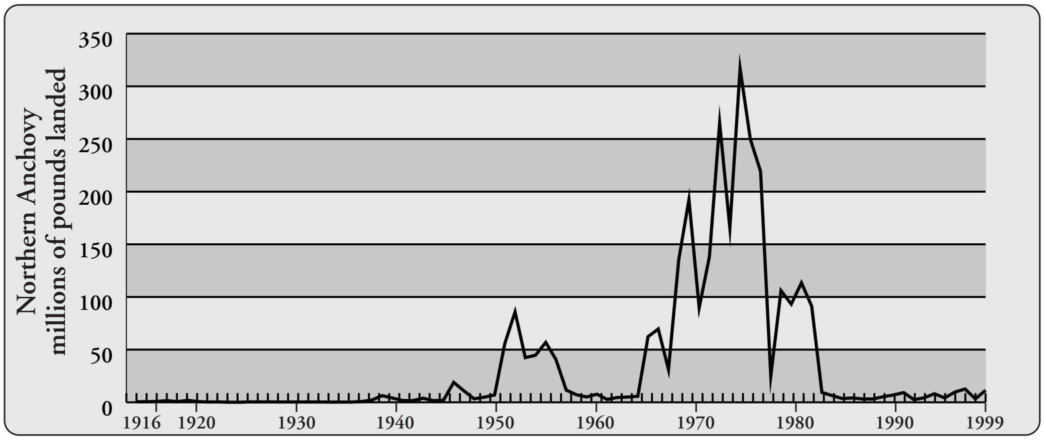
Northern anchovies are small, short-lived fish typically found in schools near the surface. They rarely exceed four years of age and seven inches total length, although individuals as old as seven years and nine inches have been recorded. There is a great deal of regional variation in age composition (number of fish in each age group) and size at age with older fish and larger fish found at relatively offshore and northerly locations. In warm years, relatively old and large fish are found farther north than during cool years. These patterns are probably due to northern and offshore migration of large fish, regional differences in growth rate, and water temperatures. Northern anchovies in the central subpopulation are typically found in waters that range from 54° to 71° F.

Information about changes in anchovy abundance during 1780 to 1970 is available from scales counted in sediment cores from the Santa Barbara basin. These data indicate significant anchovy populations existed throughout the time period and that biomass levels during the late 1960s were modest relative to those during most of the 19th and early 20th centuries.

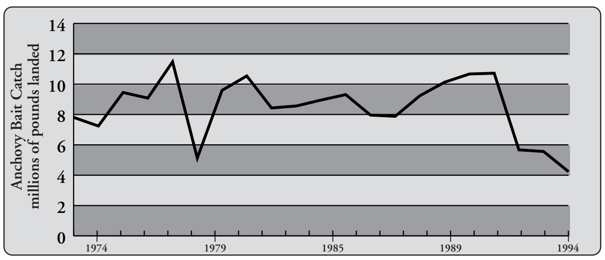
The age at which northern anchovy become vulnerable to California fisheries depends on the location of the fishery and type of fishery. Fish become vulnerable to the inshore live bait fishery at an earlier age than they become vulnerable to the reduction fishery. However, substantial numbers of zero and one-year-old fish are taken by both fisheries in most years.

Anchovy are all sexually mature at age two. The fraction of one-year-olds that is sexually mature in a given year depends on water temperature and has been observed to range from 47 to 100 percent. They spawn during every month of the year, but spawning increases during late winter and early spring and peaks during February to April. Spawning has been observed over a temperature range of 54° to 71° F. Individual females spawn batches of eggs throughout the spawning season at intervals as short as seven to 10 days. The eggs are found near the surface, and require two to four days to hatch, depending on water temperatures. Eggs and larvae are both found near the surface.

Northern anchovy are subject to intense predation throughout all life stages. Anchovy eggs and larvae fall prey to an assortment of invertebrate and vertebrate



Commercial Landings 1916-1999, Northern Anchovy
Data Source: DFG Catch Bulletins and commercial landing receipts.



Live Bait landings of anchovy in CA, 1974-1994
Data source: DFG Database

planktivores. As juveniles in nearshore areas, anchovies are vulnerable to a variety of predators, including birds and some recreationally and commercially important species of fish. As adults offshore, anchovies are fed upon by numerous marine fishes (some of which have recreational and commercial value), mammals, and birds, including the state and federally listed California brown pelican. A link between brown pelican breeding success and anchovy abundance has been documented.

Northern anchovy eat plankton either by filter feeding or biting, depending on size of the food. Adult anchovy are known to filter anchovy eggs and it is possible that this type of cannibalism is an important factor in regulating population size.

Status of the Population

Estimates of the biomass of northern anchovy in the central subpopulation averaged 359,000 tons from 1963 through 1972, increased rapidly to over 1.7 million tons in 1974 and then declined to 359,000 tons in 1978. Since 1978, biomass levels have tended to decline slowly, falling to an average of 289,000 tons from 1986 through 1994. Anchovy biomass during 1994 was estimated to be 432,000 tons.

Total anchovy harvests and exploitation rates since 1983 have been below the theoretical levels for maximum sustained yield, and stock biomass estimates are unavailable for recent years but, based on abundance index data, the stock is thought to be stable at a modest biomass level. The size of the anchovy resource is now being determined mostly by natural influences, such as ocean temperature.

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Pacific Mackerel

History of the Fishery

Pacific mackerel (*Scomber japonicus)*, also called chub mackerel or blue mackerel, are harvested by three separate fisheries – the California commercial fishery, a sport fishery based primarily in southern California, and the Mexican commercial fishery. In the commercial fisheries, Pacific mackerel are landed by the same boats that catch jack mackerel, Pacific sardine, and market squid.

Pacific mackerel supported one of California's major fisheries during the 1930s and 1940s and again in the 1980s. The canning of Pacific mackerel began in the late 1920s and increased as greater processing capacities and more marketable packs were developed. Landings decreased in the early 1930s, due to the economic depression and a decline in demand, and then rose to a peak of 73,214 tons in 1935. During this period, Pacific mackerel was second only to Pacific sardine in annual landings. The mackerel fishery then experienced a long, fluctuating decline. A moratorium was placed on the fishery in 1970 after the stock had collapsed.

In 1972, legislation was enacted which imposed a landing quota based on the age one-plus biomass. A series of successful year classes in the late 1970s initiated a recovery, and the fishery was reopened under a quota system in 1977. During the recovery period from 1977 to 1985, various adjustments were made to quotas for directed take of Pacific mackerel and to incidental catch limits. These measures were intended to lessen the impact of the recovering population on the jack mackerel fishery, and to accommodate the development of the Pacific mackerel fishery as the population increased. From 1990 through 1999, Pacific mackerel accounted for 87 percent of total mackerel landings in California. Pacific mackerel ranked third in volume of California finfish landings throughout the 1990s.

Before 1928, when canning began, Pacific mackerel were landed incidentally in the sardine fishery and used primarily as fresh fish. For many years, demand for canned mackerel was steady and exceeded supply. Following the recovery, the market for canned mackerel has fluctuated due to availability and economic conditions. At present, most Pacific mackerel is used for human consumption, canned, or used for pet food, with a small but increasing amount sold as fresh fish. Minor amounts of Pacific mackerel are used by anglers for live and dead bait. Mackerel prices increased from $45 per ton in 1956 to $315 in 1981, but have declined to $120 per ton in 1999. Domestic demand for canned Pacific mackerel appears to have decreased in recent years. During the early fishery, Pacific mackerel were taken by lampara boats, which were replaced in the 1930s by the same purse seine fleet that fished for sardines. The purse seiners fished for Pacific mackerel until the moratorium in 1970, and were able to fish for jack mackerel, northern anchovy, and other species until the fishery reopened in 1977. Fishing originally occurred near port, but by the late 1930s it extended along the entire coast from San Diego to Santa Barbara, and included the Channel Islands. Beginning in the 1952-1953 season, fishing extended to Tanner and Cortez Banks.

Pacific Mackerel, *Scomber japonicus*
Credit: DFG

Until the mid-1950s, there was a seasonal pattern to the fishery. Pacific mackerel were mostly unavailable from January through May, then increased in availability until late fall. Most of the catch was taken by purse seiners until September, when the sardine fishery began. During the declining years of the fishery, catches became more sporadic, with no apparent seasonal patterns.

At present the purse seine fleet fishes the Southern California Bight, including the Channel Islands and offshore banks. A small portion of the catch (approximately 10 percent in recent years) is taken in the Monterey Bay area. The purse seine fleet fishes year-round. Landings are typically slow during April and May, increase beginning in June, peak during the third quarter of the year, and decrease after September. As of June 2000, 63 purse seiners hold permits to participate in the NMFS limited entry fishery for coastal pelagic species, which is in effect south of 39° N. latitude (Pt. Arena, California). North of this area, there is open access to the fishery. These vessels participate not only in the Pacific mackerel fishery, but also take jack mackerel, Pacific sardine, northern anchovy, and market squid. Other types of gear take Pacific mackerel incidentally.

Pacific mackerel fisheries in California were managed by the state through 1999, and a fishery management plan (FMP) for coastal pelagic species, including Pacific mackerel, was implemented by the Pacific Fishery Management Council (PFMC) in January 2000. State regulations, enacted in 1985, had imposed a moratorium on directed fishing when the total biomass was less than 20,000 tons, and limited the incidental catch of Pacific mackerel to 18 percent during a moratorium. The fishing season for Pacific mackerel was set to extend from July 1 to June 30 of the following year. A seasonal quota, equal to 30 percent of the total biomass in excess of 20,000 tons had been allowed when the biomass was between 20,000 and 150,000 tons, and there was no quota when the total biomass was 150,000 tons or greater. From 1985 to 1991, the biomass exceeded 150,000 tons and no quota restrictions were in effect. The quotas from the period 1992 through 2000 averaged 24,445 tons, with a high at 47,200 tons set by the PFMC for the 1999-2000 fishing season.

Pacific mackerel have ranked among the top 11 most important sportfish caught in southern California waters, primarily because they are abundant rather than desirable. The recreational catch of Pacific mackerel averaged 1,500 tons per year from 1977 through 1991, and 700 tons per year from 1993 through 1999. During the commercial fishing moratorium, the sport fishery became the largest exploiter of Pacific mackerel in California. The recreational catch increased during the late 1970s and early 1980s, with more than one million fish per year caught from 1979 through 1981. Recent estimates of annual recreational catches indicate a steady decline since 1981 to about 200 tons of Pacific mackerel in southern California in 1999. The catches from commercial passenger fishing vessels (CPFVs) have declined from a peak in 1980 of over 1.31 million Pacific mackerel, and an average of over 700,000 fish per year during the 1980s, to an average of slightly over 330,000 fish per year through the 1990s. The reported CPFV catch in 1998 totaled only 136,614 fish.

Demand for Pacific mackerel in Baja California, Mexico increased after World War II. Mexican landings remained stable for several years, rose to 8,000 tons in 1963, then declined to a low of 100 tons in 1968. Catches remained insignificant until the mid-1970s. During the period 1990 to 1999, annual landings of Pacific mackerel in Ensenada peaked twice, first in 1990 at 39,426 tons, and again in 1998 at 55,916 tons. The average for Baja California annual landings during the 1990s was 20,108 tons per year. Mexican landings of Pacific and jack mackerels, Pacific sardines, northern anchovy, and round herrings, are primarily used for reduction into fishmeal, and approximately 20 percent used for human consumption.

Status of Biological Knowledge

Pacific mackerel occur worldwide in temperate and subtropical coastal waters. In the eastern Pacific, they range from Chile to the Gulf of Alaska, including the Gulf of California. They are common from Monterey Bay, California to Cape San Lucas, Baja California, but are most abundant south of Point Conception, California. Pacific mackerel usually occur within 20 miles of shore, but have been taken as far offshore as 250 miles.

Adults are found in water temperatures ranging from 50.0° to 72.0° F and larvae in 57.2° to 70.0° F. Adults occur from the surface to 1,000 feet deep. Sub-adult and adult Pacific mackerel in the northeastern Pacific move northward along the coast during the summer. The most northerly records occur during El Niño events. There is an inshore-offshore migration off California, with increased abundance inshore from July to November and increased abundance offshore from March to May. Pacific mackerel are typically found near shallow banks, and juveniles are commonly found off sandy beaches, around kelp beds, and in open bays.

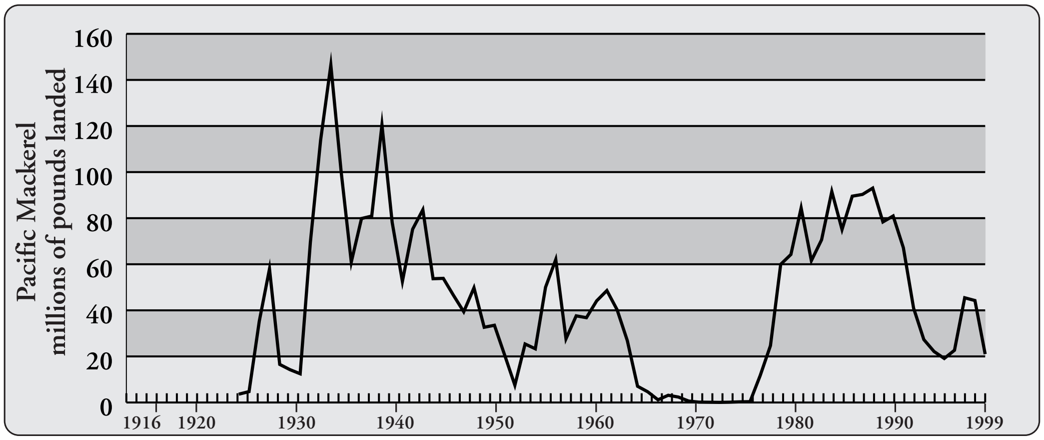
The largest recorded Pacific mackerel was 24.8 inches and weighed 6.4 pounds, although commercially harvested Pacific mackerel seldom exceed 16 inches and two pounds. Growth is believed to be density-dependent, as fish reach much higher weights-at-age when the population size is small. The oldest recorded age, determined by otolith reading, was 12 years, but most Pacific mackerel in the commercial catch are less than four years old. Some Pacific mackerel mature as one-year olds, although most are not sexually mature until age two or three. Pacific mackerel become available to the commercial fishery in their first year of life and are not fully recruited to the fishery until age four. However, substantial numbers of younger fish are taken by the commercial fishery and make up the bulk of the catch.

Recruitment of Pacific mackerel is variable and loosely linked to the size of the spawning biomass. Reproductive success is somewhat cyclical, with periods of roughly three to seven years. The annual rate of natural mortality is thought to be approximately 40 percent in the absence of fishing.

There are three spawning stocks in the northeastern Pacific – one in the Gulf of California, one near Cape San Lucas, and one along the Pacific coast north of Punta Abreojos, Baja California. Spawning occurs from Eureka, California to Cape San Lucas, two to 200 miles offshore, and in the Gulf of California.

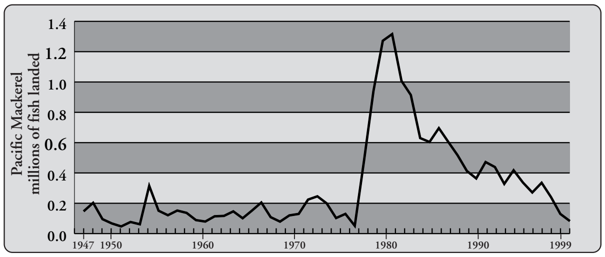
Off California, spawning occurs from late April to July at depths to 300 feet. Individual fish may spawn eight times or more per year and release at least 68,000 eggs per spawning. Off Baja California, spawning occurs from June through October.

Pacific mackerel larvae eat copepods and each other. Larvae normally begin to feed within 50 hours of hatching. Juvenile and adult Pacific mackerel feed primarily on small fishes, fish larvae, squid, and pelagic crustaceans such as euphausiids.



Commercial Landings 1916-1999, Pacific Mackerel
Data Source: DFG Catch Bulletins and commercial landing receipts. Pacific mackerel were aggregated as unclassified mackerel prior to 1926.

Pacific mackerel larvae are subject to predation from a number of invertebrate and vertebrate planktivores. Juvenile and adults are eaten by larger fishes, marine mammals, and seabirds. Pacific mackerel school as a defense against predation, often with other pelagic species, including jack mackerel and Pacific sardine. Principal predators include porpoises, California sea lions, brown pelicans, striped marlin, black marlin, sailfish, bluefin tuna, white seabass, yellowtail, giant sea bass, and various sharks.



Recreational Catch 1947-1999, Pacific Mackerel
Data source: DFG commercial passenger fishing vessel (CPFV) logbooks

Status of the Population

Historical estimates of Pacific mackerel biomass along the Pacific Coast indicate a decline in total biomass from 1932 until 1952. After a brief resurgence, the population reached a peak in 1962, then declined to less than 10,000 tons by 1966, and remained low until the late 1970s.

A series of successful year classes beginning in 1976 brought about a resurgence, and the age one-plus biomass peaked in 1982, at over one million tons. Since then, it has precipitously declined. Recent stock assessments indicate that biomass in the late 1990s was approximately 120,000 tons. Information derived from deposits of Pacific mackerel scales on the sea floor indicates that the prolonged period of high biomass during the late 1970s and 1980s was an unusual event that might be expected to occur about once every 60 years.

It is estimated that the maximum long-term yield of Pacific mackerel might be 29,000 to 32,000 tons under management systems similar to that in current use. It is difficult to assess the effects on the catch of recent warm temperatures, possible changes in availability of young fish, and the deteriorating markets. However, it is unlikely that the recent high harvest levels can be sustained.

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Jack Mackerel

History of the Fishery

The jack mackerel (*Trachurus symmetricus*), originally known as horse mackerel, was reported in the commercial catch as early as 1888, and was a minor component of the coastal pelagic species (CPS) fishery until 1947. The CPS fishery uses encircling nets (purse and drum seine, and lampara nets) to target market squid, Pacific sardine, Pacific mackerel, northern anchovy, and jack mackerel in the waters off California. Much of the catch between 1926 and 1946 was taken incidentally with sardine and Pacific mackerel and was sold at fresh fish markets where it did not spoil as quickly as Pacific mackerel. Landings were low, varying between 200 and 15,000 tons annually and comprising less than three percent of the CPS landings each year.

In 1947, jack mackerel landings increased almost tenfold to 65,000 tons as the canning industry turned to jack mackerel in the face of the collapsing sardine fishery. The U.S. Food and Drug Administration authorized changing the common name from horse mackerel to jack mackerel in 1947 to increase consumer appeal. Between 1947 and 1979, jack mackerel landings ranged from 800 to 73,000 tons, comprising six percent to 65 percent of the annual CPS landings.

The recovery of the Pacific mackerel population in the late 1970s shifted effort away from jack mackerel. The CPS fleet prefers Pacific mackerel, because jack mackerel occur farther from port and tend to aggregate over rocky bottom where there is increased chance of damage to the encircling nets. The recovery of the Pacific sardine and increased demand for squid worldwide have also contributed to the decline in jack mackerel landings in California.

Since 1991, jack mackerel has been caught primarily from December through April, with landings low during the remainder of the year. Landings have averaged less than 2,000 tons each year, comprising only two percent of the CPS landings. Most of the catch occurs in southern California.

The CPS fleet catches jack mackerel only when the young fish, less than six-years-old form schools near the surface. As jack mackerel grow older, their behavior changes, and they inhabit deeper waters farther offshore. The unpredictable availability of jack mackerel also plays a part in the erratic catches, since there are times when the fleet cannot find jack mackerel schools for several months.

Large, adult jack mackerel were taken incidentally in the Pacific whiting (hake) trawl fishery off California in the 1970s and 1980s. Because of this, jack mackerel was included in the Pacific Fisheries Management Council's (PFMC) Pacific Coast Groundfish Fishery Management Plan (FMP). The allowable biological catch (ABC) and equivalent quota for jack mackerel was set at 13,230 tons from 1983 to 1990 for the fishery which occurs north of 39° latitude (Point Arena). The fishery south of 39° is not regulated. In 1991, the ABC was raised to 57,990 tons and the quota to 51,530 tons where it remained throughout the 1990s.

Since much of the trawl-caught jack mackerel is discarded at sea, total catch is not available. Estimates of jack mackerel caught by Pacific whiting trawlers has ranged from less than 500 tons to over 2,000 tons in the 1970s and 1980s. After a US-USSR survey of jack mackerel conducted in 1991, an experimental fishery was attempted off California. Large factory trawlers from Alaska came south searching for jack mackerel, but found few fish and the fishery never developed.

In the early 1990s, southern California fishermen and processors became concerned over the possible expansion of the jack mackerel fishery and lobbied heavily for Federal management of the CPS fishery. In 1999, the Coastal Pelagic Species Fishery Management Plan (CPS FMP) was adopted by the PFMC and jack mackerel was included in the plan as a monitored species and dropped from the Pacific Coast Groundfish FMP. The CPS FMP sets the ABC at 52,910 tons with a quota of 34,170 tons based on the portion (65 percent) of the population in US waters. Should the jack mackerel catch exceed the quota for two consecutive years, the PFMC would have to decide whether to change the fishery to active status, resulting in a need for an annual biomass estimate and subsequent harvest guideline.

In addition to the whiting trawl fishery, a few adult jack mackerel are also taken in the northern California salmon troll fishery. Landings from the salmon fishery are a small portion (less than one percent) of the total jack mackerel landings.

Large jack mackerel have occasionally contributed to the commercial passenger fishing vessel (CPFV or partyboat) sport fishery. In 1953, a run of large fish was encountered in southern California, which contributed 13 percent of the CPFV catch in southern California and 8.6 percent

Jack Mackerel, *Trachurus symmetricus*
Credit: DFG

statewide. That was an exceptional year and, since then, jack mackerel have been of minor importance in the CPFV catch. Smaller jack mackerel are caught at times from fishing piers in southern and central California. Since 1980, recreational landings have been highly variable, ranging from an estimated 5,000 fish to over 350,000, based on data collected by Pacific States Marine Fisheries Commission samplers. These data are expanded from direct observations and information collected from anglers. For minor recreational species, such as jack mackerel, these expansions may greatly over-estimate the catch. Live bait landings of jack mackerel in the 1990s have been negligible due to a preference for Pacific sardine and northern anchovy as bait by sport anglers.

Status of Biological Knowledge

Jack mackerel are actually members of the jack family, Carangidae, and are not true mackerel. They are widely distributed throughout the northeastern Pacific Ocean, where young fish (up to six years and 12 inches fork length) are found schooling over shallow rocky reefs, generally less than 200 feet deep, and along rocky shorelines of the coast and islands off southern California and Baja California. Large fish (16 years and older and 20 inches fork length) are found offshore and farther north, east of a line that goes from Cabo San Lucas to the eastern Aleutian Islands, and includes the Gulf of Alaska. The offshore segment of the population does not form the dense, shallow-water schools observed in young fish. The distribution of jack mackerel between six and 15 years is not well known. The movement of the larger fish into the Gulf of Alaska appears to be related to summer warming of the surface waters. Not all of the large fish migrate north, since some large jack mackerel are caught off southern California and Baja California waters throughout the year.

Jack mackerel spawn in the offshore waters (60 - 300 miles) between Punta Eugenia and Point Conception from March through July. The center of offshore spawning activity moves north as the season progresses. There is little production in the inshore waters (up to 80 miles) of the Southern California Bight until July, presumably when the young fish begin to spawn. Little is known about the seasonal and geographic limits of the offshore and northern spawning areas. A 1955 survey found jack mackerel eggs and larvae offshore (100 - 1,000 miles) off Oregon and Washington in August. A second survey in October 1972 found an area of spawning jack mackerel 200 to 600 miles off Washington.

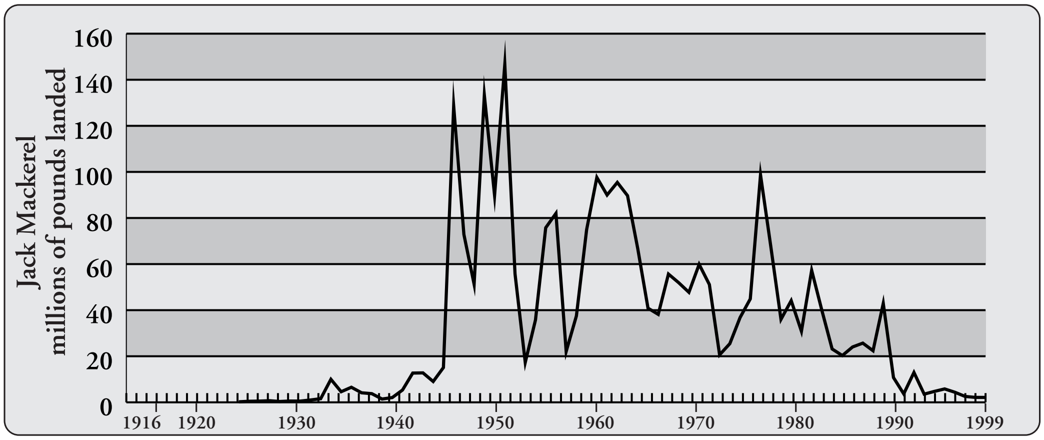
Like anchovy and Pacific mackerel, jack mackerel appear to be multiple spawners, with females spawning on average every five days and 25 times per year. Batch fecundity (number of eggs per spawning event) changes over time with females producing almost 104,000 eggs during the first spawning event and 73,000 during subsequent events. Most (70 percent) female jack mackerel from the southern California fishery become mature around their first birthday. By their second birthday, 90 percent of the females are spawning. Most of the eggs are spawned in 57° to 61° F water. Eggs are about 0.04 inches in diameter and float free in the ocean for three to five days before hatching, depending on the water temperature.

Larval jack mackerel feed primarily on copepods. Juvenile jack mackerel seem to prefer copepods, pteropods, and euphausiids, although at times they feed almost exclusively on juvenile squid and anchovies. Food habits of the older, offshore fish are unknown. Jack mackerel are preyed upon by large fish like tuna and billfish. Smaller fish and marine birds are unlikely to feed on jack mackerel, except young-of-the-year and yearlings, because they are too large to be eaten. A study of the diet of the California sea lion in the northern Channel Islands from 1981 to 1995 found that jack mackerel ranked as the fourth most frequently occurring species. The importance of jack mackerel in the diet of other marine mammals is not well known.

Status of the Population

The most recent estimate of total biomass was made-more than 17 years ago, in 1983. Total biomass was estimated at 1.63 to 1.99 million tons with spawning biomass accounting for 1.50 million tons. These estimates must be viewed as tentative approximations of the population because of two factors. First, at the time, the spawning frequency of jack mackerel was not known, and estimates were based on the spawning frequencies of northern anchovy (15 percent of females spawn each day during the peak spawning months) which has similar gonad morphology and a protracted spawning season like jack mackerel. Second, estimates were derived from plankton surveys for eggs and larvae in the Southern California Bight, which did not cover the entire range of the spawning population, and assumptions were made for the contribution of older jack mackerel outside the survey area. A recent study estimated the spawning frequency for jack mackerel at 20 percent of the spawning population. Using a spawning frequency of 20 percent would have yielded a lower biomass estimate in 1983. Although we now have an estimate of spawning frequency, no other biomass estimates have been produced since 1983.

There has been a decrease in the percentage of older fish (three to six years) in the catch since the 1960s, which has caused some concern. It is unclear whether this change



Commercial Landings 1916-1999, Jack Mackerel
Data Source: DFG Catch Bulletins and commercial landing receipts. Jack mackerel were aggregated as unclassified mackerel prior to 1926.

is due to a decrease in the number of older fish or to a change in the distribution of these fish.

Management Considerations

See the Management Considerations Appendix A for further information.

Jan Mason
National Marine Fisheries Service

Revised by:
Traci Bishop
California Department of Fish and Game

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Commercial Landings - Coastal Pelagics

Year	Market Squid Pounds	Anchovy Pounds	Anchovy Live Bait Pounds	Jack Mackerel Pounds	Pacific Mackerel Pounds	Unclassified Mackerel Pounds	Sardine[1] Pounds
1916	275,620	531,209	- - - -	- - - -	- - - -	1,113,998	15,648,839
1917	439,438	528,753	- - - -	- - - -	- - - -	3,345,563	104,103,331
1918	361,714	868,161	- - - -	- - - -	- - - -	4,005,906	157,652,811
1919	3,698,242	1,609,548	- - - -	- - - -	- - - -	2,654,596	153,877,179
1920	508,199	569,774	- - - -	- - - -	- - - -	2,997,308	118,520,914
1921	432,559	1,946,881	- - - -	- - - -	- - - -	2,914,613	59,332,305
1922	209,641	652,516	- - - -	- - - -	- - - -	2,466,762	93,399,900
1923	1,180,446	307,074	- - - -	- - - -	- - - -	3,553,954	158,159,356
1924	6,831,029	346,951	- - - -	- - - -	- - - -	3,227,300	242,685,958
1925	1,891,220	93,071	- - - -	- - - -	- - - -	3,506,103	315,294,986
1926	3,135,561	60,157	- - - -	235,151	3,610,098	- - - -	286,741,250
1927	6,014,113	368,201	- - - -	462,539	4,728,903	- - - -	342,275,289
1928	1,351,992	357,470	- - - -	538,446	35,251,298	- - - -	420,269,665
1929	4,660,572	382,445	- - - -	698,290	57,973,952	- - - -	651,771,904
1930	10,969,462	319,561	- - - -	368,828	16,531,364	- - - -	502,062,747
1931	1,738,621	307,494	- - - -	563,108	14,254,081	- - - -	364,351,801
1932	4,229,743	299,217	- - - -	536,409	12,473,746	- - - -	422,609,716
1933	824,543	317,292	- - - -	1,010,850	69,613,680	- - - -	626,397,481
1934	1,530,450	257,505	- - - -	1,581,274	113,848,585	- - - -	1,119,931,099
1935	815,944	178,970	- - - -	9,983,924	146,427,202	- - - -	1,095,758,548
1936	945,439	195,122	- - - -	4,599,382	100,542,214	- - - -	1,463,543,700
1937	501,662	226,229	- - - -	6,541,026	60,936,701	- - - -	1,071,490,525
1938	1,599,319	735,144	- - - -	4,133,918	79,848,015	- - - -	1,023,389,489
1939	1,162,056	2,147,901	- - - -	3,760,155	80,909,374	- - - -	1,160,793,581
1940	1,800,632	6,317,797	- - - -	1,432,637	120,504,412	- - - -	905,973,403
1941	1,431,136	4,105,382	- - - -	2,068,685	78,167,200	- - - -	1,262,480,393
1942	943,783	1,694,290	- - - -	5,348,501	52,553,663	- - - -	969,747,099
1943	9,164,361	1,570,803	- - - -	12,698,974	75,214,799	- - - -	972,269,915
1944	10,936,595	3,891,029	- - - -	12,777,077	83,656,900	- - - -	1,147,207,882
1945	15,225,664	1,616,880	- - - -	9,032,987	53,716,765	- - - -	845,062,774
1946	38,024,528	1,921,627	- - - -	15,093,321	53,875,327	- - - -	510,759,173
1947	14,542,649	18,940,521	- - - -	129,048,507	46,478,362	- - - -	255,513,948
1948	19,255,687	10,835,930	- - - -	72,898,335	39,385,801	- - - -	362,037,087
1949	6,859,129	3,322,273	- - - -	51,250,088	49,771,273	- - - -	633,379,791
1950	5,996,335	4,878,687	- - - -	133,255,752	32,649,969	- - - -	714,522,761
1951	12,382,869	6,954,852	- - - -	89,838,095	33,518,520	- - - -	328,900,731
1952	3,670,923	55,782,870	- - - -	146,521,673	20,604,761	- - - -	14,330,420
1953	8,917,114	85,835,478	- - - -	55,750,855	7,502,181	- - - -	9,468,892
1954	8,155,105	42,410,364	- - - -	17,333,581	25,392,604	- - - -	136,504,017
1955	14,271,968	44,691,582	- - - -	35,754,707	23,310,302	- - - -	145,607,749
1956	19,483,984	56,920,585	- - - -	75,762,110	50,013,009	- - - -	69,554,345
1957	12,449,121	40,547,526	- - - -	82,011,785	62,043,775	- - - -	45,862,106
1958	7,457,418	11,602,724	- - - -	22,065,801	27,648,485	- - - -	207,445,837
1959	19,653,013	7,173,739	- - - -	37,507,227	37,602,134	- - - -	74,366,856
1960	2,561,520	5,058,603	- - - -	74,945,453	36,808,690	- - - -	57,532,719
1961	10,285,791	7,711,573	- - - -	97,606,304	44,110,194	- - - -	43,169,064
1962	9,368,149	2,764,003	- - - -	89,978,933	48,578,820	- - - -	15,362,952
1963	11,560,854	4,570,380	- - - -	95,442,284	40,242,676	- - - -	7,131,221
1964	16,433,624	4,975,089	- - - -	89,692,911	26,827,881	- - - -	13,137,483
1965	18,619,893	5,733,024	- - - -	66,666,380	7,050,059	- - - -	1,924,219
1966	19,025,879	62,280,236	- - - -	40,862,409	4,629,504	- - - -	878,359
1967	19,601,922	69,609,377	- - - -	38,180,547	1,166,607	- - - -	148,766
1968	24,932,713	31,076,116	- - - -	55,667,682	3,133,446	- - - -	124,088
1969	20,779,382	135,277,718	- - - -	51,921,162	2,357,194	- - - -	105,273
1970	24,590,865	192,485,074	- - - -	47,746,509	621,919	- - - -	442,319
1971	31,517,408	89,705,068	- - - -	59,882,985	155,847	- - - -	297,886
1972	20,159,312	138,201,573	- - - -	51,117,573	108,078	- - - -	372,230
1973	12,061,632	265,271,871	- - - -	20,615,827	56,848	- - - -	151,599
1974	28,904,678	165,433,480	7,813,185	25,457,593	133,446	- - - -	14,050
1975	23,621,984	317,021,422	7,242,187	36,779,231	287,121	- - - -	5,300
1976	20,306,005	249,838,707	9,451,220	44,893,081	353,729	- - - -	16,190
1977	28,243,779	219,368,803	9,078,638	98,711,993	11,757,254	- - - -	11,023
1978	37,798,628	24,808,622	11,468,450	67,803,179	24,676,345	- - - -	8,818
1979	43,407,642	106,029,137	5,132,363	36,012,516	59,961,335	- - - -	35,274

Commercial Landings - Coastal Pelagics, cont'd

Year	Market Squid Pounds	Anchovy Pounds	Anchovy Live Bait Pounds	Jack Mackerel Pounds	Pacific Mackerel Pounds	Unclassified Mackerel Pounds	Sardine[1] Pounds
1980	33,917,646	93,156,343	9,594,520	44,134,347	64,240,508	- - - -	74,957
1981	51,829,718	113,463,125	10,544,713	30,842,675	84,445,878	- - - -	61,729
1982	35,953,265	91,238,321	8,428,274	57,284,923	61,544,255	- - - -	284,396
1983	4,020,353	9,327,760	8,558,347	39,892,652	70,609,664	- - - -	762,800
1984	1,243,458	6,411,044	8,950,770	23,157,360	91,566,810	- - - -	509,268
1985	22,652,461	3,527,397	9,310,124	20,304,577	75,074,026	- - - -	1,285,295
1986	46,908,622	4,142,487	7,963,099	24,025,981	89,542,966	- - - -	2,524,293
1987	44,056,904	3,139,383	7,879,323	25,690,471	90,303,561	- - - -	4,543,728
1988	82,080,486	3,183,476	9,235,167	22,392,355	93,035,089	- - - -	8,210,016
1989	90,152,660	5,313,141	10,128,039	42,939,441	78,369,937	- - - -	8,476,775
1990	62,714,437	6,957,790	10,674,786	10,745,332	80,944,937	- - - -	6,106,806
1991	82,426,950	9,224,142	10,718,878	3,675,106	67,150,611	- - - -	16,810,250
1992	28,902,795	2,477,996	5,670,291	12,958,774	40,939,848	- - - -	39,564,164
1993	94,185,070	4,307,833	5,557,855	3,558,261	27,317,483	- - - -	30,518,596
1994	122,345,905	8,113,013	4,239,490	4,746,553	22,134,415	- - - -	29,586,040
1995	159,480,780	4,146,896	- - - -	5,820,205	19,107,467	- - - -	95,790,868
1996	177,255,664	9,742,229	- - - -	4,376,177	22,676,752	- - - -	71,767,091
1997	155,174,427	12,606,034	- - - -	2,559,567	45,448,302	- - - -	101,844,762
1998	6,381,504	3,212,136	- - - -	2,138,484	44,253,397	- - - -	90,513,000
1999	201,762,132	11,417,742	- - - -	2,123,052	21,003,443	- - - -	125,105,739

- - - - Landings data not available.
1 1916 - 1969 sardine data include reduction fishery.

Recreational Landings - Coastal Pelagics

Year	Pacific Mackerel No. of Fish[1]
1947	148,041
1948	203,012
1949	95,158
1950	66,969
1951	47,188
1952	76,568
1953	61,467
1954	315,037
1955	151,018
1956	121,136
1957	151,960
1958	136,607
1959	88,952
1960	79,370
1961	113,988
1962	116,738
1963	146,560
1964	101,219
1965	151,896
1966	205,090
1967	108,366
1968	78,933
1969	120,036
1970	129,770
1971	224,223
1972	245,882
1973	199,104
1974	102,619
1975	129,944
1976	51,441
1977	484,722
1978	940,204
1979	1,272,038
1980	1,315,971
1981	1,007,198
1982	914,238
1983	630,006
1984	604,324
1985	695,708
1986	605,716
1987	517,166
1988	412,924
1989	363,700
1990	472,006
1991	438,979
1992	327,747
1993	417,640
1994	336,655
1995	271,150
1996	335,240
1997	240,977
1998	129,747
1999	83,634

All data based on CPFV logbooks.

1 All data presented in number of fish.

Highly Migratory Species: Overview

Highly migratory species include the tunas, billfishes, pelagic sharks, and dolphinfish. As a group, they contribute to some of the most valuable commercial fisheries and are also very important in the sport fishery, especially in southern California. Currently, the harvest of highly migratory species is regulated by the state. However, beginning in 2001, the Pacific Fishery Management Council has proposed adopting a fishery management plan regulating the take of highly migratory species within and outside the Exclusive Economic Zone. Upon completion of the fishery management plan process, which may take more than two years, jurisdiction over the harvest of these species will pass to the federal government.

Currently, five distinctive gear types are used to take highly migratory species commercially. The oldest and most common is hook and line gear. The gear may be used to take any highly migratory species but, traditionally, most of the fishing has been for tunas. The majority of albacore are taken by trolling vessels with a small portion of fish landed by pole-and-line fishing using live bait. Albacore are taken along the West Coast of the U.S. and Canada, as well as on the high seas of the north and south Pacific Oceans. A very small fleet of bait boats continues to target the tropical tunas, yellowfin and skipjack tuna, off Mexico and Central America. Southern California has a small harpoon fleet (< 50 vessels) pursuing swordfish during the summer months. This is in contrast to the more than 200 vessels fishing during the 1950s and 1960s. They generally operate within the Channel Islands but occasionally may venture as far north as Morro Bay. The third type gear used to take highly migratory species is the purse seine. Two distinct fleets exist; a small remnant high seas fleet that fishes for tropical tunas in the eastern Pacific and 40 wetfish vessels that occasionally land tuna when they are locally available. The high-sea purse seine fleet fishes in an area regulated by the Inter-American Tropical Tuna Commission and is subject only to state licensing and landing taxes on fish landed in the state. The wetfish fleet targets bluefin tuna during the summer but also takes yellowfin and skipjack tuna. Occasionally, in some years, they may catch significant amounts of albacore.

California currently allows drift gillnet vessels fishing with large mesh nets to take swordfish, tunas and sharks. They generally fish off southern California in the summer and move north with the fish in the fall. Access is limited and the vessels are restricted by seasonal and area closures. In addition, the fishery must be in compliance with federal regulations governing the take of marine mammals and protected species. To this end, the National Marine Fisheries Service has established a Take Reduction Team to reduce the catch of marine mammals. The state has followed the recommendation of the team and implemented regulations covering gear, area and seasonal closures to assure few marine mammals are taken. The drift gillnet fishery also operates under a December 2000 NMFS biological opinion which closes central California from August 15 through October 31 to protect leatherback turtles, and southern California during August and January of El Niño years to protect loggerhead turtles.

The final gear type is pelagic longline. While the state does not allow longline vessels to fish in the exclusive economic zone, they may file for offshore fishing declarations, fish outside 200 miles and return to the state with their catch. Offshore longline vessels usually target swordfish but will fish for tunas during times of local abundance. Currently there are no longlining restrictions except fishing is not allowed within 200 miles of shore.

Recreational anglers using hook and line gear target highly migratory species whenever the opportunity arises. Commercial passenger fishing vessel and private boat anglers pursue these species in U.S. waters and territorial seas of Mexico. Oceanic regimes play a major role in determining availability and which species will be harvested. During 1999, highly migratory species accounted for over 9.5 percent of all fish landed by California anglers. During eight of the past 10 years, tropical species such as yellowfin tuna, skipjack tuna, and dolphinfish have dominated the catch. Temperate tunas (albacore and bluefin tuna) have only contributed significant catches in the years following a major El Niño event. Catches of sharks and billfish are important to anglers of the state, but constitute a minor portion of the overall catch. When the highly migratory species fishery developed at the turn of the century, fishing activity was confined to southern California with most of the effort at Santa Catalina Island. As fishing vessels developed the capability to go further, sport anglers followed the fish to the offshore islands and banks. San Clemente, Santa Barbara, San Nicholas, the Channel Islands, plus associated banks started to play a greater role in the fishery. Sport fishing for albacore started in northern California following World War II but never reached the magnitude of the southern California fishery because of the lack of anglers and fish. Trips from San Diego to northern Mexico originated in early 1930s, and expanded to the offshore islands and southern Baja California in the late 1940s. Extended long-range trips off Mexico, greater than 800 miles, started in the late-1950s and continue to be popular today with both party boat and private boat anglers.

Currently, the stocks of all highly migratory species are considered to be healthy although common thresher shark may face some reductions in take under the Council's fishery management plan because they were overfished in the 1980s. Most of the controversy surrounding the take of highly migratory species centers around user conflicts, take of state and federally protected species, longlining inside 200 miles, and bycatch. User conflicts exist between commercial gear types (harpoon vs. drift gillnets, drift gillnets vs. longline) but a more controversial issue is the conflict between commercial fishers and sport anglers. Area and time closures have helped to eliminate some of the conflicts between drift gillnets and sport marlin anglers and prohibiting longlines inside 200 miles has also helped to reduce the conflict. Some conflicts arise over the take of tuna when sport anglers encounter purse seiners fishing in areas they are fishing. Finally, the environmental community is concerned over the take of marine mammals, protected species, and bycatch in the commercial fishery. Their concerns have been alleviated to some extent by implementation of recommendations from the take reduction team for the drift gillnet fishery and the recent Biological Opinion on the take of sea turtles in the fishery. Bycatch will continue to be an issue in the drift gillnet and longline fisheries until effective measures are developed which reduce the catch to close to zero. This is especially true for shark bycatch.

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California Department of Fish and Game

Albacore

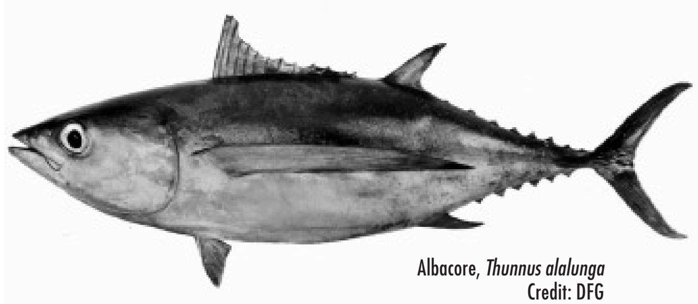
History of the Fishery

Albacore (*Thunnus alalunga*) is a highly migratory species that has been targeted by California's recreational anglers and commercial fishermen for more than 100 years. Currently, it ranks among the state's most important marine fish resources, in terms of both economic value and sport-related benefits. Commercial landings of albacore at California ports have increased from $4 million to $10 million (ex-vessel dollars) on an annual basis since 1996. In recent times, the recreational fishery for albacore has contributed at least $25 million per year to California's economy through angling-related expenditures.

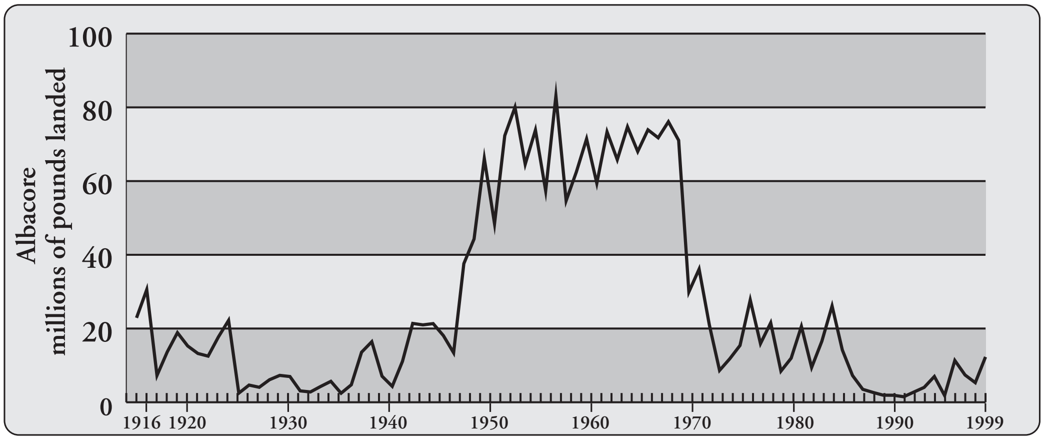
The commercial fisheries for albacore developed rapidly following the first canning operations of this species in 1903 in San Pedro Bay, California. The vast majority of albacore commercially harvested by California fishermen is processed as canned "white meat" tuna that generally commands premium prices in the marketplace. Through the first quarter of the 20th century, the tuna-canning industry and its related fisheries endeavored to meet increasing demands for seafood, particularly packed products that had a long shelf life. The commercial fisheries for albacore continued to expand through the mid-1940s, extending northward to coastal waters off northern California, Oregon, and Washington, and westward to the central Pacific Ocean, several hundred miles off the California coast. The geographic expansion of the fisheries slowed during the 1950s through the mid-1960s, but the flourishing market continued, with record landings during this period that averaged roughly 30 million pounds annually. During the mid-1970s, the commercial fishing fleet extended farther into the central Pacific Ocean, with some vessels fishing north and west of the Hawaiian Islands, as far as the International Date Line. Since the 1980s, the albacore fisheries of California have typically operated within roughly 900 miles of the U.S. Pacific coast; the distance largely dependent on the stock's migratory route in any given year. California's commercial fishery for albacore has generally concentrated on the North Pacific albacore stock during the summer and fall seasons as the fish move through waters of the northeastern Pacific Ocean during their annual migration. However, in recent years during the winter months, some vessels have also targeted the South Pacific albacore stock that inhabits waters off New Zealand's east coast between the International Date Line and 110˚W longitude. Commercial landings of albacore in California have varied over the last decade, ranging from a high of 12.3 million pounds in 1999 to a low of 1.8 million pounds in 1995.

During the early years of California's commercial fisheries for albacore, pole-and-line (live bait fishing) and troll (artificial-jig fishing) gears were used extensively. Other gears, such as longlines, purse seines, and drift gillnets have also been used by California fishermen, but trolling operations have dominated since the early 1980s and now contribute over 90 percent of the annual catch of albacore. Generally speaking, troll, pole-and-line, purse seines, and drift gillnet vessels operate in surface fisheries that target two to five-year-old fish (juvenile albacore) in the upper portions of the water column, and longline vessels operate in subsurface fisheries that harvest five to ten year-old fish (adult albacore) from deeper waters. California-based troll vessels, or jig boats, can be broadly classified into two groups – relatively small boats (30-50 feet in length) that typically carry a crew of two or three fishermen, spend one to three weeks at sea, and target albacore in inshore waters; and larger boats (50-90 feet in length) that commonly operate with three to five fishermen, spend one to two months at sea, and fish both inshore and offshore waters. Historically, commercial fishing effort for albacore has fluctuated over the past 100 years, based primarily on market and oceanic conditions. For example, from 1916 to 1925, about 300 vessels equipped for one-day trips participated in the fishery, operating exclusively in coastal waters. The commercial fleet that fished the central Pacific Ocean, as well as inshore waters, grew steadily over the next 25 years, reaching 3,000 boats in 1950. The number of vessels declined during the 1950s, and by 1960, 1,000 boats were involved in the fishery. During the 1970s, the commercial fleet began to increase once again to over 2,000 vessels, but by the late 1980s and through the 1990s, fewer than 500 boats typically landed their commercial catches at California ports.

Albacore are harvested commercially by countries other than the United States, including Japan, Taiwan and South and North Korea in the western Pacific Ocean, and Canada and Mexico in the eastern Pacific Ocean. Currently, the California troll fishery accounts for roughly 10 percent of the total commercial landings of North Pacific albacore, with Japan (75 percent) contributing the largest amount, followed by Oregon/Washington, Taiwan, and Canada (about five percent each). In a typical year, during the late spring and summer, the Japanese pole-and-line fleet will target the juvenile albacore as they



Albacore, *Thunnus alalunga*
Credit: DFG



Commercial Landings 1916-1999, Albacore
Data Source: DFG Catch Bulletins and commercial landing receipts. Data includes shipments and landings from areas north and south of the state between 1916 and 1969.

form identifiable schools and begin their annual migration in waters off the east coast of Japan to the central Pacific Ocean (Emperor Seamount). In the summer and into the fall, the U.S. and Canada troll fleets will follow the albacore as they continue their migration to the eastern Pacific Ocean and coastal waters off the U.S. Pacific Coast.

Recreational fishing for albacore developed during the early 1900s, when vessel owners in southern California first realized that the angling community was very willing to charter their boats for fishing. As the popularity of albacore increased, as a food and sport fish, so did the partyboat (commercial passenger-carrying fishing vessels or CPFV) industry. In the very early years of the sport fishery, only a few CPFV trips were made, concentrating in waters around the Channel Islands; however, by the mid 1950s, more than 100 CPFVs carried anglers to other inshore waters in pursuit of the stock as it conducted its annual migration. The CPFV industry continued to grow during the 1960s, with increases in fishing capacity and range, which allowed boats to carry more anglers and venture further from port in years when the albacore remained farther offshore. Over the last 10 years, from 40 to 60 large CPFVs, that typically accommodate from 15 to 60 anglers for one-to three-day trips, have fished for albacore in California waters, mostly based in southern California, with several operations further north in Morro Bay and San Francisco. Additionally, from 60 to 90 smaller CPFVs have routinely operated in California since the early 1990s, with these vessels usually carrying six to 10 anglers on one-day fishing excursions. Catches of albacore on CPFV trips have been highly variable over the years, based largely on the migratory behavior of the stock in any given year. For example, in 1994, as the stock approached the coast of North America, the bulk of the population traveled north to waters off Oregon and Washington, resulting in a poor fishing season for recreational anglers in California, where less than 200 albacore were landed on CPFV-related trips. In 1999, the stock took a more southerly route as it neared the U.S. Pacific Coast and spent much of the summer and fall in inshore waters off southern California and northern Mexico, where anglers on CPFVs landed a total of 258,448 fish – the highest total on record. The long tradition of albacore sport fishing in California is not only due to the CPFV industry, but also an increasing number of anglers that fish from privately-owned boats. Both represent an enthusiastic sport fishery that anxiously awaits the arrival of the first pulse of albacore to California's inshore waters each summer. Sport fishing in California typically peaks during the mid-summer months (July and August) as the bulk of the stock travels to inshore waters off the U.S. Pacific Coast. However, arrival and departure times associated with the stock's migration through U.S. owned fishing grounds have varied substantially over the years, with spring arrivals and winter departures frequently observed.

The actual operations of most fisheries, including those associated with albacore, are essentially defined in accordance with the biological characteristics and ecological relations exhibited by the species. This is particularly true for albacore and its related fisheries, given that the migration and distribution patterns of this species are highly influenced by the prevailing oceanographic conditions.

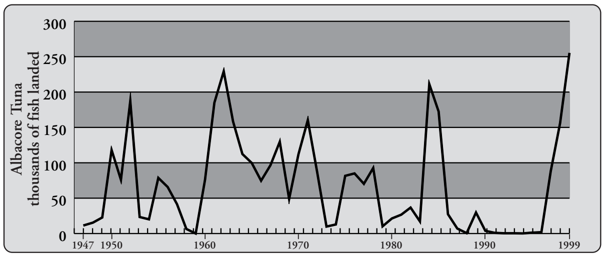
Status of Biological Knowledge

Albacore are members of the Scombridae family, which includes 40 to 50 species of tuna and mackerel, 23 of which are found, for at least a part of their life, in North American waters. Albacore, as well as other species of tuna, have unique biological characteristics that enable them to swim continuously at very high speeds and cover vast areas during annual migrations. Albacore are literally built for speed, with torpedo-shaped (fusiform) bodies, smooth skin, and streamlined fins, and can reach speeds of more than 50 miles per hour for short periods of time. Albacore are metallic dark blue along the back, with dusky to silvery white coloration along the sides and on the belly. The pectoral fins are exceptionally long, extending to nearly half the length of the body, and albacore are commonly referred to as longfin tuna. In addition to these morphological adaptations, albacore possess highly specialized physiological functions that allow for rapid movement and sustained endurance. First and foremost, many tuna, including albacore, have a highly evolved circulatory system that includes countercurrent exchangers that act to reduce the loss of heat generated by increased muscular activity, allowing them to regulate their body temperature and ultimately, increase the efficiency of their muscles. Additionally, albacore have higher blood pressure and volume than most of the other species of fish.

Albacore are widely distributed throughout the world's oceans in tropical, sub-tropical, and temperate zones. The North Pacific albacore stock, the population targeted by both the commercial and recreational fisheries of California, is centered around 35° N latitude in the Pacific Ocean. This stock's distribution extends from the central (west) coast of Mexico to the Gulf of Alaska in the eastern Pacific Ocean, and from the equator to the north (east) coast of Japan in the western Pacific Ocean. The actual boundaries of the stock's range depend largely on the season of the year and oceanic conditions. Currently, fishery researchers are uncertain whether the population of albacore inhabiting the North Pacific Ocean is strictly a single stock or possibly, composed of two (or more) stocks. Results from some tagging experiments indicate that substocks of albacore may exist in the North Pacific Ocean, based on differences in migratory routes, growth and mortality rates, and size distributions of the commercial catches. However, more information concerning albacore biology and genetics is needed before definitive conclusions can be drawn regarding the stock structure of the North Pacific population of albacore.

As stated previously, the North Pacific albacore stock, particularly juveniles, typically complete an expansive annual migration that begins in the spring and early summer off Japan, continues throughout the late summer into inshore waters off the U.S. Pacific Coast, and ends late in the year in the western Pacific Ocean. It is generally believed that oceanic conditions strongly influence both the timing and geographical extent of the albacore's migration in any given year. Migrating albacore concentrate along thermal discontinuities (oceanic fronts) associated with waters of the Transition Zone in the North Pacific Ocean. The vast majority of albacore are caught in waters with sea-surface temperatures (SSTs) that range from 59˚-67˚F. The migrating fish are typically bounded by these thermal gradients as they conduct their round-trip travel across the Pacific Ocean. Although the bulk of the migrating stock is typically observed within this SST range, telemetry studies have shown that this species will spend brief periods of time in much colder water (49˚F). Upwelling, where nutrient-rich waters from the ocean depths rise to the surface, is another important phenomenon associated with oceanic fronts and ultimately, an event that highly influences the distribution of the migrating albacore. It is likely that the albacore are attracted to upwelling fronts, given these areas are very productive and contain much forage for predatory fish such as albacore. Although scientists are quite certain that oceanic fronts define albacore distribution and thus, vulnerability to fisheries, they feel other oceanographic parameters also influence the migratory behavior of the stock, including salinity, ocean color and clarity, and vertical thermal/density structure. In general, catches from the commercial fisheries indicate that albacore are most abundant along the warm side of upwelling fronts in clear blue oceanic waters that are associated with salinity gradients between 33 and 35 parts per thousand and well defined thermoclines. Recent research indicates that the fish adjust their behavior to very different oceanic conditions when passing through at least four distinct physical regimes (geographical strata) of the North Pacific Ocean. Thus, determining what are the most influential environmental parameters depends on where in the ocean and what time of year the assessment is conducted.

Albacore are top carnivores in the ocean ecosystem and opportunistically prey on schooling stocks, such as sardine, anchovy, and squid. Albacore are preyed upon by man, as well as the larger species of billfish, tuna, and sharks. Similar size albacore travel together in school groups that contain small aggregations of fish, which collectively, can be up to 19 miles wide. At the onset of the migration, during the spring and summer months in the western Pacific Ocean, the young albacore form relatively small, loose, and broadly scattered groups. As the seasons progress, the groups become more compact and contain greater numbers of schools. The more sedentary, older albacore typically form more compact schools. Generally



Recreational Catch 1947-1999 , Albacore Tuna
Data Source: DFG, commercial passenger fishing vessel logbooks.

speaking, albacore schools are not as large or as dense as those of some of the larger schooling tunas, such as yellowfin and skipjack. Bluefin, yellowfin, and skipjack tunas are occasionally caught along with albacore by the surface fisheries off the U.S. Pacific Coast. Although albacore spend much of their time in the surface waters of the ocean, they will also explore deeper waters of the thermocline in search of prey.

North Pacific albacore mature at roughly five to six years of age (approximately 33 inches in length). Peak spawning of albacore in the Pacific Ocean is generally believed to occur in subtropical waters centered around 20˚N and 20˚S latitude. It is assumed that the North Pacific albacore stock spawns from March through July on grounds located in the western and central Pacific Ocean. There is some information, albeit limited, that albacore may spawn multiple times in a year. Albacore are believed to be pelagic spawners that broadcast their gametes in open water, often near the surface, with fertilization being external. Estimates of female fecundity (number of eggs) range from 0.8 to 2.6 million eggs per spawning. The early life history of albacore is not clearly understood, but very young albacore (larvae and juveniles in their first year of life) are believed to remain relatively close to the spawning grounds and eventually, congregate in waters south and east of Japan prior to beginning their first migration.

Approximate growth rates for North Pacific albacore are as follows: age-one fish are 14.2 inches and 2.2 pounds; age-two fish are 20.5 inches and 6.5 pounds; age-three fish are 25.6 inches and 12.7 pounds; age-four fish are 30 inches and 20.3 pounds; age-five fish are 33.5 inches and 28.3 pounds, and age 10-12 fish can reach up to 55.0 inches and over 100 pounds. Albacore are believed to reach a maximum age of roughly 11-12 years, although interpretations of age for older fish are typically subject to increased uncertainty and thus, longevity cannot be strictly defined at this time. The sex ratio of juvenile albacore is approximately one to one, but males appear to outnumber females as the fish age, e.g., the sex ratio of the catches from the longline fisheries, which target adult fish, is generally skewed towards higher numbers of males than females.

Status of the Population

Fishery researchers generally agree that the North Pacific albacore population is currently a relatively healthy stock that has responded favorably to rates of exploitation over the last decade or so. Recent assessments of the entire stock indicated that sustainable yields, on a global basis, likely range between 176.4 and 220.5 million pounds, roughly the level of total annual catch observed during the latter part of the 1990s. For example, the combined commercial and recreational landings in 1999 (U.S. and foreign) was approximately 209.5 million pounds. Catches and fishing effort associated with U.S. fisheries for albacore, both commercial and recreational, were considerably higher in the latter part of the 1990s than during the early and mid 1990s, which is baseline information that generally indicates the population has responded relatively well to recent levels of exploitation. Catch-per-unit-effort (CPUE) data from the U.S. troll fishery, a fishing statistic often used as an index of population size, has been relatively constant over the last 10 years (30 to 60 fish per day), with the exception of 1996 and 1998, when fishing success peaked at roughly 100 fish per day. The CPUE statistics from the pole-and-line fishery of Japan, which harvests juvenile albacore similar to the U.S. troll fleet, have been generally consistent since the early 1990s as well, with the trend increasing noticeably during the late 1990s. The CPUE time series associated with the Japan longline fishery, which targets adult albacore and larger juveniles, indicates a productive stock that has been increasing in size since the early 1990s. It is more difficult to assess the status of the overall population using CPUE data from the recreational fisheries, given the influence of oceanic factors on albacore's migratory behavior. It is likely that catch and fishing effort associated with the North Pacific albacore stock will remain at or slightly above current levels into the near future, given favorable oceanographic and market conditions.

Although fishing pressure is likely an important factor that influences albacore abundance in the North Pacific Ocean, it must necessarily be interpreted in the context of the overall condition of the stock's environment. That is, albacore abundance in the North Pacific Ocean has fluctuated considerably over the last several decades, with strong and weak periods occurring intermittently, based largely on the ocean's carrying capacity in any given year.

Management Considerations

See the Management Considerations Appendix A for further information.

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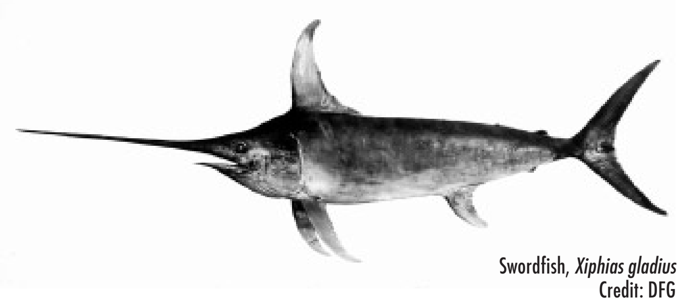
Swordfish

History of the Fishery

Swordfish (*Xiphias gladius)* is an important resource supporting major fisheries in all oceans of the world. The quality of swordfish flesh is excellent and is marketed both frozen and fresh. Major Pacific fishing areas include the waters off Japan, the North Pacific Transition Zone north of Hawaii, the west coasts of the U.S., Mexico, Ecuador, Peru, Chile, and off Australia and New Zealand. Much of the Pacific catch is taken incidentally in longline fisheries targeting tunas. Reported annual Pacific-wide landings averaged 26 million pounds per year between 1950 and 1986. Recent landings peaked in 1992 at 75 million pounds and now average around 65 million pounds annually. Japan, Taiwan and the U.S. account for about 70 percent of current reported production, with Mexico, Ecuador and Chile providing the remainder. In the eastern Pacific, swordfish are primarily harvested using longlines, drift nets and hand-held harpoons.

Early coastal and island middens of American Indians provide the first evidence of swordfish being utilized as a food source. The California harpoon fishery dates back to the early 1900s and the Tuna Club of Avalon reported the first record of a recreationally caught swordfish in 1909 that weighed 339 pounds. In 1931, the State Legislature required commercial fishing licenses and allowed only harpoons for the commercial take of swordfish. Recreational anglers were allowed to harpoon swordfish until 1935. Participation in the harpoon fishery peaked in 1978 with 309 vessels landing 2.6 million pounds before being largely displaced by the more efficient drift net fishery. A small number of harpoon vessels continue to fish swordfish off southern California from May to December. Primary fishing areas are from San Diego to Point Conception during the early season although these fishermen operate as far north as Oregon during periods of warm water. Harpooners require calm waters to see the swordfish finning, or basking, at the surface. When a finning swordfish is spotted, the fisherman guides his vessel over the fish and throws the harpoon from the bow plank extending far beyond the vessel bow. Harpooned fish are recovered using an attached line, buoys and marker flag. Use of spotter aircraft greatly improved catches by allowing takes of fish swimming just below the surface and not visible from the vessel. Most harpoon vessels sell their catch fresh daily and achieve a premium price above that for longline and drift net-caught fish.



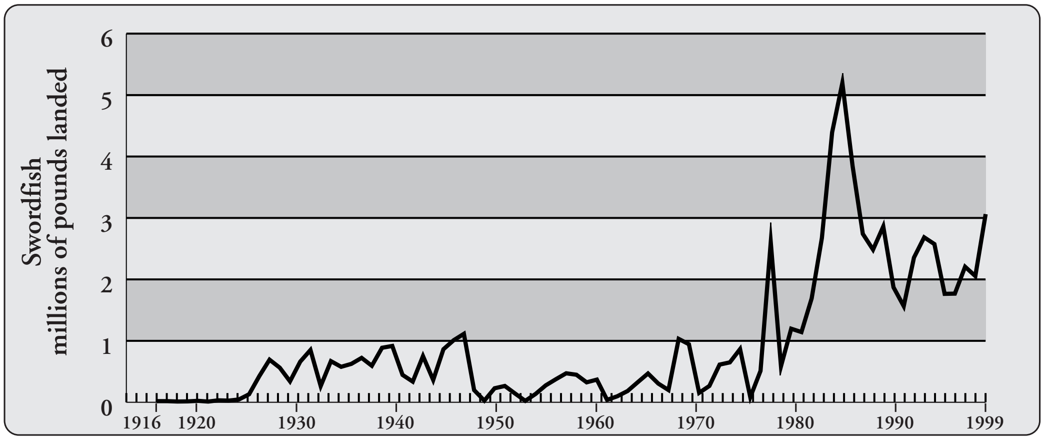
Swordfish, *Xiphias gladius*
Credit: DFG

The harpoon fishery remained the only legal gear until the late 1970s when a few drift gillnet vessels began targeting common thresher sharks. This rapidly developed into the successful drift net fishery for swordfish and thresher sharks, which proved more cost effective in terms of fuel economy and yielded greater catches than was possible with harpoon gear.

Annual landings of drift net caught swordfish increased rapidly peaking in 1984 at 5.2 million pounds valued at 10.3 million dollars. These vessels use nets up to 6,000 feet in length with mesh sizes ranging between 14 to 22 inches. The netting is attached to a floatline and a weighted leadline at the bottom allows the webbing to hang as a loose curtain in which the swordfish become entangled. Drift nets are set at sunset and hauled at sunrise. Regulations enacted in 1985 were designed to reduce fishing effort and landings, limit the number of permits to 150, restrict the season of operation and provide for several time-area closures aimed at reducing bycatch and interactions with recreational anglers. Drift net vessels, which numbered 220 in 1985, have decreased due to those regulations and now number about 120 vessels, of which only about 100 are fully active. These fishermen ply the waters from the Mexican border to Oregon and offshore to 200 miles. Approximately two-thirds of the landings and earnings occur in southern California, while one-third are landed in northern California, less than two percent of the landings occur in Oregon and Washington. This fishery is in a period of steady production with annual yields of 2.6 million pounds worth an estimated $5 million dollars. This level of production, along with imports from Mexico, has been known to saturate local markets, driving down ex-vessel prices.

Hawaii's longline fishery began targeting swordfish in 1988 and landings expanded to 13.2 million pounds worth 21 million dollars by 1998. These long-range vessels operate over a vast area of the north central Pacific accounting for as much a 36 percent of U.S. production in the Pacific. A small California-based, high seas longline fishery, operating beyond the EEZ, developed in 1991. These vessels were joined by other vessels from the Gulf Of Mexico in 1993 and numbered 31 by 1994. Most of these vessels returned home by 1995. Judicial ruling in Hawaii closed a vast area north of Hawaii to longline fishing in 2000. This resulted in nearly 20 longline vessels departing their Hawaiian base of operations to operate out of southern California ports.

In 1983, Mexico restricted the use of longlines along their coast by limiting the catch of billfish within 50 miles of



Commercial Landings 1916-1999, Swordfish
Data Source: DFG Catch Bulletins and commercial landing receipts.

their coast. A small fleet of drift net vessels, based in Ensenada began fishing swordfish in 1986. They operated from Ensenada moving south along the Baja peninsula and generally within 100 miles of the coast. They averaged nearly one million pounds of swordfish between 1986 and 1993. Concerns over bycatch of sport and protected species, prompted the Mexican government to issue permits in 2000 allowing these drift net vessels to convert to longline gear.

Status of Biological Knowledge

Broadbill swordfish, is the single species within its own family Xiphidae. It is characterized by a long, flat bill in contrast to the smooth, round bill of the marlins. Swordfish are elongate, round bodied, and lack teeth and scales as adults. They have a tall, non-retractable dorsal fin, and pelvic fins are lacking. They reach a maximum size of 14 feet and 1,190 pounds. The International Game Fish Association's all tackle angling record is for a 1,182-pound fish taken off Chile in 1953.

Swordfish are found in all tropical, subtropical, and temperate waters, sometimes entering sub-temperate water as well. In the western Pacific, it ranges from 50° N to 45° S whereas in the eastern Pacific, from 50° N to 35° S. Swordfish tend to concentrate where major ocean currents meet, and along temperature fronts. They are epi- and meso-pelagic, inhabiting the mixed surface waters where temperatures are greater than 55° F but also can move into water as cool as 41° F for short periods aided by specially adapted brain and eye heat exchange organs.

Areas of high apparent abundance in the North Pacific are north of Hawaii along the North Pacific transition zone, along the west coasts of the U.S. and Mexico and in the western Pacific, east of Japan. Migration patterns have not been described although tag release and recapture data indicate an eastward movement from the central Pacific north of Hawaii toward the U.S. West Coast. Catch records from Japanese longliners suggest greatest catches from Baja California, Mexico in the spring and summer, while catch data from the California drift net fishery show swordfish moving through coastal waters from August to January. Acoustic tracking indicates some diel movement from deeper depths during the daytime and moving into the mixed surface water at night. At times, they appear to follow the deep scattering layer, and small prey, as they undertake these vertical movements.

It is generally believed that females grow larger than males, as males over 300 pounds are rare. Females mature at four to five years of age in northwest Pacific and males mature first at about three to four years although there is some controversy as to size at first maturity in different areas. In the North Pacific, batch spawning occurs in water warmer than 75° F from March to July and year round in the equatorial Pacific. Reproductive material from nearly 500 female swordfish, of mature sizes, examined from the California drift net fishery contained no mature oocytes indicating swordfish were not reproductively active while vulnerable to that fishery.

Adult swordfish forage from surface waters to the bottom in coastal areas and are reported to 1,600 feet in the open ocean. Prey includes pelagic fish including small tuna, dorado, barracuda, flying fish, mackerel as well as benthic species of hake and rockfish. Squid are also important when available. Swordfish likely have few predators as adults although juveniles are vulnerable to predation by large pelagic fish.

Status of the Population

The condition of the swordfish stocks in the Pacific Ocean is unclear. Results of assessment studies so far have a large margin of uncertainty, owing in part to uncertainty in the stock structure of the population. Recent genetic studies suggest swordfish off the western coast of the Americas mix with swordfish from the central and western North Pacific. This result tends to support the hypothesis of a single stock in the Pacific with an uneven distribution that results in areas of high and low abundance. Studies of catch rates, on the other hand, suggest three or more stocks as demonstrated by high catch rates persisting in distinct areas that are separated by areas of low to zero catch rates in between. Also, genetic studies in the western Pacific found significant differences between southern and northern swordfish, indicating little mixing. Stock assessment studies using both hypotheses have concluded that the stocks appear to be in good condition and with exploitation at or below estimated MSY levels. These studies, however, have not included fishery statistics from recent years when some fisheries expanded significantly, nor have they taken into account the complex biology, such as sexual dimorphism and diurnal behavior, of swordfish indicating a need for more current stock assessment.

With recent expansion of the fisheries and indications that the expansion will continue, an up-to-date and accurate stock assessment is critically needed. Without such an assessment, it is difficult to rationally evaluate fishery management options for conservation and for implementing the precautionary approach.

In September 2000, major fishing nations in the Pacific agreed to an international convention on the Conservation and Management of Highly Migratory Fish Stocks of the western and central Pacific Ocean. This convention provides a mechanism for comprehensive monitoring and collection of data from swordfish fisheries, international cooperation in performing an up-to-date swordfish stock assessment, and implementation of conservation measures by all major fishing nations. In addition, swordfish will soon be covered in the fishery management plan for the West Coast highly migratory species being developed for the Pacific Fishery Management Council. Although swordfish is not a species of immediate concern to this convention, the convention provides a mechanism for comprehensive monitoring and collection of data from the swordfish fisheries, international cooperation in performing an up-to-date swordfish stock assessment, and implementation by all major fishing nations of conservation measures, including the use of the precautionary approach.

Management Considerations

See the Management Considerations Appendix A for further information.

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National Marine Fisheries Service

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Pacific Northern Bluefin Tuna

History of the Fishery

Fishing for Pacific northern bluefin tuna (*Thunnus orientalis*) began in California as a sport in 1898. Prior to World War I, many large fish were taken, particularly by vessels based at Santa Catalina Island. The largest of these fish weighed 251 pounds. More recently, the average size of the sport-caught fish has been roughly 50 pounds, although large fish are still taken. A large portion of the sport-caught fish is taken by fishermen who are directing their efforts primarily toward albacore.

The commercial fishery for Pacific northern bluefin began in 1918. Since bluefin are rarely caught by the troll, bait boat, or gillnet fisheries, the catches by purse seiners have far exceeded those by any other type of gear. From 1918 until about 1960, most of the vessels were relatively small, with fish-carrying capacities less than about 200 short tons. None of them fished exclusively for bluefin. The smaller ones, sometimes referred to as wetfish vessels, fished chiefly for sardines, mackerel, and pelagic fish other than tropical tunas, and the larger ones fished mostly for yellowfin and skipjack. During 1959 and 1960, most of the larger tuna bait boats were converted to purse seiners and, during the ensuing years, many new purse seiners were built. During the 1960s, 1970s, 1980s, and 1990s, many of the smaller, older vessels sank or dropped out of the fishery, and the new vessels that replaced them tended to be larger. As a result, there are now more large purse seiners and fewer small ones than there were during the early 1960s.

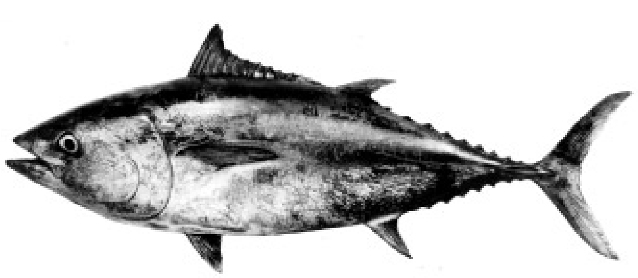
Bluefin are now taken by vessels of all sizes, but the smaller ones (capacities less than about 400 tons) account for a proportionally larger share of the catch. The proportion of the bluefin catch made by the wetfish fleet is less now than it was during the early years of the fishery because there are now fewer wetfish vessels and because many of the fish are intercepted by larger vessels fishing off Baja California before they reach the area where these vessels normally fish. Most of the fish caught by purse seiners weigh less than 50 pounds, but larger ones have sometimes been caught, including one weighing 1,009 pounds.

Most of the information regarding distribution of the catches of Pacific northern bluefin by tuna purse seiners has been obtained from the logbook records of these vessels. Bluefin are rarely encountered south of Cabo San Lucas, Baja California, or north of Point Conception, California. Within this area, a considerable change has taken place during the 20th century. Until 1930, fishing was conducted only off California. During that year, bluefin were discovered off Isla Guadalupe, Baja California, and about 40 percent of the catch was made in that area. From 1930 through 1947, fishing was conducted off California and Baja California, but in most years the majority of the catch came from off California. From 1948 to the present, however, most of the catch has been made off Baja California. The average annual catches made off California during the 1960s, 1970s, 1980s and 1990s have been considerably less than the average annual catches made in the same area from 1918 to 1929.

From January through April, there are typically only light and sporadic catches. Most of these are made off the coast of Baja California between 24° N and 26° N and in the vicinity of Isla Guadalupe. In May and June, the catches increase, and most of them are made between 24° N and 27° N. In July, the fishing area expands to the north and is at its broadest distribution of the year; most of the catch is made between 25° N and 33° N. In August, there are usually only light catches at the southern end of the fishing area, most of the catch is being made between 28° N and 33° N. In September, most of the catch is made in the same area as in August, but the amount of catch is usually considerably less. In October, the catches continue to decline, and most of them are made north of 30° N. In November and December, as in the first months of the year, the catches are light and sporadic.

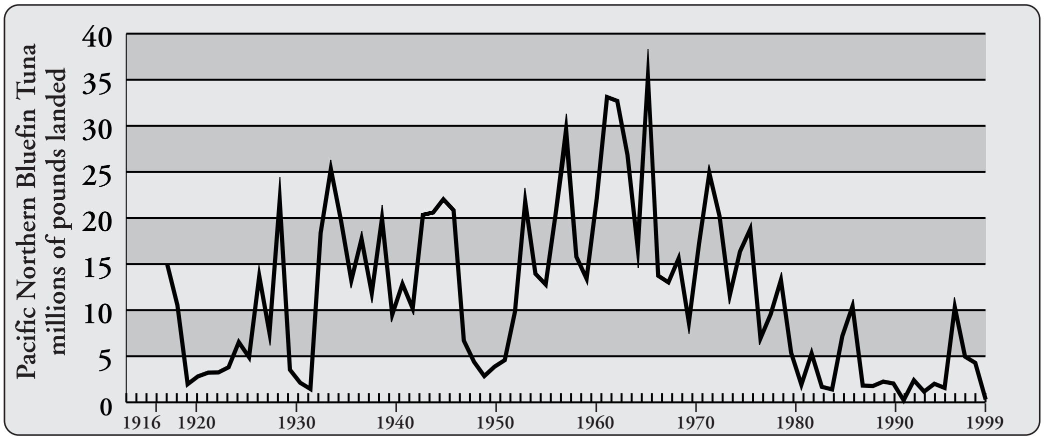
Small amounts of Pacific northern bluefin are caught off the California coast by drift gillnets and further offshore by longline vessels. Extremely large bluefin are caught in some years off southern California, principally during November and December. Nearly 1,000 such fish were caught during the period between October 31, l988, and January 3, 1989. Most of these were flown to Japan, where they brought high prices.

The total annual catches of Pacific northern bluefin by commercial and sport vessels in the eastern Pacific Ocean, prior to 1918, were negligible. The data for 1918 through 1960 include only the catches landed in California, but it is believed that the catches landed elsewhere, prior



Pacific Northern Bluefin Tuna, *Thunnus orientalis*
Credit: DFG

Commercial Landings 1916-1999, Pacific Northern Bluefin Tuna
Data Source: DFG Catch Bulletins and commercial landing receipts. Data includes shipments and landings from areas north and south of the state between 1916 and 1969.

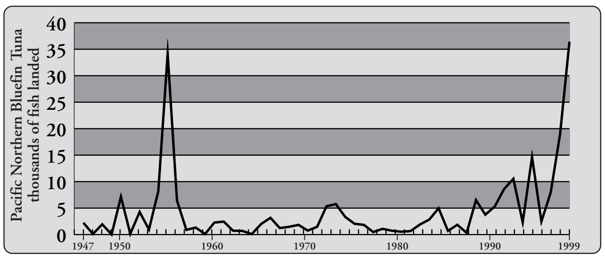


to 1961, were inconsequential. The catches tended to be greater during the 1960s and 1970s than during the previous period, probably because of the conversion during 1959 and 1960 of most of the tuna bait boats to purse seiners, and the addition of many new purse seiners to the fleet.

Status of Biological Knowledge

Spawning of Pacific northern bluefin occurs between Japan and the Philippines in April, May, and June, off southern Honshu in July, and in the Sea of Japan in August. The larvae, postlarvae, and juveniles produced south of Japan are carried northward by the Kuroshio Current toward Japan. Fish in their first year of life, about six to 24 inches in length, are caught in the vicinity of Japan during the summer, fall, and winter. The results of tagging experiments indicate that some of these remain in the western Pacific Ocean and others depart for the eastern Pacific during the fall or winter of their first year of life or the summer, fall, or winter of their second year of life. The journey from the western to the eastern Pacific takes as little as two months, or perhaps even less.

The fish that migrate from the western to the eastern Pacific form the basis for the fishery in the eastern Pacific.



Recreational Catch 1947-1999 , Pacific Northern Bluefin Tuna
Data Source: DFG, commercial passenger fishing vessel (CPFV) logbooks.

Most of the fish caught are in their second or third year of life, but some older, larger fish are also taken. After a sojourn in the eastern Pacific, which may or may not be interrupted by temporary visits to the central or western Pacific, the survivors return to the western Pacific, where they eventually spawn. Spawning probably first occurs at about five or six years of age.

The approximate lengths and weights attained by Pacific northern bluefin at various ages are: age one, 23 inches and 10 pounds; age two, 33 inches and 28 pounds; age three, 43 inches and 60 pounds; age four, 53 inches and 109 pounds; and age five, 63 inches and 177 pounds.

Pacific northern bluefin consume many species of fish and invertebrates in the eastern Pacific, including anchovies, red crabs, sauries, squid, and hake. Red crabs are a significant part of the diet only south of 29° N. "Boiling" and jumping schools of fish are much more common north of that latitude, where fish are the principal item of the diet. The differences in behavior in the two areas could be due to differences in the food, i.e., filter feeding might be employed for feeding on red crabs, while pursuit of individual fish would be required for feeding on fish. Japanese scientists have reported that bluefin are heavily dependent upon sardines for food in the western Pacific. Albacore, yellowtail, barracuda, and mackerel compete with bluefin for food in the eastern Pacific.

Status of the Population

The catches of Pacific northern bluefin in the eastern Pacific have been less, on average, during the 1980s and 1990s than during the 1960s and 1970s. Catch data, length-frequency data, and data on fish tagged in the western Pacific and recaptured in the eastern Pacific suggest that this decline is due to a decrease in the availability of bluefin in the eastern Pacific (i.e., a decrease in the proportion of the population which has migrated to the eastern Pacific) and a decrease in the number of boats which direct their effort at bluefin.

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Inter-American Tropical Tuna Commission

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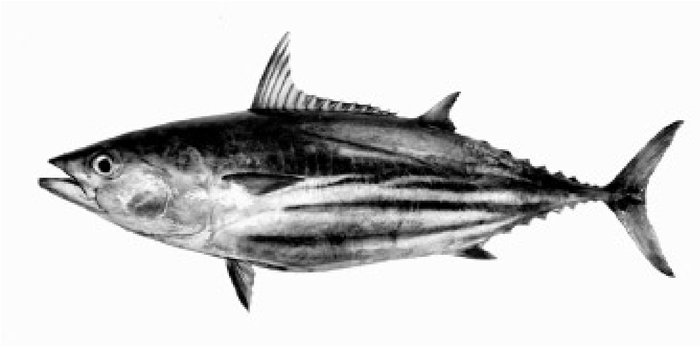
Skipjack Tuna

History of the Fishery

Skipjack tuna (*Katsuwonus pelamis*) have been harvested in the eastern Pacific by commercial bait boats since the early 1900s, and later by commercial purse seine, gillnet, troll fisheries and recreational fisheries. Skipjack tuna mixed with yellowfin tuna are frequently caught by these fisheries. Skipjack tuna are highly migratory and have been fished by many different countries such as the U.S., Mexico, Ecuador, France, and Spain. Landings from these countries are marketed throughout the Pacific Rim, Puerto Rico, and the European Community. Fisheries landing skipjack tuna in California operate between 150°W longitude and the coast of the Americas and between 40°N and 20°S latitude. California landings of skipjack tuna are important to both commercial and recreational fisheries.

Commercial landings of skipjack tuna in California started in 1918, and mainly supplied canneries where skipjack tuna were processed as light meat tuna. Small quantities of skipjack tuna were also sold to local markets. Commercial landings of skipjack tuna in California increased from three million pounds in 1918 to 156 million pounds in 1954. The landings, while fluctuating considerably, then decreased to a low of 30 million pounds in 1973 before peaking again at its highest level (174 million pounds) in 1980. Since 1976, skipjack tuna landings in California declined to average 10 million pounds from 1985 to 1999. The decline in commercial landings in California can be attributed to the relocation of cannery operations to American Samoa and Puerto Rico and the re-flagging of some vessels. Currently, only one cannery is operating in California. Prices paid by the canneries for skipjack tuna are based on fish size and market conditions and from 1990 to 1994 varied from $200 to $1,000 per ton. Based on a cannery price of $900 per ton, the 1999 California landings of skipjack tuna was worth approximately $4 million. The majority of the commercial skipjack tuna landings in California are from the purse seine and bait boat fisheries. Some fish are also caught in troll, gillnet, and longline fisheries.



Skipjack Tuna, *Katsuwonus pelamis*
Credit: DFG

Before the 1960s, bait boats supplied the majority of the commercial skipjack tuna landings in California. The first bait boats operated in coastal waters off southern California and Mexico. They could only make short trips because they used ice to preserve catches and relied on catching bait close to the coast and offshore islands. In the 1930s, with the development of new refrigeration techniques and construction of larger vessels, the fishery expanded to areas farther south and offshore. Bait boats ranged from 30 to 200 tons of carrying capacity. The U.S. fleet that operated in the eastern Pacific decreased from 75 vessels in 1976 to one in 1999. From 1984 to 1999, bait boat landings averaged 12 percent of the total skipjack tuna landings in California.

Purse seiners started to replace bait boats in the late 1950s and by 1961 supplied the majority of the commercial skipjack tuna landings in California. Purse seiners usually catch skipjack tuna in sets on free-swimming schools or in sets on schools associated with floating objects. Skipjack tuna are usually caught mixed with yellowfin and bigeye tunas. The carrying capacity of purse seiners ranged from 150 tons to 2000 tons. The U.S. fleet operating in the eastern Pacific decreased from 141 vessels in 1976 to nine in 1999. From 1984 to 1999, purse seine landings of skipjack tuna accounted for 80 percent of the total commercial skipjack tuna landings in California.

From 1991 to 1999, other commercial fisheries, troll, longline, and gillnet, landed less than one percent of the annual skipjack tuna landings in California. These fisheries catch skipjack tuna incidentally while targeting other tunas, sharks or swordfish.

California recreational fisheries for skipjack tuna typically operate in waters off southern California and Mexico. The duration of trips is usually one to seven days. The fleet consists mainly of commercial passenger-carrying fishing vessels (CPFV) and some private fishing vessels. Recreational anglers use rod and reel fishing gear. Skipjack tuna landings from the CPFV fishery reached highs of 103,000 fish in 1983, and 52,000 fish in 1990. Since 1990, skipjack tuna recreational landings have generally decreased to 14,000 fish in 1998.

U.S. commercial vessels that fish for skipjack tuna in the eastern Pacific must comply with all state and federal regulations and regulations proposed by the Inter-American Tropical Tuna Commission (IATTC) and any other international regulatory agency to which the U.S. is a member. These include compliance with the Marine Mammal Protection Act and a mandatory logbook program under the High Seas Fishing Compliance Act of 1995 that requires a license and submission of the IATTC logbook.

Recreational fishermen must carry California state fishing licenses, comply with state regulations, and purchase Mexican fishing licenses while fishing in the Exclusive Economic Zone (EEZ) of Mexico. Currently, California limits the recreational take of skipjack tuna to 10 fish per day.

Status of Biological Knowledge

Skipjack tuna occur throughout the tropical, subtropical waters and warm temperate waters of all oceans. There are two stock structures hypothesized for Pacific skipjack tuna, a single stock with isolated subgroups or two or more different stocks. This description considers skipjack tuna in the eastern Pacific east of 150° W longitude.

In the eastern Pacific, skipjack tuna are generally distributed between 40°N and 40°S latitude and between 150°W longitude and the coastlines of the U.S., Mexico, Central and South America. During El Niño events skipjack tuna may be found as far north as 50°N along the U.S. West Coast. Fishing concentrations are located in the northeastern Pacific near Baja California, the Revillagigedo Islands, and Clipperton Island, and in the southeastern Pacific near Central America, northern South America, Cocos Island-Brito Bank, and the Galapagos Islands and offshore south of 10°N. Skipjack tuna migrate from the equatorial spawning grounds in the eastern Pacific in two migrating groups, one migrates to the Baja California fishing grounds and the other to the Central and South American fishing grounds. The groups remain on the fishing grounds for several months before returning to the equatorial spawning grounds

Skipjack tuna typically prefer sea surface temperatures between 59° F and 86° F. Aggregations of skipjack tuna tend to be associated with convergence zones, boundaries between cold and warm water masses (*i.e.,* the polar front), up welling zones, and other hydro-graphical discontinuities. Skipjack tuna are found in surface waters and to depths of 850 feet during the day, but seem to stay closer to the surface at night than during the day. Skipjack tuna are most frequently found in surface schools aggregated around floating objects in the eastern Pacific. The larger fish are found in free-swimming unassociated schools. Smaller yellowfin and bigeye tunas (less than 40 inches) are frequently found in schools mixed with skipjack tuna.

Skipjack tuna spawn throughout the year in equatorial waters of the eastern Pacific, and from spring to early fall in subtropical waters. The spawning season is abbreviated as distance from the equator increases. Females mature at about 16 inches. However, in some areas of the eastern Pacific, the minimum size at maturity has been noted at 20 to 22 inches. Egg production is estimated between 0.1 to 2.0 million eggs per spawning.

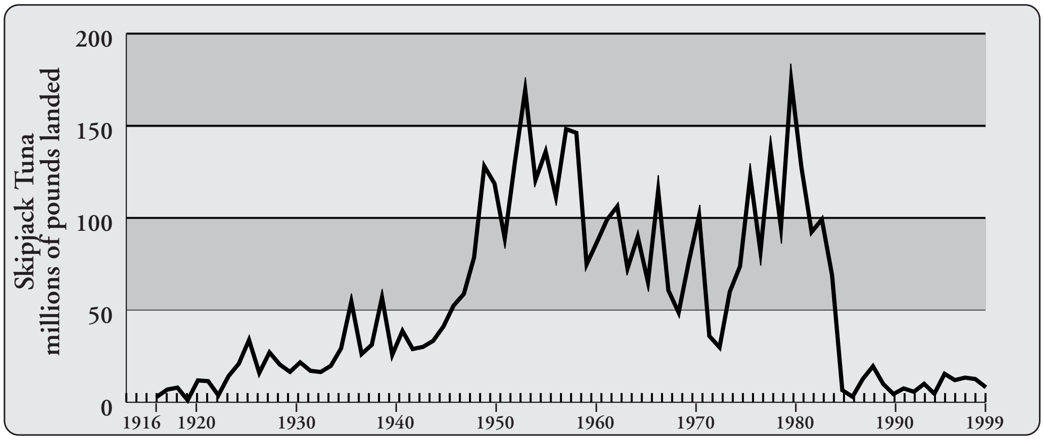
Skipjack tuna can grow to approximately 42.5 inches or 77 pounds. They have dark purplish-blue backs and, silvery sides with four to six longitudinal dark bands. They have a strong keel on each side of the caudal fin base between two smaller keels. Skipjack tuna enter surface fisheries at approximately 10 inches (0.5 pound) and commonly reach lengths up to 31.5 inches (26 pounds). Some longline fisheries also catch large skipjack tuna. Skipjack tuna growth is rapid and approximate sizes at age are: one year, 12 inches, 1.1 pound; two years, 20 inches, six pounds; three years, 25 inches, 12.8 pounds; four years, 20 inches, 19 pounds. Maximum age is probably around seven years.

Skipjack tuna feeding is opportunistic on fish, crustaceans and cephalopods. Stomach samples of skipjack tuna in the eastern Pacific contained 59 percent pelagic crabs, 37 percent fish, and three percent squids. A high percentage of stomach samples were empty. Larger fish tended to have higher percentages of crustaceans and lower percentages of fish in their stomachs. Predators of skipjack tuna include billfish, sharks and other large tunas, including skipjack tuna.

Status of the Population

In general, the population of skipjack tuna in the eastern Pacific is underutilized by fisheries operating in the area and is well above levels that are needed to produce maximum sustainable yield (MSY). The apparent abundance of skipjack tuna in the eastern Pacific is highly variable. This variability is apparently caused more by effects of environmental conditions than by the effects of the fishery. The simplest estimate of abundance can be obtained from trends in catches. Catches peaked at 186,800 tons in 1978, and decreased to 54,500 tons in 1985. During the period from 1986 to 1994, catches varied between 69,000 and 100,000 tons before increasing to 266,000 tons in 1999. Other abundance estimates for skipjack tuna, standardized catch per days fishing (CPDF), have been developed by the IATTC. However, these estimates are not considered satisfactory and indicate that further studies are needed. In general, the estimates show CPDF in the 1960s, between nine and 15 tons per days fishing, and fluctuating between two and seven tons per day fished from 1972 to 1996.

The status of skipjack tuna in the eastern Pacific is monitored annually by the IATTC. They are reasonably certain that skipjack tuna stocks in the eastern Pacific are under fished. Traditional age-based analyses and production models cannot be used to verify this conclusion



Commercial Landings 1916-1999, Skipjack Tuna
Data Source: DFG Catch Bulletins and commercial landing receipts. Data includes shipments and landings from areas south of the state between 1916 and 1969.

due to the violation of the unit stock concept. However, skipjack tuna catches in the western Pacific are near one million tons, and tagging studies there have shown that catches could easily double without adversely affecting the stock. Based on this, it seems that further increases in the eastern Pacific skipjack tuna catch could be attained. However, caution should be exercised until the exchange between the eastern and western Pacific is fully understood. The IATTC also notes that its assessment of skipjack tuna in the eastern Pacific could change and studies to learn more about this species and its relationships to the environment are needed.

Management Considerations

See the Management Considerations Appendix A for further information.

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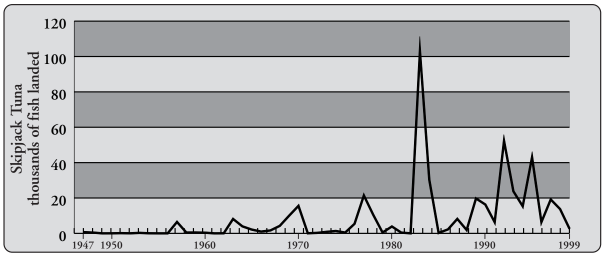


Recreational Catch 1947-1999 , Skipjack Tuna
Data Source: DFG, commercial passenger fishing vessel logbooks.

Yellowfin Tuna

History of the Fishery

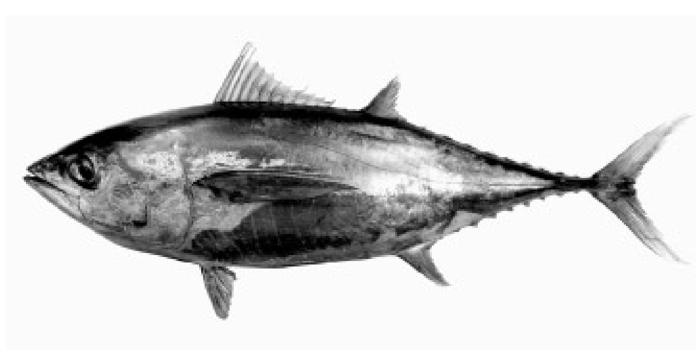
Yellowfin tuna (*Thunnus albacares*) have been harvested, in the eastern Pacific, by commercial bait boat fisheries since the early 1900s, and later by commercial purse seine, longline, gillnet, troll and recreational fisheries. Yellowfin tuna, frequently caught in schools mixed with skipjack and bigeye tuna, are highly migratory and have been fished in the eastern Pacific by many different countries. U.S. fisheries that land yellowfin tuna in California operate between 150° W longitude and the coast of the Americas and between 40° N and 20° S latitude. California landings of yellowfin tuna are important to both commercial and recreational fisheries.

California landings of commercially caught yellowfin tuna date back to 1919. These landings supplied canneries mainly in California, where yellowfin tuna were processed as light meat tuna. In recent years, some commercial, yellowfin tuna landings were also purchased by local markets and restaurants. Cannery prices paid for yellowfin tuna depend on fish size and canned tuna market conditions. During the early 1990s, prices ranged from $200 to $1,100 per ton. Commercial landings of yellowfin tuna in California, while fluctuating, generally increased from 350,000 pounds in 1919 to 280 million pounds in 1976. Since 1976, yellowfin tuna landings declined steadily to three million pounds in 1999. Assuming a cannery price of $1,000 per ton, the estimated value of the 1999 California commercial yellowfin tuna landings was $1.5 million. The decline in commercial landings in California can be attributed to the relocation of cannery operations to American Samoa and Puerto Rico and the re-flagging of some U.S. vessels. Currently, only one cannery is operating in California. Purse seine and bait boat fisheries supply the bulk of the California commercial yellowfin tuna landings. Some commercial landings are also supplied by longline, troll, and gillnet fisheries.

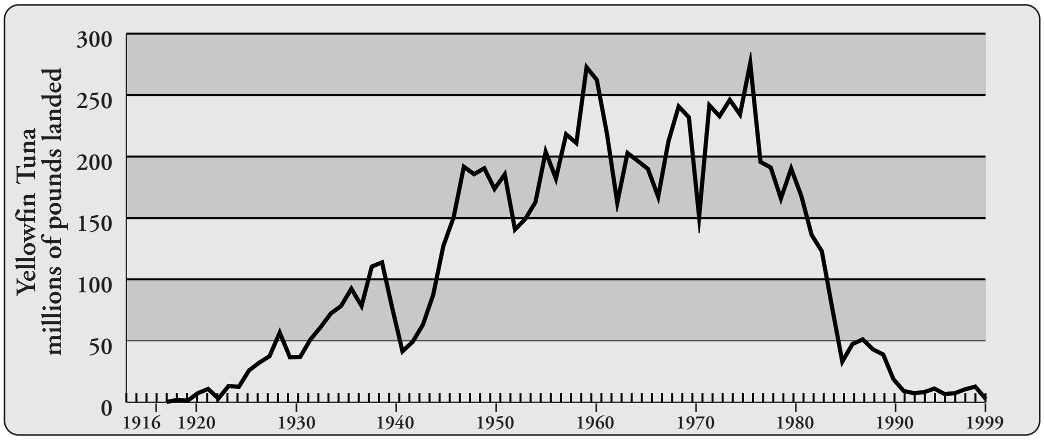
Before the 1960s, bait boats supplied the majority of the commercial yellowfin tuna catch. Initially, bait boats operated in coastal waters of southern California and Mexico. The vessels could only make short trips because they used ice to preserve catches and relied on catching bait close to the coast and offshore islands. In the 1930s, improvements in refrigeration methods and construction of larger vessels enabled the fishery to expand farther south and offshore. From 1984 to 1999, California bait boat landings averaged 11 percent of the total landings of yellowfin tuna in California. Bait boat carrying capacity ranged from 30 to 200 tons carrying capacity. The U.S. fleet that operated in the eastern Pacific ranged from 75 bait boats in 1976 to one in 1999. While bait boat fisheries dominated landings in the early days of the eastern Pacific yellowfin tuna fishery, catches and effort from this fishery gave way to the more efficient purse seine method.

Purse seiners started to replace bait boats in the late 1950s, and by 1961, supplied the majority of the commercial yellowfin tuna landings in California. Purse seine carrying capacity ranged from 150 tons to 2,000 tons. Purse seiners, because of their size and ability to stay at sea for long-periods of time, expanded the fishery to areas between southern California and Peru and out to 150°W longitude. Historically, three types of sets have been used to catch yellowfin tuna: sets on fish associated with schools of dolphins, sets on fish in free-swimming schools and sets on fish associated with floating objects. Until the 1990s, U.S. purse seiners in the eastern Pacific primarily caught yellowfin tuna in sets associated with schools of dolphins. Purse seiners employed a standard purse seine with the exception of a porpoise panel that was used to reduce entanglement of dolphins. The purse seines were deployed with a seine skiff and, when fishing dolphin schools, speedboats were used to herd the dolphins into a compact school so that the net could be set around them. Once the schools of tuna and dolphins were surrounded, the net was pursed and a backdown procedure was used to free the trapped dolphins. In the mid 1970s, marine mammal regulations were enacted to reduce dolphin mortality associated with purse seine fishing and in the 1990s canneries stopped buying yellowfin tuna caught on dolphins. The canneries "dolphin safe" policy drove many U.S. purse seiners to the western Pacific and as a result, the U.S. fleet that operated in the eastern Pacific decreased from 141 purse seiners in 1976 to nine in 1999. From 1984 to 1999, purse seine landings averaged 86 percent of the total yellowfin tuna landings in California.

Longliners, based in California, started fishing in the eastern Pacific in 1991. These vessels usually targeted bigeye tuna or swordfish outside the California 200-mile Exclusive Economic Zone (EEZ) and yellowfin tuna are an incidental catch in this fishery. Longliners usually fish between 30°N



Yellowfin Tuna, *Thunnus albacares*
Credit: DFG



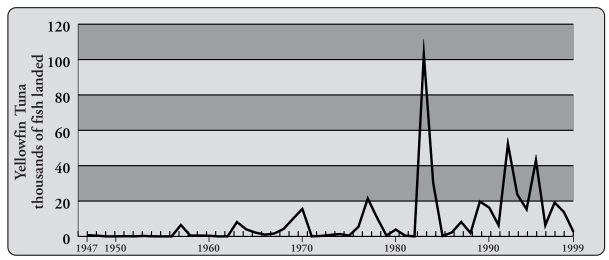
Commercial Landings 1916-1999, Yellowfin Tuna
Data Source: DFG Catch Bulletins and commercial landing receipts. Data includes shipments and landings from areas south of the state between 1916 and 1969.

and 40°N latitude between Hawaii and the U.S. West Coast EEZ. The U.S. longline fleet uses standard longline gear with floats and branch lines. The gear is deployed at various depths, depending on the target species sought, and light sticks are used to attract fish. From 1991 to 1999, longline-caught yellowfin tuna were less than one percent of the total yellowfin tuna landed in California.

From 1984 to 1999, commercial troll and gillnet fishing gears supplied less than three percent of the annual yellowfin tuna landings in California. These gears incidentally catch yellowfin tuna inside the EEZ south of San Francisco. Gillnet fisheries usually target swordfish and sharks, while troll fisheries typically target albacore.

California recreational fisheries for yellowfin tuna typically operate in waters off southern California and Mexico. The duration of trips is usually from one to seven days. The fleet consists mainly of commercial passenger-carrying fishing vessels (CPFV) and some private fishing vessels. Recreational anglers use rod and reel fishing gear. Yellowfin tuna landings from the CPFV fishery, reached a record high of 120,000 fish in 1983, decreased to 4,000 fish in 1985, and averaged 81,000 fish from 1995 to 1998. Since the recreational catch cannot be sold, the value of the recreational fishery is difficult to determine, but must reach millions of dollars and extend to many sectors of the business community. Anglers buy equipment, fly in from various locations and stay in local hotels. Vessel operators collect fares that are based on trip length but also collect fees for food and equipment rentals. Anglers may catch yellowfin tuna, but they also catch bluefin, skipjack, bigeye and albacore tuna, and other fish.

U.S. commercial vessels that fish for yellowfin tuna in the eastern Pacific must abide by all federal and state regulations, including those proposed by the Inter-American Tropical Tuna Commission (IATTC), and any other international regulatory agency in which the U.S. is a member. These include a mandatory logbook program under the



Recreational Catch 1947-1999 , Yellowfin Tuna
Data Source: DFG, commercial passenger fishing vessel logbooks.

High Seas Fishing Compliance Act of 1995, which requires a license and submission of the IATTC logbook. U.S. purse seiners fishing for yellowfin tuna associated with dolphins in the eastern Pacific must also abide by dolphin quotas stipulated in the Marine Mammal Protection Act, and all large purse seiners (greater than 400 tons) must carry observers.

Status of Biological Knowledge

Yellowfin tuna in the eastern Pacific are distributed throughout areas between 40°N and 40°S latitude and between 150°W longitude and the coastlines of the U.S., Mexico, Central, and South America. The eastern Pacific stock is generally considered a separate population that is not believed to interact appreciably with stocks in the central and western Pacific. Yellowfin tuna are typically found in sea surface temperatures between 65°F and 88°F and are usually confined to the upper 330 feet of the water column, or between the surface and the thermocline. Seasonal migrations are primarily along the coast. Surface schools of small yellowfin tuna in the eastern Pacific can be found aggregated around floating objects or in free-swimming unassociated schools, while larger yellowfin tuna are usually found in schools associated with dolphins. Small yellowfin tuna (less than 40 inches) are frequently found in schools mixed with skipjack and bigeye tuna, whereas larger yellowfin tuna usually do not mix with other tunas.

Yellowfin tuna spawn throughout the year and across their entire range. However, 75°F is probably the lower temperature limit for yellowfin tuna spawning. Off Mexico and Central America, spawning can occur throughout the year, with peak spawning occurring at different times in different areas. Spawning is likely abbreviated and more sporadic in coastal areas than in offshore northern equatorial areas. Most females mature at sizes above 36 inches and produce from two to seven million eggs per spawn.

Yellowfin tuna can grow to approximately 83 inches. The larger fish have very large anal and second dorsal fins that may extend to over 20 percent of the fork length. Approximately 20 broken, nearly vertical lines cross the sides of the fish and a yellow coloration are present on the sides, dorsal and anal fins and finlets. Yellowfin tuna enter surface fisheries at approximately 10 inches and commonly reach lengths up to 60 inches. Growth is rapid at these approximate sizes at and ages: one year, 19 inches; two years, 34 inches; three years, 50 inches; four years, 59 inches; five years, 68 inches. Maximum age is probably around 10 years.

Yellowfin tuna are opportunistic feeders and therefore have a very diverse diet; however, a few fish, cephalopods and crustaceans are dominant in stomach samples from fish in the eastern Pacific. The most dominant are bullet tuna and pelagic crabs. Other organisms include fish commonly found around flotsam such as skipjack tuna, black skipjack, flying fish, light fish, and squid. Predators of yellowfin tuna include sharks, billfishes and other large tuna, including yellowfin tuna.

Status of the Population

In general, the population of yellowfin tuna in the eastern Pacific is being fully utilized by fisheries operating in the area and is at levels that will produce the maximum sustainable yield (MSY). The IATTC has recommended an annual yellowfin tuna catch quota in the eastern Pacific since 1966 to maintain the stock at MSY. Catches peaked at 277,300 tons in 1976, decreased to 111,500 tons in 1983, peaked again in 1989 at 337,000 tons, and then decreased to 301,400 tons in 1997. Because of management-imposed measures, it is difficult to use strictly catch as an indicator of overall population abundance. However, four abundance indices, one based on estimates of standardized catch-per-days fishing, two based on age models, and one based on a searching-time method, have been developed and indicate that abundance dropped steeply from the late 1960s to historically low levels in the early 1980s. Abundance estimates rebounded substantially in 1986 and since then have remained fairly constant at slightly lower levels than in 1986.

Stock assessments for yellowfin tuna in the eastern Pacific are conducted annually by the IATTC. The latest assessment indicated that the eastern Pacific yellowfin tuna fishery could continue to harvest approximately 297,000 tons annually without further lowering the stock size. In accordance with these findings, the IATTC set the annual 1998 yellowfin quota at 231,000 tons, with 16,500 ton increments added at the discretion of the IATTC. Closure of the fishery based on this quota in 1988 was in November.

Management Considerations

See the Management Considerations Appendix A for further information.

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Striped Marlin

History of the Fishery

Striped marlin (*Tetrapturus audax*) support important commercial and recreational fisheries in the central and eastern Pacific and in the Indian oceans. They were directly targeted by high seas fisheries in the 1960s and 1970s, although today most are taken as incidental catch in tuna longline fisheries. Pacific-wide landings currently average near 26.5 million pounds per year and represent about 86 percent of world landings.

Striped marlin are seasonal visitors to southern California waters providing recreational billfish anglers an opportunity to fish for local large gamefish during summer and fall. Recreational and commercial fishing for striped marlin began off southern California in the early-1900s using hand-held harpoons or rod-and-reel. The California Legislature banned the use of harpoons to take striped marlin in 1935 and further curtailed the sale and import of striped marlin in 1937 thus preserving the southern California fishery entirely for recreational anglers. Currently, most striped marlin fishing is from privately owned boats based in local southern California marinas. Generally, fish begin arriving in the coastal and insular waters off southern California in June and remain until at least October. The number of fish moving into the Southern California Bight during any particular year is associated with water temperatures. Warmer water generally means more fish, better catches and higher catch rates. The colder water north of Point Conception usually limits their northward distribution, although during El Niño years they commonly range north to San Francisco and persist for extended periods. A 31-year-long angler survey indicates fairly low, but steady, catch rate averaging 0.10 fish per anger fishing day but ranging to 1.0 or greater during El Niño periods. The southern California catch of striped marlin taken by the commercial passenger fishing vessel (CPFV) fleet averages six striped marlin per year. Commercial landings in Oregon and Washington are legal but rare.

Striped Marlin, *Tetrapturus audax*
Credit: DFG

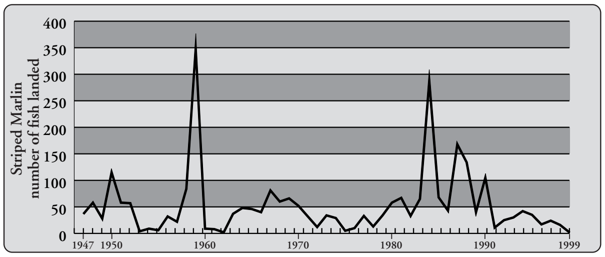
In Mexican waters, striped marlin are taken for local markets and export to other countries. These fisheries include both artisan, using hand-hauled gillnets and longlines, and larger drift net vessels targeting swordfish and sharks. The water off the southern tip of the Baja California peninsula to Manzanillo, Mexico, is an area of high striped marlin abundance, which supports a large recreational fishery. Mexican tourist enterprises aggressively advertise to attract billfish anglers to the area. The striped marlin catch rate is greatly improved off Baja where anglers average 0.3 to 0.65 striped marlin per day of fishing. Estimated recreational catches of striped marlin off Los Cabos, Baja California Sur, averaged 12,000 fish annually between 1992 and 1996, but only averaged 260 fish off Mazatlan. The estimated incidental catch from the longline shark fishery in Mazatlan averaged 680 striped marlin over the same period.

Interest in angler-based tagging and survey programs have intensified greatly in recent years. The trend toward catch and release and tagging of striped marlin has also increased as anglers became more aware of perceived conservation needs. Current estimates of striped marlin released off southern California have exceeded 80 percent of those captured. Annual marlin tournaments now award points to anglers for releasing fish and the first all-tag and release marlin tournament was held in San Diego in September 2000.

Status of Biological Knowledge

The striped marlin (family Istiophoridae) is a large, oceanic fish with a long, round bill, small teeth and tall dorsal fin which decreases in height ending just before the second dorsal fin. The species is widely distributed throughout most tropical, sub-tropical and temperate waters of the Pacific and Indian oceans but does not occur in the Atlantic except for occasional strays off western South Africa. Japanese longline data indicate a horseshoe-shaped distribution across the central North and South Pacific with a continuous distribution along the west coast of Central America. It is apparently more abundant in eastern and north central Pacific than elsewhere.

Movements tend to be diffusive, as this species does not under take annual migrations as seen in some tunas. Striped marlin do not form dense schools but rather occur singularly or in groups of several fish, usually segregated by size. Adult fish are found in the north and south central Pacific where spawning occurs. Larvae are recorded from North Pacific west of 150° W, in the South Pacific and more recently have been found off central Mexico. Subadult fish move east toward the coast of Mexico where they are found in high abundance around the tip of the Baja peninsula. Tag-recapture data indicate movement



Recreational Catch 1947-1999 , Striped Marlin
Data Source: DFG, commercial passenger fishing vessel logbooks.

from southern California to Baja California Sur but show little or no movement in the reverse direction. Also, tag-recapture data reveal movements from off Mexico and southern California to near Hawaii, Peru, and the South Pacific near the Marquises Islands. Striped marlin are epipelagic, and are commonly bounded by 68° to 78° F temperature regime during all stages of their life-cycle. Acoustic telemetry studies indicate they spend 86 percent of their time in the mixed layer above the thermocline and avoid temperature changes greater than 14° F.

Stock structure in the Pacific is unclear. Current evidence indicates striped marlin are probably a single Pacific-wide stock because of the continuous distribution throughout the Pacific, spawning in the south and northwest Pacific and eastern Pacific off Mexico, and from tag-recapture studies. The possibility of separate North and South Pacific stocks does exist and is based on catch-per-unit effort (CPUE) analysis, temporal and geographically separate spawning areas, and morphological differences. Genetic data further indicate some population structuring in the Pacific which implies discrete spawning areas for fish from Hawaii, Australia, and the eastern tropical Pacific.

Striped marlin mature between 55 and 63 inches eye-to-fork length (EFL) and reach a maximum size of nearly 12 feet and more than 450 pounds. The International Gamefish Association all-tackle record is for a 494-pound fish caught near New Zealand in 1986. Most striped marlin caught in the southern California sport fishery are three to six years old, and weigh 120 to 200 pounds. Examination of gonad material from the recreational and drift net fisheries indicates that striped marlin off southern California are not reproductively active while in residence.

Striped marlin are opportunistic feeders primarily on epipelagic fishes including mackerel, sardine, anchovy, and will take invertebrates including squid and red crab when available. Off southern California, they are often seen feeding at the surface on these small coastal fish. Predation on adult marlin has not been documented but may occur from large pelagic sharks or toothed whales.

Status of the Population

The Pacific striped marlin resource appears healthy regardless of whether a single Pacific-wide stock or two separate north and southern stocks are assumed. The relationship between catch and fishing effort in the Japanese longline fisheries show sustained catches over a wide range of fishing intensities, suggesting Pacific-wide catches are below the estimated maximum sustainable yield of 53 million pounds. Catches are fairly stable at around 25 to 30 million pounds. Angler catch and effort surveys indicate CPUE off California and Mexico has changed little since 1985.

Management Considerations

See the Management Considerations Appendix A for further information.

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Shortfin Mako Shark

History of the Fishery

Since the late 1970s, the shortfin mako (*Isurus oxyrinchus*) has been taken incidentally in the commercial drift gillnet fisheries for thresher shark and swordfish. Up until 1987, there were no fisheries that specifically sought mako.

There are several reasons why mako sharks took so long to become a primary target of a commercial fishery. Although readily marketable, shortfin makos off southern California averaged only 34 pounds dressed, while threshers had an average dressed weight of about 150 pounds. As long as threshers were plentiful, fishermen paid little attention to mako sharks. This situation might have changed during the mid-1980s when the thresher population began to show signs of decline, but the drift gillnet fleet, which pursued the thresher, also took a more valuable species – swordfish. Swordfish had a commercial value of $4 per pound, compared to $1 per pound for most sharks, and they averaged nearly 200 pounds dressed. As a result, the drift gillnet fleet gave little regard to the mako shark resource.

It took the application of an entirely different fishing gear to create commercial interest in the mako. During 1988, the California Fish and Game Commission established an experimental shark fishery for mako and blue sharks using drift longlines. This gear proved much more efficient than drift gillnets. By 1990, stringent regulations were implemented that included an annual quota, time-area closures, and a requirement to reduce the bycatch and waste of blue sharks by establishing a market. In 1992, the commission did not renew the longline permits and the experimental fishery ended. This was due to the inability of the fishermen to establish a market for the bycatch of blue sharks and a well organized opposition by the sport fishing industry to a directed commercial fishery for mako sharks.

Shortfin Mako Shark, *Isurus oxyrinchus*
Credit: DFG

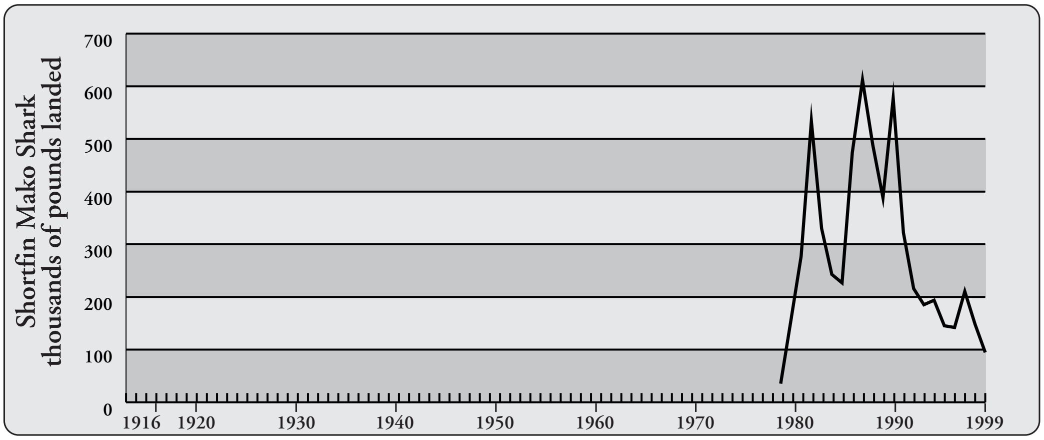
Currently, mako sharks are taken by drift gillnets and hook-and-line. Most mako sharks, however, are taken in the drift gillnet fishery for thresher sharks and swordfish. Annual landings have fluctuated from over 600,000 pounds in 1987 to less than 100,000 pounds in 1999.

The shortfin mako shark is also taken by the high seas shark and swordfish drift longline fishery, which developed between 1991 and 1994. This fishery operates outside the 200-nautical-mile Exclusive Economic Zone in international waters. A small portion of the catch is landed in California ports with annual landings ranging from 128,116 to 9,523 pounds between 1991 and 1999.

Makos have long been esteemed as prized game fish along the East Coast of the U.S. During the early-1980s, the mako captured the attention of the southern California sport fishing public. In the mid-to late-1980s, estimates of the number of California angler trips for sharks grew ten-fold from 41,000 to 410,000 annually. The principal target of these trips was the shortfin mako shark. After the increase during the 1980s, the sport fishery for mako sharks has stabilized at a relatively high level. Total annual landings (sport and commercial) peaked in 1987 at 464,308 pounds and again in 1994 at 394,792 pounds. In both cases, landings declined rapidly in the two years following the peaks. Currently, commercial passenger fishing vessels run fishing trips on a regular basis from nearly all ports in southern California.

Status of Biological Knowledge

The shortfin mako shark is distributed in temperate and tropical seas worldwide. In the eastern Pacific, it is distributed from Chile to the Columbia River and can be found off the U.S. West Coast from southern California northward to Washington. However, it is most common off southern California and is seldom caught north of the Mendocino Escarpment. It is considered an oceanic species, occurring from the surface to at least 500 feet



Commercial Landings 1916-1999, Shortfin Mako Shark
Data Source: DFG Catch Bulletins and commercial landing receipts. All shark landings were aggregated until 1977.

in depth, and is rarely found in areas where the water temperature falls below 61° F.

Evidence from size and mark-recapture data suggest that the Southern California Bight, which extends from Point Conception to the Mexican border, is an important pupping and nursery area for the shortfin mako shark. High recapture rates for tagged juveniles show that newly born makos remain in these waters for about two years, after which they appear to move offshore or to the south. Many fish tagged in the Southern California Bight have been recaptured locally, but others have been caught as far north as Point Arena, northern California; as far south as Acapulco, Mexico; and as far west as Hawaii in the central Pacific. Although some of the tagging data have not been subjected to formal analyses and no migratory pattern has become obvious, these documented movements suggest that the California-Mexico stock is wide-ranging and is not an isolated population.

There is an ongoing disagreement surrounding the proper aging of shortfin mako sharks, particularly in large size classes. Results differ among age-growth studies, which may be due to stock differences, different aging interpretations of the periodic deposition of vertebral rings, and the difficulty of interpreting growth rings, especially in older specimens. Young makos appear to grow fairly rapidly, reaching nearly five feet in total length (TL) by the age of two. After two years, however, growth rate is less defined. Males reportedly mature at six feet TL and as early as four years old, while females reach maturity at nine feet TL and not before seven or eight years old. Females either mature at a much later age than males, or the sexes grow at greatly differing rates. The maximum size of a mako shark is reported to be approximately 13 feet and possibly as old as 40 years.

Like the thresher shark, shortfin makos are ovoviviparous. The embryos have no umbilical attachment to the mother and receive all their intrauterine nourishment by eating other eggs. It is estimated that females have from four to 30 pups. The gestation period is estimated to last from 12 to 19 months. At birth, pups are approximately 2.0 to 2.5 feet TL.

The shortfin mako is a top carnivore in the ocean food chain. It is known to prey upon many species of fish such as mackerel, sardine, anchovy, tuna, other sharks, and squid. Other items in the adult diet probably include several marine mammals. The mako, however, is an opportunistic feeder like many of its oceanic relatives. It may eat whatever is abundant in its surroundings.

Status of the Population

The present status of the shortfin mako shark in state and federal waters off California is not known but is of concern. Adult mako sharks do not frequent California's coastal waters; therefore, they are not subject to local fisheries. The real threat to the mako population off California and in the eastern Pacific lies in the potential for over-development of fisheries within the coastal nursery. This threat is particularly insidious, as the effect of overfishing would not become apparent until the missing juveniles were of an age to become the spawning stock. Since a sudden population collapse could follow, efforts to monitor the shortfin mako shark are needed.

Management Considerations

See the Management Considerations Appendix A for further information.

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Thresher Shark

History of the Fishery

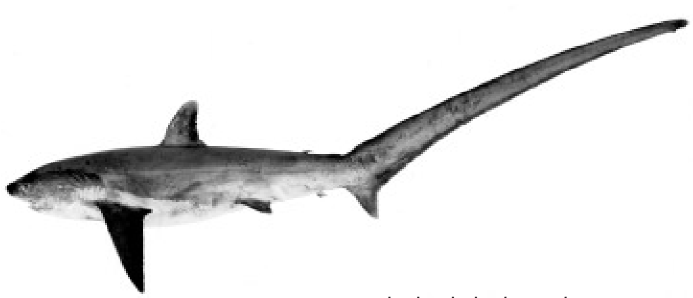
The common thresher shark (*Alopias vulpinus*) is the leading commercial shark in California, although landings are much less than they were during the first decade of the drift gillnet fishery. In the early years, from 1977 through 1989, annual commercial landings averaged 1.1 million pounds dressed weight (dw) per year, ranging from 0.1 million pounds in 1977 to a peak of 2.3 million pounds in 1982. More recently, catches from 1990 through 1998 have averaged about 0.4 million pounds with a low of 0.3 million in 1995 and a high of 0.8 million pounds in 1991, remaining at 0.4 million pounds over the past three years. In 1998, the average ex-vessel price was $1.36 per pound. Fish are taken primarily by drift gillnets (78 percent) followed by set gillnets (18 percent), and other assorted gears (4 percent). Two other species of thresher shark, the pelagic (*A. pelagicus*) and the bigeye thresher (*A. superciliosus*) also occur off California, but these species are much less common, averaging only about one and nine percent, respectively, of the total drift net thresher catch in the 1990s.

The early thresher shark drift net fishery began in southern California and expanded rapidly, reaching a peak in 1982 when 225 vessels were permitted in the fishery. Fishing then expanded northward first to Morro Bay and then to Monterey and San Francisco. By 1987, experimental fishing was being conducted off Oregon and Washington. The drift net fishery was initially developed to target common thresher, but emphasis later shifted to broadbill swordfish, with thresher and shortfin mako shark being secondary market species. Also, catches of threshers off California soon began to decline, and some of the most heavily exploited size classes were observed to disappear from the catches after the mid-1980s. These size/age classes were thought at the time to be all immature fish approximately three to six years old, but more recent maturity data suggest that many may also have been mature individuals four to seven years old. Regulatory measures in California, particularly area and season closures imposed after the mid-1980s, were instituted to address swordfish user conflicts (gill-netters versus harpooners versus recreational anglers), to protect marine mammals, and to protect thresher shark. In 1990, a California state voter initiative banned gillnetting within three miles and completely prohibited drift net fishing on threshers during peak seasons and in nearshore areas. Since January 1996, the landing of shark fins detached from any carcass has been prohibited, except for threshers, which can be landed with the fins and tails removed providing that a corresponding carcass is also landed.

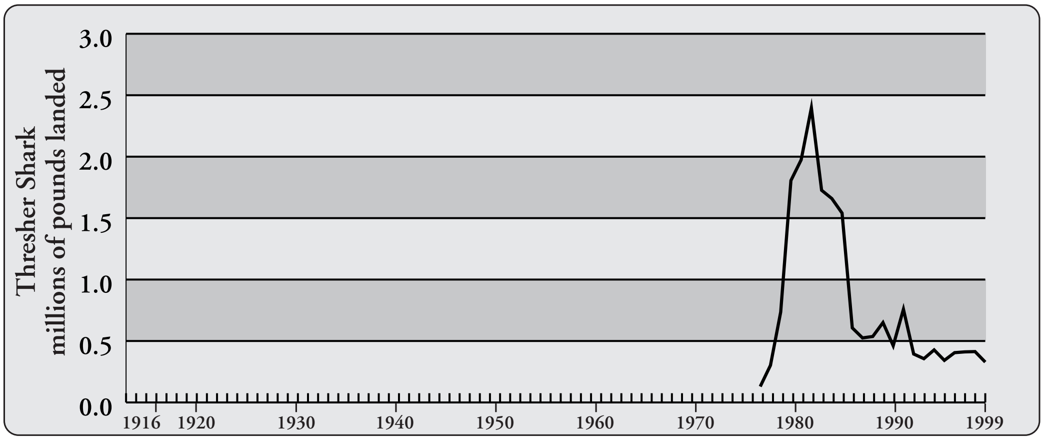
Currently, the fishery is under a non-transferable permit system and takes place from the Mexican border north to central Oregon in waters up to 200 miles offshore in depths from 30 to 2,000 fathoms over banks, escarpments and canyons. Up until recently, because of various time/area closures and seasonal availability of swordfish, most of the annual fishing effort occurred between mid-August through January outside of state waters to about 150 miles offshore. In addition to various existing time/area closures, beginning August 15, 2001, the area between Point Conception and 45 degrees north latitude will be closed to drift gillnet fishing through October 31 to reduce interactions with leatherback sea turtles. If an El Niño condition is predicted, or is occurring, the area south of Point Conception will be closed to drift gillnet fishing from August 15 to August 31, and during the month of January, to reduce loggerhead sea turtle impacts through recreational angling for thresher sharks, especially from private boats and skiffs, which have become increasingly popular in recent decades in coastal waters between San Diego and Santa Barbara, California. Currently, there are about eight shark fishing tournaments held annually in southern California. Party boat catches, which are thought to represent a relatively small portion of the total sport catch, have averaged about 55 fish per year, with a peak of 163 fish taken in the 1993 El Niño year. Title 14 of the California Fish and Game Code limits the take of thresher sharks to two per day, but sport anglers may possess more than this limit depending on the length of the fishing trip. A one-inch square of skin must be left on each fillet, if filleted at sea.

Status of Biological Knowledge

The common thresher shark is a large pelagic shark with a long scythe-like tail, which makes up nearly half of its total body length. Its body is white below and blue-gray to gray above with a slight wash of bronze. It is generally distinguished from other species of thresher sharks by the white of the abdomen that extends in a splotchy pattern above the base of the pectoral fins;



Thresher Shark, *Alopias vulpinus*
Credit: DFG



Commercial Landings 1916-1999, Thresher Shark
Data Source: DFG Catch Bulletins and commercial landing receipts. All shark landings were aggregated until 1977.

unlike the bigeye and pelagic thresher, which are uniformly pigmented blue-gray to gray above the pectoral fins. The common thresher also does not possess the large eyes distinctive of the bigeye thresher or the deep lateral grooves on the sides of the head.

The distribution of the common thresher shark is circumglobal. In the eastern Pacific, it occurs from Goose Bay, British Columbia south to off Baja California, and off Panama and Chile. Abundance in the Pacific Ocean is thought to decrease rapidly beyond 40 miles from the coast, although catches off California and Oregon do occur as far as 100 miles offshore and sometimes beyond. It is found in temperate and warm oceans penetrating into tropical waters, seeming to prefer areas characterized by high biological productivity, the presence of strong frontal zones separating regions of upwelling and adjacent waters, and strong horizontal and vertical mixing of surface and subsurface waters. Such habitats are conducive to production and maintenance of schooling pelagic prey upon which it feeds. Adults, juveniles, and post-partum pups occur within California waters.

After parturition and during their first few years of life, the young occur close to shore off beaches and in shallow bays, often near the surface of the water. During most years, concentrations of young threshers may be found within two to three miles off the beaches from Santa Monica Bay into Santa Barbara County, and as far north as Monterey Bay and San Francisco Bay during warm water years. One young thresher was tracked in Morro Bay for 18 hours where it spent 70 percent of the time in shallow water over mudflats, increasing its activity at the onset of darkness and during high tide periods. Larger mature individuals over 10 feet in total length tend to show a greater range of habitat and more offshore distribution.

Some anecdotal evidence and patterns of observed catches suggest seasonal north-south migration of this species between San Diego and Baja California, Mexico, and Oregon and Washington. This migration hypothesis is derived from patterns of early catches in the drift gillnet fishery prior to seasonal and area restrictions, and the incidence in the 1980s of thresher sharks taken off California carrying Japanese longline hooks, indicating an origin outside the U.S. EEZ. It has been proposed that large adult common thresher sharks pass through southern California waters in early spring of the year, remaining in offshore waters from one to two months during which time pupping occurs. Pups are then thought to move into shallow coastal waters. The adults then continue to follow warming water and perhaps schools of bait northward, and by late summer, arrive off Oregon and Washington. Subadult individuals appear to arrive in southern California waters in early summer, and as summer progresses they move up the coast as far north as San Francisco. In fall, these sub-adults are thought to move south again. Little is known about the presumed southward migration of the large adults, which do not appear along the coast until the following spring. Recent satellite pop-up tagging by NMFS has confirmed active transboundary migration in this species. Two common thresher sharks tagged in June off Laguna Beach and Santa Monica Bay, California, were relocated off Baja California, Mexico, and 540 miles southwest of La Paz, Mexico, within 120 and 210 days of tagging. Recent genetic analyses of tissue biopsies collected off the U.S. West Coast and Mexico (with samples from off Oregon-Washington grouped together and compared to samples collected off California and Baja California, Mexico) showed no significant differences in haplotypic frequencies, indicating a single homogenous West Coast population.

Reproduction is ovoviviparous; normal brood size appears to be two to four fetuses. Brood sizes of up to seven fetuses have been recorded off Spain, indicating there may be some plasticity in this trait. The developing fetuses are oophagous. Mating presumably takes place in midsummer along U.S. West Coast EEZ with a gestation period of about nine months. Parturition is thought to occur in the spring months off California, judging from the number of post-partum-sized pups that have been taken in the catch at this time.

Maximum size reported is 20 feet total length, but off California the largest ever recorded was 18 feet long. Size at first maturity has been variously estimated and interpreted. A re-examination of male and female maturity data suggests that off the U.S. West Coast, size and age at first maturity is about 10 feet in total length and about five years old.

Size at birth varies considerably, ranging from 45 to 61 inches long, with only slight variation among geographical regions around the world. The species has been variously estimated to reach a maximum age of from 19 to 50 years.

Feeding is primarily on small to medium-sized schooling fishes and pelagic invertebrates. Prey items include anchovy, Pacific sardine, herring, mackerel, Pacific hake, lancetfish, lanternfish, Pacific salmon, squid, octopus, pelagic red crab, and shrimp. A recent study of the diet of fish taken in the drift gillnet fishery found in addition, Pacific and jack mackerel, shortbelly rockfish, louvar, grunion, white croaker, queenfish, and Pacific sanddab. Thresher sharks have been observed to use their long caudal fin to bunch up, disorient and stun prey at or near the surface and are often caught tail-hooked by longlines. Predation on this species, other than by man, has not been documented.

Status of the Population

In 1990, this species came under the oversight of the Pacific States Marine Fisheries Commission, which has provided a general forum for coordinating thresher shark management among the states of California, Oregon and Washington, guided by an interjurisdictional fishery management plan for thresher shark. No quotas were ever established, but the three states did agree to an annual coastwide landings guideline of 750,000 pounds dressed weight of thresher shark, which since 1991 has never been approached. A stock assessment of this species is currently underway, and it has been included as a management unit species within the Pacific Fisheries Management Council's fishery management plan for highly migratory species, currently being drafted.

There are indications that management actions taken after the mid-1980s and resulting reduction in fishing pressure may have contributed to a rebuilding in the stock over the last decade. In the early-1990s, some mid-sized fish were beginning to reappear in wholesale market samples in California. More recently, an increase in average size of fish and in catch-per-unit of effort has been noted in the thresher shark catch off Point Conception – an area that historically has had the most consistent and highest thresher catches. It is not known, however, to what extent environmental changes and shifts in distribution might influence these observations, since this area is but a small portion of the total coastal range of the species. The potential annual rate of population increase for the common thresher shark at the maximum sustainable yield population level has been estimated at four to seven percent per year.

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Blue Shark

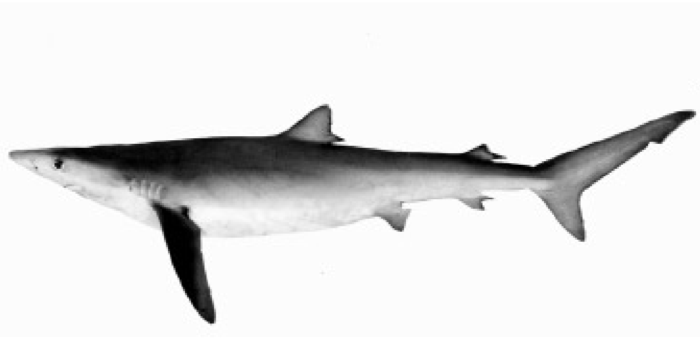
History of the Fishery

Blue sharks (*Prionace glauca*) are not a major target of California's recreational or commercial fisheries. Urea stored in their blood system quickly turns to ammonia when the shark dies, thus rendering the meat unpalatable. Development of a quality meat product has been the limiting factor in creating commercial interest. Only two serious attempts at developing a quality food product in California have occurred. The first took place in 1979 and 1980 when one vessel fished blue sharks experimentally with longline gear. Product quality was judged to be good enough to establish blue shark as a viable alternate fishery, and 150,000 pounds dressed meat were sold at about $0.25 per pound. Although market interest developed in several western states, a steady demand could not be assured and the fishery was discontinued.

The second attempt at developing a food product began in 1988 with an experimental longline fishery directed at shortfin mako and blue shark. Participants in the fishery were required to develop a market for human consumption with the bycatch of blue sharks, which were not released alive. In 1989 and 1990, a total of 54,000 pounds of blue shark was sold for making jerky and "fish and chips." It was clear from these attempts, however, that a quality food product and related market had not been achieved. Participants in the fishery substantially reduced the incidental mortality of blue sharks by developing a hook removal tool, which allowed up to 88 percent of the blue shark catch to be released alive. As a result, the requirement to develop a wholesale market for blue sharks was dropped in 1991. Between 1991 and 1999, the commercial harvest of blue sharks dropped to 37,500 pounds.

The recreational catch of blue sharks grew tremendously throughout the 1980s. Estimated annual catch increased ten-fold between 1981 and 1988 with over 400,000 angler-trips on private boats, which had "sharks" (including mako sharks) as the primary or secondary target species. Although angler effort for "sharks" remained high throughout the 1990s, blue shark harvest continually declined. This may be due to the fact that most blue sharks are released alive. Shark fishing trips aboard commercial passenger fishing vessels (CPFVs) are offered from most southern California sport fishing landings from two to seven nights per week during the summer.

The greatest source of fishing mortality for southern California blue sharks in the past three decades probably occurred as a result of their incidental capture during the developing years of the drift gillnet fishery for swordfish and thresher sharks. Annual estimated bycatch in the late 1970s and early 1980s was between 15,000 and 20,000 blue sharks. Changes in season length, fleet size, time-area closures and the use of large mesh nets substantially reduced blue shark mortality, although there are no reported estimates of current mortality in this fishery.



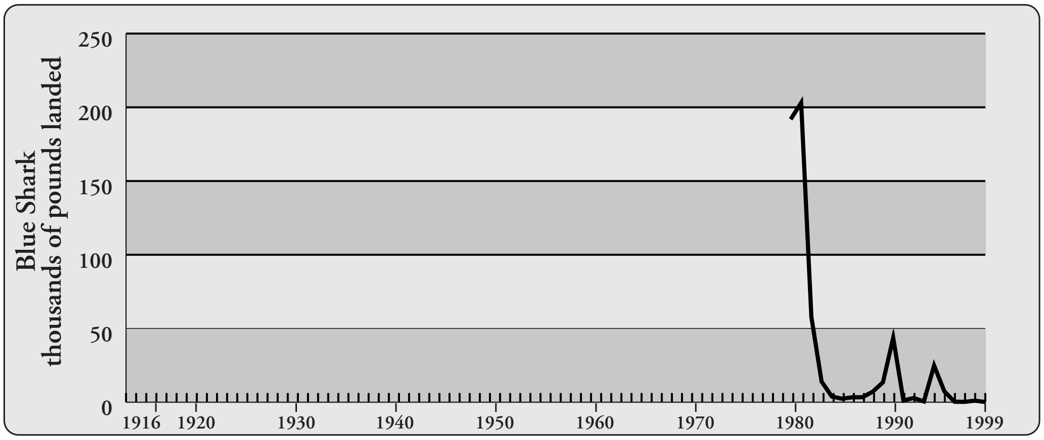
Blue Shark, *Prionace glauca*
Credit: DFG

Status of Biological Knowledge

The blue shark is an oceanic-epipelagic and fringe littoral species with a circumglobal distribution. It is found in all temperate and tropical oceans and is thought to be the most wide-ranging shark species. Although this species can be found in oceanic waters between 43˚F and 82˚F, it is most commonly found in cooler water temperatures between 45 F and 61˚F. In tropical waters, blue sharks show submergence and are typically found at greater depths. In temperate waters, blue sharks are caught within the mixed layer and generally range between the surface and the top of the thermocline, but have been documented as deep as 2,145 feet. In the Pacific, blue sharks are most predominant between 35˚N and 45˚N.

Age and growth studies of blue sharks indicate that they may reach maturity in six to seven years, although there may be regional differences in growth. They are thought to be opportunistic feeders at all life stages and prey primary on small pelagic fishes, crustaceans, and cephalopods. Blue sharks off southern California have also been shown to exhibit seasonal dietary shifts when prey such as squid become abundant during their mass spawning events.

The blue shark is viviparous with a yolk-sac placenta. Litter size is quite variable ranging from four to 135 pups and may be dependent on the size of the female. In the Pacific, it is thought that mating occurs during the summer months in the equatorial region from May through August. Gestation period is thought to range from nine to 12 months and may vary depending on location. Off California, mating occurs in late spring to early winter. The Southern California Bight is a major birthing area and is generally considered a nursery area for immature blue



Commercial Landings 1916-1999, Blue Shark
Data Source: DFG Catch Bulletins and commercial landing receipts. All shark landings were aggregated under the market category "unspecified shark" until 1977.

sharks. Female blue sharks have been shown to exhibit sperm storage, which may also explain variability in gestation period estimates. Late-term pregnant females are found in the northern Pacific in summer months where they give birth to large, well-developed pups averaging 14 inches. This suggests that mature females in the Pacific may only reproduce every other year.

Seasonal migrations are thought to occur in the Atlantic, Pacific, and Indian Ocean populations with seasonal periods of sexual segregation. A shark tagging program recently initiated by the department may further elucidate the migratory movements of blue sharks in the eastern Pacific. However, because no blue shark-tag and recapture programs have been initiated in the central Pacific, the extent of blue shark migration in the central Pacific is still unconfirmed.

Blue sharks appear to aggregate in loose schools and are generally caught more frequently over depths greater than 3,300 feet. They exhibit daily diving behavior similar to that of other pelagic fishes and sharks and appear to show a fair degree of niche overlap with swordfish. Blue sharks are incidentally caught in pelagic longline tuna and swordfish fisheries in the Pacific and can seasonally comprise the largest percentage of the catch in these fisheries. In recent years, there has been an increase in the number of blue sharks taken in the tuna and swordfish longline fishery in Hawaii, where sharks are "finned" at sea, and the fins are then sold to Asian markets. The meat is seldom landed and sold at market due its low commercial value.

Based on spatial and temporal changes in blue shark abundance in the Pacific, it is suspected that the north-south difference in catch rates of blue sharks is mediated by the transition zone. This is the area of water between the cooler Aleutian Current and the warmer water from the North Pacific Current. This transition zone shifts from 31° N and 36° N in the winter to 41° N and 36° N in the fall. Most of the larger catches of blue sharks have been made in or just south of this zone.

Diel movements of blue sharks acoustically tracked off southern California and in the North Atlantic indicate that adult blue sharks increase their activity at night and make shallower dives than during the day. Sharks tracked off southern California ventured inshore at night, presumably to feed on seasonally available spawning squid. The cyclical diving behavior is thought to serve as a hunting, orientation, and/or thermoregulatory function.

Although adult blue sharks are opportunistic feeders and prey mainly on small pelagic fishes, cephalopods, and crustacean, they have also been observed scavenging on marine mammal carcasses at sea. Unfortunately, there are few data on the diet composition of blue sharks in the central Pacific.

Status of the Population

The size of California's blue shark stock is unknown. Local abundance undergoes major seasonal fluctuations with juveniles to three year olds most abundant in the coastal waters from early spring to early winter. Mature adults are uncommon in coastal waters.

Fishery-dependent data needed for determining abundance, mortality, etc. are lacking because blue sharks are usually discarded at sea and the catch often goes undocumented. Local abundance depends on recruitment of juveniles and immigration of individuals from Mexico and offshore into California waters. Although there are no abundance estimates (local or Pacific-wide), some fishermen and field biologists speculate that there are fewer blue sharks than there were 10 to 20 years ago. The combined mortality from recreational anglers, commercial set net and drift net fisheries, Mexican fisheries and foreign high seas fisheries undoubtedly has the potential to impact the population and the local blue shark stock to an unknown extent. Currently though, all research and statistics indicate that blue shark populations within California waters remain within healthy levels.

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Other Mackerel Sharks

History of the Fishery

The mackerel sharks (*Order Lamniformes*) are a small, but diverse group containing seven families, six of which occur along the California coast. In addition to mako and thresher sharks, there are three additional mackerel shark species that are caught or have been fished along the coast, the basking shark (*Cetorhinus maximus*), white shark (*Carcharodon carcharias*), and salmon shark (*Lamna ditropis*).

The basking shark was the object of a localized harpoon fishery off the central California coast, but the fishery was sporadic due to periodic declines in the stocks. As with most shark species, the basking shark is slow growing, long-lived and probably produces relatively few young. The California basking shark fishery began in the 1930s, and peaked during the 1940s and 1950s. They were fished for their oil-rich livers, which were used for tanning leather and as a base for paints and cosmetics. In addition, they were utilized for food for human consumption, and their fins were used as soup stock. Presently, there is no fishery for these sharks in state coastal waters.

Since they are not abundant enough to be of commercial importance, there has never been a directed fishery for white sharks off California. They are often taken incidentally in commercial catches and by sport anglers. The meat is of good quality, the fins may be used as soup stock, and the teeth and jaws as decorations or jewelry. Although they have not been targeted in California, the state nevertheless imposed a ban on white shark fishing in 1993. This followed similar bans in Australia and South Africa where local artisan fisheries for this species had taken place.

Salmon sharks are not very abundant off California and are mainly taken as a bycatch to other species. The meat is of high quality and is readily sold along with the fins, which are used for soup stock. Fishermen often consider salmon sharks an annoyance because they destroy fishing gear used in more commercially important fisheries such as those for salmon.

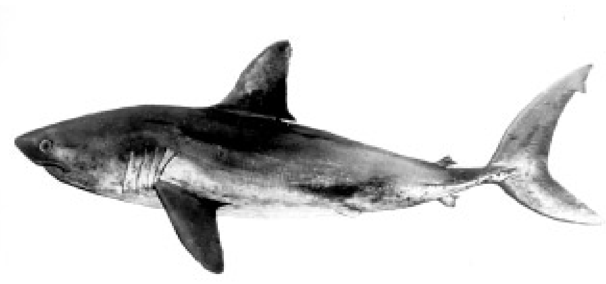
Status of Biological Knowledge

The basking shark is a coastal pelagic species usually found in areas where the water temperature is between 46° and 57° F. They are found close inshore to well offshore at depths of over 330 feet, but usually over the continental shelf. A common species from the Gulf of Alaska to the Gulf of California, although they appear to be less abundant south of Point Conception.

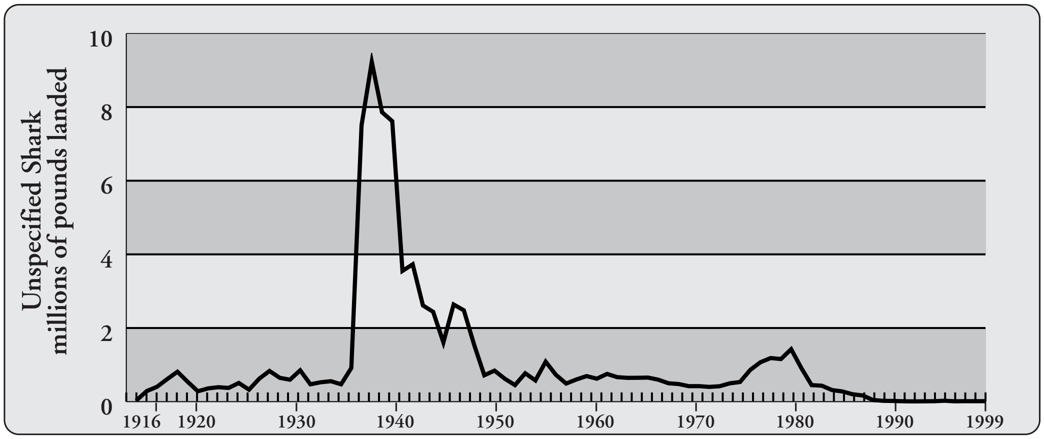
Basking sharks are presumed to be ovoviviparous, but whether they have intrauterine cannibalism like other lamnoids is uncertain. Gravid females have never been observed in this species. Males mature at about 13 to 16 feet, and females at about 27 to 29 feet. The maximum size for this species is 36 feet. The smallest recorded free-living basking shark measured 5.6 feet, but size at birth is unknown. Maturity has been estimated at six to seven years, although the aging technique has never been verified for this species and may underestimate the age by one-half. These sharks may live for 30 to 50 years or

Basking Shark, *Cetorhinus maximus*
Credit: DFG

White Sharks circling research boat, Carcharodon carcharias
Credit: DFG



Salmon Shark, *Lamna ditropis*
Credit: DFG



Commercial Landings 1916-1999, Unspecified Shark
Data Source: DFG Catch Bulletins and commercial landing receipts. All shark landings were aggregated until 1977.

more. Basking sharks grow at an estimated rate of about 16 inches per year, but with the onset of maturity this rate slows considerably.

The basking shark is one of three gigantic filter-feeding species of shark and feeds almost exclusively on small planktonic organisms that it traps in its gill rakers. The prey items include small copepods, barnacles, crustaceans, and fish eggs and larvae. Approximately one-half ton of food material may be present in the stomach of an individual shark. It has been estimated that an adult basking shark cruising at a constant speed of two knots passes approximately 2,000 tons of water over its gills per hour. Adult basking sharks probably have few predators due to their enormous size, young specimens though are preyed upon by white sharks, sperm whales, and killer whales.

Basking sharks are highly migratory, appearing and then disappearing seasonally at specific localities. These sharks are especially abundant between October and April off the California coast but move northward to Washington and British Columbia during late spring and summer. Basking sharks are very social animals and are often observed in small groups of three to 10, but at times number up to 500 or more individuals.

The white shark has a worldwide distribution from cold temperate to tropical waters, though it is most common in temperate waters between 53° and 68° F. In the eastern North Pacific the white shark occurs from the Gulf of Alaska to the Gulf of California. It is fairly common off central California and around the offshore islands of southern California.

The white shark occurs along the nearshore waters of the California coast, including bays and estuaries, but sometimes may be oceanic since individuals are common around the offshore islands. There seems to be some spatial segregation by size, as young white sharks under eight and older ones over 16 feet are common off southern California, while intermediate sized animals are more common in northern California waters.

White sharks are oviphagous, with litters of between three and 14 young. The low frequency with which pregnant females have been captured suggests that they may segregate away from the main population and that only a small proportion of the population may be gravid at any one time. The Channel Islands off southern California seem to be an area where large females and small white sharks are occasionally captured, leading to speculation that females may give birth there. Size at maturity is somewhat problematic for females since few pregnant individuals have been captured and accurately measured, but 15 to 16.5 feet appears to be a close approximation. Males mature at about 12 feet and grow to about 18 feet. The largest reliably measured white shark from California waters measured 18.8 feet; however, there is an unconfirmed record of one individual that measured 33 feet. The size at birth is four to five feet. The growth rate of white sharks has been estimated to be around 12 inches per year, and they may live to a maximum age of 30 years or more.

The white shark is perhaps the most formidable of large marine predators. It has a broad spectrum of prey species that includes bony fishes, other sharks, rays, and marine mammals. Sharks over 10 feet long tend to feed on marine mammals while those less than 6.5 feet feed more on bony and cartilaginous fishes. White sharks tend to congregate around seal rookeries, especially when these mammals are breeding. Sub-adult and young non-breeding adult seals appear to be most susceptible to predation.

The salmon shark range in the eastern Pacific Ocean is from the Bering Sea to central Baja California. It is a coastal and oceanic shark of subarctic and temperate waters, most often found in temperatures of less then 64° F and depths less than 1,200 feet. The salmon shark is common on continental offshore waters to close inshore, but also ranges far from land, over deep oceanic waters.

Salmon sharks are oviphagous with litters of two to five young. Birth usually occurs in the spring between March and May after a 12-month gestation. Males mature between six and eight feet, and females at 6.25 to 8.25 feet. The maximum reported size is 10 feet. Size at birth is 25.5 to 31.5 inches. Estimated age at maturity is five years for males and nine or 10 years for females, with a maximum age of between 20 and 30 years.

The salmon shark feeds mostly on bony fishes. They may follow their main prey, salmon, as they migrate around the North Pacific Ocean basin. Salmon sharks are known to forage in groups of 30 to 40 individuals using social facilitation to hunt salmon and other schooling species. When attacking a school of salmon these sharks usually initiate the attack from below and catch their prey by running it down in a high-speed chase rather than ambushing it.

Status of the Populations

The basking shark has not been commercially fished for more than 30 years, and no recent stock assessment has been made.

Although no demographic studies exist to estimate the white shark's population in our area, circumstantial evidence suggests that their numbers may be increasing in response to the burgeoning marine mammal population. With California's increasing human population this may inevitably lead to more human-shark interactions. One researcher has estimated that between 10 and 20 white sharks are caught per year along the California coast. Unfortunately, more accurate data are unavailable.

There is virtually no information on the salmon shark's abundance and stock structure in the eastern North Pacific.

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US Abalone

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Opah

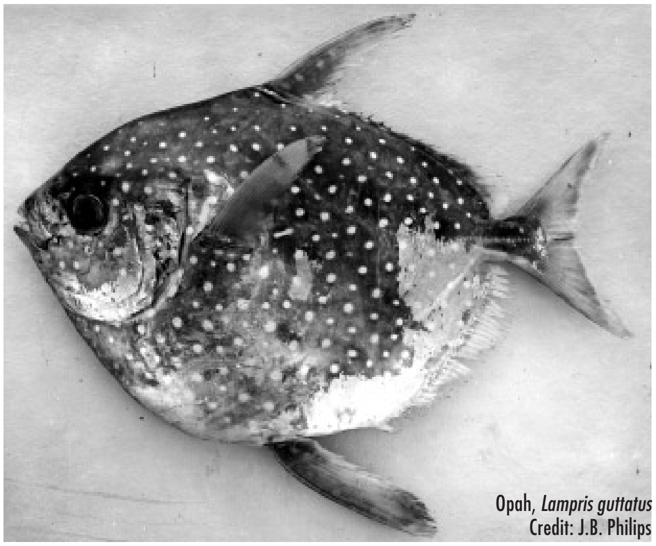
History of the Fishery

Opah (*Lampris guttatus*) are taken commercially as an incidental catch in the drift gillnet fishery (94 percent), but are also captured in the high seas longline fishery (three percent) beyond the U.S. Exclusive Economic Zone (200 mile limit) off California. Prior to 1976, they were also recorded as incidental catch in the Pacific halibut, sardine, salmon, and albacore fisheries.

Between 1976 and 1989, only 1,660,856 pounds of opah were landed in California, with no landings in some years, and the largest landings following the 1982-1983 El Niño (516,126 pounds in 1984). Between 1990 and 1999, approximately 1,470,653 pounds of opah were landed in California, with annual landings ranging from 81,669 to 246,530 pounds. The highest landings of the decade occurred in 1998; once again associated with a warm water event (the 1997-1998 El Niño). Although the majority of opah landed in California since 1990 were landed from San Luis Obispo County south (about 50 percent from San Diego County alone), landings were reported as far north as Crescent City.

Sport fishermen targeting albacore from British Columbia to Baja California occasionally catch opah. Within California, many sport caught opah are taken from the northern Channel Islands south to the Coronado Islands, just below the U.S.-Mexico border. Anglers state that opah hit live bait or artificial lures with considerable fury.

Opah flesh is tasty, can be prepared in a variety of ways, and is excellent when smoked. The salmon-colored flesh, darker over the pectoral fin, is very fatty just below the skin but is otherwise rich, dry, firm and delicate.



Opah, *Lampris guttatus*
Credit: J.B. Philips

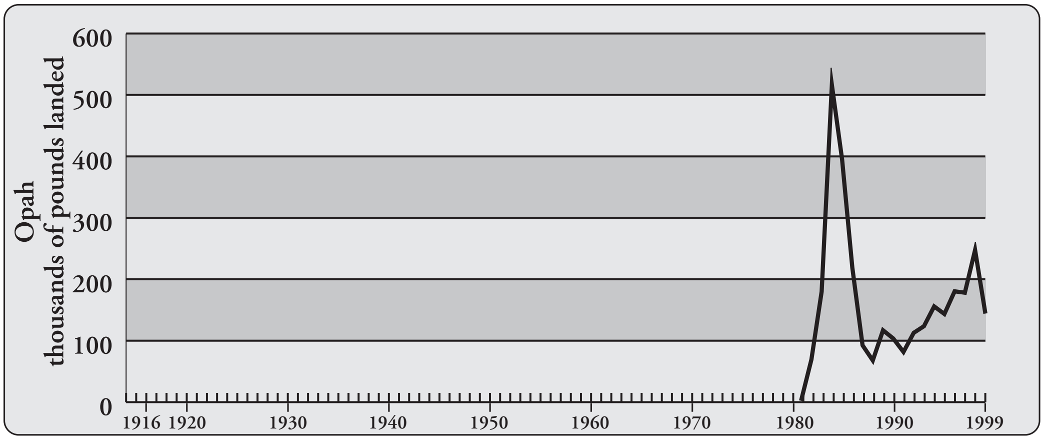
Status of Biological Knowledge

One of two living species known within the Lampridae family, this species is most commonly referred to by its West African name, opah; however, it may also be called African pompano, giant pompano, Hawaiian moonfish, moonfish, mariposa or Jerusalem haddock. The genus *Lampris* is derived from the Greek *lampros* meaning radiant, while the species *guttatus* is likely derived from the Latin word for spot, *guttat*. The opah's laterally compressed, oval body is an iridescent, silvery-blue with round to oval white spots. The snout, lips and fins are a brilliant red. The bones of the small, toothless mouth are capable of protruding forward, forming an unusual upper jaw mechanism employed during feeding. The forked caudal fin and lateral red musculature likely function in low-speed swimming, the caudal fin and lateral white musculature in acceleration and the moderately long pectoral fins in maintaining normal cruising speeds. The modes of locomotion associated with the opah's musculature are well-suited to its pelagic lifestyle. Many pelagic fishes undergo periods of sustained swimming with intermittent bursts of speed used during activities such as feeding. The opah maintains neutral buoyancy by means of a functional air bladder and a skeletal structure of oil-filled, porous bones.

Opah occur worldwide in temperate and tropical seas. In the eastern Pacific, they occur from Chile to the Gulf of Alaska. All life stages of this species are pelagic and oceanic, occurring from the sea surface to a depth of 1,680 feet. Seasonal movements are not known in the northeastern Pacific, but in the northeastern Atlantic opah catch has been reported in the North Sea and waters off Iceland solely during the summer.

Little is known about opah reproduction. Spawning locations and seasons are unknown; however, a mature female was taken in the spring off California. Neither reproductive capacity nor the size of eggs is known. Very small opah, nearly one-half inch long, resemble miniature adults in body form, and have a complete set of fin rays. Fish up to eight inches in length are referred to as juveniles while those greater than 41 inches are called adults, although the exact size and age at maturity is unknown. Opah are known to grow to at least 54 inches in length, but have been reported to reach 72 inches. They are known to reach a weight of at least 160 pounds and have been reported to reach 500 to 600 pounds. The maximum age of opah is unknown.

The diet of larvae and juveniles is undetermined. As adults, opah are midwater predators that eat cephalopods, crustaceans and bony fishes such as anchovy, lancetfish, and cutlassfish. Aside from humans, predators of opah have not been documented.



Commercial Landings 1916-1999, Opah
Data Source: DFG Catch Bulletins and commercial landing receipts. Commercial landing data not available for Opah prior to 1976.

Status of the Population

The size of the opah population, worldwide or off the coast of California is not known. Opah are probably solitary fish as few are encountered at any one time. It is not known whether local subpopulations exist or how far individual opah travel. Based upon trends over the last two decades, opah landings in California are likely to increase after El Niño events.

Management Considerations

See the Management Considerations Appendix A for further information.

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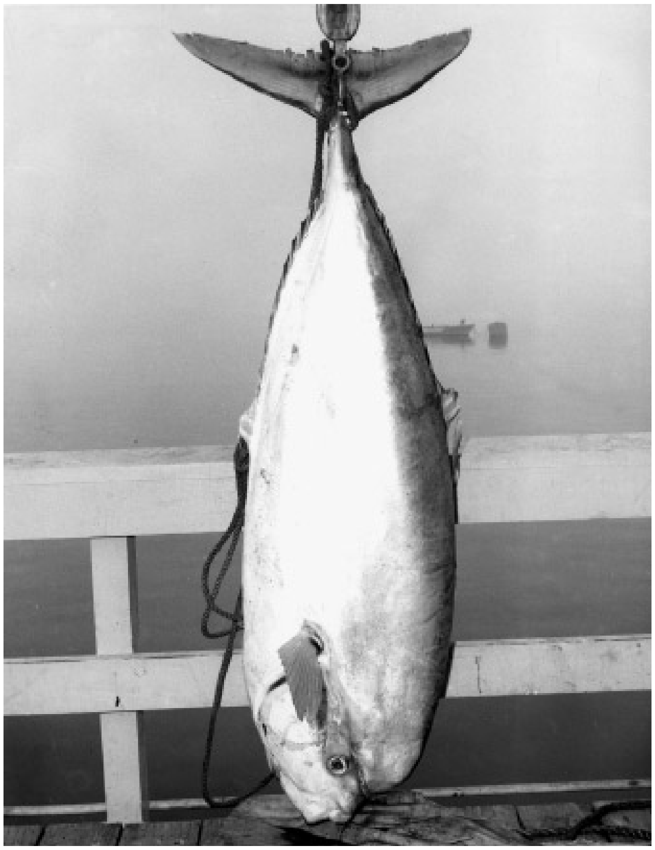
Louvar

History of the Fishery

Off California, louvar (*Luvarus imperialis*) tend to be seasonal transients associated with warm water currents late in the year. When present, they are considered a desirable, but incidental catch species primarily in the shark and swordfish drift gillnet fishery. Although primarily taken in this fishery, landings from other gear types such as set gillnet, hook-and-line, harpoon, trawl, and round haul nets have been recorded. The majority of catches occur off the Southern California Bight, with success being highest in the area encompassing Point Loma, San Clemente Island, and Cortez Bank. In the drift gillnet fishery, fish tend to be caught at depths of 18 to 78 feet. Inasmuch as louvar are strongly associated with warmer water currents, catches of this species typically increase during the late summer through fall and show a dramatic rise during strong El Niño events. Louvar occasionally are found stranded on the beach or drifting dead at the sea surface. There is not a significant recreational fishery for louvar.

From 1990 through 1999, a total of 95,844 pounds were landed in California; annual landings ranged from 5,190 pounds in 1994 to 17,498 pounds in 1992. Annual landings since the mid-1980s have shown fluctuations from year-to-year but overall have remained relatively stable, with an average of 10,923 pounds (1986-1989), and 9,584 pounds (1990-1999).



Louvar, *Luvarus imperialis*
Credit: Charles Cranford

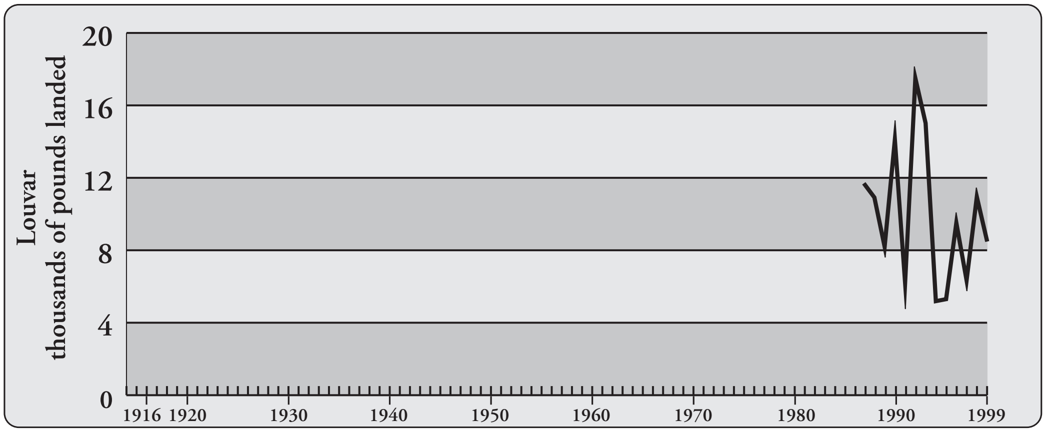
Landings off California from 1990 through 1999 had a total ex-vessel value of $297,500 with an average of $29,750 per year. The ex-vessel price per pound ranged from $2.48 in 1992 to $3.71 in 1998, with a mean value of $3.20. Although landing amounts have remained relatively constant, the average price paid for louvar has increased over three-fold since 1986. Louvar flesh is delicate and white with a mild flavor, and is considered by many fishermen to be among the most delicious of fishes. This admiration has been carried over to the markets where the fresh fish are sold to the better restaurants.

Status of Biological Knowledge

Luvarus imperialis, meaning "silver emperor," is the only member of the family Luvaridae. This streamlined fish has a strongly compressed body and a blunt head with a small, terminal, toothless mouth and a horizontal groove above each eye. The caudal fin is lunate with a keel on the caudal peduncle. Males have long filaments in front of the soft dorsal and anal fins. Adults have frothy pink bodies covered with dark spots and crimson fins, although after death the body turns silvery. Except for the blunt head, louvar are adapted for rapid swimming, with their lunate caudal fin and keeled caudal peduncle. When swimming slowly, louvar presumably scull with their caudal fin.

Louvar occur worldwide in temperate and tropical seas. In the eastern Pacific they are found from central Washington to Chile. Although generally uncommon, they are relatively abundant in southern California. All life stages of this species are pelagic and oceanic. Adults occur from the sea surface to a depth of 1,970 feet, but most are found at depths below 660 feet. The larvae have been taken at temperatures of 70.9-82.2° F. Spawning occurs in temperate waters between 40° N and 40° S latitude, from late spring to summer in the Northern Hemisphere. A ripe individual was taken off Morro Bay, California in May. Louvar fecundity is very high, which is typical of non-schooling, oceanic fishes; a female 66.9 inches (5.6 feet) long had a fecundity of 47.5 million eggs.

Larvae range from 0.14 to 0.42 inches in length. The larvae and small juveniles look sufficiently different from the adult that they were once thought to be different species. They have strong, serrated dorsal and anal spines and a short body. The smallest juveniles have long, deep fins and dark spots on the body. Larger juveniles (four to eight inches) are similar to the adult but have longer dorsal and anal fins.



Commercial Landings 1916-1999, Louvar
Data Source: DFG Catch Bulletins and commercial landing receipts. Commercial landing data are not available prior to 1984.

The size and age of louvar at first maturity is not known; however, a 295-pound female was mature. Louvar grow to at least 74 inches and 305 pounds. Because the otoliths are tiny and not useful for aging, the maximum age is unknown.

As midwater browsers, they feed primarily on gelatinous zooplankton such as jellyfish, ctenophores, and free-swimming tunicates (salps and pyrosomes), but occasionally eat small fish. Only about 20 percent of the louvar taken have had food in their stomachs.

The louvar stomach is lined with numerous papillae and the coiled intestine is extremely long. The intestine of adults is about eight to nine times as long as the fish. These features presumably are adaptations for feeding on jellyfish.

An eight-inch louvar was found in the stomach of a wahoo. Otherwise, predators other than man are not known. The gastrointestinal areas of louvar are often parasitized by digenean trematodes.

Status of the Population

The size of the louvar population worldwide or off California is not known. Louvar are solitary fish and few are taken at any one time. Because the population is worldwide in tropical and temperate seas, the California fishery probably has little impact on the species as a whole. It is not known whether local subpopulations exist or how far individual louvar travel. Using recent landings as an indicator, the local availability of the species is likely to become more abundant off California following warm water periods or El Niño events. Although commercial landings of louvar are recorded by the California Department of Fish and Game, the louvar is not presently a target species and the fishery is not actively managed.

Management Considerations

See the Management Considerations Appendix A for further information.

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Dolphin

History of the Fishery

The dolphin (*Coryphaena hippurus*), also known as mahi mahi, or more commonly in California, as dorado, occurs in the California recreational catch primarily during warm water years. Most catches occur in the Southern California Bight, especially south of Los Angeles. Before 1972, the annual California commercial passenger fishing vessel (CPFV) catches during the July through October fishing season seldom exceeded a few hundred fish. Thereafter over 1,000 were taken in 23 of the next 25 seasons. A major shift occurred in 1990 when the catch exceeded 31,000 fish, and averaged 15,602 fish per year between 1990 and 1997 (range: 1,000 to 31,548).

In commercial fisheries, an estimated average of 1,084 dolphin have been landed and 324 released per year by the high seas longline fishery landing in California during the period August 1,1995, through December 31, 1999. It is occasionally taken by albacore bait and troll boats and tuna purse seine vessels. It is rare in the drift gillnet catch, possibly because its surface-swimming habits take it above the reach of the top of these nets. Judging from the length of net extenders deployed, observed sets have averaged about 35 feet below the surface over the past decade. During the summer of 1996, when over 21,000 dorado were taken by the CPFV fleet, the >68˚ F layer was observed to be less than 33 feet deep, indicating a very shallow suitable habitat zone for dolphin. This is also a species that commonly associates with surface floating objects, and thus may have evolved avoidance capabilities that prevent it from becoming entangled in drifting materials.

Dolphin, *Coryphaena hippurus*
Credit: NMFS

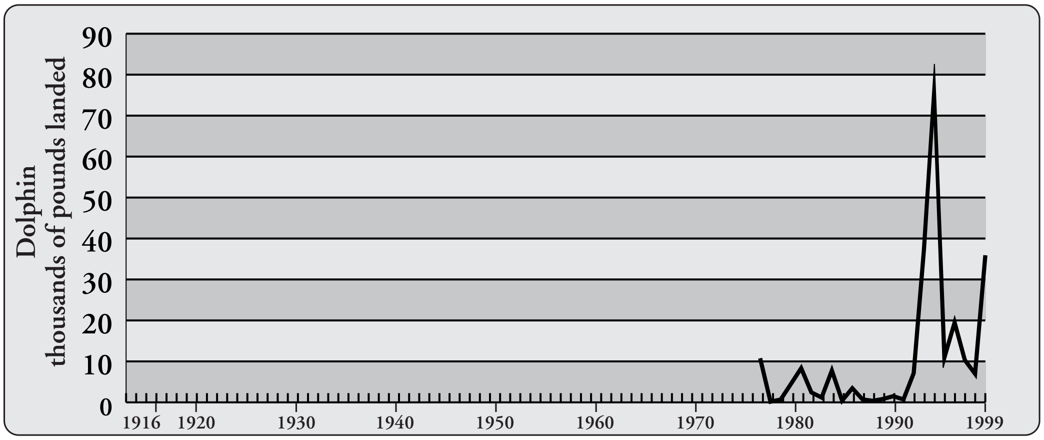
Status of Biological Knowledge

Growth in dolphin is extremely rapid. Fish reach maturity in less than a year (at about 14 inches or seven months old) and only rarely live beyond three to four years. Actual growth rates vary among regions and are sensitive to prevailing water temperatures. In captivity, dolphin grow about 0.05 inches per day at 64˚F, 0.13 inches per day at 77˚F, and 0.23 inches per day at 84˚F. Length/age data from fish taken in the wild show dolphin have an average growth of about a 0.09 inches per day. In the western Pacific, dolphin reach a length of 15 inches the first year, 27 inches the second year, 35 inches the third year, and 43 inches the fourth year.

Larval dolphin feed mainly on crustaceans, particularly pontellid copepods, with fish larvae appearing in the diet of young juveniles greater than eight inches. Adult dolphin are mainly piscivorous, with flying fish being the most important in volume and occurrence. Jacks, mackerels, rabbitfishes, squids and portunid crabs are also taken in various parts of their range. Adults can swim faster than 33 feet per second, and can feed at low light levels. All life stages of dolphin serve as prey for other oceanic fishes, particularly marlin, epipelagic sharks, swordfish, sailfish, and other dolphin.

There is little information about Pacific Ocean migrations, but dolphin are thought to migrate relatively long distances in the western Atlantic and Mediterranean. In the eastern Pacific, temperature seems to be an important factor in defining the range and possibly the movements of this species, the northern barrier being the California Current, and in the south, the Peru Current. Various authors report seasonal patterns in catches, possibly relating to spawning migrations or seasonal intrusion of preferred warm water temperatures. Norton noted the dramatic increase in recreational catches of dolphin off southern California and northern Mexico over the past 30 years (especially during the last decade). He suggested that the habitat of dolphin has been expanding northward in response to an oceanic and atmospheric regime shift that has brought periods of warmer water and enhanced northward current flow to California. It has also brought less cold water upwelling off northern Mexico, which had formerly inhibited northward dispersal.

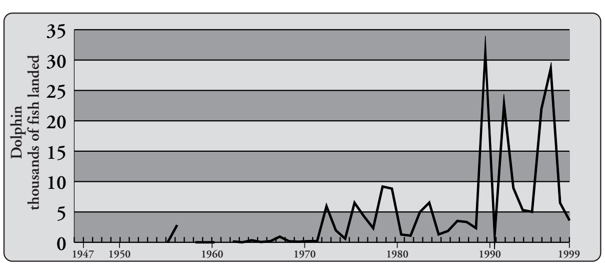
Dolphin are oviparous with pelagic eggs and larvae; fertilization is external. Spawning is thought to occur year round in waters above 75˚ F, although there may be



Commercial Landings 1916-1999, Dolphin
Data Source: DFG Catch Bulletins and commercial landing receipts. No commercial landings are reported for dolphin prior to 1977.

reproductive peaks with eggs released in batches within a given reproductive pulse. Fecundity increases sharply with size, and assuming three spawns a year, estimated total egg production varies from about 240,000 to almost 3 million eggs per year for fish. Certain times of the year may be more conducive to larval survival, e.g., in Hawaii the strongest cohorts are spawned in July. Spawning of the California-Mexico dolphin population evidently takes place in waters south of the U.S. West Coast EEZ. In CalCOFI larval fish surveys, larvae have been collected off central and southern Baja California, Mexico, and only occasionally in warm water years, off southern California, with peak abundance in August and September. Age at female maturity is 0.6 years with maximum reproductive age at four.

Little is known of stock structure in the Pacific. Because of the dolphin's brief life-cycle and seasonal catch patterns, it seems unlikely that the U.S.-Mexico stock is shared with Hawaii or fishing nations in the central and western Pacific, however, stock mixing cannot be ruled out. The relationship of the Mexico stock to stocks occurring further south along the Pacific coast of Central and South American is not known. Because seasonal migrations in the North Pacific show a reverse tendency to that in the Southern Hemisphere, there may be at least two stocks in the Pacific Ocean separated by the equator.



Recreational Catch 1947-1999 , Dolphin
Data Source: DFG, commercial passenger fishing vessel logbooks.

Status of the Population

The status of the population is unknown. Since California is on the northern range of dolphin, our fisheries may be subject to a great deal of variation due to changes in oceanographic patterns and even moderate variations in stock size.

Management Considerations

See the Management Considerations Appendix A for further information.

Susan Smith
National Marine Fisheries Service

Stephen J. Crooke
California Department of Fish and Game

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Commercial Landings - Highly Migratory Finfish and Sharks

	Tunas				Sharks			
Year	Albacore Tuna[1] Pounds	Bluefin Tuna[1] Pounds	Skipjack Tuna[2] Pounds	Yellowfin Tuna[2] Pounds	Blue Shark[3] Pounds	Shortfin Mako Shark[3] Pounds	Thresher Shark[3] Pounds	Unspecified Shark[3] Pounds
1916	22,899,309	----	----	----	----	----	----	36,247
1917	30,556,242	----	----	----	----	----	----	287,872
1918	7,265,422	----	3,022,964	----	----	----	----	403,093
1919	13,630,899	14,990,860	6,892,427	348,081	----	----	----	612,683
1920	18,876,647	10,530,272	7,957,277	1,965,024	----	----	----	811,349
1921	15,276,727	1,971,813	1,134,993	1,297,451	----	----	----	539,333
1922	13,231,823	2,811,283	11,857,833	7,405,279	----	----	----	282,018
1923	12,514,833	3,218,090	11,462,522	10,836,925	----	----	----	360,363
1924	17,695,362	3,241,110	3,774,058	3,063,398	----	----	----	392,634
1925	22,206,923	3,803,677	14,222,453	13,237,898	----	----	----	372,332
1926	2,469,921	6,526,533	20,951,348	12,564,986	----	----	----	506,723
1927	4,656,959	4,898,465	33,805,960	25,933,966	----	----	----	325,653
1928	4,065,729	13,700,870	15,946,910	32,253,206	----	----	----	623,816
1929	6,110,330	7,526,857	27,066,588	37,444,924	----	----	----	833,985
1930	7,288,685	21,921,282	20,485,587	56,657,768	----	----	----	647,297
1931	6,976,401	3,534,030	16,506,761	36,581,376	----	----	----	596,134
1932	3,087,215	2,125,001	21,636,577	36,923,410	----	----	----	850,888
1933	2,794,452	1,449,828	17,093,041	51,075,630	----	----	----	471,030
1934	4,287,296	18,357,828	16,409,439	61,137,102	----	----	----	526,280
1935	5,678,793	25,319,614	19,803,954	72,294,127	----	----	----	555,256
1936	2,456,004	19,669,935	29,271,030	78,361,272	----	----	----	471,861
1937	4,743,709	13,217,984	54,698,995	92,406,606	----	----	----	914,205
1938	13,574,635	17,732,359	26,152,974	78,363,005	----	----	----	7,504,329
1939	16,423,234	11,835,715	31,186,950	110,417,801	----	----	----	9,227,750
1940	7,078,334	19,970,268	56,910,522	113,898,209	----	----	----	7,860,030
1941	4,314,508	9,519,012	25,707,064	76,701,820	----	----	----	7,617,334
1942	11,091,866	12,844,564	38,735,228	41,466,614	----	----	----	3,551,566
1943	21,384,864	10,178,768	28,893,784	49,261,328	----	----	----	3,729,334
1944	20,989,479	20,343,550	30,037,236	63,143,891	----	----	----	2,613,431
1945	21,333,779	20,594,309	33,347,896	87,331,440	----	----	----	2,438,096
1946	18,077,899	22,031,802	41,087,994	127,246,675	----	----	----	1,608,846
1947	13,427,281	20,837,673	52,460,168	150,459,384	----	----	----	2,637,926
1948	37,609,789	6,696,987	58,771,706	191,723,981	----	----	----	2,480,555
1949	44,290,320	4,389,471	78,574,657	185,612,094	----	----	----	1,550,992
1950	66,123,624	2,846,841	128,041,078	190,446,466	----	----	----	717,247
1951	48,436,233	3,864,530	118,637,672	173,668,653	----	----	----	842,324
1952	72,328,772	4,576,685	88,891,667	185,517,690	----	----	----	623,238
1953	80,022,721	9,835,062	130,653,919	140,544,952	----	----	----	449,753
1954	64,573,673	21,795,967	169,463,946	149,103,693	----	----	----	770,337
1955	73,846,973	13,952,523	120,524,989	162,818,007	----	----	----	576,201
1956	57,377,986	12,788,843	135,995,434	203,885,507	----	----	----	1,085,314
1957	83,089,272	20,637,570	111,436,303	182,041,635	----	----	----	728,900
1958	54,673,098	31,477,208	148,158,256	218,075,149	----	----	----	491,713
1959	62,482,446	15,797,703	146,194,191	210,992,058	----	----	----	602,191
1960	71,452,175	13,416,411	74,798,635	272,648,098	----	----	----	694,191
1961	59,414,251	22,155,190	86,747,632	262,310,262	----	----	----	623,972
1962	73,354,129	33,119,729	99,059,469	218,148,910	----	----	----	753,177
1963	65,804,803	32,701,801	106,284,833	162,326,222	----	----	----	665,367
1964	74,720,964	26,831,939	72,554,280	202,855,729	----	----	----	646,569
1965	68,025,134	16,734,506	89,919,213	196,435,355	----	----	----	648,265
1966	73,908,838	37,939,210	65,225,532	189,844,772	----	----	----	653,790
1967	71,747,685	13,735,595	114,958,800	167,251,535	----	----	----	596,898
1968	76,099,731	13,016,373	60,673,827	212,238,450	----	----	----	499,947
1969	71,055,426	15,607,319	48,680,081	240,746,510	----	----	----	478,235
1970	29,931,714	8,655,295	76,480,634	231,956,638	----	----	----	420,318
1971	36,116,734	17,250,966	101,377,638	150,941,111	----	----	----	421,335
1972	21,001,214	24,877,721	35,944,884	241,704,982	----	----	----	400,769
1973	8,640,852	20,187,207	29,809,281	232,793,961	----	----	----	418,694
1974	11,806,150	11,605,792	59,975,341	246,110,479	----	----	----	497,359
1975	15,412,778	16,360,774	73,810,130	234,252,185	----	----	----	533,954
1976	27,759,376	18,789,445	122,694,052	276,064,610	----	----	----	862,204
1977	15,904,840	6,939,994	81,620,289	195,596,189	----	19,911	129,522	1,070,685
1978	21,549,428	9,561,343	137,185,991	191,100,304	----	----	302,073	1,184,411
1979	8,442,098	13,273,516	94,796,032	165,845,675	----	35,334	735,743	1,157,227

Commercial Landings - Highly Migratory Finfish and Sharks, cont'd

Year	Albacore Tuna[1] Pounds	Tunas Bluefin Tuna[1] Pounds	Skipjack Tuna[2] Pounds	Yellowfin Tuna[2] Pounds	Blue Shark[3] Pounds	Sharks Shortfin Mako Shark[3] Pounds	Thresher Shark[3] Pounds	Unspecified Shark[3] Pounds
1980	11,958,760	5,371,000	174,406,052	190,185,117	192,130	155,336	1,806,007	1,423,633
1981	20,584,321	1,912,748	127,578,862	167,751,112	203,074	277,345	1,974,037	909,596
1982	9,436,938	5,301,256	92,381,839	136,176,299	57,838	533,839	2,397,171	449,024
1983	16,545,410	1,682,296	99,196,795	122,885,366	13,983	330,260	1,726,646	433,410
1984	26,126,747	1,400,998	68,896,983	77,299,186	3,864	242,837	1,659,104	314,251
1985	14,197,002	7,173,299	6,562,190	33,123,315	2,385	226,695	1,540,799	277,951
1986	7,248,173	10,431,044	3,000,340	47,436,173	3,316	473,684	606,595	201,201
1987	3,511,503	1,814,041	12,619,100	51,149,000	3,410	612,020	525,104	167,867
1988	2,669,538	1,771,706	19,539,462	43,033,185	7,147	489,217	536,711	44,236
1989	1,918,914	2,246,118	9,932,415	38,834,297	13,521	388,322	649,984	22,775
1990	1,902,318	2,040,073	4,472,810	18,759,062	43,675	577,128	461,606	18,111
1991	1,493,811	228,896	7,511,801	9,209,749	1,200	322,097	758,266	10,704
1992	2,772,642	2,396,650	5,700,648	7,384,579	2,880	215,876	394,192	6,966
1993	4,027,882	1,163,581	10,006,587	8,254,649	522	185,254	356,059	9,773
1994	6,989,093	2,012,277	4,653,967	11,141,997	24,828	193,782	427,513	12,422
1995	1,833,340	1,567,454	15,428,051	6,685,493	7,360	145,278	342,335	25,076
1996	11,332,004	10,327,599	12,024,568	7,376,529	320	142,013	405,042	9,618
1997	7,398,111	4,958,129	13,381,560	10,524,823	236	210,518	411,487	12,919
1998	5,311,746	4,281,798	12,614,505	12,736,163	1,070	148,331	413,775	11,867
1999	12,294,268	364,508	8,286,038	2,981,179	116	94,646	328,415	13,354

- - - - Landings data not available.

1 Data includes shipments and landings from areas north and south of the State between 1916 and 1969.

2 Data includes shipments and landings from areas south of the State between 1916 and 1969.

3 All shark landings were aggregated until 1977.

Commercial Landings - Highly Migratory Finfish and Sharks, cont'd

Year	Dolphin Fish Pounds	Louvar Pounds	Opah Pounds	Swordfish Pounds
1916	----	----	----	----
1917	----	----	----	----
1918	----	----	----	18,442
1919	----	----	----	18,252
1920	----	----	----	12,513
1921	----	----	----	14,803
1922	----	----	----	23,256
1923	----	----	----	11,691
1924	----	----	----	31,833
1925	----	----	----	27,045
1926	----	----	----	45,543
1927	----	----	----	130,288
1928	----	----	----	426,001
1929	----	----	----	693,081
1930	----	----	----	562,729
1931	----	----	----	340,769
1932	----	----	----	661,470
1933	----	----	----	850,699
1934	----	----	----	263,958
1935	----	----	----	669,283
1936	----	----	----	577,402
1937	----	----	----	625,307
1938	----	----	----	722,478
1939	----	----	----	594,360
1940	----	----	----	887,168
1941	----	----	----	916,739
1942	----	----	----	445,908
1943	----	----	----	336,386
1944	----	----	----	751,596
1945	----	----	----	363,093
1946	----	----	----	863,494
1947	----	----	----	1,009,957
1948	----	----	----	1,113,808
1949	----	----	----	198,361
1950	----	----	----	26,494
1951	----	----	----	228,034
1952	----	----	----	265,690
1953	----	----	----	142,831
1954	----	----	----	23,055
1955	----	----	----	134,659
1956	----	----	----	275,174
1957	----	----	----	375,986
1958	----	----	----	471,775
1959	----	----	----	448,220
1960	----	----	----	324,754
1961	----	----	----	368,855
1962	----	----	----	39,057
1963	----	----	----	98,074
1964	----	----	----	183,023
1965	----	----	----	327,174
1966	----	----	----	468,772
1967	----	----	----	305,067
1968	----	----	----	199,398
1969	----	----	----	1,031,583
1970	----	----	----	944,745
1971	----	----	----	154,418
1972	----	----	----	265,982
1973	----	----	----	613,544
1974	----	----	----	649,502
1975	----	----	----	865,536
1976	----	----	2,458	83,623
1977	10,646	----	----	511,388
1978	159	----	----	2,604,233
1979	694	----	----	586,529
1980	4,507	----	----	1,197,187
1981	8,344	----	2,989	1,142,897
1982	2,424	----	69,347	1,691,161
1983	1,183	----	179,914	2,675,218
1984	7,774	18,009	516,126	4,393,278
1985	424	----	394,873	5,196,685
1986	3,453	----	218,769	3,845,932
1987	714	11,674	92,493	2,741,015
1988	377	10,917	67,868	2,484,428
1989	828	8,196	116,966	2,861,277
1990	1,510	14,105	103,606	1,871,535
1991	713	6,147	81,678	1,564,946
1992	7,123	17,498	112,785	2,354,831
1993	37,250	15,020	123,614	2,684,569
1994	82,211	5,191	155,811	2,574,758
1995	10,915	5,300	143,473	1,764,736
1996	19,502	9,512	180,340	1,768,544
1997	10,318	6,343	178,147	2,205,694
1998	6,970	10,951	247,586	2,054,089
1999	35,795	8,509	144,947	3,054,630

---- Landings data not available.

[1] Data includes shipments and landings from areas north and south of the State between 1916 and 1969.

[2] Data includes shipments and landings from areas south of the State between 1916 and 1969.

[3] All shark landings were aggregated until 1977.

Recreational Catch - Highly Migratory Finfish

Year	Albacore Tuna No. of Fish	Bluefin Tuna No. of Fish[1]	Skipjack Tuna No. of Fish[1]	Yellowfin Tuna No. of Fish[1]	Striped Marlin No. of Fish[1]	Dolphin Fish No. of Fish[1]
1947	11,445	2,194	698	137	37	15
1948	15,414	104	460	18	58	- - - -
1949	22,692	1,941	9	11	28	- - - -
1950	118,087	27	31	6	115	1
1951	75,924	7,142	132	56	58	- - - -
1952	187,267	145	38	34	57	2
1953	23,363	4,276	279	- - - -	4	- - - -
1954	20,098	966	50	- - - -	9	12
1955	78,688	8,179	10	1	6	- - - -
1956	65,814	34,187	13	78	32	2
1957	41,540	6,428	6,453	325	22	2,805
1958	6,482	884	491	13	84	- - - -
1959	39	1,330	514	4	349	4
1960	76,075	97	378	2,124	9	1
1961	184,891	2,268	11	21	8	3
1962	229,314	2,453	40	3	2	- - - -
1963	158,372	737	8,149	80	37	139
1964	112,358	693	3,961	103	48	4
1965	99,771	92	2,142	101	46	341
1966	74,680	1,998	1,012	241	40	48
1967	96,497	3,166	1,656	10,801	81	198
1968	129,710	1,231	4,250	8,499	60	929
1969	48,887	1,470	9,998	4,210	66	170
1970	112,106	1,833	15,561	3,840	52	103
1971	160,361	749	62	6,622	32	188
1972	86,890	1,470	281	849	12	206
1973	9,858	5,347	855	1,783	34	5,941
1974	12,814	5,765	1,345	2,524	29	1,967
1975	81,562	3,348	455	2,556	5	604
1976	84,973	2,040	5,400	4,437	10	6,509
1977	70,274	1,838	21,423	7,689	33	4,300
1978	92,646	479	10,520	6,708	13	2,330
1979	10,196	1,087	487	4,042	34	9,184
1980	21,309	729	3,891	11,217	58	8,840
1981	26,648	542	435	4,559	67	1,281
1982	36,690	665	32	2,035	33	1,099
1983	17,161	1,912	103,040	116,298	65	4,992
1984	211,285	2,834	30,357	8,648	287	6,532
1985	172,493	4,980	238	3,898	68	1,307
1986	27,322	693	2,249	5,505	43	1,866
1987	7,046	1,859	8,181	14,794	168	3,518
1988	559	321	1,898	20,065	134	3,349
1989	29,728	6,519	19,736	19,076	40	2,341
1990	3,816	3,756	16,305	49,118	105	31,548
1991	1,009	5,289	6,319	11,453	11	1,301
1992	380	8,586	52,302	73,739	25	22,727
1993	393	10,535	23,823	37,142	30	8,952
1994	171	2,309	15,327	46,831	42	5,318
1995	1,296	14,648	43,048	87,347	35	5,022
1996	1,873	2,478	6,356	72,449	17	21,939
1997	88,133	7,974	19,170	89,097	24	28,606
1998	155,985	18,985	13,735	75,367	16	6,485
1999	254,983	36,390	2,707	21,215	2	3,633

- - - - Landings data not available.
All data based on CPFV logbooks.
[1] All data presented in number of fish.

Groundfish: Overview

More than 80 species of marine fish are included under the Pacific Coast Groundfish Fishery Management Plan (FMP) that was adopted by the Pacific Fishery Management Council (PFMC) in 1982. In general, the FMP provides for management of bottom dwelling finfish species (including all rockfish and whiting) that are found in U.S. EEZ waters off Washington, Oregon and California. Of these, fewer than 20 of the commercially and recreationally most important have ever been comprehensively assessed. Each year, stock assessments are conducted on five to 10 species, typically as part of a three-year rotation. Only Pacific whiting is assessed each year. Species and species groups that are actively managed under the FMP are: "Minor rockfish" (which includes most rockfish); Pacific Ocean perch; sablefish; thornyheads; Dover sole; whiting; canary rockfish; widow rockfish; yellowtail rockfish; bocaccio; chilipepper rockfish; cowcod; darkblotched rockfish; splitnose rockfish; and lingcod.

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

The current status of many rockfish and lingcod off the west coast is poor, and significant changes in the groundfish fishery have been necessary to address this situation. There are over 60 different species of rockfish in California. Formal assessments of these fish populations are challenging, due to the number of species and the large commitment of time and effort to conduct the necessary research and analysis. To date, 15 rockfish species have been formally assessed, and the results are not encouraging. Nearly all of these species are currently below optimal abundance levels. Lingcod and six rockfish species, including four that are important to California anglers and commercial fishermen (bocaccio, canary rockfish, widow rockfish and cowcod), are at such low levels (estimated at or below 25 percent of the pristine population of each species) that they have been declared overfished by the PFMC. Federal law requires that steps be taken to rebuild overfished stocks under strict guidelines that place an emphasis on a reasonable likelihood of achieving success within specified time periods for each species.

Several factors affect the abundance of rockfish and lingcod and the ability to manage them effectively. Recent analyses have shown that rockfish stocks are not as productive as previously thought. This is due in part to improved information about rockfish life history (such as age, growth, and reproduction), better stock assessments and environmental conditions that generally have not been favorable to rockfish reproduction or survival for many years. As a result, rockfish cannot support harvest rates as high as previously thought. Management is further complicated because the habitats and ranges of many rockfish species overlap, so that it is difficult to catch one species without catching other species at the same time. Fishing must be reduced for an entire group of rockfish in order to realize lower catches that are necessary to rebuild overfished stocks. For example, although a few shelf rockfish species such as chilipepper and yellowtail appear to be comparatively healthy, their allowable harvest has been set at levels below the potential yield to protect the weaker species of shelf rockfish that tend to be caught with them, such as bocaccio and canary.

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

No individual sector is responsible for creating the current situation. For example, since 1982 commercial landings accounted for about 56 percent of all lingcod and about 81 percent of all rockfish catches in California, while the recreational fishery took the remainder. In order to return depressed rockfish and lingcod stocks to a healthy condition, everyone has been asked to share in the conservation measures needed for recovery. For the recreational fishery, bag limits have been reduced, gear restrictions imposed, seasons closed, and minimum size limits established. In the commercial fishery, the aggregate rockfish quota for 2001 was reduced by about 57 percent compared to 1997, and the allowable commercial lingcod landings were reduced by about 83 percent during the same period. Rockfish rebuilding plans call for decades of ongoing special efforts to allow the overfished species to recover, while lingcod is more prolific and is expected to be restored much more quickly, by 2009. Although the lingcod stock seems to be responding favorably to the initial stages of the rebuilding plan, it will be important to coordinate lingcod and rockfish management because they are found on the same fishing grounds and are often caught together.

A total of about 1,900 businesses in California are directly affected by commercial groundfish catch regulations. Most of the affected businesses are fishing vessels. There are approximately 1,580 commercial fishing vessels in California that catch and sell groundfish as part of their operations. That fleet is comprised of two main elements -- the limited entry fleet and the open access fleet.

Vessels in the limited entry fleet have a federal permit that gives greater rights concerning the harvest of groundfish. Consequently, vessels with limited entry permits generally rely heavily on groundfish as a major source of income. There are 288 limited entry vessels in California.

Vessels that land groundfish under open access provisions may or may not depend on groundfish as a major source of income. Many vessels that predominately fish for other species also may inadvertently catch and land groundfish. Although 1,295 open access vessels landed groundfish in California during 1997, most landed less than 1,000 pounds. A total of 525 open access vessels each landed more than 1,000 pounds of groundfish during the calendar year. In addition to the commercial fishing fleet, there are approximately 325 wholesale fish buying businesses in California that purchase groundfish from commercial fishing vessels.

The 1999 California commercial groundfish harvest was approximately 34.0 million pounds, with an ex-vessel value of $19.7 million. This was a 12-percent decline in value from 1998 ($22.3 million), and the lowest total in recent history. Groundfish production exhibited a long-term downward trend in landings during the 1990s, with annual landings reduced by roughly 60 percent during the decade. For the first time, rockfish became the most significant element of the groundfish fishery during 1998, when they comprised over 50 percent of the value and nearly 37 percent of the tons landed. Another traditionally important component was the "DTS Complex" (Dover sole, thornyheads, sablefish), which accounted for most of the remainder of the landings. The number of federal limited entry groundfish permits registered to fishermen in California continued a slow decline during 1999 for all three gear types; at mid-season there were 162 vessels with trawl permits, 113 longline permits, and 13 trap permits.

In response to the sharp decline in groundfish landings and the generally poor condition of West Coast groundfish stocks, the secretary of commerce formally announced a disaster determination for the fishery in January 2000. The intent of the declaration was to minimize economic and social impacts on fishing communities while protecting and rebuilding groundfish stocks. Although, the declaration did not include relief funding, it was the first step in the process of securing funds from Congress to assist affected fishermen.

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Bocaccio

History of the Fishery

Bocaccio (*Sebastes paucispinis*), sometimes called red snapper, rockcod, grouper, salmon grouper, or tomcod (as juveniles), was the dominant rockfish in California's early longline fishery. It was the most abundant rockfish in the bottom trawl fishery from Morro Bay to Fort Bragg until the mid-1980s. In the late 1980s, two-thirds of the bocaccio landed were taken by trawl, with the remainder being taken by set net, longline, and the recreational fishery. Before 1970, estimated landings by all fisheries averaged approximately six million pounds per year. Following 1970, combined landings increased, peaking in 1983 at over 15 million pounds. Landings have declined steadily since then, and fell below 0.5 million pounds in 1998. In 1978, nearly 40 percent of the sampled trawl landings contained half or more bocaccio by weight, but this value has declined to a very small percentage of landings in recent years.

Recreational catches of bocaccio are generally made on rocky reefs by party boat fishermen at depths of 250 to 750 feet. In some years, however, juveniles concentrate in shallow sandy areas near piers off central and southern California, where they are easily taken on small baited hooks. Estimated catches for the recreational fishery are available from 1980 onward and averaged 15 percent of the total landings in recent years. Recreational catches since 1984 have shown the same decline as the trawl fishery.

Status of Biological Knowledge

Bocaccio range from central Baja California to Kodiak Island, Alaska, and are common from northern Baja California to the Washington-British Columbia border. Genetic studies indicate partial separation between the bocaccio population off the Pacific Northwest and that off California.

Among rockfishes, bocaccio are noted for their relatively rapid growth, large adult size, and high variation in year-class strength. They are known to attain a length of 36 inches, a weight of 15 pounds, and a maximum age of about 50 years. Some fast growing individuals are caught with trawl gear at age one, and substantial numbers are landed by age two at lengths of about 16 inches.

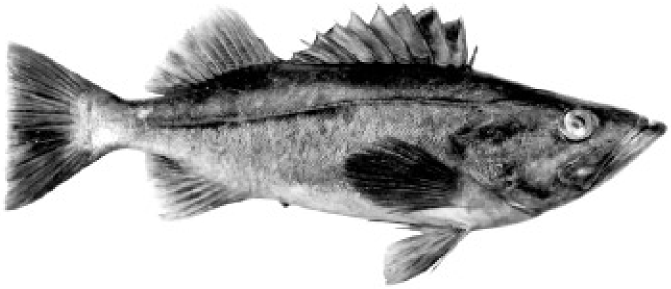
Bocaccio are live-bearing fish. At extrusion (release), larvae are about 0.25 inch in length and absorb yolk from the egg stage during the first eight to 12 days. They grow rapidly to about seven inches by the end of their first year. A few mature when they are three years old, about 14 inches long and one pound. Fifty percent are mature at 16.5 inches and four years. Males mature at a slightly smaller size than females. By the time they are 10 years old, they average over 24 inches and weigh five pounds. The number of developing eggs increases from 20,000 in a 15-inch fish to about 2.3 million in a fish 30.5 inches long.

Off central and northern California, larval release occurs from January through May, peaking in February. In southern California spawning takes place from October through July, peaking in January. In central California, most larvae that survive to the juvenile stage are born in January and February, but months of successful reproduction can shift substantially from year to year. In southern California, some females produce as many as three broods in a season, but multiple brooding is uncommon farther north.

Larval bocaccio are initially pelagic and are most common within 100 feet of the sea surface, where they feed on plankton. Larval bocaccio have been captured in plankton nets as far as 300 miles from shore. By late May or early June, they settle to the bottom at lengths of 1.5 to 2.5 inches, often in kelp beds. Before completing their first year of life, these fast growing young-of-the-year start eating the young of other rockfishes, surfperch, jack mackerel, and various small inshore fishes. Adults are found from depths of 60 to 1550 feet. They feed on smaller rockfishes, sablefish, anchovies, lanternfish, and squid.

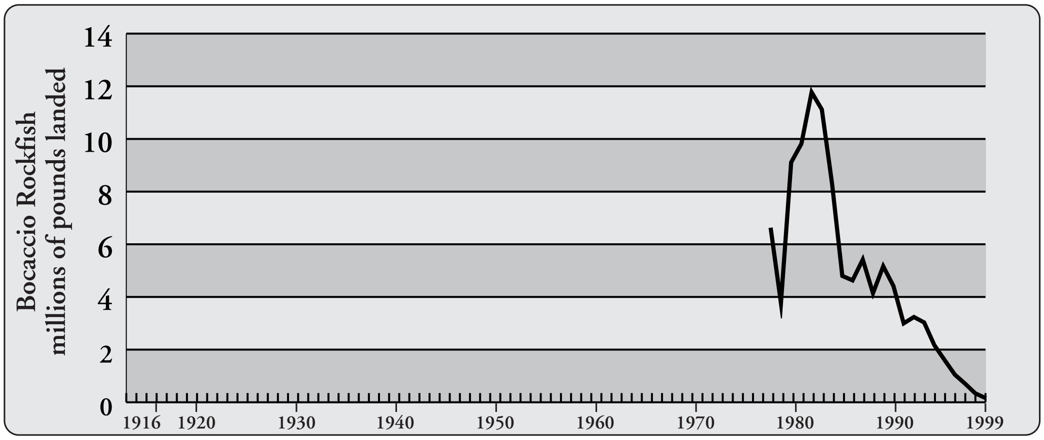
Status of the Population

During the past two decades bocaccio landings have been dominated by the 1977, 1984, and 1986 year classes. A long string of recruitment failures occurred from 1989 to 1998, which under intense fishing led to a severely depleted population. By 1999, abundance had fallen to about three percent of the level seen in 1969, and the Pacific Fishery Management Council declared the population as "overfished." Evidence from entrainment of young fish at the San Onofre Nuclear Generating Station indicates that the 1999 year class is large.



Bocaccio, *Sebastes paucispinis*
Credit: DFG

Commercial Landings 1916-1999, Bocaccio Rockfish
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Expansion data not available for years prior to 1978.



Management Considerations

See the Management Considerations Appendix A for further information.

David H. Thomas
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Revised by:
Alec D. MacCall
National Marine Fisheries Service

Historic photo of a catch of boccaccio and chilipepper being unloaded from a trawler. Credit: DFG

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Cowcod

History of the Fishery

Cowcod (*Sebastes levis*) are important to commercial and recreational fisheries in California. Estimated total catch peaked in 1976 at 213 tons, and then trended downward to 14 tons in 1999. Recreational catch of cowcod exceeded commercial landings between 1959 and 1980 but commercial catch has been larger since. Recreational landings peaked in 1976 at 154 tons, and then declined to less than two tons from 1997 through 1999. Commercial landings reached a record 155 tons in 1984. Fishing grounds nearest to major ports have been progressively exploited. Most of the remaining productive cowcod fishing grounds in the Southern California Bight are found well offshore, out-of-range for many private skiffs.

Cowcod reach the largest size of any rockfish in central and southern California, and are a highly prized trophy in the recreational fishery. The official California record for sport caught cowcod is 21 pounds 14 ounces, but the recreational fishery has produced confirmed specimens as large as 34 pounds in recent years.

Cowcod are caught along with other species of rockfish by the recreational fishery. Recreational effort is directed at cowcod from private fishing boats and commercial passenger fishing vessels (CPFVs). CPFVs include both charter boats (carrying a prearranged or closed group of anglers), and party boats (generally open to the general public, without prior reservation). The CPFV industry began in southern California around 1919, and by 1939 the fleet consisted of over 200 boats. CPFV operators targeted numerous species prior to 1950, such as tuna, giant sea bass, marlin, swordfish, mackerel, California halibut, kelp and sand bass, bonito, barracuda, and yellowtail. However, early reports do not list rockfish as a CPFV target group during the first half of the century.

Following World War II, there was a notable expansion of the CPFV fleet, and in 1953 it totaled about 590 boats. By 1963, the statewide CPFV fleet had declined to 476 vessels, 450 of which operated out of central and southern California ports. The majority of the 1963 CPFV fleet (256 vessels) was based in the Southern California Bight. Species of preference for the southern California CPFV fleet in 1963 did not include *Sebastes*, although rockfish were listed as an important part of the catch. As recently as 1969, there were reports that "some [CPFV] fishermen would rather fish for yellowtail, and catch little or nothing, than to take home a sack of rockfish. Those who prefer rockfish to yellowtail are in a minority." However, by 1974 attitudes of the typical CPFV fisherman had changed, and there was increased effort directed toward rockfish. With the decline in availability of "traditional" sportfish in the 1960-1970s, less lively "food" fish such as *Sebastes* were sought in order to maintain angler satisfaction.

Although highly sought in recent decades, cowcod have consistently composed a very small fraction of the recreational rockfish catch. Cowcod were estimated to comprise greater than one percent of the CPFV rockfish catch in 1961, 0.4 percent of total rockfish during the 1970s, and only 0.3 percent from 1985 through 1987. Cowcod seasonal catch in the sport fishery tends to peak in late autumn through early spring, which is the time of year when southern California CPFVs normally target bottom fishes.

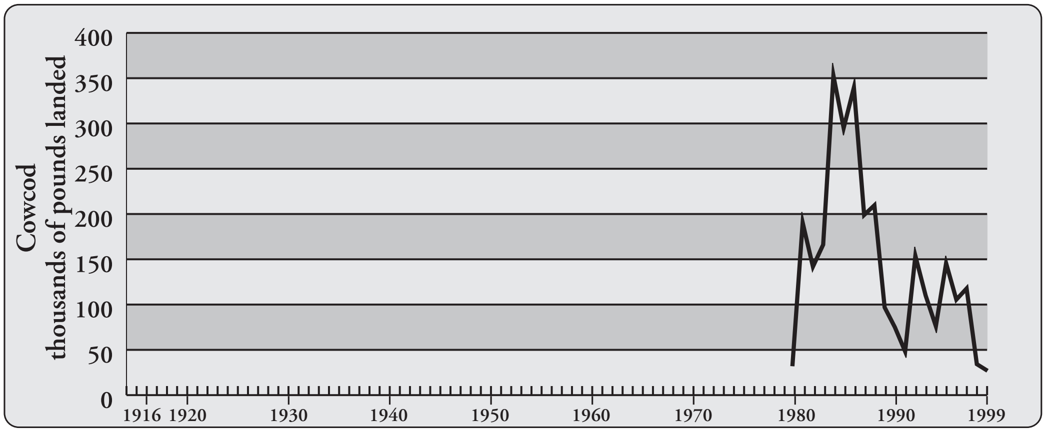
Historically, commercial landings were highest in the Southern California Bight but landings in the Monterey area have been larger during most recent years. Hook-and-line and set net gear fished in deep water on rocky bottom accounts for the bulk of historical landings in the commercial fishery. Set net catches declined after 1989, but hook-and-line has remained important. Trawling accounts for most cowcod landings in northern areas. Trawls tend to take cowcod that are smaller and more often immature than fish taken by hook-and-line. Prior to 2000, discard of cowcod in commercial and recreational fisheries was probably insignificant. Beginning in 2000, new regulations limited commercial landings to one fish per trip, which may have resulted in increased discards.

Fourteen species of rockfish have been landed in the cowcod market category; of these, the bronzespotted rockfish is the most common. Species associated with cowcod vary by gear type. In the trawl fishery, which is primarily in the Monterey management area, the main species taken with cowcod are chilipepper, bocaccio, and widow rockfish. In the hook-and-line and set net fishery, which is primarily in the Conception management area, bronzespotted rockfish, bocaccio, and vermilion rockfish are most important.

Cowcod are valuable in the commercial fishery. Fishermen received $1.37 per pound for cowcod in 1998, more than

Cowcod, *Sebastes levis*
Credit: DFG

Commercial Landings 1916-1999, Cowcod
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Cowcod landings expansion data not available for 1979 and years prior to 1978.



cowcod landed by hook-and-line command higher prices than those landed by set net or by trawl.

Prior to 2000, the Pacific Fishery Management Council managed cowcod under regulations established annually for commercial groundfish, the *Sebastes* complex and remaining rockfish. Remaining rockfish were managed as a group without specific allowable biological catch or optimum yield levels for individual species. During those years, *Sebastes* complex cumulative trip limits were high relative to landings of cowcod, and it is unlikely that the regulations had affected commercial fishing for cowcod. Specific regulations to limit the commercial and recreational take of cowcod were first established in 2000. In order to achieve an optimum yield of 5.5 tons for recreational and commercial landings combined, the recreational bag limit in 2000 was reduced to one cowcod (with a maximum of two cowcod per boat), and commercial regulations allowed only one cowcod to be landed per fishing trip.

Status of Biological Knowledge

Cowcod range from central Oregon to central Baja California, and offshore to Guadalupe Island. The geographic center of distribution is the southern California Bight. They are uncommon off Oregon and northern California. Adult cowcod habitat is primarily rocky reefs from 165 to 1,000 feet, most of which are found in the vicinity of offshore banks and islands in the Southern California Bight. Smaller fish generally occur at the shallower end of the depth range.

As with other species of *Sebastes*, fertilization is internal and females give birth to first-feeding stage planktonic larvae during the winter. Gonad-somatic indices of females are highest from November through April. Peak abundance of cowcod larvae is January through April, with some larvae present from November through August. Larvae spend about 100 days in the plankton and settle to the bottom as juveniles at about two to 2.4 inches in length. In Monterey Bay, juveniles recruit to fine sand and clay sediments at depths of 130 to 330 feet during the months of March through September. Adults are found at depths of 300 to 1,680 feet usually on high relief rocky bottom. Cowcod reach 37 inches FL and 33 pounds.

Cowcod have been aged by counting annuli in sectioned and polished otoliths. Although age determinations have not been validated, there was good agreement among independent readers. Based on a sample of 259 specimens collected in the 1970s and 1980s, the youngest fish in the landings was age seven, and the oldest was age 55. Cowcod are thought to become fully recruited to recreational and commercial fisheries at age 17, which is similar to the age at which all females become mature.

The approximate length (inches) and age of first, 50 percent and 100 percent maturity is as follows:

	Male		Female	
Maturity	**Length (in)**	**Age**	**Length (in)**	**Age**
First	13.5	8	16.5	11
50%	17.5	12	17	11
100%	19	14	20	16

Status of the Population

Cowcod were reported to be abundant off southern California in the 1890s. However, the first formal stock assessment of cowcod was in 1999. Results of the assessment suggest that spawning biomass in 1916 was near the virgin level and it remained stable through a rather long historical period (1916-1950). Biomass began to decline slowly in the 1950s and accelerated through the 1970s. Recruitment declined dramatically and biomass continued to decline after the early 1980s. The best estimate of cowcod spawning biomass in the Southern California Bight during 1998 is 262 tons, which is about seven percent of the estimated unfished stock size.

Based on the results of the 1999 stock assessment, cowcod were formally declared overfished by the National Marine Fisheries Service in 2000. A rebuilding plan will be adopted to provide assurance that abundance will be restored to 40 percent of the unfished stock size in a minimal length of time. However, due to the unproductive nature of the stock, it is likely that rebuilding will require many decades.

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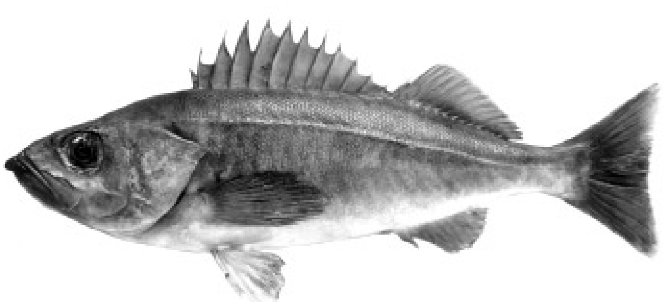
Chilipepper

History of the Fishery

The chilipepper (*Sebastes goodei*) is one of California's most important rockfish species; it is a major contributor to commercial and sport landings. In fact, from 1996 through 1998 chilipepper was ranked first in statewide commercial rockfish landings, with an annual average of over 3.8 million pounds. Important ports of landing are throughout central and much of northern California, including Fort Bragg, Bodega Bay, San Francisco, Princeton, Monterey, Moss Landing, and Morro Bay. Chilipepper also contribute to southern California rockfish landings, although not so heavily.

In the late 1800s, chilipepper and most other rockfish were caught by Portuguese longline fishermen who fished Monterey Bay from small two or three-person vessels. Longlines provided most, if not all, rockfish landings until the mid-1940s. Improvements in otter trawl technology subsequently led to trawl gear replacing longlines as the primary gear used to catch rockfish. Trawl gear enabled fishermen to make much larger landings with larger vessels. Trawlers have since accounted for the great majority of chilipepper landings, followed by set gill net and hook-and-line gears. During the 1990s, gill net landings have declined to very low levels, whereas hook-and-line gears have comprised a relatively higher portion of the catch.

Historically, chilipepper was not considered an important component of the party boat angler's catch in central and northern California due to its deep offshore distribution. In the early 1980s, Monterey and Santa Cruz party boat skippers began fishing chilipepper schools in the vicinity of the Monterey underwater canyon in late spring through summer. In contrast, southern California chilipepper partyboat landings peak during the winter months. Chilipepper was ranked third among rockfishes taken off central and northern California in 1989-1990, but its relative importance in the recreational fishery has dwindled throughout the 1990s. Since 1995, sport landings have comprised less than two percent of the total chilipepper catch.



Chilipepper, *Sebastes goodei*
Credit: DFG

Status of Biological Knowledge

Chilipepper range from Queen Charlotte Sound, British Columbia to Magdalena Bay, Baja California. Adults are found on deep rocky reefs, as well as on sand and mud bottoms, from 150 to 1,400 feet; juveniles school and are frequently found in shallow nearshore waters, particularly in kelp beds. Spawning occurs from September to April with a peak occurring in December and January. About 50 percent of female chilipepper are sexually mature at four years when they are between 11 and 12 inches, while males mature at two years and between eight and nine inches. Chilipepper attain a maximum age of 35 years and a size of up to 23 inches, with females growing substantially larger than males.

Adults feed on krill and other small crustaceans, squid, and a variety of small fishes. Probable predators of chilipepper include marine birds and mammals, king salmon, lingcod, Pacific hake, sablefish, and other rockfish.

Status of the Population

The last stock assessment of chilipepper, conducted in 1998, indicated that unlike most other rockfish populations, the stock was in quite good condition. At that time, the population size was determined to be 35,000 tons, which is about 50 percent of the unexploited level. The healthy status of the chilipepper stock has been due to a very strong 1984 year-class that supported the fishery throughout the 1990s, although recent recruitments have been lower and the stock is slowly but steadily declining. Based on the assessment, the Pacific Fishery Management Council set the acceptable biological catch at 4,100 tons, although the Council lowered the total allowable catch (TAC) to 2,000 tons out of concern for bocaccio bycatch in chilipepper fisheries. Even with the lower TAC, the various fisheries have not been catching the quota.

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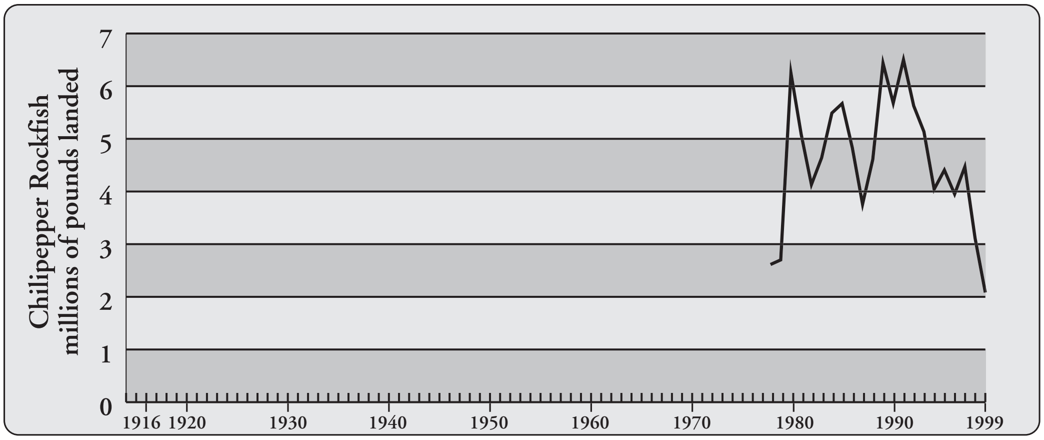
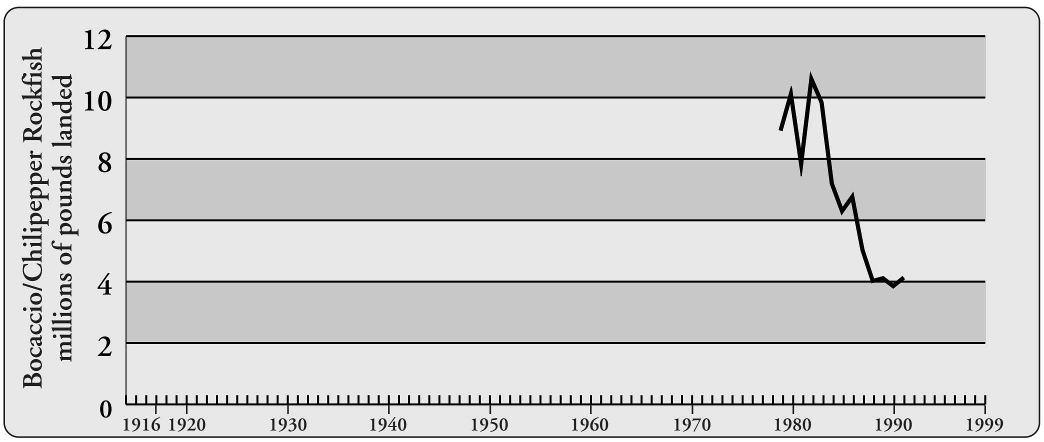


Commercial Landings 1916-1999, Chilipepper Rockfish
Data Source: CalCom Database utilizing DFG commercial landing receipts. Expansions of port samples are conducted by Pacific States Fishery Management Council with input from DFG.



Commercial Landings 1916-1999, Bocaccio/Chilipepper Rockfish
Data Source: DFG Catch Bulletins and commercial landing receipts. The market category Bocaccio/ Chilipeper Rockfish were aggregated within the market category Rockfish prior to 1979.

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Blackgill Rockfish

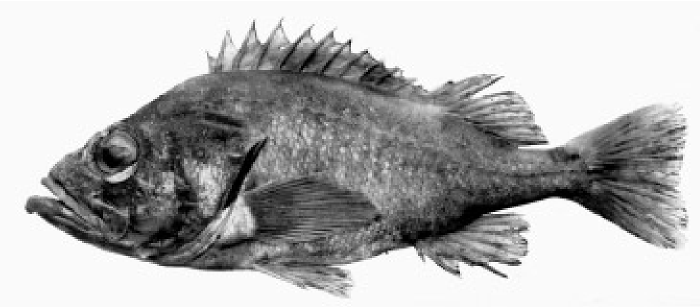
History of the Fishery

Until the 1970s, the relative abundance of shallow-water rockfishes precluded substantial commercial exploitation of blackgill rockfish (*Sebastes melanostomus*). Beginning in the mid-1970s, a fishery developed in deep waters off southern California and spread northward. Most blackgills are taken in central and southern California. The fishery was first conducted with vertical longlines and then with longlines and gill nets. Currently, most blackgills in southern California are taken with horizontal setlines, while trawls take the majority of fish further north. Statewide landings increased dramatically, peaking in 1983, then declined to about one-third in the late 1990s. From a recent stock analysis, it appears that the blackgill population has been substantially reduced on particular reefs. Blackgills are a very important rockfish species in the Asian fish markets of southern California. In 1998, the California commercial catch of about 336,000 pounds was worth $231,000. In recent years, as the rockfish recreational fishery moved to deep banks, blackgills have become an occasional catch in southern California.

Status of Biological Knowledge

This is a spiny and heavy-bodied species. Juveniles are reddish with distinct brown saddles and a dark blotch on the gill cover. Adults are dark red or dark pink with or without dark saddles and have a black edge on the rear of the gill cover. Blackgills reach two feet in length.

Blackgills are found from at least central Vancouver Island (British Columbia), and perhaps to northern Vancouver Island, to Isla Cedros, (central Baja California). Pelagic juveniles have been taken as far south as Punta Abreojos (southern Baja California), strongly implying that adults live in southern Baja California. Blackgills are relatively uncommon from Oregon northward. It appears that some records from north of Washington probably refer to rougheye and shortraker rockfishes. Adults are found in 288 to 2,520 feet, usually deeper than 660 feet, and are most abundant from 825 to 1,980 feet. Juveniles live in the shallower part of the depth range.



Blackgill Rockfish, *Sebastes melanostomus*
Credit: DFG

Pelagic juveniles settle out of the plankton at a minimum of about one inch long, generally in waters greater than about 660 feet. Small immature individuals are taken in bottom trawls on flat substrates, but seldom over rocks. They are also found on shell mounds of some deeper-water oil platforms. Adults live on deep high relief rock outcrops in areas with extensive caves and crevices. Although they are often seen hiding in crevices or closely associated with rocky substrates, fishermen have reported taken them in midwater above reefs.

Blackgills live to at least 87 years, although the largest specimens have not been aged. However, no age validation has been done on this species. Females reach a larger size and probably live longer. By the middle of their life span, females tend to be larger at any given age. Males reach maximum lengths earlier than females. Off northern and central California, males appear to mature at a smaller length than females; this is not the case off southern California. Based on two California studies, the smallest mature fish are 12 inches, 50 percent are mature at 14 inches and all are mature at 16 inches. Off Oregon, 50 percent maturity for males is 15 inches and for females is 16 inches. Blackgills appear to mature at a very late age. One percent of females is mature at about 13 years, 50 percent at 20 years, and 99 percent at about 26 years. Similarly, one percent of males is mature at about 13 years, 50 percent at about 19 years, and 95 percent at about 24 years. Off southern California, females release larvae from January to June, off northern and central California from February to April (both with February peaks) and off Oregon in April. Females produce between about 152,000 and 769,000 eggs per season in one brood. Blackgills feed primarily on fishes, including lanternfishes.

Status of the Population

The first stock assessment of this species, completed in 1998, estimated that the current fishable/mature biomass was at between 40 and 54 percent of the virgin level.

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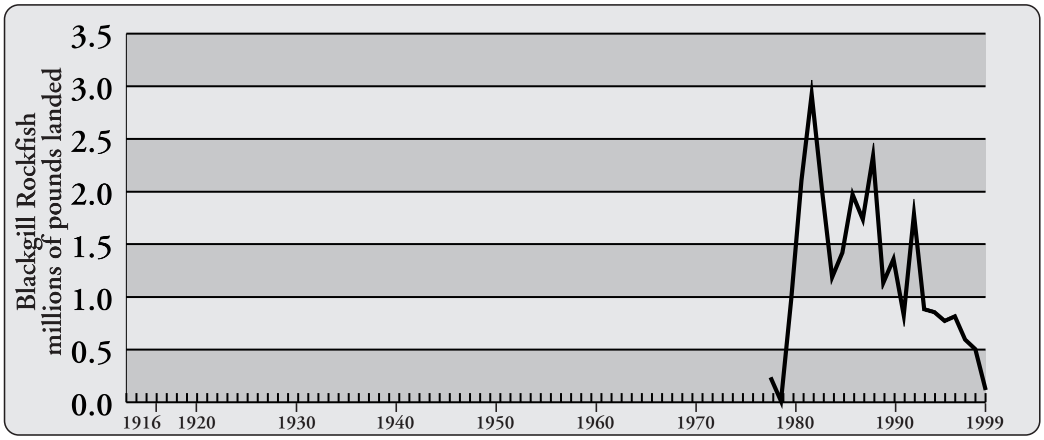

Commercial Landings 1916-1999, Blackgill Rockfish
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Expansion data not available for years prior to 1978.

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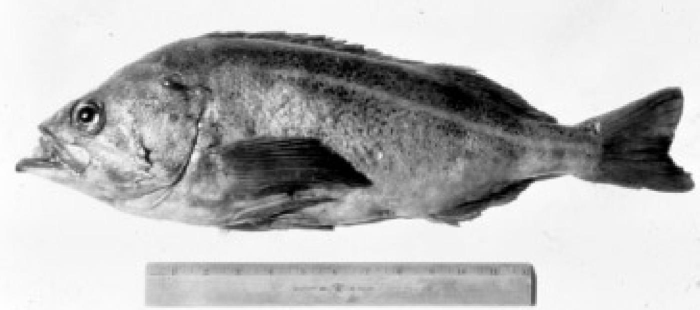
Widow Rockfish

History of the Fishery

Widow rockfish (*Sebastes entomelas*) is one of the top three rockfish species in California commercial landings, although it is a minor constituent in the recreational fishery. During the 1970s, there were occasional reports of large trawl catches of "brownies" made incidental to the harvest of other rockfish, but commercial landings were small until markets improved in 1979 and the midwater trawl fishery exploded. At that time, fishermen began targeting widow rockfish and annual California landings exceeded 10,000 tons by 1982. Since 1983, however, strict regulations have limited the commercial harvest and recent landings in California have been in the vicinity of 1,000 tons. Along the entire U. S. Pacific Coast, annual landings are restrained by a quota imposed by the Pacific Fishery Management Council that applies to the fisheries of California, Oregon and Washington. Trip landings and frequency are adjusted in order to maintain a year-round fishing season.

Over 50 percent of the widow rockfish commercial catch is landed in the most northern portion of the state (*i.e.*, Eureka and Crescent City), while San Francisco and Bodega Bay have also been historically important, accounting for about 30 percent of all landings. Although a small amount of catch is landed at Fort Bragg and Monterey, very little appears further south. When processed, widow rockfish are typically filleted and marketed as Pacific red snapper or rockcod, with the ex-vessel landed value generally in the vicinity of $1,000,000 annually. Widow rockfish are almost exclusively caught by trawlers, which have accounted for over 80 percent of the catch each year. Before the advent of restrictive trip landing limits, most of the fish were caught with very large midwater trawls, and during the early days of the fishery, it was often difficult to avoid capturing more widow rockfish in one tow with a midwater trawl than trip limits allowed. As a consequence, many vessels now use less efficient bottom trawls. Widow rockfish are also taken in the gill net and longline fisheries, although the gill net catch has declined from its peak in 1987, when it accounted for 21 percent of landings.

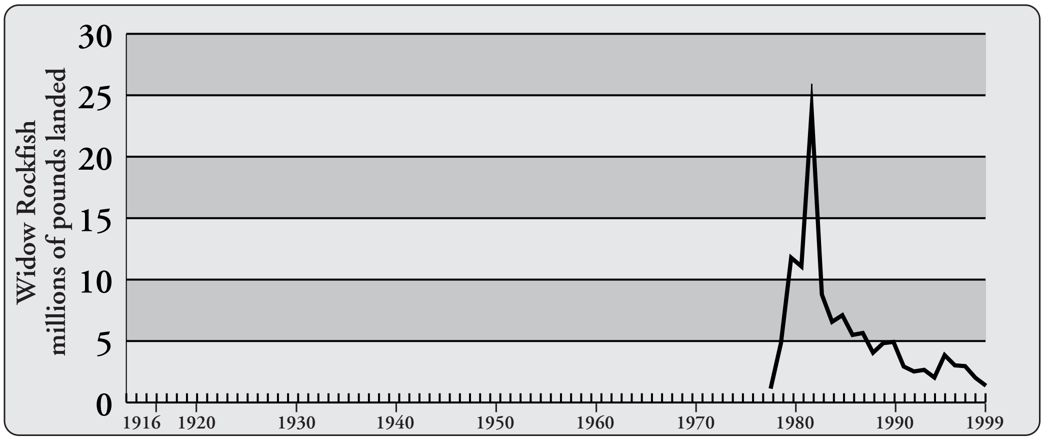


Widow Rockfish, *Sebastes entomelas*
Credit: DFG

Status of Biological Knowledge

Widow rockfish are found from Todos Santos Bay, Baja California, to Kodiak Island, Alaska. Peak abundance is off northern Oregon and southern Washington, with significant aggregations occurring south to central California. While many commercial catches occur at bottom depths between 450 and 750 feet, young fish occur near the surface in shallow waters, and adults have been caught over bottom depths to 1,200 feet. Widow rockfish often form midwater schools, usually at night, over bottom features such as ridges or large mounds near the shelf break. The schooling behavior of widow rockfish is quite dynamic and probably related to feeding and oceanographic conditions. There appears to be some seasonal movement of fish among adjacent grounds, and there is evidence that fish move from area to area as they age, with fish of the same size tending to stay together.

The maximum recorded age for widow rockfish is 59 years, but fish older than 20 years are now uncommon. Most are less than 21 inches long, corresponding to a weight of just under five pounds. The maximum size is 24 inches or about 7.3 pounds. At first, growth is fairly rapid and by age five widow rockfish average 13.5 inches. By age 15, growth slows greatly, when the average size is about 19 inches for females and 17.5 inches for males. Widow rockfish do not become reproductive until years after birth. For example, only 50 percent are mature by age five, but almost all are mature by age eight when they are 16.5 inches long. Off California, fecundity ranged from 55,600 eggs for a 12.8-inch female to 915,200 eggs for an 18.8-inch fish. The release of larvae by widow rockfish peaks in January-February and appears to occur in the same areas where they are caught during that season. The larvae are about 0.2 inch when released. The young fish lead a pelagic existence until they are about five months old. During the latter part of the pelagic stage, the two-inch fish feed mostly on copepods and small stages of euphausiids. Adult widow rockfish feed on midwater prey such as lantern fish, small Pacific whiting euphausiids, sergestid (deep-water) shrimp, and salps. Juvenile rockfish, including widow rockfish, are important prey items for sea birds and chinook salmon in May and June. Little is known about predation of adult widow rockfish.



Commercial Landings 1916-1999, Widow Rockfish
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Expansion data not available for years prior to 1978.

Status of the Population

The population was virtually unfished prior to 1979. By 1982, it became obvious that the population was being rapidly depleted and would soon be overfished, if catches were not restricted. The fishery was placed under stringent regulations in 1983. Even so, the stock was recently declared overfished by the Pacific Fishery Management Council because spawning potential was reduced to below 25 percent of the unfished condition. In response, a rebuilding plan for the stock will be implemented in 2002 that will reduce catches to less than 1,000 tons per year. With a harvest rate of less than three percent the stock should rebuild in about 35 to 40 years to the productive fishery it once was, with yields in excess of 3,000 tons per year.

Management Considerations

See the Management Considerations Appendix A for further information.

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Yellowtail Rockfish

History of the Fishery

Yellowtail rockfish (*Sebastes flavidus*), frequently called "greenies" by commercial fishermen, are a major component of the groundfish fishery. Over the period from 1983 to 1998, yellowtail rockfish accounted for 13 percent of all rockfish landed on the U.S. West Coast and six percent of all groundfish, exclusive of Pacific whiting. Among the rockfish/rockcod, only widow rockfish have supported a greater West Coast harvest. The center of yellowtail rockfish population abundance is off the states of Oregon and Washington, with lower abundance off California. Even so, from 1980 to 1998, the total combined landings among all yellowtail rockfish fisheries in the state have ranged from 370 to 2,460 tons per year, with an average catch over that period of 1,080 tons per year. Catches exceeded 2,200 tons per year during 1982 and 1983, declined to 550 tons per year through 1988, rose to levels above 1,100 tons per year from 1989 through 1992, and then declined to about 550 tons per year thereafter. After bocaccio and blue rockfish, yellowtail rockfish was the third most abundant rockfish taken in the California recreational fishery for several years.

Over the last two decades, the recreational fishery has been responsible for a substantial portion of the yellowtail rockfish catch in California, accounting for over one-third of all landings. Among the commercial fisheries, trawl fishing has produced the greatest catch (28 percent of total landings), but hook-and-line and setnet fisheries have also been important, accounting for 24 percent and 13 percent, respectively. Thus, yellowtail rockfish have been harvested in significant quantities by all groundfish fisheries in the state, perhaps more so than any other species, with the exception of bocaccio.

The northern distribution of the yellowtail rockfish stock is distinctly evident in the commercial landings statistics compiled from each port of landing within the state. Of the combined "greenie" catch, 94 percent has been taken from Monterey north. Similarly, in the recreational fishery 86 percent of the catch has come from northern California waters. There are, however, differences in the types of commercial fishing conducted at each port. For example, from Fort Bragg north, trawling has been the primary method of harvesting yellowtail. In contrast, commercial fisheries in San Francisco, Bodega Bay, and Monterey have relied more heavily on hook-and-line and setnet fixed gear to capture this species. In recent years, the setnet fishery has declined to negligible quantities, but from 1983 to1986 large quantities of yellowtail rockfish were taken in the gill net fishery that operated between Monterey and San Francisco.

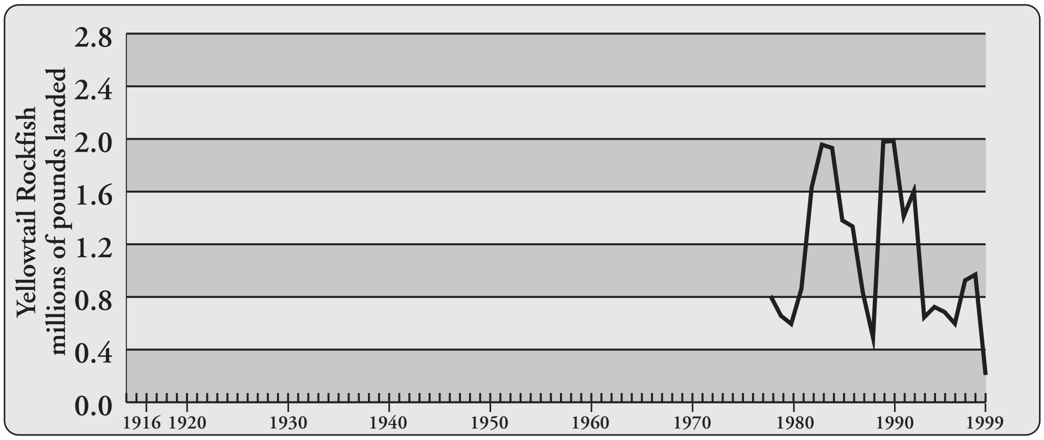
Yellowtail Rockfish, *Sebastes flavidus*
Credit: J. Mello DFG

Status of Biological Knowledge

Yellowtail rockfish are found from Kodiak Island, Alaska to San Diego, although they are rare south of Point Conception. They are wide-ranging and are reported to occur from the surface to 1,800 feet and are known to form large schools, either alone or in association with other rockfish, including widow rockfish, canary rockfish, redstripe rockfish, and silvergray rockfish. They are primarily distributed over deep reefs on the continental shelf, especially near the shelf break, where they feed on krill and other micronekton.

There is some controversy about the existence of distinct stocks of this species. Some allozyme and parasitological evidence supports the view that multiple stocks exist, whereas other genetic data indicate one single coastal stock. Within U.S. waters, the species is currently managed as two stocks, with a separation at Cape Mendocino, although that boundary is purely based on human considerations, including differences in fishing patterns and data availability.

Like many other species of rockfish, yellowtail are long-lived. The age distribution of fish sampled in commercial fisheries off Oregon and Washington can span six decades, with the oldest known specimen a 64-year-old male. They typically reach their maximum size at about 15 years of age and the largest recorded specimen was a 28-inch female. Females begin to mature at 10 to 15 inches, with half reaching maturity by a size of 15 to 18 inches; males do not grow quite as large as females.



Commercial Landings 1916-1999, Yellowtail Rockfish
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Expansion data not available for years prior to 1978.

Status of the Population

A recent assessment of the northern portion of the population indicates that unlike many of our rockfish stocks, the resource is very healthy. Based on a wide variety of information collected over the last 30 years or more, population abundance is currently believed to be about 77,000 tons, down to 60 percent of the virgin population size, but still well above the target population size, which is 40 percent of the unexploited level.

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Thornyheads

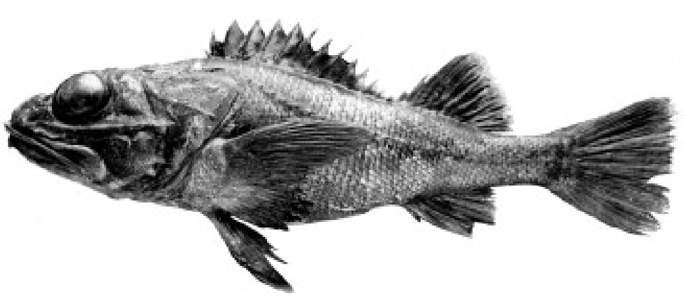
History of the Fishery

Longspine (*Sebastolobus altivelis*) and shortspine (*S. alascanus*) thornyheads are both important to commercial fisheries in California, Oregon, Washington, Canada and Alaska, but are insignificant in recreational fisheries. In California, Oregon and Washington, thornyheads are taken in the deepwater commercial fishery for Dover sole, thornyheads, and sablefish, known as the DTS complex. In terms of landed weight and ex-vessel value, the DTS complex is the most important element in the California groundfish fishery.

Fishing for thornyheads is typically by bottom trawl and longline gear on sand or fine sediment, and in relatively deep water (1,800 to 3,000 feet, although some fishing grounds are as shallow as 600 feet). Fishermen report that there are areas where both thornyhead species are found together and other areas where one or the other is prevalent. Most of the thornyheads landed in California are taken in the Eureka, Fort Bragg, and Morro Bay areas. Few thornyheads are taken south of Point Conception.

Although there are physical differences between the two species and shortspine thornyheads grow to larger size, distinguishing between them can be difficult under field conditions. Landings and other data for each species may, therefore, be less reliable than data for thornyheads as a group. It is likely that thornyhead landings were mostly shortspine during the early years when the fishery operated in relatively shallow water. Longspine thornyheads were not landed in large quantities until later when the fishery expanded into deeper water. The long-term trend is toward a lower proportion of shortspine in landings. During the 1980s, thornyhead landings were about 75 percent shortspine, which decreased to only 25 percent shortspine thornyheads in the 1990s.

The west coast fishery for thornyheads first developed in northern California during the 1960s, when large thornyheads (primarily shortspine, minimum size 12-14 inches) were marketed as rockfish fillets in domestic markets.



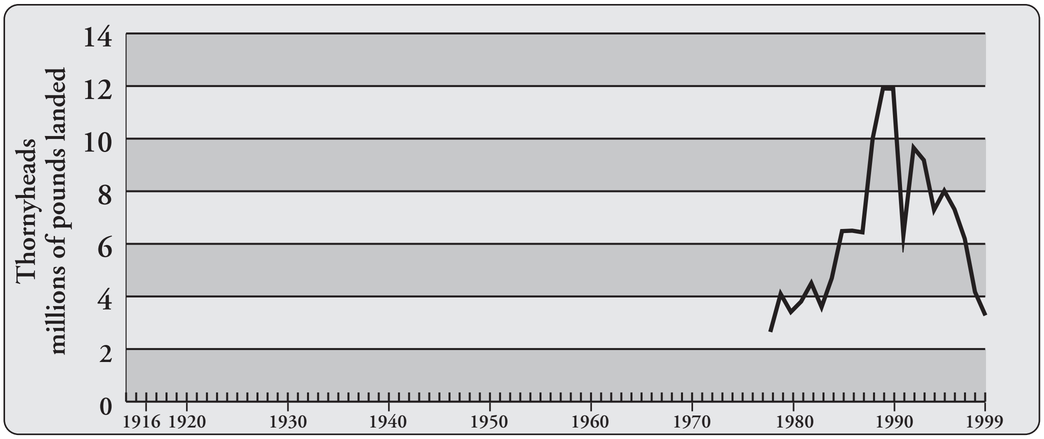
Longspine Thornyhead, *Sebastolobus altivelis*
Credit: DFG

Increased landings during the 1980s were the result of higher prices and demand for thornyheads, primarily as a headed and gutted product exported to Japan. As markets for thornyhead matured, minimum marketable size decreased and smaller longspine thornyheads became valuable. During the 1980s, most processors began accepting fish as small as 10 inches, the fishery expanded into deeper waters, and landings of longspine thornyhead increased. By the 1990s, a two-tier price structure (higher prices for large fish) replaced the minimum size limits that had been previously imposed by the buyers.

Market factors and fishery regulations effect discard rates, particularly for small fish. Discard rates have changed over time but have often been substantial. During the late 1990s, trip limits imposed by fishery managers caused additional discarding of shortspine thornyhead because shortspine trip limits were reached before the limits for longspine. In 1999, managers assumed a 30 percent discard rate for shortspine thornyheads, and a five percent discard rate for longspine thornyheads.

California landings of thornyheads are consistently the largest on the West Coast. During most years, the California fishery accounted for over one-half of the combined California, Oregon and Washington landings. From 1953 to 1969, annual thornyhead landings in California were below 440 tons. Thornyheads became more common in landings when California trawlers began fishing intensively for Dover sole in the early 1970s. Landings averaged 1,540 tons annually from 1970 to 1979, increased throughout the 1980s, and reached a record high of 7,800 tons in 1992. Following the record high, landings during the remainder of the 1990s trended sharply downward due to harvest restrictions, to a low of 1,628 tons in 1999.

As export markets developed in the 1980s, nominal prices paid to fishermen increased by more than 60 percent, from $0.23 in 1983 to $0.38 per pound by the end of the decade. Gross revenues for thornyheads landed in California rose from $728,000 in 1980 to $5,971,000 in 1990 (dollar amounts not adjusted for inflation) as the result of increased prices and landings. The relative value of thornyheads in the groundfish fishery also increased during that time. Revenues from thornyheads were only 12 percent of total revenues for the deepwater fishery (DTS complex) during 1980, but increased to 39 percent by 1990. The value of California thornyhead landings trended upwards through the mid-1990s, and reached a high of $8,292,000 in 1995, which coincided with record high ex-vessel prices (excluding live fish) of $1.05 per pound. Annual thornyhead revenues declined after 1995 due the decreased tons landed and slightly lower prices (excluding live fish). Annual revenues from landings totaled about $3,286,000 during both 1998 and 1999.



Commercial Landings 1916-1999, Thornyheads
Data for total thornyhead includes landings for lonspined thornyhead, shortspined thornyhead, and unspecified thornyhead. Expansion data not available for years prior to 1978. Landings data for lonspined thornyhead, shortspined thornyhead, and unspecified thornyhead are presented in the landings tables at the end of Groundfish Chapter. Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers.

An important specialty market has developed for live thornyheads since 1993, which takes advantage of their lack of a swim bladder and ability to survive after capture at depth, and ex-vessel prices that are several times higher than for dead fish. Landings of live thornyhead increased from two tons in 1993 to an estimated 107 tons in 1999. Despite steady growth, the live fishery has remained a minor part of the total tons of thornyheads landed. However, due to the high ex-vessel prices, live fish accounted for a significant fraction (18.8 percent, or $619,000) of the total value of thornyhead landings in 1999.

With the 4.5-inch mesh cod ends currently used in the commercial trawl fishery, thornyheads become vulnerable to bottom trawls at about five to seven inches in length and at an age of about eight to nine years. Thornyheads are seldom taken by gill nets or in the recreational fishery because of the depths at which they live.

Thornyheads are managed by the Pacific Fishery Management Council under the Groundfish Management Plan. Shortspine and longspine thornyheads were first regulated in 1990. Annual quotas and associated fishing regulations were established for thornyheads as a group during 1990-1994 because of difficulties in separating the two species in the landings. Beginning in 1995, individual quotas and trip limits were adopted and enforced for each species. The separate trip limits for each species resulted in a requirement that catches be sorted by species prior to weighing. Shortspine trip limits have been about 75 percent smaller than limits for longspine in recent years, which has likely caused some discards of shortspine because vessels could continue fishing for longspine after the shortspine limits were reached. During 2000, the total West Coast optimum yield for shortspine thornyheads was 1,250 tons of landed catch, and for longspine thornyhead it was 4,980 tons.

Status of Biological Knowledge

Thornyheads (genus *Sebastolobus*) belong to the same family (Scorpaenidae) as the rockfishes (*Sebastes* spp.) but are distinguished from them in having more dorsal and head spines, in losing their swim bladder at the time they settle to the bottom, and in spawning gelatinous egg masses. Shortspine thornyheads grow to larger size and when small are found in shallower water than longspine thornyheads. Population dynamics of the two species differ. Shortspine thornyheads have longer life span, lower natural mortality, and smaller biomass than longspine thornyheads. Consequently, shortspine thornyheads are less productive than longspine thornyheads with respect to fishery yields.

Shortspine thornyheads tend to migrate toward deep water as they grow, and larger shortspine thornyheads may be found in deeper water with longspine thornyheads. Longspine thornyheads, in contrast, spend their entire lives in a more narrow range of depth. The adults of both species are major components of the assemblage of fishes on the continental slope. Both species have special enzymatic adaptations that allow metabolic activity despite the high pressure, low oxygen, and low temperature at the depths where they live. Peak spawning biomass for both species is in the deep "oxygen minimum zone" at 1,200 to 3,000 feet, where concentrations of dissolved oxygen may be less than 0.5 parts per thousand. Longspine thornyheads have been described as "oxygen minimum zone specialists."

Estimates of ages for both species are based on counts of growth rings in thin-sectioned otoliths. Shortspine thornyheads can grow to 30 inches and may be quite long-lived. Radiochemical analysis of otoliths from shortspine thornyheads suggest larger size-at-age than were obtained by annuli counts. It is particularly difficult to determine the age of older individuals, but recent estimates indicate that the maximum age of shortspine thornyheads off California may be in excess of 100 years. Longspine thornyheads grow to a maximum length of 15 inches. Their maximum age is probably at least 45 years.

Shortspine thornyhead are found at depths of about 100 to over 5,000 feet along the west coast of North America from northern Baja California to the Bering Sea and across the North Pacific to the coast of Japan. It is not known if separate stocks exist. Off California, shortspine thornyhead spawn during late winter and early spring. Males off Alaska may spawn at about 6.5 inches in length (estimated age five). About half of all females off California are sexually mature at 8.25 inches in length (estimated age 13) and almost all are sexually mature at 13.5 inches (estimated age 28). A female may release as many as 400,000 eggs annually in gelatinous egg masses that float to the surface. Larvae free themselves from the egg when about 0.25 inch in length and transform to juvenile fish at about 0.75 inch. Larvae and young juveniles are pelagic for 14 to 15 months and settle to the bottom when about one inch long during January to June of the year after they hatch. Juveniles settle in shallow water along the upper boundary of their habitat and move to deeper water as they grow. They spend the rest of their lives closely associated with the bottom. Shortspine thornyheads in Alaska are known to eat crustaceans, crabs, worms, clams, octopus, sea cucumbers, and fish. Longspine thornyheads feed primarily on polychaetes and small crustaceans.

Longspine thornyheads are found from Cape San Lucas, Baja California to the Aleutian Islands in water from about 1,000 to over 5,000 feet deep. It is not known if separate stocks exist. Like shortspine thornyheads, longspine thornyheads spawn in the late winter and early spring. Half of the females are sexually mature at about 7.5 inches (estimated age 14) and most are mature at 8.75 inches (estimated age 18). A female may produce as many as 100,000 eggs annually, which, like the eggs of the shortspine thornyhead, are released in gelatinous egg masses that float to the surface. Two to four batches of eggs may be spawned each year. Larval fish are pelagic after hatching and transform into juveniles during July to December. Young juveniles are pelagic for as long as 20 months and begin settling to the ocean bottom when about two inches long. Settlement starts during the summer of the year after they hatch. Juvenile longspine thornyheads settle in deeper water than do shortspine thornyheads, with newly settled juveniles occupying the same depth range as adults. There does not appear to be a tendency for individuals to move deeper as they grow.

Status of the Population

Stock assessments are carried out for both longspine and shortspine thornyheads. Results are used by fishery managers to determine allowable fishing mortality each year. Shortspine thornyheads along the west coast of the U.S. were assessed in 1998 by two independent analyses. Both assessments used data from the fishery and data from scientific trawl surveys. Based on the combined results, the stock in 1999 had declined to 32 percent of unfished abundance. The best estimate of spawning biomass from central California to the U.S./Canada boundary in 1998 was 32,365 tons, compared to an estimated unfished stock size of 95,755 tons. Maximum surplus production and yield for thornyheads probably occurs at biomass levels greater than 40 percent of unfished stock size. Consequently, current abundance of shortspine thornyhead is less than desired, and recent fishing quotas have been set at levels to allow some growth in stock size.

The most recent assessment of longspine thornyheads was done in 1997, using fishery and survey data to estimate changes in abundance and associated uncertainty. The assessment covered the portion of the stock found from central California to the U.S./Canada international boundary. Results indicate that spawning biomass steadily declined in recent decades, from a high of 36,958 tons in 1964 to 20,203 tons in 1996. The degree to which longspine thornyheads have been fished down is generally thought to be appropriate for attaining maximum fishery yields from the stock, based on biological characteristics and population dynamics of the species.

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Bank Rockfish

History of the Fishery

Most bank rockfish *(Sebastes rufus)* are taken commercially by trawls, although gill nets were also important early in the fishery. Most of the catch occurs off California, although substantial landings are occasionally made off southern Oregon. Until the 1980s, bank rockfish were a relatively minor part of the commercial catch. However, as fishing effort off California expanded into deeper waters, landings of this species sharply increased. From 1981 to 1992, banks ranked among the top 10 rockfish species taken in California, averaging 1,115 tons annually, and ranked among the top three rockfish species landed at Monterey and Morro Bay. In general, catches after 1992, though variable, have remained somewhat steady. Since the 1970s, there has been a decrease in both age and length of individuals in the fishery. In 1998, about 450,000 pounds of bank rockfish were caught in the California commercial fishery; these were valued at about $207,000.

While bank rockfish are rarely caught in the recreational fishery north of Pt. Conception, California, they are a frequent catch of recreational anglers in deep waters off southern California.

Status of Biological Knowledge

Bank rockfish are oval-shaped fish with small head spines. They are dusky red or red-brown, often with a clear pinkish-orange zone along the lateral line and black spotting on the body and spinous portion of the dorsal fin. However, some individuals may not have spots. This species reaches a maximum length of 21.7 inches.

Bank rockfish are found from Queen Charlotte Sound, British Columbia to central Baja California and Isla Guadalupe (off central Baja California). They are abundant from the southern Oregon-northern California area to at least southern California. They live in depths between 100 and 1,500 feet, but most commonly between 300 and 800 feet.

Bank Rockfish, *Sebastes rufus*
Credit: DFG

Juveniles and sub-adults tend to be found in shallower waters than adults are.

Demersal juveniles and adults often are found over high relief boulder fields or steep cliff faces with plenty of crevices and caves. They also are found over cobblestones or on mixed mud-rock bottoms, where they shelter near or beneath the hard substrate. Small numbers have been observed around the bottom of deeper offshore oil platforms. Banks usually are found either alone or in small groups of up to 30 individuals, often hiding in, or very close to, sheltering sites. It is also possible that this species previously formed large schools before it was subjected to intense fishing pressure. In southern California, banks are often found with blackgill rockfish.

Bank rockfish live to at least 53 years. They are among the slowest growing of the rockfishes. Females grow larger than males and, at least among older fish, appear to be larger at a given age. Males reach maximum length at a slightly faster rate than females and mature at a smaller size than females. A few males are mature at 11 inches and 10 years, and all are mature at 14.8 inches and 20 years. Off California, banks release larvae from December to May (peaking in January and February) and from January to April off Oregon. Individual females produce between about 65,000 and 608,000 eggs. Off southern California, females release larvae in several batches per season, although this is not the case further north. Little is known of their food habits, although krill and gelatinous zooplankton have been found in their stomachs.

Status of the Population

In 2000, a partial stock assessment was made on bank rockfish. This assessment implied that there has been a substantial decrease in the bank rockfish population, particularly in the 1990s.

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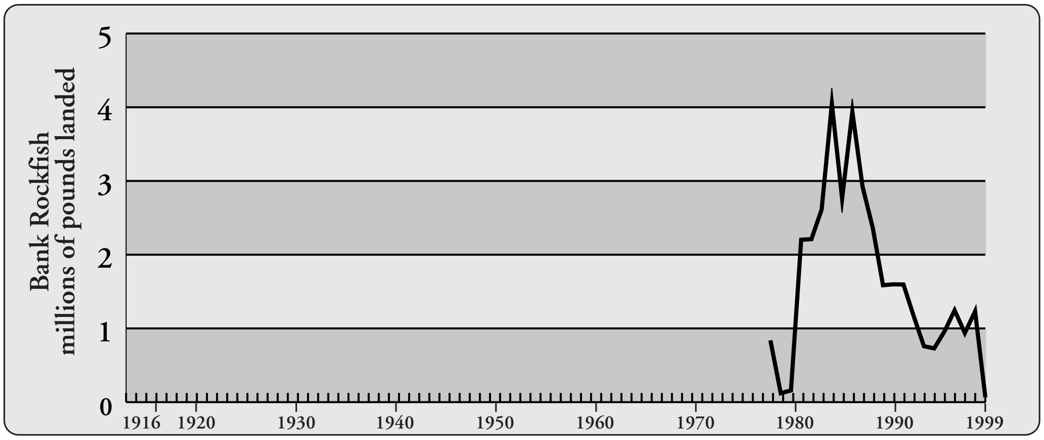

Commercial Landings 1916-1999, Bank Rockfish
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Expansion data not available for years prior to 1978.

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Shortbelly Rockfish

History of the Fishery

The shortbelly rockfish *(Sebastes jordani)* is the most abundant rockfish off California but has been fished very little. A directed fishery occurred in 1982, when a joint venture with the USSR caught 700 tons off central California. Otherwise, a few shortbelly rockfish occasionally appear with other rockfish landed in California ports. There is no domestic market for shortbelly rockfish at present. If a market develops, special fishing permits will be required, because fishing with legal mesh sizes is not practical for this small species. Large catches of shortbelly rockfish can be made using midwater or bottom trawls with fine mesh cod ends. Research has shown, however, that while directed fishing for shortbelly rockfish results in low incidental catches of other species when midwater trawls are used, high incidental catches can occur when bottom trawls are used. Because of the concern that bottom trawls would take unacceptably high numbers of small fish of other important species, scientists have recommended against the use of bottom trawls for shortbelly rockfish.

The potential fishery for shortbelly rockfish is controversial. Some fishermen express concern that significant amounts of salmon may be caught incidentally to fishing for shortbelly rockfish, but scientists have not observed incidental salmon catches on numerous research cruises and believe that a fishery for shortbelly rockfish is likely to be offshore from concentrations of salmon. Fishermen and environmental groups also express concern because young-of-the-year shortbelly rockfish are forage for salmon, sea birds and marine mammals. Scientists have recommended quotas that are thought to be sufficiently low so as not to impact either the recruitment or the availability of young-of-the-year shortbelly rockfish for forage. Scientists have also recommended close monitoring of fishing for shortbelly rockfish to verify that high incidental catches of this species and/or depletion of forage do not occur.

Shortbelly Rockfish, *Sebastes jordani*
Credit: David Ono, DFG

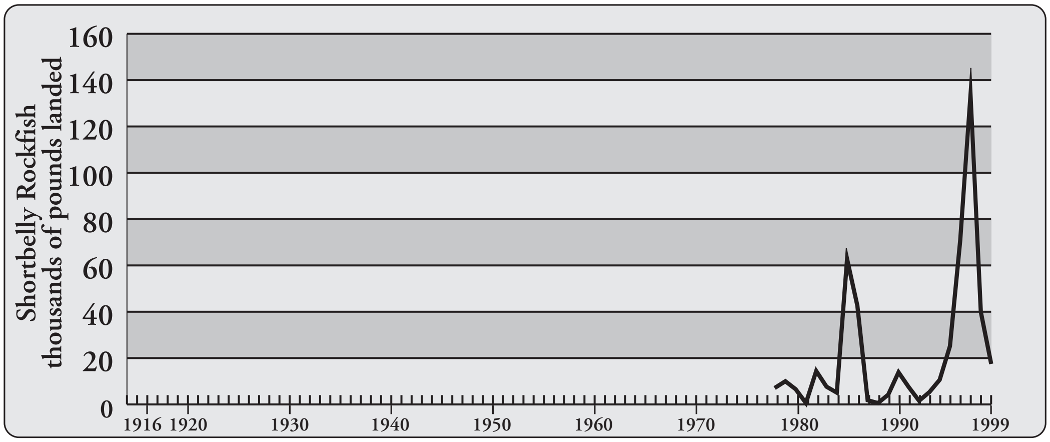
The quota for catches off California, Oregon and Washington in 2000 is 13,900 tons. Applications by joint venture companies to fish for shortbelly rockfish submitted in the early 1990's were not approved. Those companies intended to use the catch for surimi (artificial crab). There has been little current interest in development of a fishery. Bocaccio is one of the most common bycatch species. Since bocaccio has been declared an overfished species, it is unlikely that a commercial fishery for shortbelly rockfish will be allowed to develop in the foreseeable future.

Status of Biological Knowledge

Shortbelly rockfish are found from Punta Baja, Baja California, to La Perouse Bank, British Columbia. Largest numbers are found between the Farallon Islands and Santa Cruz, and off the Channel Islands. Young-of-the-year shortbelly rockfish have been observed in the surf line, and adults have been reported as deep as 930 feet. The peak abundance of adults is over bottom depths of 400 to 700 feet. Adults commonly form very large schools over smooth bottom near the shelf break. Schools are often near or on the bottom during the day and tend to be less dense and higher in the water column at night. The size of shortbelly rockfish tends to increase with bottom depth.

The maximum reported age for shortbelly rockfish is 32 years, but fish older than 10 years are uncommon. Most are less than 11.5 inches in length, which corresponds to a weight of 0.5 pound. The largest measured specimen was 13.4 inches, about 0.7 pound. Early growth is fairly rapid, and by age three the average size is 7.8 inches for males and 8.3 inches for females. Growth slows by age eight, when the average size is 9.7 inches for males and 10.3 inches for females. About 50 percent of female shortbelly rockfish are mature by age three, and almost all are mature by age four. Fecundity ranges from 6,200 eggs for a 6.8-inch fish to 50,000 eggs for a 12.0-inch fish.

Plankton surveys during the January-April parturition season indicate that larvae are released in the same areas inhabited in the summer and fall by large aggregations of adults. However, the fish may be more dispersed during late winter because aggregations of adults have been difficult to locate then. Larvae are about 0.2 inch when released. The young fish lead a pelagic existence until June, when they are about five months old, after which they settle out to lead a semi-pelagic existence. In June, the young shortbelly rockfish begin to take on the behavior of adults. Divers have occasionally observed them in large, compact schools in fairly shallow water. Large numbers of moribund young-of-the-year shortbelly rockfish are sometimes found on beaches after periods of wind patterns that are thought to cause currents, which carry



Commercial Landings 1916-1999, Shortbelly Rockfish
Data Source: CalCom, a cooperative survey with input from Pacific Fisheries Information Network (PacFin), National Marine Fishery Service (NMFS), and California Department of Fish and Game (DFG). Data are derived from DFG commercial landing receipts with expansions based on port samples collected by PacFin samplers. Expansion data not available for years prior to 1978.

them into shallow waters. These fish did not appear to be either starved or diseased. They appear to be maladapted to contact with the abrasive bottom when in the nearshore environment.

During the latter part of the juvenile pelagic stage, the two to three-inch shortbelly rockfish feed mostly on copepods and young stages of euphausiids. Adults feed primarily on euphausiids but also consume some copepods. Young-of-the-year shortbelly rockfish are important prey for salmon and sea birds. They have also been found in the diet of lingcod and northern fur seals. Adult shortbelly rockfish are occasionally found in the diet of large fish such as lingcod.

Status of the Population

The population is at the unfished level. Biomass estimates have been attempted on four hydroacoustic surveys from Santa Cruz to the Farallon Islands in 1977, 1983, 1986, and 1989. Large aggregations needed for the hydroacoustic technique were found only on two of the four surveys. The two estimates of biomass were 168,000 tons and 325,000 tons. It was estimated that the biomass in this area could support annual catches of at least 14,800 tons without reducing the spawning stock below levels thought to be needed to maintain good recruitment. Recent larval abundance surveys have suggested that recruitment is low which may be related to unfavorable oceanographic conditions.

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Dover Sole

History of the Fishery

The stature of Dover sole (*Microstomus pacificus*) has evolved from that of an undesirable by-product of bottom trawling prior to the 1940s, to the most abundant groundfish in statewide landings. This phenomenal rise was the result of market demand during and following World War II and technological advances in fish handling and processing.

At the advent of trawling in the 1870s, Dover sole were inadvertently caught by lateen sailboats using paranzella nets. California's Dover sole fishery expanded from its beginning in San Francisco Bay to its present scope extending from Santa Barbara to the Oregon border. The developing trawl fishery experienced major changes in vessels and netting. Sailboats were replaced by steam, gasoline, then diesel-powered vessels. The original paranzella trawl net was supplanted by the more efficient otter trawl in the 1920s. By the 1980s, some trawl fishermen began to use roller or bobbin trawls to capture Dover sole and other deep-slope groundfish instead of more conventional trawls with rubber mudlines between the trawl doors and footrope to create a fish-herding mud cloud. A quick-freezing method, developed during World War II, hardened the soft flesh of the Dover sole to produce marketable fillets. This advance and the wartime demand for fish allowed trawlers to turn their attention to the large north coast population of Dover sole.

The directed Dover sole fishery began in 1943 when 28 tons were landed. Between 1944 and 1947, landings ranged from 62 tons to 1,400 tons. The fishery expanded to 3,600 tons in 1948, at which time Dover sole landing records were separated from nominal or unspecified sole landings, and rose further to 5,850 tons by 1952. Annual landings then remained stable at approximately 4,000 tons until 1969. From 1969 through 1989, landings averaged 10,200 tons and from 1990 through 1999, average landings dropped to 5,892 tons.

Commercial Dover sole landing limits were imposed coastwide in 1989 and 1990 by the Pacific Fishery Management Council (PFMC) as a trip limit on the aggregate poundage of Dover sole, thornyheads, and sablefish (the DTS complex). Prior to that time, market demand and gear regulations controlled statewide Dover sole landings. The intent of this regulation was to reduce the harvest of sablefish by restricting effort for the DTS complex. While reduced quotas and increasingly restrictive trip limits were placed on the DTS complex coast-wide during the 1990s, the major reason for the decline in California Dover sole landings was a reduction in market demand. The port of Eureka has historically supported the largest Dover sole fishery and was strongly impacted by the loss of a major Army contract. Fort Bragg, Crescent City, San Francisco, Monterey, and Morro Bay are other ports with significant Dover sole landings.

Dover Sole, *Microstomus pacificus*
Credit: DFG

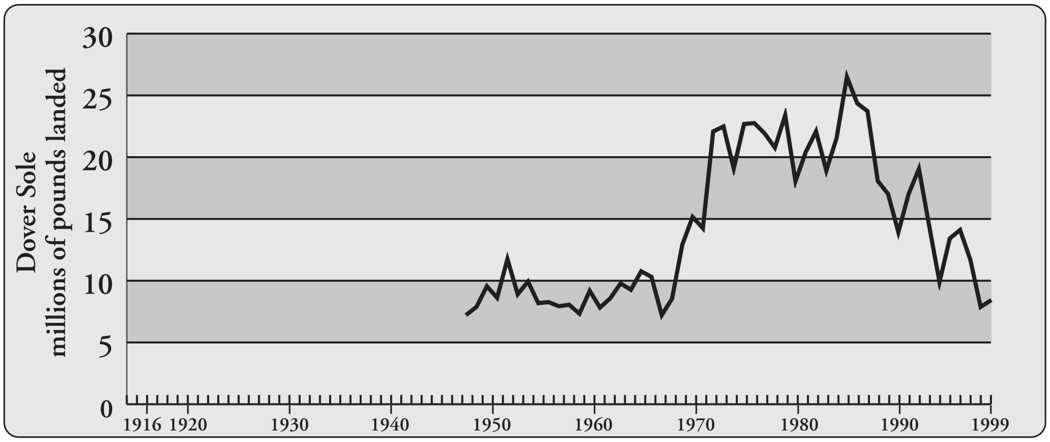
Sport utilization of Dover sole is practically nonexistent. The depth distribution of Dover sole normally places them beyond most sport fishing activity, and Dover sole, because of their feeding habits, are not vulnerable to hook-and-line fishing.

Status of Biological Knowledge

Dover sole occur from the Bering Sea to northern Baja California on mud bottoms at depths from 180 to 4,800 feet. Although early tagging experiments off Oregon and California suggested Dover sole move inshore in the summer, a more recent California Department of Fish and Game (DFG) tagging study discovered that not all Dover sole participate in the summer inshore movement. Most of the mature fish tagged and released in deep water were recovered in deep water regardless of season. The DFG tagging data indicate that two substocks may exist – one that migrates and one that does not. Juvenile Dover sole settle on the continental shelf and gradually move down the slope over their lifetime, reaching the oxygen-minimum zone as they become sexually mature.

Growth is rapid during the early years of life but decreases with age. Five-year-old Dover sole grow 0.7 inch per year, but by 10 years of age, growth slows to 0.4 inch annually. Dover sole may attain an age of over 50 years and reach 30 inches in length. Fifty percent of Dover sole females 12 inches long are mature. The youngest mature Dover sole in 1987-1988 studies was six years old, whereas earlier studies reported mature five-year-old females.

Dover sole may spawn nine batches to release all eggs in a spawning season. Egg production is correlated with size. Fish of 0.6 pound produce 33,000 eggs, while 2.4-pound fish produce 54,000 eggs on average. Incubation time for the buoyant eggs may vary from 10 days to one month depending on the ambient water temperature. Larvae are unusually large (one to two inches long) and have a



Commercial Landings 1916-1999, Dover Sole
Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important. Data Source: DFG Catch Bulletins and commercial landing receipts.

prolonged pelagic life of at least one year before settling to the bottom. Larvae have been found along the entire California coast, as far as 60 miles south of the U.S.-Mexico border and up to 280 miles offshore.

Dover sole feed commonly on polychaete worms, pelecypod and scaphopod mollusks, shrimp, and brittle stars. Only Pacific sleeper sharks and spiny dogfish are known to prey on Dover sole.

Status of the Population

In 1987 and 1988, the National Marine Fisheries Service (NMFS) conducted two surveys to assess the adult biomass of Dover sole in the area from Point Conception to Monterey Bay. The surveys found that 98 percent of the spawning biomass of Dover sole in central California waters live on the continental slope between 2,100 and 3,300 feet deep, an area characterized by low oxygen concentrations and very cold temperatures. A 1991 assessment using 1990 NMFS bottom trawl survey data provided estimates of biomass and yields for the area from Cape Mendocino, California to Cape Blanco, Oregon (Eureka area). Another assessment, conducted in 1992, included the Eureka area and the Columbia area and another completed in 1995 included the northern Monterey area as well as the US Vancouver area.

The last Dover assessment, conducted in 1997, treated the entire population in the Monterey area through the U.S. Vancouver area as a single stock based on research on the genetic structure of the population. The Point Conception area population has yet to be fully assessed. Using yield recommendations presented in the 1997 assessment, the PFMC set a coastwide landed catch limit of 8,955 tons. This stock is believed to be in equilibrium and near the target biomass level that would provide maximum sustainable yield.

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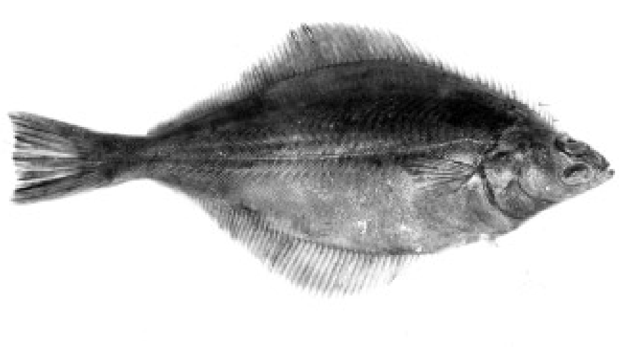
English Sole

History of the Fishery

English sole (*Pleuronectes vetulus*) has been commercially important since the introduction of the first trawl net, the paranzella, in San Francisco in 1876. The use of trawl nets made the catch of "sole" species one of the leading categories of fish landed in California, and English sole was the leading flatfish in that group until Dover sole took first place in 1949. Since then, English sole has been second in pounds landed except for 1970 through 1972, when petrale sole was second. The peak year for English sole was 1929, when 8.7 million pounds were caught off central California and at new fishing areas off Fort Bragg and Eureka. Annual landings in California averaged 2.8 million pounds during the 10 years from 1980 to 1989 and dropped to an average 1.3 million pounds between 1990 and 1999. The majority of recent California landings were made by trawlers fishing on the grounds off Eureka and San Francisco. Little is taken commercially south of Point Conception.

English sole are fished primarily by trawling in water 120 to 900 feet deep on sandy bottoms. Because of the shallow water in which this species is found, relatively small vessels can participate in the fishery. A very small portion of the catch is taken by commercial hook-and-line or by gill net, and it is not an important species for recreational fishing. Female fish greater that 11 inches comprise the majority of landings because females tend to be longer and heavier than males, and markets request fish of at least 11 inches in order to produce reasonable size fillets. While English sole fillets are desirable for the market and restaurant trade, demand is affected by the abundance of other flatfish and roundfish as well as the availability and price of imported fish products.



English Sole, *Pleuronectes vetulus*
Credit: DFG

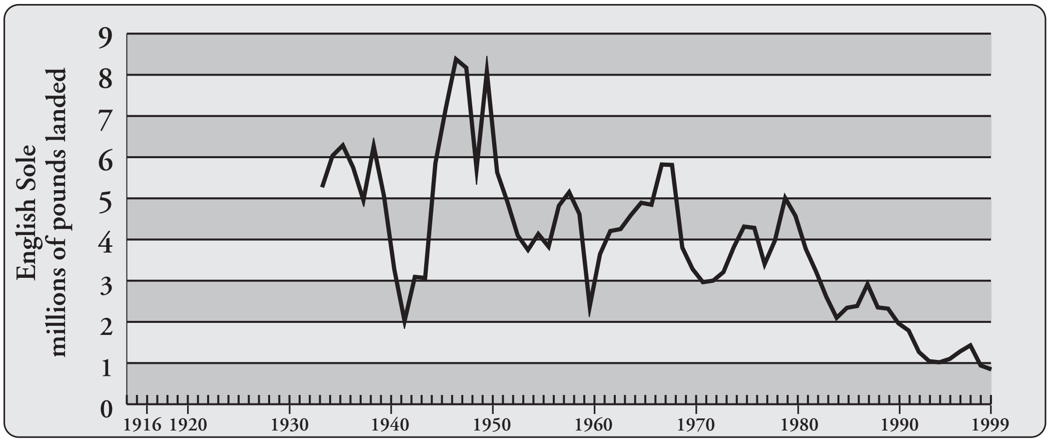
Status of Biological Knowledge

English sole range from San Cristobal Bay, Baja California to northwest Alaska in water as deep as 1,800 feet. Fish tend to move to deeper water in the winter and shallower water in the summer, and fishing effort follows these movements. Tagging studies in California, Oregon, Washington, and British Columbia show that, although there is little overall migration, small seasonal north-south movements probably occur, and some fish have been found to move in excess of 200 miles. Analysis of tag returns also suggest that four separate stocks are found in California: south of Point Conception, Point Conception to Bodega Bay, Monterey to Eureka, and Eureka to southern Oregon. The overlap in areas is a result of apparent north-south movement of the stocks. Some seasonal intermingling between stocks probably also occurs.

Three-year-old female English sole, on average, are only about eight inches, while 10-year-old females are about 14 inches. Fifty percent of female English sole are usually mature at five years and nine inches. Spawning generally occurs over sand and mud-sand bottoms at depths of 200 to 360 feet from September to April. In California, peak spawning occurs from December through February, with annual variations in timing apparently related to water temperature. Each fish probably spawns only once per year. Egg diameter is approximately 0.04 inch. Fertilized eggs are buoyant when first released, but shortly before hatching they begin to sink into the water column.

When the eggs hatch, in four to 12 days, the larvae are approximately 0.1 inch long. Typically the larvae are in the midwater column but sink deeper as they approach metamorphosis. During development, the larvae may be carried toward shore on lower-level water currents. Spawning and development during times of rapid plankton growth may result in good recruitment. During their pelagic phase of six to 10 weeks, the larvae grow to about 0.75 inch, then settle to the bottom and metamorphose to the adult benthic body form.

After metamorphosis, and for the first year of life, juvenile English sole are found in shallow bays and estuaries and feed all the way up to the intertidal zone. Juveniles are found in sand, mud, and eelgrass habitats. The population density of juvenile English sole in estuaries is several times higher than on the open coast; however, it is not known how important estuaries are to survival of juvenile English sole. In southern California, the shallow open coast may be more important as juvenile habitat than it is further north. As the fish grow they tend to move to deeper water. While in the estuary and nearshore shallow-water environment, juveniles feed on copepods, the palps of segmented worms, siphons of small clams, brittle stars, and other small invertebrates. At the end of their first



Commercial Landings 1916-1999, English Sole
Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important. Data Source: DFG Catch Bulletins and commercial landing receipts.

year of life (about five inches), most juveniles have moved to offshore waters.

Adult fish are seldom found in estuaries. They are opportunistic feeders eating shallowly burrowed or surface-active prey such as worms, small crustaceans, clams, and occasionally small fish, crabs, and shrimp. Adults can also dig into the sediment to reach deeper prey. The largest recorded English sole, from British Columbia, was 22.5 inches, and 21-inch fish have been taken in California. The oldest recorded age is 22 years. English sole are aged by counting the annual rings on the interopercular bone. The English sole is capable of interbreeding with the starry flounder producing an inter-generic hybrid called the hybrid or forkline sole or flounder.

Status of the Population

Little information is available to estimate the status of the English sole stock in California. Catch-per-unit-of-effort data exist but are complicated by the multiple species aspect of trawl fishing. In 1993, an assessment using data collected from 1977 through 1992, was conducted for the English sole stocks off Oregon and Washington. Results indicate that the biomass increased steadily during the assessment period, which was attributed to high recruitment. The author concluded that English sole stocks can sustain a high exploitation rate because a large portion of the spawning stock is comprised of small females that are not caught by the fishery due to the small size-at-maturity.

The California fishery is currently managed by the Pacific Fishery Management Council through gear regulations such as trawl net mesh size and a recommended Acceptable Biological Catch (1,100 metric tons at present). Landings are monitored and populations continually assessed for signs of biological stress.

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Petrale Sole

History of the Fishery

The California fishery for petrale sole (*Eopsetta jordani*) began in the San Francisco Bay area during the late 1880s. Petrale were then, as they are now, a highly desirable flatfish. Most are filleted for the fresh market, with the remainder being cleaned and smoked or dried. The majority of the petrale sole landed are taken commercially with bottom trawls, along with various other flatfishes and rockfishes, although some are caught by longline or entangling nets. The sport fishery is negligible, with only a few thousand pounds being landed annually. The principal sport catch is made by partyboats fishing for bottomfish species such as rockfishes.

In 1924, there were 66,000 pounds of petrale sole landed. From 1924 through 1933, annual landings averaged about 250,000 pounds, with over 1.4 million pounds landed in 1931. The trawler fleet increased greatly in size and efficiency following World War II. New gear technology allowed trawling on new grounds at greater depths, resulting in larger landings. Also contributing to increased production was the discovery of winter spawning grounds at depths of 900 to 1,200 feet. Concentrations here were very dense and catches increased accordingly. Over five million pounds were landed in 1948. Between 1982 and 1991, landings averaged 1.7 million pounds. From 1992 to 1999 landings averaged 1.3 million pounds.

Status of Biological Knowledge

Petrale sole are found from the Bering Sea to northern Baja California on sandy bottoms at depths ranging from 60 to 1,500 feet. These fish have been known to move great distances; tagged fish released off Eureka, California have been recovered in British Columbia. Nevertheless, most tagged petrale sole are recovered within short distances of the release point.

Pertrale Sole, *Eopsetta jordani*
Credit: DFG

Tagging studies in Washington, Oregon, and California indicate that petrale sole concentrate for spawning in deep water during winter and, shortly after spawning, disperse inshore and northward through the spring and summer months. During fall and winter, they show an offshore and southerly movement again concentrating on local deep water spawning grounds. Seasonal landing distributions show the same pattern. During winter, a targeted fishery occurs in deep water and large catches and landings of petrale are made, while during summer, they are caught in association with many other groundfish and individual petrale landings are relatively small. Within California, four spawning populations of petrale sole have been delineated by tagging experiments and by locating spawning fish. These are in the Cape Mendocino, Point Delgado, Point Montara, and Point Sal areas.

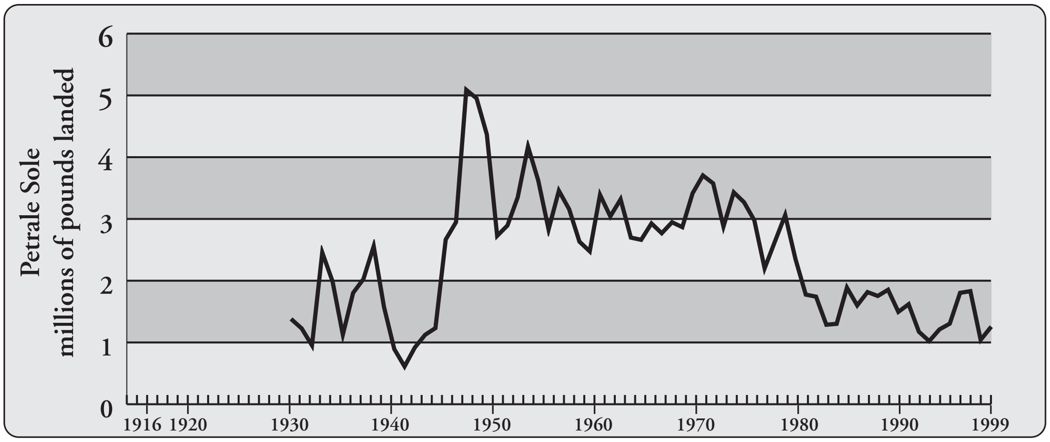
Age and growth studies on petrale sole in California have been very limited. However, growth appears to be rapid during the first few years for both male and female fish, after which the growth rate becomes disproportionate, with females growing more rapidly than males. The maximum recorded sizes and ages of California petrale sole are 19.5 inches and 21 years for males and 25.2 inches and 25 years for females. Petrale sole enter the fishery at about three years of age, but most of the petrale catch consists of females between five and seven years old and about 14 to 17 inches long.

Petrale sole reproduce in water between 900 and 1,200 feet deep from November through March, with peak spawning during January and February. Males reach first maturity at three years of age and 11.7 inches long, and females at four years and 12.5 inches. About 50 percent of the males are mature at seven years and 16 inches. The largest immature male recorded was 15.2 inches and eight years; the largest immature female, about 18.5 inches and nine years. Eggs are pelagic and hatch in about 8.5 days at 44.6 F.

Petrale sole are among the largest California flatfish. They feed on euphausiids, shrimp, anchovies, herring, juvenile hake, small rockfish, and other flatfish.

Status of Population

A 1999 stock assessment, which focused on petrale stocks off Oregon and Washington did not estimate absolute
biomass or offer a harvest projection for California. However, the authors did examine some limited data from California including a set of shelf survey indices of biomass and noted that this index has been steadily



Commercial Landings 1916-1999, Petrale Sole
Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important. Data Source: DFG Catch Bulletins and commercial landing receipts.

increasing since 1980. This assessment suggests recent California catches are sustainable, prompting the PFMC to retain a statewide acceptable biological catch of 3.3 million pounds.

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Rex Sole

History of the Fishery

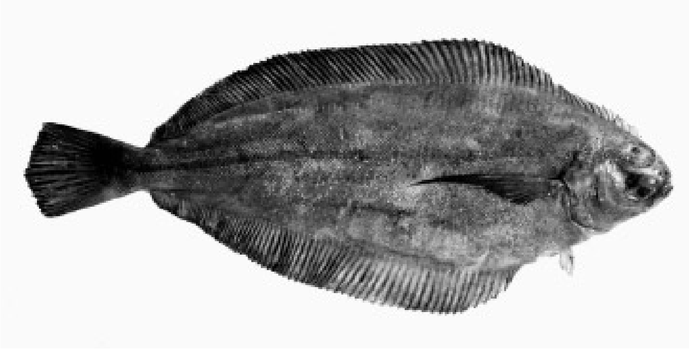
The rex sole (*Errex zachirus*, formerly *Glyptocephalus zachirus*) is taken commercially by bottom trawl nets from southern California to the Bering Sea at depths of 300 to 1,200 feet. Despite its wide-distribution, this species does not lend itself to a high-production targeted fishery, because it rarely aggregates in any one location at any certain time of year. It is rarely taken by sport fishermen.

The commercial fishery for rex sole in California had been steady and stable between 1970 and 1989, with most catches made incidentally to other groundfish species. Annual California landings of rex sole from 1970 to 1989 averaged 1.6 million pounds, with a range of 1.3 to 2.0 million pounds. However, during the 1990s landings declined along with landings of other groundfish. By the end of the 1990s, landings were down to approximately 630,000 pounds worth $243,772 to fishermen. Prices have been steady at $.35 to $.40 per pound for the past decade. Traditionally, the majority of the landings in California have come from the Eureka-Crescent City area. Since 1985, rex sole landings from other ports as far south as Morro Bay have grown relative to landings in the Eureka-Crescent City area.

Rex sole is primarily processed for the fresh food market, where it is held in high esteem by seafood connoisseurs because of its bright, white flesh and its sweet, distinctive taste. Most rex sole are marketed in a dressed form (eviscerated with the head off), which gives processors a 35 to 45 percent yield by weight. Rex sole is generally not filleted because its thin, slight body does not allow for efficient recovery.

Status of Biological Knowledge

The rex sole belongs to the family Pleuronectidae, the right-eyed flounders. It is distinguished by a long narrow pectoral fin on the eyed side of the body, a short compressed head, a small mouth, and a nearly straight lateral line that lacks an accessory branch.



Rex Sole, *Errex zachirus*
Credit: DFG

Rex sole first appear in the trawl catch when they are about 12 inches long and 10.5 years of age. They can attain a length of 23.25 inches and an age of 24 years. Male rex sole first spawn in their second year when about five inches long. Females first spawn at age three and about eight inches. Rex sole become fully mature at age four and about nine inches in length. After 3.5 years of age, females grow somewhat faster than males; they also tend to live longer.

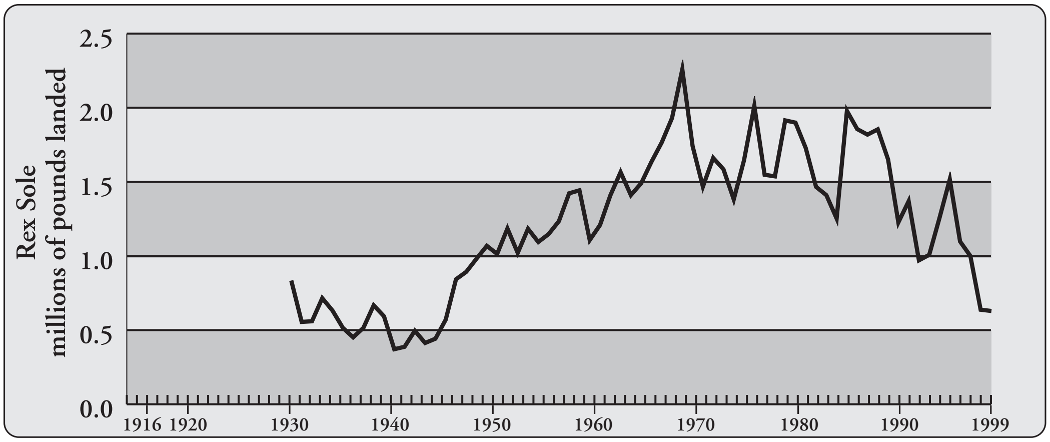
Although rex sole in spawning condition have been collected throughout the year, peak spawning activity is from February through March off San Francisco and during the summer off Eureka. Spawning rex sole are most abundant at depths of 300 to 900 feet.

The number of eggs produced by a single female rex sole increases with size. A 9.5-inch female will produce about 3,900 eggs, while a 23.25-inch female can have as many as 238,000 eggs. Rex sole eggs average about 0.10 inch in diameter, are fertilized near the sea bed, become pelagic, and probably require a few weeks to hatch.

Rex sole eggs hatch to produce pelagic larvae that are about 0.25 inch in length. Larvae have been collected from nearshore to 200 miles offshore during California Cooperative Oceanic Fishery Investigations (CalCOFI) surveys and are most abundant from April to July. The larvae retain an extended pelagic existence for about a year before settling out to the bottom as two-inch-long juveniles. The long pelagic phase may make rex sole larvae more susceptible to dispersal and drift by currents, a factor that might affect survival and subsequent year-class strength. Juveniles are common on the outer edge of the continental shelf, which is possibly used as a nursery area, at depths of 490 to 660 feet.

Little is known about rex sole movements and migrations. They are found from shallow water (60 feet usually deeper than 200 feet) to depths of 2,100 feet. They show a preference for a muddy-sandy bottom but also frequent both sand and mud bottoms.

Stomach analyses show that rex sole feed primarily on amphipods and polychaetes; shrimp are also eaten. Rex sole are preyed upon by sharks, skates, rays, lingcod, and some rockfish.



Commercial Landings 1916-1999, Rex Sole
Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important. Data Source: DFG Catch Bulletins and commercial landing receipts.

Status of the Population

The rex sole is listed under the "other flatfish" category in the Pacific Coast groundfish plan. It is believed to be adequately protected by trawl mesh-size regulations, which result in the retention of only the larger fish. Yet, insufficient information is available to determine possible trends in stock abundance. Increased restrictions on trawling effort may be partially responsible for recent reductions in landings.

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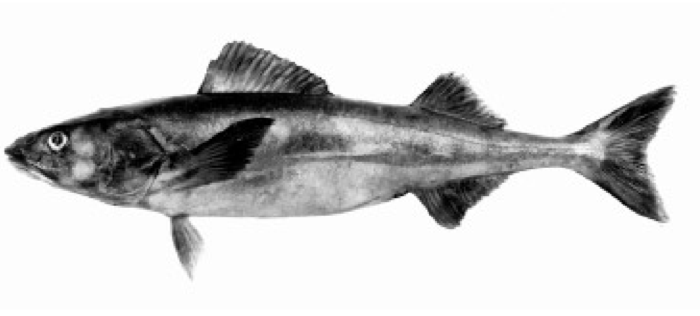
Sablefish

History of the Fishery

The sablefish (*Anoplopoma fimbria*) resource off California has a lengthy history of commercial exploitation. Prior to 1935, landings averaged about 500 tons annually. By 1935, annual landings had risen to 1,400 tons at a time when sablefish livers, because of their high vitamin A content, commanded a higher price than the edible parts of the fish. Landings increased to over 3,000 tons in 1945 due to strong wartime market demand, then varied from approximately 770 to 2,200 tons per year until 1972. More intensive exploitation of sablefish began in 1972 with the development and widespread use of sablefish traps, which proved highly effective. Foreign fishing fleets from the U.S.S.R, Japan, and the Republic of Korea fished for sablefish off California from 1967 to 1979, catching relatively minor quantities in most years. However, in 1976 the Republic of Korea reported a catch of 9,500 tons off California. The establishment of the U.S. 200-mile fishery conservation zone in 1977 phased out foreign fishing in those waters; consequently Japan, the principal foreign market for sablefish, became increasingly reliant on imports of U.S.-caught sablefish. Japanese demand for sablefish helped drive California landings to a record high of 14,287 tons in 1979, followed by a market collapse the next year to just 5,141 tons.

The first commercial sablefish landing limits were imposed coastwide in 1982 by the Pacific Fishery Management Council. Prior to that time, market demand, not resource availability or quotas, was the dominant force controlling statewide sablefish landings. From 1982 to 1989, regulations constrained statewide sablefish landings to an average of approximately 6,175 tons. Annual coastwide landing quotas remained at 19,183 tons from 1982 to 1984, then gradually declined to 9,800 tons in 1990 as the stock was fished down to the recommended long-term target level. Between 1990 and 2000, the Allowable Biological Catch (ABC) was reduced slightly to 10,661 tons.

The economic importance of sablefish to California has increased considerably in recent years. In 1989, sablefish, worth $3.63 million, ranked fourth in ex-vessel value among groundfish species. Between 1990 and 1999, California landings had an average ex-vessel value of 5.1 million dollars. Sablefish are marketed commonly as "black cod" and smaller fish are often filleted and sold as "butterfish." The high oil content of the flesh produces an excellent smoked product, and most of the large individuals are sold domestically in this form. Sablefish are typically exported in frozen, dressed (headed-and-gutted) form. There is a large price difference with size.



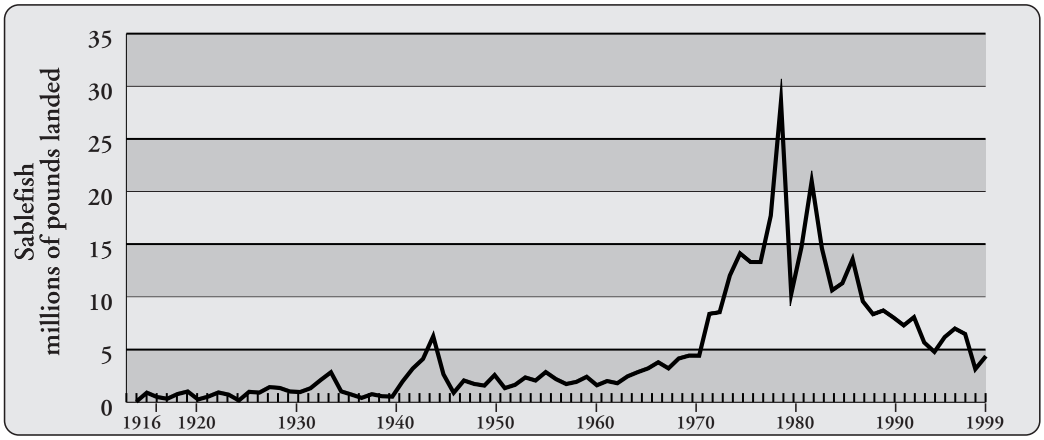
Sablefish, *Anonlopoma fimbra*
Credit: DFG

Sport utilization of sablefish is negligible, with rare instances of large catches when schools of small sablefish concentrate around public piers. The depth distribution of sablefish normally places them beyond most sport fishing activity.

Sablefish are captured commercially with longline, trap, bottom trawl, and gill net gears. Before 1943, sablefish were landed principally by small two- to three-man longline boats fishing deep for large sablefish for the smoked fish market. Catches by trawlers became significant in 1944. The distribution of landings among gear types has varied considerably over time, but bottom trawlers have accounted for about 70 percent of annual California landings in recent years. In recent years, a small number of sablefish have been caught in the recently developed live-fish fishery.

Trawls and gill nets capture sablefish in mixed-species catches with a variety of other groundfishes, whereas longline and trap gears target on sablefish. Off California, most trawl-caught sablefish are taken in association with Dover sole and thornyheads in deep (1,200-4,200 feet) water. Longlines and traps are also fished at such depths for sablefish, but gill net-caught sablefish commonly are captured with rockfish at depths less than 900 feet.

Because of the immense fishing power of the West Coast groundfish fleet and a robust market demand, rather intensive management of sablefish became necessary in the 1980s to prevent overexploitation and to accomplish other management goals. Trip landing and frequency limits, a 22-inch minimum size limit, user-group allocations, as well as more commonly used quotas and gear restrictions, have been applied to the commercial sablefish fishery by the PFMC. Trip landing and frequency limits prevent early quota attainment, thereby reducing the discard of sablefish by-catch in non-directed fisheries and providing year-round availability of fresh sablefish to domestic consumers. The minimum size limit, implemented in 1983, prevents the excessive harvest of juvenile sablefish. Quota allocation distributes the harvest among user groups to achieve social and economic goals. Quotas and gear restrictions are designed to ensure the optimal long-term harvest of sablefish.



Commercial Landings 1916-1999, Sablefish
Data Source: DFG Catch Bulletins and commercial landing receipts.

The sablefish resource is unique among West Coast groundfishes, for the annual commercial catch quota has been allocated between trawl and non-trawl gears since 1986. Trawl/non-trawl allocations, based on historical shares and incidental catch requirements, have ranged from 58:42 to 52:48 during 1986 to 2000. Separate allocations are needed because trawl-landing restrictions put trawlers at a disadvantage with non-trawl fishermen when both groups compete for a joint quota. Most non-trawl fishermen land only sablefish; thus an unrestricted open fishery followed by a closure is acceptable to them. Quota allocation allows each group to use their optimal harvest strategy within regulatory constraints.

Status of Biological Knowledge

The geographic distribution of sablefish extends from the Asiatic coast of the Bering Sea to northern Baja California. Tagging studies by the National Marine Fisheries Service (NMFS), Department of Fisheries and Oceans-Canada, and the Alaska Department of Fish and Game indicated that adult sablefish are relatively sedentary, as most fish were recaptured within 50 nautical miles of release sites. However, some sablefish, particularly those tagged in southern California, have moved in excess of 1,000 nautical miles. Adult sablefish are found from less than 300 to more than 4,800 feet deep, but peak abundance off California is at about 1,200 to 1,800 feet. Length and age generally increase with depth.

The spawning season extends from October through February. A central California study determined that spawning occurs at depths greater than 2,700 feet. Initially, larval sablefish inhabit surface waters offshore; later they move into nearshore nursery areas. Juveniles aggregate in water depths of continental slope and abyssal areas. The diet of juvenile sablefish includes copepods, amphipods, euphausiids, fish eggs, and fish larvae. Adults eat euphausiids, tunicates, and fish.

Approximately 50 percent of female sablefish reach maturity at 23.6 inches long and six years of age off California. Females grow faster than males from age two and attain a larger maximum size. Sablefish may attain an age of over 50 years and reach a size of 47 inches and 126 pounds but are usually less than 30 inches and 25 pounds. Sablefish enter the trawl fishery as early as one year of age but are fully selected by trawl and nontrawl fisheries at ages four to six. Large, older fish are most selected by the trap and longline fisheries.

Sablefish are conventionally aged using the broken and burnt otolith method. There is very poor agreement among agers and therefore the estimated ages are questionable. This is in spite of a considerable amount of research on the problem.

Status of Population

For management purposes, a unit stock is assumed to exist in waters off California to the Canadian border. Considerable progress has been made in the 1980s towards understanding the dynamics, structure, and size of this stock. Two types of fisheries-independent surveys were conducted by the NMFS, triennial groundfish trawl surveys (initiated in 1977) from Monterey Bay to the Canadian border and biennial sablefish trap surveys in the INPFC Conception to Eureka areas (Mexican border to 43° 00’ N latitude). In 1991, the biennial trap survey was discontinued due to a lack of funding. In addition, a systematic landings sampling program and trawl logbook data provided insight into catch-per-effort, and age- and length-composition trends. In general, these disparate data sets presented a somewhat equivocal picture of stock status in California waters.

Fisheries-independent and dependent studies have had conflicting results. Stock assessments have been hampered by the lack of reliable age data. In 1998, two independent stock assessments were performed which resulted in biomass estimates ranging between 33,000 and 319,000 tons. Given the highly uncertain status of the population, it is unclear whether management has been too liberal or too conservative.

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Pacific Hake

History of the Fishery

The Pacific hake (*Merluccius productus*), also known as Pacific whiting, makes up more than 50 percent of the potential annual harvest of West Coast groundfish off Washington, Oregon, and California and is the largest groundfish resource managed under the Pacific Fishery Council's Groundfish Management Plan. Pacific hake was considered an underutilized domestic species until 1991, the first year the entire harvest was captured and processed by the U.S. seafood industry.

A member of the cod family, Pacific hake is a delicate fish that requires careful handling to achieve a marketable product. The fish must be chilled, processed, and frozen soon after the harvest. Also, Pacific hake are infected with a myxosporidian parasite that can appear as black spots within the flesh. Protease enzymes associated with the parasite can cause degradation of the flesh if the fish are not handled properly.

The Pacific hake fishery is a high-volume, low-value fishery (ex-vessel prices have ranged from $0.025-$0.08 per pound). Its product contains, on average, about 15 percent protein and three percent fat. Domestic production had been primarily geared towards the frozen headed and gutted market, shipped in high volume on a penny-a-pound margin. However, with the growth of the domestic fishery in the 1990s, there has been significant growth in the production of surimi (fish paste), Individual Quick Frozen (IQF) fillets, and frozen blocks. Today 60 to 80 percent of production is surimi, 10 to 20 percent headed and gutted, 10 to 20 percent fillets. A significant proportion of the waste products is processed into fishmeal and fertilizers including hydrolosate and compost-based products.

Economic contributions to the Pacific Coast states of hake harvesting/processing vary according to product form and harvest/processing mode. Each pound harvested and processed in headed-and-gutted form contributes about $0.38 per round pound. For surimi, the state contribution is between $0.27 and $0.32 per round pound. In 1999, the hake fishery generated an estimated cumulative economic impact to West Coast states of between $134 and $185 million dollars.

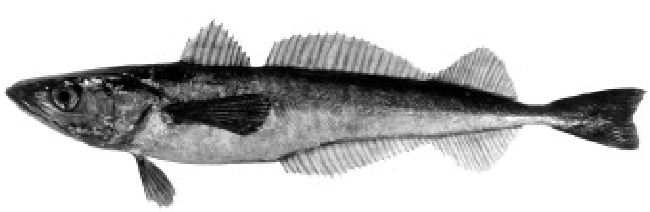
The fishery has been multi-national in character, having been exploited commercially since before 1900 by the U.S. fishing industry and since 1966 by foreign fleets. A small domestic fishery has existed for coastal hake since at least 1879. Most catches prior to 1960 were made incidental to the pursuit of more valuable trawl-caught species and were either discarded or delivered to reduction plants producing animal food and fishmeal. The average annual California catch from 1959 to 1966 was 248 tons.

In 1964, the National Marine Fisheries Service (NMFS) demonstrated that large catches of hake (to 60,000 pounds per half-hour haul) could be achieved off coastal Washington and Oregon using newly developed depth telemetry systems on midwater trawlers. This fishery grew from 484 tons in 1964 to 15,883 tons in 1967.

Knowledge of the large hake resource off the West Coast attracted a large fleet of Soviet trawlers and accompanying support vessels in 1966. Between 1973 and 1976, Poland, the Federal Republic of Germany (West Germany), the German Democratic Republic (East Germany), and Bulgaria entered the fishery. Japan also participated in the fishery before 1977; their peak harvest was 9,104 tons in 1974. The estimated catches of Pacific hake during this period of expansion ranged from 130,000 tons to 262,000 tons. Catches peaked in 1976 and were subsequently reduced due to restrictions on foreign effort imposed by the Magnuson Fisheries Conservation and Management Act (MFCMA) of 1976.

Two types of fishing operations involving foreign vessels were conducted off Washington, Oregon, and northern California after the implementation of the MFCMA in 1977. In one fishery (the foreign trawl fishery or "directed fishery"), fish were caught and processed by foreign vessels. In a second fishery, known as the joint venture (JV) fishery, U.S. trawl vessels deliver their catch to foreign processing vessels at sea.

The joint venture fishery for Pacific hake started in 1978 between foreign nations and the United States and Canada. Consistent with the intent of the MFCMA to encourage development of domestic fisheries, landings of hake declined in the foreign directed fishery while increasing in the JV fishery. In 1978, the foreign catch amounted to 98 percent of the total hake catch in the U.S. management zone. The foreign catch declined to 11 percent of the total by 1988, and in 1989 there was no foreign catch. U.S. fishermen harvested the entire annual hake quota in 1989, eliminating the foreign directed fishery, and in 1991



Pacific Hake, *Merluccius productus*
Credit: DFG

domestic processors were able to process the entire catch thereby eliminating the JV fishery.

The phase out of foreign fisheries opened development to domestic fisheries. This took the form of domestic factory trawlers, which catch and process their catch, motherships which take fish at sea from catcher vessels, and the development of shoreside processing plants. Development was accelerated by the discovery of enzyme inhibitors that made it possible to utilize hake for surimi.

The domestic at-sea and shore-based fisheries grew through the 1990s with the at-sea sector harvest increasing from 4,700 tons in 1990 to 197,000 in 1991. The Pacific Fisheries Management Council (PFMC) reduced the at sea harvest in following years to allow growth in the shoreside sector. Prior to 1991, shore-based deliveries of Pacific hake were relatively small with an annual harvest of less than 10,000 tons. Between 1985-1991, the shore-based fishery concentrated off northern California with processing plants at Eureka and Crescent City. As the domestic shoreside fishery grew, additional processing plants were opened in Oregon and Washington. Shoreside deliveries increased from 8,115 tons in 1990 to 87,862 in 1998. In California, landings have increased from 41 tons in 1980 to about 11,000 tons in 1999.

In the early 1990s, fishing seasons began April 15. Since 1998, PFMC has used a season-ending, forward-counting protocol to estimate the season opening for the shore-based sector only (the offshore sector still opens May 15). Using October 15 as the season ending date, the PFMC estimates daily harvesting and processing capacity and shore-based quotas to determine the season opening date. The greater the quota or the lower the daily capacity, the earlier the season opening. Before 1995, the season opened April 15, between 1995 and 1998 the season opened May 15, (mostly to avoid salmon bycatch), and since 1998 the season has opened June 15. The shift in season opening date has had a significant effect on improving economic benefits (recovery, quality, price, and growth).

In 1996, the Makah Tribe in Washington requested an allocation of hake as part of its treaty entitlement. NMFS allocated 15,000 tons of the domestic TAC to the Makahs, increasing it to 25,000 in 1997 and 1998, and to 32,000 in 1999. The fish are harvested by Makah trawl vessels and delivered to a floating processor mothership. The fishery is limited to the Makah's "usual and accustomed" fishing grounds off the northern Washington coast.

In 1997, the PFMC adopted a sector allocation formula dividing U.S. non-tribal hake harvest guideline between factory trawlers (34 percent), vessels delivering to at-sea processors (24 percent), and vessels delivering to shore-based processing plants (42 percent). Shortly after this allocation agreement was approved by the PFMC, fishing companies with factory trawler permits established the Pacific Whiting Conservation Cooperative (PWCC). The primary role of the PWCC is to allocate the factor trawler quota between its members. Benefits of the PWCC include more efficient allocation of resources by fishing companies, improvements in processing efficiency and product quality, and a reduction in waste and bycatch rates relative to the former "derby" fishery in which all vessels competed for a fleet-wide quota.

The rapid development that took place in the 1990s has resulted in full utilization of the combined U.S. and Canadian hake catch. The 1994 combined catch reached 359,000 tons, the largest yield since the inception of the fishery. Since 1994, the total hake harvest has declined slightly, as biomass declined from high levels, and averaged 312,000 tons from 1996 to 1999.

Status of Biological Knowledge

Pacific hake are distributed from the Gulf of Alaska to the Gulf of California. Four major stocks have been identified within this area. The most abundant and widely distributed stock (which is the subject of this report) spawns between central California and northern Baja California and is referred to as the "coastal stock." Two of these stocks are generally referred to as the "inside stocks;" they live and spawn in Puget Sound and the Strait of Georgia. A fourth major stock occurs off the west coast of southern Baja California.

The hake that spawn in Puget Sound and Strait of Georgia are considered a separate genetic stock from oceanic coastal hake. These hake spawn and live their lives entirely within Puget Sound, are small in size (14 to 18 inches total length), and lack the specific myxosporidian parasite that causes rapid postmortem flesh decomposition in coastal stocks. The differences in parasitization between inside and offshore stocks indicate the absence of interchange between populations.

The oceanic coastal stock of adult Pacific hake is migratory and inhabits the continental slope and shelf within the California Current system from Baja California to British Columbia. It is often classified as a demersal species (living on or near the sea bed), but its distribution and behavior suggests a pelagic existence. It exhibits extreme night and day movement during spring and summer feeding migrations as it feeds on a variety of pelagic fishes or zooplankton. It is commonly found at depths of 160 to 1,500 feet but has been found from the surface to 2,600 feet.

Coastal Pacific hake are pelagic spawners that appear to spawn from January to March. The location of spawning appears to center on the Southern California Bight, but spawning may take place within an area from San Francisco to Baja California at depths of 660 to 1,600 feet and as far as 300 miles offshore. Active spawners aggregate in loose, stationary bands that can be up to 150 feet thick.

Coastal stock females mature at 16 inches total length or larger, and at weights greater than 0.9 pounds. These minimum sizes are achieved by some three-year-old fish and most four-year-old fish. Fecundity estimates range from 80,000 to 500,000 eggs per female, depending on body size. The pelagic eggs drift with the ocean currents and hatch in about three days. Larval hake are abundant from December through April within 25 miles of the coast from central California to northern Baja California. Peak occurrences of eggs and small larvae pinpoint January and February as the chief spawning months. The majority of eggs and larvae are found over the areas of the continental slope where bottom depths ranged from 430 to 1,640 feet.

Hake reach about 70 to 75 percent of their maximum length and about 50 percent of their maximum weight by age 4.3 years. As hake get older, differential growth is observed between the sexes with females attaining larger lengths and weight at age than males. Average maximum sizes are 22 inches fork length (FL) and 2.25 pounds for males, and 24 inches FL and three pounds for females. The largest female hake measured off California was 34 inches FL.

In late winter, following spawning, adult hake migrate north in deep water overlying the continental slope to the summer feeding grounds off northern California, Oregon, Washington, and Vancouver Island. The peak period of northward migration appears to be in March and April. The migration behavior of hake is strongly age dependent, and influenced by oceanographic conditions. In warm years, a significant portion (up to 50 percent) of the stock may move into Canadian waters off Vancouver Island. Large adults may travel up to 1,100 miles, while newly mature hake may travel a maximum of 900 miles from southern California spawning grounds during the summer feeding period. Hake caught from Oregon to Vancouver Island range from 16 to 18 inches FL and are four to 10 years old. Young-of-the-year are usually concentrated off central and northern California, and one year old hake are found in nearshore waters from central California to northern Oregon.

Range extensions to the north occur during El Niños, as evidenced by reports of whiting from southeast Alaska during warm water years. During the warm periods experienced in 1990s, there have been changes in typical patterns of distribution. Spawning activity has been recorded north of California, and frequent reports of unusual numbers of juveniles from Oregon to British Columbia suggest that juvenile settlement patterns have also shifted northward. Because of this, juveniles may be subjected to increased predation from cannibalism and to increased vulnerability to fishing mortality.

When northward-migrating hake inhabit waters overlying the continental shelf and slope, they form schools, which may be characterized as long, narrow bands whose axis is usually oriented parallel to the depth contours. Exceptions to this generality are those schools that align perpendicular to the edge of the continental shelf and extend offshore at a uniform depth, such that they are high-off the bottom over the continental slope. School sizes may vary in length from several hundred feet to 12 miles. The widths of schools have reached 7.5 miles at times. Most schools usually have a vertical height of 20 to 70 feet.

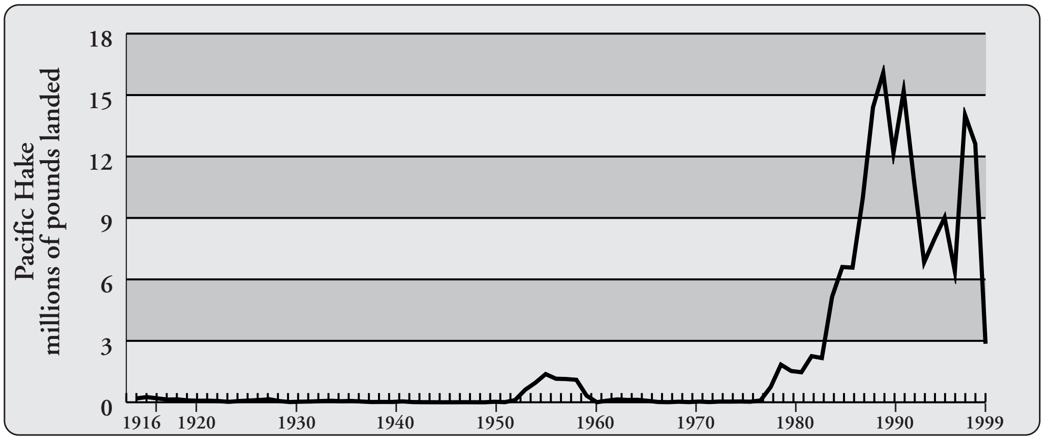
During the summer, when feeding adults are distributed over the continental shelf, schools exhibit pronounced movement into midwater associated with nighttime feeding activities. Hake feed during the evening on euphausiids, shrimp, and pelagic fishes. Vertical movement away from the sea bed occurs at nightfall and descent back towards the bottom occurs near dawn. At dawn, coastal hake descend and begin to regroup into schools near the sea bed (seven to 70 feet above the ocean floor), usually in the same area where they were the day before. The degree to which hake congregate during the day appears to be related to the type of food that was available during the feeding period. Schools are more dispersed when feeding on fish and other mobile nekton, but more compact when feeding on euphausiids.

The southward spawning migrations of the adults appears to occur in November and December, just prior to the spawning period. Availability of Pacific hake to bottom and midwater trawls off Oregon, Washington, and Vancouver Island drops sharply in November and is practically nil during winter.

Hake are a favorite prey for a great many creatures, especially marine mammals such as seals, sea lions, porpoises, and small whales. Hake have also been found

A catch of Pacific Hake is brought aboard
Credit: DFG

Commercial Landings 1916-1999, Pacific Hake
Data reflects commercial landings that occurred at California ports, but not foreign vessel catches landed outside of California. The reduction in commercial landings of Pacific Hake in 1960 is due to a change in the recording method for hake landed for animal feed.
Data Source: DFG Catch Bulletins and commercial landing receipts.



in the stomachs of swordfish, lingcod, soupfin sharks, Pacific halibut, electric rays, and an assortment of other piscivorous fishes.

Status of the Population

The coastal Pacific hake stock is at moderate abundance. Stock biomass increased to a historical high of 5.7 million tons in 1987 due to exceptionally large 1980 and 1984 year classes, then declined as these year classes passed through the population and were replaced by more moderate year classes. The stock has fluctuated throughout its history from the irregular occurrences of strong year classes, which appear about every three or four years and remain in the fishery for about five to seven years. Recruitment is highly variable and appears to be strongly influenced by oceanic environmental conditions, especially water temperature at the time of spawning.

Over the past four years, stock size has been stable at 1.7 to 1.8 million tons. The mature female biomass in 1998 is estimated to be 37 percent of an unfished stock. Although 1998 stock size is near a historical low, it is close to average stock size under current harvest policies. The exploitation rate was below 10 percent prior to 1993, then increased to 17 percent during 1994-1998. Total U.S. and Canadian catches have exceeded the ABC by an average of 12 percent since 1993 due to disagreement on the allocation between U.S. and Canadian fisheries.

The prospects for the Pacific hake resource in the immediate future are for stable to slightly declining yields, depending on the timing of the next strong year class. An assessment survey conducted by the National Marine Fisheries Service in 1998 estimated the population biomass at 1.1 million tons, a decline of 15 percent from estimates made during a previous survey in 1995.

In the 1990s, hake recruitment averaged lower but was less variable than in the 1980s. If this pattern continues, the stock will continue to decline gradually. The most recent hake assessment projected a moderate decline in catches in 2001 as the 1994 year class, the most recent strong-year class, passes out of the population and is replaced by smaller sized year classes. However, the dependence of the hake population on occasional large year classes makes these projections highly uncertain. Widespread changes in California current ecosystem contribute to that uncertainty. A coastwide U.S.-Canada acoustic survey of the hake resource is planned for summer of 2001.

Management Considerations

See the Management Considerations Appendix A for further information.

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Commercial Landings - Groundfish and Flatfish

Year	Bank [5] Rockfish Pounds	Blackgill [2; 5] Rockfish Pounds	Bocaccio/ Chilipepper [3] Rockfish Pounds	Bocaccio [4; 5] Rockfish Pounds	Chilipepper [5] Rockfish Pounds	Shortbelly [5] Rockfish Pounds	Widow [5; 6] Rockfish Pounds	Yellowtail [5] Rockfish Pounds	Unspecified Rockfish Pounds
1916	----	----	----	----	----	----	----	----	4,918,952
1917	----	----	----	----	----	----	----	----	7,774,026
1918	----	----	----	----	----	----	----	----	8,242,754
1919	----	----	----	----	----	----	----	----	5,398,109
1920	----	----	----	----	----	----	----	----	5,633,077
1921	----	----	----	----	----	----	----	----	4,761,658
1922	----	----	----	----	----	----	----	----	4,312,014
1923	----	----	----	----	----	----	----	----	5,096,622
1924	----	----	----	----	----	----	----	----	4,742,885
1925	----	----	----	----	----	----	----	----	5,488,621
1926	----	----	----	----	----	----	----	----	7,540,969
1927	----	----	----	----	----	----	----	----	6,390,604
1928	----	----	----	----	----	----	----	----	6,419,909
1929	----	----	----	----	----	----	----	----	6,036,409
1930	----	----	----	----	----	----	----	----	7,225,424
1931	----	----	----	----	----	----	----	----	7,277,688
1932	----	----	----	----	----	----	----	----	5,636,319
1933	----	----	----	----	----	----	----	----	4,787,744
1934	----	----	----	----	----	----	----	----	4,603,536
1935	----	----	----	----	----	----	----	----	4,831,174
1936	----	----	----	----	----	----	----	----	4,603,904
1937	----	----	----	----	----	----	----	----	4,291,214
1938	----	----	----	----	----	----	----	----	3,637,137
1939	----	----	----	----	----	----	----	----	3,333,126
1940	----	----	----	----	----	----	----	----	3,570,636
1941	----	----	----	----	----	----	----	----	3,405,622
1942	----	----	----	----	----	----	----	----	1,423,440
1943	----	----	----	----	----	----	----	----	2,762,192
1944	----	----	----	----	----	----	----	----	6,422,230
1945	----	----	----	----	----	----	----	----	13,286,076
1946	----	----	----	----	----	----	----	----	11,161,222
1947	----	----	----	----	----	----	----	----	8,498,584
1948	----	----	----	----	----	----	----	----	6,507,205
1949	----	----	----	----	----	----	----	----	5,962,267
1950	----	----	----	----	----	----	----	----	8,115,102
1951	----	----	----	----	----	----	----	----	10,993,502
1952	----	----	----	----	----	----	----	----	10,727,521
1953	----	----	----	----	----	----	----	----	12,228,663
1954	----	----	----	----	----	----	----	----	12,640,729
1955	----	----	----	----	----	----	----	----	12,681,697
1956	----	----	----	----	----	----	----	----	14,943,515
1957	----	----	----	----	----	----	----	----	16,091,279
1958	----	----	----	----	----	----	----	----	17,842,163
1959	----	----	----	----	----	----	----	----	15,281,282
1960	----	----	----	----	----	----	----	----	13,713,886
1961	----	----	----	----	----	----	----	----	10,830,762
1962	----	----	----	----	----	----	----	----	9,834,393
1963	----	----	----	----	----	----	----	----	11,749,460
1964	----	----	----	----	----	----	----	----	8,117,912
1965	----	----	----	----	----	----	----	----	9,392,424
1966	----	----	----	----	----	----	----	----	10,063,592
1967	----	----	----	----	----	----	----	----	9,798,951
1968	----	----	----	----	----	----	----	----	9,444,493
1969	----	----	----	----	----	----	----	----	9,227,451
1970	----	----	----	----	----	----	----	----	10,686,844
1971	----	----	----	----	----	----	----	----	11,168,746
1972	----	----	----	----	----	----	----	----	16,421,252
1973	----	----	----	----	----	----	----	----	22,052,455
1974	----	----	----	----	----	----	----	----	21,498,984
1975	----	----	----	----	----	----	----	----	23,624,150
1976	----	----	----	----	----	----	----	----	24,603,179
1977	----	----	----	----	----	----	----	----	20,900,305
1978	832,144	232,341	----	6,611,589	2,613,559	7,195	1,167,141	805,076	20,510,364
1979	121,041	11,798	8,935,837	3,766,632	2,701,208	10,000	4,833,977	656,505	19,632,482

Commercial Landings - Groundfish and Flatfish, cont'd

Year	Bank [5] Rockfish Pounds	Blackgill [2; 5] Rockfish Pounds	Bocaccio/ Chilipepper [3] Rockfish Pounds	Bocaccio [4; 5] Rockfish Pounds	Chilipepper [5] Rockfish Pounds	Shortbelly [5] Rockfish Pounds	Widow [5; 6] Rockfish Pounds	Yellowtail [5] Rockfish Pounds	Unspecified Rockfish Pounds
1980	158,725	976,735	10,115,735	9,111,594	6,248,294	6,567	11,780,969	595,152	25,692,416
1981	2,202,588	2,104,908	7,831,367	9,816,582	5,087,316	609	11,071,879	862,289	27,295,022
1982	2,210,769	2,924,400	10,604,864	11,774,442	4,131,231	14,416	23,856,732	1,632,561	19,827,921
1983	2,613,466	2,023,211	9,841,652	11,118,007	4,639,861	7,654	8,781,700	1,956,643	19,599,497
1984	4,046,635	1,187,141	7,196,636	8,296,616	5,489,532	5,092	6,565,481	1,931,196	18,181,423
1985	2,760,142	1,420,096	6,299,317	4,799,757	5,669,493	62,749	7,101,038	1,381,153	14,383,905
1986	3,940,317	1,973,521	6,766,491	4,630,024	4,829,518	42,601	5,499,235	1,335,237	13,815,096
1987	2,922,307	1,736,977	5,029,313	5,420,165	3,759,112	1,811	5,655,481	834,014	15,816,720
1988	2,361,829	2,336,632	4,023,966	4,143,162	4,608,400	567	4,051,348	490,820	13,090,228
1989	1,585,979	1,133,985	4,110,006	5,166,105	6,437,291	4,215	4,828,775	1,978,450	15,358,303
1990	1,598,223	1,358,878	3,853,439	4,415,613	5,678,528	13,873	4,929,551	1,985,856	16,036,264
1991	1,595,339	827,030	4,122,938	2,997,035	6,502,562	7,427	2,928,155	1,412,624	11,326,256
1992	1,165,990	1,785,896	- - - -	3,237,769	5,626,573	1,568	2,525,230	1,604,573	8,613,030
1993	758,709	883,202	- - - -	3,031,592	5,135,472	5,299	2,655,014	645,218	7,177,482
1994	728,970	855,640	- - - -	2,168,035	4,043,163	10,619	2,031,959	723,745	4,329,766
1995	957,140	772,323	- - - -	1,604,367	4,406,698	25,169	3,853,755	684,933	4,329,467
1996	1,245,261	815,583	- - - -	1,050,403	3,951,518	70,953	3,023,829	596,949	3,851,420
1997	937,738	595,059	- - - -	707,066	4,468,794	134,178	2,959,535	925,866	3,859,850
1998	1,231,818	503,921	- - - -	339,060	3,115,112	39,962	2,018,093	969,512	3,019,099
1999	72,213	120,773	- - - -	160,987	2,082,043	17,683	1,390,413	210,986	639,655

- - - - Landing data not available.

1 Except where noted, rockfish commercial landings are presented as market category landings for all fishing modes rather than as individual species landings.

2 Aggregated by DFG as rockfish prior to 1986.

3 Aggregated by DFG as rockfish prior to 1979.

4 Aggregated as by DFG as Bocaccio/Chilipeper prior to 1992.

5 Data derived from CalCom Database utilizing DFG commercial landing receipts. Expansions, based on port samples, are conducted by CalCom with input from PacFin, NMFS, and DFG.

6 Aggregated by DFG as as rockfish prior to 1981.

7 Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important.

8 The reduction in commercial landings of Pacific hake in 1960 is due to a change in the recording method for hake landed for animal feed.

9 Aggregated as as rockfish prior to 1982.

10 Aggregated as as rockfish prior to 1983.

11 Aggregated as as rockfish prior to 1994.

Commercial Landings - Groundfish and Flatfish, cont'd

Year	Sole[6] Dover Sole Pounds	English Sole Pounds	Petrale Sole Pounds	Rex Sole Pounds
1916	- - - -	- - - -	- - - -	- - - -
1917	- - - -	- - - -	- - - -	- - - -
1918	- - - -	- - - -	- - - -	- - - -
1919	- - - -	- - - -	- - - -	- - - -
1920	- - - -	- - - -	- - - -	- - - -
1921	- - - -	- - - -	- - - -	- - - -
1922	- - - -	- - - -	- - - -	- - - -
1923	- - - -	- - - -	- - - -	- - - -
1924	- - - -	- - - -	- - - -	- - - -
1925	- - - -	- - - -	- - - -	- - - -
1926	- - - -	- - - -	- - - -	- - - -
1927	- - - -	- - - -	- - - -	- - - -
1928	- - - -	- - - -	- - - -	- - - -
1929	- - - -	- - - -	- - - -	- - - -
1930	- - - -	- - - -	- - - -	- - - -
1931	- - - -	- - - -	1,375,535	831,240
1932	- - - -	- - - -	1,227,223	555,558
1933	- - - -	- - - -	953,424	559,743
1934	- - - -	5,280,154	2,456,989	715,498
1935	- - - -	6,035,966	1,988,325	631,432
1936	- - - -	6,286,867	1,126,527	515,648
1937	- - - -	5,750,060	1,802,721	451,497
1938	- - - -	4,953,934	2,026,166	515,254
1939	- - - -	6,270,424	2,558,461	667,496
1940	- - - -	5,056,535	1,575,489	593,359
1941	- - - -	3,278,638	893,426	371,130
1942	- - - -	2,020,562	611,580	387,545
1943	- - - -	3,092,170	918,925	495,672
1944	- - - -	3,066,865	1,123,986	413,286
1945	- - - -	5,857,240	1,232,801	442,179
1946	- - - -	7,176,727	2,666,285	570,418
1947	- - - -	8,379,502	2,947,177	842,968
1948	7,234,438	8,171,645	5,089,684	893,248
1949	7,890,073	5,713,258	4,952,156	982,307
1950	9,548,379	8,080,693	4,366,598	1,068,456
1951	8,621,238	5,631,659	2,726,304	1,013,890
1952	11,748,215	4,911,468	2,893,619	1,185,451
1953	8,904,367	4,099,106	3,350,163	1,020,877
1954	9,930,438	3,748,245	4,171,901	1,183,538
1955	8,185,501	4,134,779	3,619,530	1,094,437
1956	8,268,424	3,826,297	2,830,158	1,147,523
1957	7,932,137	4,819,872	3,456,819	1,234,494
1958	8,053,040	5,150,234	3,157,678	1,422,891
1959	7,327,420	4,617,491	2,632,451	1,443,005
1960	9,184,814	2,375,383	2,475,661	1,107,372
1961	7,826,617	3,645,918	3,390,739	1,208,829
1962	8,581,091	4,206,048	3,041,164	1,408,245
1963	9,781,732	4,254,545	3,317,948	1,565,672
1964	9,265,238	4,592,752	2,697,670	1,410,647
1965	10,759,963	4,892,391	2,662,257	1,490,475
1966	10,311,633	4,844,868	2,927,190	1,635,399
1967	7,215,037	5,821,909	2,768,537	1,766,038
1968	8,535,521	5,811,438	2,946,605	1,930,583
1969	12,918,982	3,804,047	2,867,064	2,259,165
1970	15,160,886	3,282,316	3,415,708	1,741,479
1971	14,248,719	2,964,015	3,704,384	1,467,875
1972	22,081,697	3,001,965	3,575,245	1,661,610
1973	22,485,725	3,209,733	2,876,989	1,584,734
1974	19,087,485	3,813,499	3,430,685	1,381,737
1975	22,688,520	4,314,262	3,269,998	1,646,421
1976	22,756,812	4,282,998	2,977,557	2,012,820
1977	21,923,851	3,403,057	2,200,713	1,548,006
1978	20,770,086	3,974,782	2,634,044	1,537,347
1979	23,394,091	5,006,960	3,061,810	1,914,805
1980	18,046,924	4,573,524	2,350,525	1,899,609
1981	20,418,283	3,773,262	1,775,054	1,727,754
1982	22,089,490	3,221,471	1,741,721	1,466,411
1983	18,913,890	2,607,636	1,287,287	1,410,762
1984	21,563,452	2,098,964	1,301,912	1,252,976
1985	26,499,393	2,341,942	1,888,394	1,979,244
1986	24,365,419	2,385,989	1,600,400	1,856,179
1987	23,723,648	2,914,768	1,815,856	1,818,777
1988	18,071,140	2,351,350	1,752,940	1,854,324
1989	17,027,320	2,321,586	1,853,165	1,651,684
1990	13,933,132	1,967,050	1,495,680	1,226,691
1991	17,021,228	1,789,777	1,619,211	1,369,558
1992	19,054,146	1,268,119	1,172,949	970,859
1993	14,426,111	1,044,544	1,021,859	1,007,925
1994	9,888,498	1,019,307	1,211,845	1,256,861
1995	13,417,995	1,101,103	1,305,154	1,517,177
1996	14,107,539	1,281,212	1,803,549	1,097,983
1997	11,693,676	1,430,131	1,830,750	1,000,369
1998	7,874,411	941,187	1,042,029	637,697
1999	8,417,498	849,836	1,249,628	629,453

- - - - Landing data not available.

1 Except where noted, rockfish commercial landings are presented as market category landings for all fishing modes rather than as individual species landings.
2 Aggregated by DFG as rockfish prior to 1986.
3 Aggregated by DFG as rockfish prior to 1979.
4 Aggregated as by DFG as Bocaccio/Chilipeper prior to 1992.
5 Data derived from CalCom Database utilizing DFG commercial landing receipts. Expansions, based on port samples, are conducted by CalCom with input from PacFin, NMFS, and DFG.
6 Aggregated by DFG as as rockfish prior to 1981.
7 Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important.
9 Aggregated as as rockfish prior to 1982.10 Aggregated as as rockfish prior to 1983.
10 Aggregated as as rockfish prior to 1994.

Commercial Landings - Groundfish and Flatfish, cont'd

Year	Cowcod[5] Pounds	Pacific Hake[7] Pounds	Sablefish Pounds	All Thornyhead[5] Pounds	Longspine Thornyhead[5] Pounds	Shortspine Thornyhead[5] Pounds	Unspecified Thornyhead[5] Pounds
1916	----	189,219	83,623	----	----	----	----
1917	----	254,331	909,846	----	----	----	----
1918	----	193,018	498,937	----	----	----	----
1919	----	133,181	334,950	----	----	----	----
1920	----	141,981	781,032	----	----	----	----
1921	----	90,218	1,022,642	----	----	----	----
1922	----	74,516	268,554	----	----	----	----
1923	----	78,969	538,292	----	----	----	----
1924	----	60,780	933,310	----	----	----	----
1925	----	22,017	722,472	----	----	----	----
1926	----	58,335	175,642	----	----	----	----
1927	----	84,553	992,654	----	----	----	----
1928	----	108,648	916,955	----	----	----	----
1929	----	145,669	1,439,408	----	----	----	----
1930	----	56,088	1,359,147	----	----	----	----
1931	----	12,501	1,021,215	----	----	----	----
1932	----	29,001	975,373	----	----	----	----
1933	----	37,539	1,332,573	----	----	----	----
1934	----	56,901	2,117,048	----	----	----	----
1935	----	73,843	2,848,672	----	----	----	----
1936	----	50,791	1,035,530	----	----	----	----
1937	----	63,454	733,499	----	----	----	----
1938	----	36,428	415,836	----	----	----	----
1939	----	13,661	767,044	----	----	----	----
1940	----	18,049	573,785	----	----	----	----
1941	----	15,044	536,540	----	----	----	----
1942	----	41,981	1,972,522	----	----	----	----
1943	----	10,505	3,205,374	----	----	----	----
1944	----	4,751	4,116,451	----	----	----	----
1945	----	2,415	6,264,397	----	----	----	----
1946	----	550	2,656,873	----	----	----	----
1947	----	876	902,110	----	----	----	----
1948	----	4,600	2,068,439	----	----	----	----
1949	----	1,535	1,743,372	----	----	----	----
1950	----	500	1,584,301	----	----	----	----
1951	----	24,972	2,585,513	----	----	----	----
1952	----	6,145	1,343,867	----	----	----	----
1953	----	103,926	1,655,653	----	----	----	----
1954	----	611,522	2,357,531	----	----	----	----
1955	----	956,545	2,065,737	----	----	----	----
1956	----	1,376,217	2,868,407	----	----	----	----
1957	----	1,150,006	2,199,782	----	----	----	----
1958	----	1,135,138	1,732,992	----	----	----	----
1959	----	1,097,069	1,938,356	----	----	----	----
1960	----	325,088	2,419,024	----	----	----	----
1961	----	3,275	1,616,528	----	----	----	----
1962	----	78,530	2,015,237	----	----	----	----
1963	----	139,699	1,809,349	----	----	----	----
1964	----	111,529	2,463,452	----	----	----	----
1965	----	119,255	2,863,550	----	----	----	----
1966	----	69,002	3,215,939	----	----	----	----
1967	----	14,430	3,798,493	----	----	----	----
1968	----	6,494	3,219,455	----	----	----	----
1969	----	27,047	4,156,846	----	----	----	----
1970	----	9,775	4,428,077	----	----	----	----
1971	----	34,685	4,424,463	----	----	----	----
1972	----	10,525	8,395,714	----	----	----	----
1973	----	34,175	8,550,071	----	----	----	----
1974	----	32,210	12,038,542	----	----	----	----
1975	----	38,508	14,131,964	----	----	----	----
1976	----	28,521	13,331,261	----	----	----	----
1977	----	86,813	13,315,975		----	----	----
1978	24,653	747,709	17,715,724	2,668,993	432,833	2,229,418	6,742
1979	----	1,836,264	28,573,600	4,095,918	310,877	3,755,624	29,417

Commercial Landings - Groundfish and Flatfish, cont'd

Year	Cowcod[5] Pounds	Pacific Hake[7] Pounds	Sablefish Pounds	All Thornyhead[5] Pounds	Longspine Thornyhead[5] Pounds	Shortspine Thornyhead[5] Pounds	Unspecified Thornyhead[5] Pounds
1980	32,435	1,527,992	10,284,930	3,411,449	699,083	2,339,704	372,662
1981	190,424	1,467,276	14,727,481	3,805,719	238,829	3,542,348	24,542
1982	141,863	2,251,253	20,996,253	4,506,242	842,307	3,651,959	11,976
1983	166,142	2,160,904	14,613,392	3,596,221	436,599	3,124,112	35,510
1984	352,869	5,147,912	10,633,321	4,695,974	589,932	4,089,042	17,000
1985	294,987	6,604,729	11,305,795	6,485,049	1,140,992	5,315,642	28,415
1986	339,676	6,574,845	13,585,936	6,501,347	1,306,111	5,138,999	56,237
1987	198,967	9,959,960	9,585,601	6,438,777	1,790,910	2,872,981	1,774,886
1988	209,633	14,401,883	8,360,454	10,008,902	5,587,483	4,310,853	110,566
1989	96,880	16,088,904	8,715,410	11,906,498	4,911,249	6,905,965	89,284
1990	74,945	12,166,681	8,042,899	11,898,501	7,600,557	4,243,813	54,131
1991	48,244	15,196,946	7,300,661	6,329,277	4,085,076	2,192,086	52,115
1992	153,820	10,868,278	8,078,145	9,654,483	6,344,552	3,228,425	81,506
1993	110,041	6,834,597	5,676,270	9,182,924	5,637,099	3,471,866	73,959
1994	76,102	7,964,783	4,784,967	7,289,241	4,503,103	2,629,627	156,511
1995	145,648	9,018,285	6,185,954	8,016,679	5,681,269	2,122,323	213,087
1996	105,483	6,395,184	6,998,149	7,309,101	5,353,926	1,713,345	241,830
1997	117,747	14,028,191	6,481,886	6,194,508	4,415,693	1,531,749	247,066
1998	34,188	12,617,919	3,155,536	4,173,425	2,667,011	1,399,066	107,348
1999	27,157	2,883,014	4,342,086	3,296,044	2,255,859	952,219	87,966

- - - - Landing data not available.

1 Except where noted, rockfish commercial landings are presented as market category landings for all fishing modes rather than as individual species landings.

2 Aggregated by DFG as rockfish prior to 1986.

3 Aggregated by DFG as rockfish prior to 1979.

4 Aggregated as by DFG as Bocaccio/Chilipeper prior to 1992.

5 Data derived from CalCom Database utilizing DFG commercial landing receipts. Expansions, based on port samples, are conducted by CalCom with input from PacFin, NMFS, and DFG.

6 Aggregated by DFG as as rockfish prior to 1981.

7 Prior to 1931, all soles were combined as one group; individual species were tabulated separately when they became sufficiently important.

8 The reduction in commercial landings of Pacific hake in 1960 is due to a change in the recording method for hake landed for animal feed.

9 Aggregated as as rockfish prior to 1982.

10 Aggregated as as rockfish prior to 1983.

11 Aggregated as as rockfish prior to 1994.

Commercial Landings - Groundfish and Flatfish, cont'd

Year	Rockfish[1] Group Bolina[3] Pounds	Group Deep[9] Pounds	Group Gopher[10] Pounds	Group Red[3] Pounds	Group Rosefish[9] Pounds	Group Small[3] Pounds	Group Black/Blue[11] Pounds	Group Canary/ Vermilion[11] Pounds
1916	----	----	----	----	----	----	----	----
1917	----	----	----	----	----	----	----	----
1918	----	----	----	----	----	----	----	----
1919	----	----	----	----	----	----	----	----
1920	----	----	----	----	----	----	----	----
1921	----	----	----	----	----	----	----	----
1922	----	----	----	----	----	----	----	----
1923	----	----	----	----	----	----	----	----
1924	----	----	----	----	----	----	----	----
1925	----	----	----	----	----	----	----	----
1926	----	----	----	----	----	----	----	----
1927	----	----	----	----	----	----	----	----
1928	----	----	----	----	----	----	----	----
1929	----	----	----	----	----	----	----	----
1930	----	----	----	----	----	----	----	----
1931	----	----	----	----	----	----	----	----
1932	----	----	----	----	----	----	----	----
1933	----	----	----	----	----	----	----	----
1934	----	----	----	----	----	----	----	----
1935	----	----	----	----	----	----	----	----
1936	----	----	----	----	----	----	----	----
1937	----	----	----	----	----	----	----	----
1938	----	----	----	----	----	----	----	----
1939	----	----	----	----	----	----	----	----
1940	----	----	----	----	----	----	----	----
1941	----	----	----	----	----	----	----	----
1942	----	----	----	----	----	----	----	----
1943	----	----	----	----	----	----	----	----
1944	----	----	----	----	----	----	----	----
1945	----	----	----	----	----	----	----	----
1946	----	----	----	----	----	----	----	----
1947	----	----	----	----	----	----	----	----
1948	----	----	----	----	----	----	----	----
1949	----	----	----	----	----	----	----	----
1950	----	----	----	----	----	----	----	----
1951	----	----	----	----	----	----	----	----
1952	----	----	----	----	----	----	----	----
1953	----	----	----	----	----	----	----	----
1954	----	----	----	----	----	----	----	----
1955	----	----	----	----	----	----	----	----
1956	----	----	----	----	----	----	----	----
1957	----	----	----	----	----	----	----	----
1958	----	----	----	----	----	----	----	----
1959	----	----	----	----	----	----	----	----
1960	----	----	----	----	----	----	----	----
1961	----	----	----	----	----	----	----	----
1962	----	----	----	----	----	----	----	----
1963	----	----	----	----	----	----	----	----
1964	----	----	----	----	----	----	----	----
1965	----	----	----	----	----	----	----	----
1966	----	----	----	----	----	----	----	----
1967	----	----	----	----	----	----	----	----
1968	----	----	----	----	----	----	----	----
1969	----	----	----	----	----	----	----	----
1970	----	----	----	----	----	----	----	----
1971	----	----	----	----	----	----	----	----
1972	----	----	----	----	----	----	----	----
1973	----	----	----	----	----	----	----	----
1974	----	----	----	----	----	----	----	----
1975	----	----	----	----	----	----	----	----
1976	----	----	----	----	----	----	----	----
1977	----	----	----	----	----	----	----	----
1978	----	----	----	----	----	----	----	----
1979	----	----	----	----	----	----	----	----

Commercial Landings - Groundfish and Flatfish, cont'd

Year	Rockfish[1] Group Bolina[3] Pounds	Group Deep[9] Pounds	Group Gopher[10] Pounds	Group Red[3] Pounds	Group Rosefish[9] Pounds	Group Small[3] Pounds	Group Black/Blue[11] Pounds	Group Canary/ Vermilion[11] Pounds
1980	39,213	- - - -	- - - -	263,829	- - - -	35,608	- - - -	- - - -
1981	- - - -	- - - -	- - - -	208	- - - -	- - - -	- - - -	- - - -
1982	58,421	36,025	- - - -	250,750	361,583	3,487	- - - -	- - - -
1983	94,343	50	53	2,203,793	1,077,155	86,560	- - - -	- - - -
1984	84,585	405	26,103	3,834,957	1,343,759	356,287	- - - -	- - - -
1985	84,095	40,430	43,811	243,999	1,593,975	549,829	- - - -	- - - -
1986	95,834	681	72,714	2,090,707	1,359,133	560,443	- - - -	- - - -
1987	96,714	1,876	95,702	1,670,231	1,143,584	620,535	- - - -	- - - -
1988	163,983	- - - -	156,017	2,045,468	911,889	1,016,713	- - - -	- - - -
1989	168,133	- - - -	158,110	2,623,254	803,828	687,511	- - - -	- - - -
1990	135,187	578	147,435	2,804,469	1,028,221	1,030,960	- - - -	- - - -
1991	203,945	257	183,231	2,326,611	910,364	808,536	- - - -	- - - -
1992	162,071	1,063	172,256	168,459	854,455	497,502	- - - -	- - - -
1993	102,927	500	170,079	1,274,651	756,903	774,437	- - - -	- - - -
1994	73,732	2,368	147,069	1,354,763	549,425	1,099,405	10,309	147
1995	56,230	36,572	167,911	1,044,059	650,930	924,333	384	227
1996	97,338	6,138	221,345	1,225,811	594,180	1,210,981	2,226	33
1997	126,021	4,332	141,643	850,384	773,483	1,487,399	8,192	58
1998	125,799	379	135,196	710,134	2,761,055	1,236,840	2,695	- - - -
1999	108,878	- - - -	28,375	242,840	409,839	288,096	487	164

- - - - Landing data not available.

1 Except where noted, rockfish commercial landings are presented as market category landings for all fishing modes rather than as individual species landings.
2 Aggregated by DFG as rockfish prior to 1986.
3 Aggregated by DFG as rockfish prior to 1979.
4 Aggregated as by DFG as Bocaccio/Chilipeper prior to 1992.
5 Data derived from CalCom Database utilizing DFG commercial landing receipts. Expansions, based on port samples, are conducted by CalCom with input from PacFin, NMFS, and DFG.
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8 The reduction in commercial landings of Pacific hake in 1960 is due to a change in the recording method for hake landed for animal feed.
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10 Aggregated as as rockfish prior to 1983.
11 Aggregated as as rockfish prior to 1994.

Salmonids: Overview

California's salmonid populations were a vital component of American Indian society long before European settlers arrived, and they still play a significant role in today's coastal communities. Salmon provide a living for commercial fishermen, generate recreational marine and freshwater angling opportunities, support tourism within our coastal and riverside communities, fulfill Native American cultural and economic needs, and are important elements of California's highly diverse marine and freshwater ecosystems.

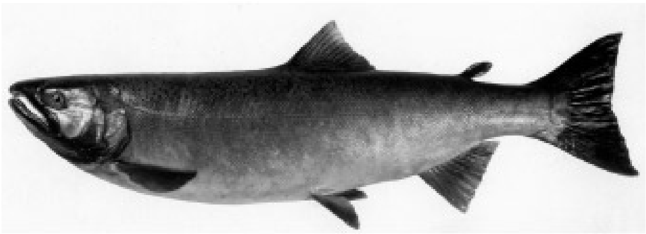
There are seven salmonid species in California. The California fisheries primarily harvest chinook or king salmon *(Oncorhynchus tshawytscha),* which is the salmonid most often encountered by fishermen. Coho or silver salmon (*Oncorhynchus kisutch*) are observed in small numbers but are presently under a no-retention catch policy. Occasionally in odd-numbered years, pink salmon *(Oncorhynchus gorbuscha*) are landed. No fisheries exist for sockeye salmon (*Oncorhynchus nerka*) and chum salmon (*Oncorhynchus keta*) due to their limited numbers in California waters. Steelhead *(Oncorhynchus mykiss)* are caught recreationally in streams and rivers from the Central Valley basin north to the California/Oregon border. Small numbers of cutthroat trout (*Oncorhynchus clarkii*) are found in northern coastal streams, lagoons, and estuaries.

Several government agencies are involved in the management of California salmon. The Pacific Fishery Management Council (PFMC) manages sport and commercial fisheries in the Exclusive Economic Zone (three to 200 miles offshore), the California Fish and Game Commission (FGC) manages inland sport and ocean sport fisheries in state waters (to 3 miles offshore), and the California Department Fish and Game (DFG) manages commercial fisheries in state waters via a delegation from the California Legislature. California continues to have productive commercial and recreational fisheries due to the various conservation measures enacted by the PFMC, FGC, and National Marine Fisheries Service (NMFS). These measures allow for reduced harvest levels on Central Valley and Klamath River fall chinook stocks, while safeguarding the recovery of endangered or threatened chinook and coho populations.

While Central Valley and Klamath River fall chinook stocks continue to be healthy, three salmonid species and ten distinct populations, or Evolutionary Significant Units (ESU), are listed under the federal Endangered Species Act (ESA): Sacramento River winter chinook (endangered), Central Valley spring chinook (threatened), California coastal chinook (threatened), central California coastal coho (threatened), southern Oregon/northern California coho (threatened), southern California steelhead (endangered), northern California steelhead (threatened), and Central Valley, central California, and south-central California steelhead (threatened). In addition, three ESUs are also listed under the California Endangered Species Act (CESA): Sacramento River winter chinook (endangered), Central Valley spring chinook (threatened), and central California coastal coho (endangered).

California's main salmon conservation management objectives are as follows:

- Klamath River fall chinook: a minimum adult natural escapement rate of 33-34 percent, with a minimum spawner escapement of 35,000 adults in natural areas is required.
- Sacramento River fall chinook: an escapement goal of 122,000 to 180,000 hatchery and natural adult fish
- Sacramento River winter chinook: the ESA jeopardy standard is a 31 percent increase in the adult spawner replacement rate relative to the observed mean rate for 1989 to 1993.
- Central Valley spring chinook: the Central Valley spring chinook population is under an NMFS finding of "no jeopardy," and it also benefits from Sacramento River winter chinook conservation measures.
- Coastal California chinook: the ESA jeopardy standard limits the ocean harvest rate for age-four Klamath River fall chinook to 17 percent.
- California coastal coho: the ESA objective requires no retention of coho in any California fishery and limits marine fishery impacts to no more than 13 percent, as measured by projected impacts on Rogue/Klamath hatchery coho.
- Steelhead: fishing regulations were revamped to enact time and area closures, catch and release fishing, or retention of hatchery steelhead only (marked with an adipose fin clip).



Coho Salmon, *Oncorhynchus kisutch*
Credit: DFG

The annual economic value of California's commercial salmon fishery from 1996 to 2000 ranged from 7.7 to 20.9 million dollars to the state's economy, as assessed by the PFMC'S Fishery Economic Assessment Model. The PFMC's economic estimate for California's recreational ocean salmon fishery ranged from 13.9 to 22.5 million dollars for the same period. A 1985 economic analysis estimated that steelhead fishing in the Sacramento River and tributaries directly generated around 7.2 million dollars. Using the above estimates, all salmon fisheries generate approximately 28.8 to 50.6 million dollars annually to the California economy. The indirect economic benefits are difficult to separate and quantify, but it is clear that California's salmonid stocks are a significant revenue source for the state.

As the population of California continues to increase, our relationships with our natural resources also change. Traditional approaches for identifying and solving environmental issues, while still important, must evolve to be effective with today's complex problems. California's salmon fisheries have been increasingly regulated to rebuild threatened or endangered populations, to equitably allocate available fish among stakeholders, and to achieve natural and hatchery spawning escapement goals. Freshwater habitat restoration and revised water management policies are necessary to return natural salmon production to former levels. A collaborative combination of marine and freshwater measures is needed to ensure that salmonid populations will thrive and provide fishing opportunities, economic benefits, and ecological value for all Californians, now and in the future.

Scott Barrow and **Marc Heisdorf**
California Department of Fish and Game

Pacific Salmon

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

History of the Fishery

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

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

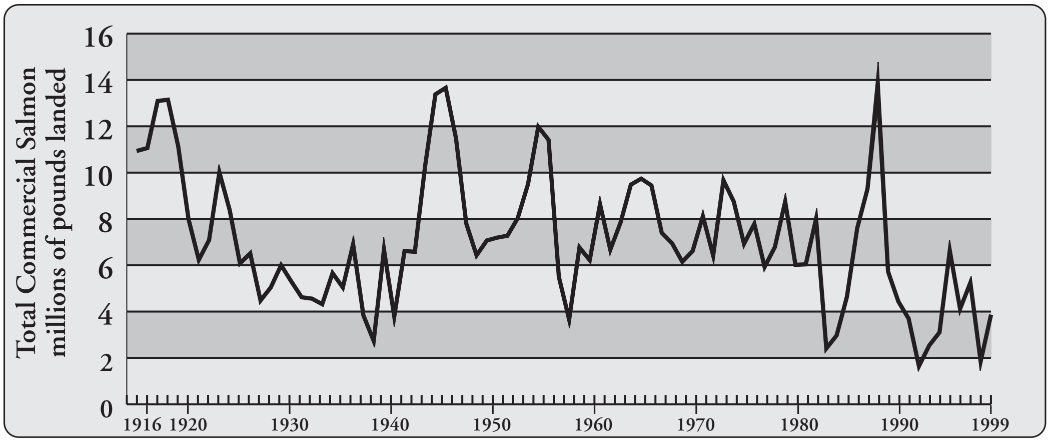
Commercial salmon fishing in California began in the early 1850s, coincidental with the massive inflow of miners into the gold country. By 1860, these gillnet salmon fisheries were well established in Suisun Bay, San Pablo Bay, and the lower Sacramento and San Joaquin Rivers. The fishery gradually spread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

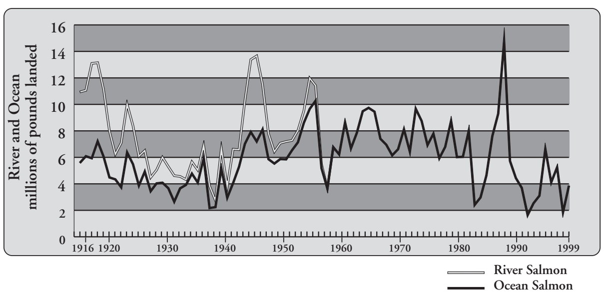
The commercial ocean troll fishery began in Monterey Bay during the 1880s. These early fishers trolled for salmon using small sailboats that supported two hand rods, one over each side with one hook and leader attached to each line. The leader was approximately 30 feet long and carried a lead sinker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

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

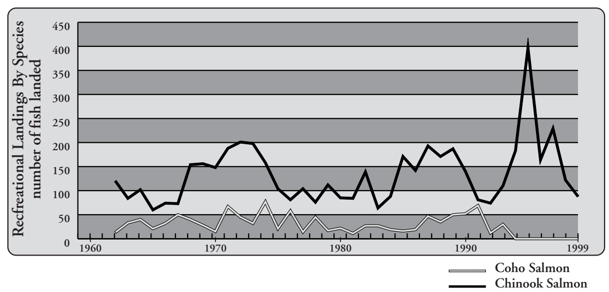
Chinook Salmon, *Oncorhynchus tshawytscha*
Credit: DFG

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

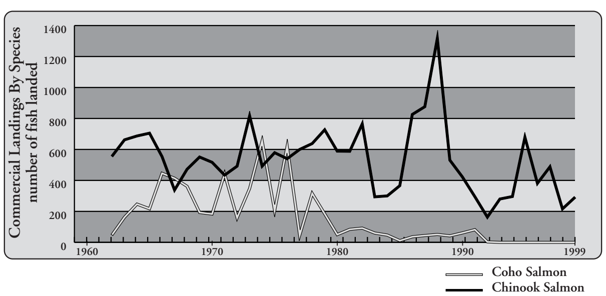




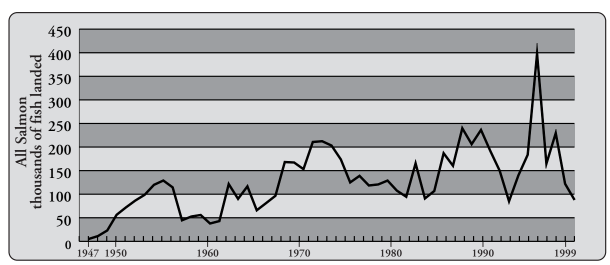
Commercial Catch 1947-1999 , River and Ocean
Data Source: DFG Catch Bulletins and commercial landing receipts. Catch Data includes salmon taken in the ocean, and coastal rivers including the Sacramento and Klamath. The Klamath River commercial fishery closed after 1933; and the Sacramento commercial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



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



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



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

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

Today's salmon troller still uses the basic fishing techniques developed during the 1940s, including powered gurdies and four to six main trolling lines. Now, however, the vessels are also equipped with various electronic devices that greatly aid in finding and staying on the fish. Radio communications are possible among several vessels simultaneously over large distances. Highly sensitive sonar equipment aids the troller in finding the salmon or baitfish schools and in pinpointing the depth at which to position lures. Precise vessel positioning is made possible through the use of global positioning systems. It is easy today to replicate a troll path or "tack" within a few feet of a previous or suggested path. Collectively, these instruments have probably more than doubled the efficiency of the modern troller compared to 70 years ago.

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

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

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

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

Salmon Management History

In 1948, the Pacific Marine Fisheries Commission (PMFC) was formed by the states of Alaska, Washington, Oregon, Idaho and California. A primary objective of the compact was to make better use of the marine resources shared by the member states. Prior to that time, there was minimal coordination of marine fishing regulations between the states. For example, in 1947 California had a 25-inch minimum size limit and an April 1 to September 15 season for both chinook and coho. Washington and Oregon both had a 27-inch limit and year-round season for chinook and a July 1 to November 15 season for coho. Washington had an 18-inch limit for coho, while Oregon had no size limit for the species. The first commercial salmon recommendation of the PMFC was a 26-inch total length minimum size and March 15 to October 31 maximum season length for chinook. For coho the recommended season was June 15 to October 31 except that California could open May 1 provided it retained its 25-inch minimum size limit for the species. For many years the states uniformly adopted the 26-inch standard and an April 15 opening date for commercial chinook fishing with a general September 30 closing date. The coho season opening was June 15 in both Oregon and Washington with no, or a very low, minimum size limit. California retained its 25-inch coho standard until about 1970 when it was dropped to 22 inches and the season opening date delayed until May 15.

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

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

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

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

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

Status of Biological Knowledge

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

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

Chinook salmon

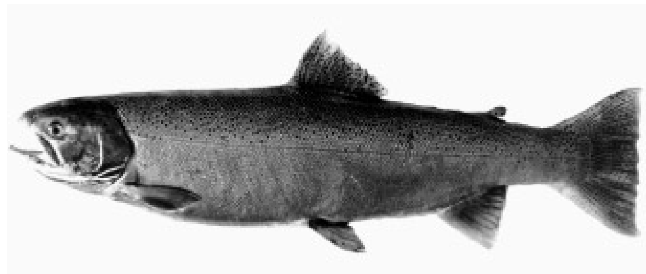
Chinook are the largest of the salmon species. Historically, juvenile chinook have been reported in coastal streams as far south as the Ventura River in southern California. Currently, they spawn in suitable rivers from the Sacramento-San Joaquin system northward. Spawning migrations can require minimal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

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

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

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

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



Steelhead, *Oncorhynchus mykiss*
Credit: DFG

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

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

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

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

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

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

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

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

Coho salmon

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

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

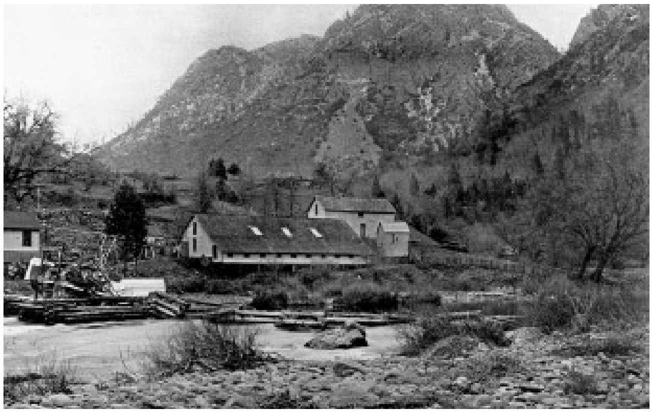
Within California river systems, coho salmon populations include only one race, or run, which is generally consistent as to spawning area used and time of spawning. Most spawning occurs between December and February. The juveniles usually spend a little more than a year in fresh water before migrating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

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

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

Status of Spawning Populations

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

Salmon: Discussion

Challenges to Inland Salmon Management

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

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

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

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

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

Challenges to Ocean Management

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

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

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

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

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

Management Considerations

See the Management Considerations Appendix A for further information.

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Steelhead Rainbow Trout

History of the Fishery

Steelhead (*Oncorhynchus mykiss* formerly *Salmo gairdneri*) were once abundant in California coastal and Central Valley rivers and streams. American Indians utilized this resource for subsistence, trade, and ceremonial purposes. Salmon and steelhead were harvested year-round by central coast and Central Valley tribes, and primarily during late summer and fall months by north coast tribes. Nets, spears, traps, and weirs were utilized to capture the fish. Today, American Indians employ gillnets to capture salmon and are limited to the Klamath River system. These gillnet fisheries target chinook salmon, but an unknown number of adult steelhead is also taken.

There is no commercial steelhead fishery in California. Commercial salmon trollers cannot legally possess steelhead, and very few are taken incidentally in the commercial salmon catch. However, there is a well-established, popular steelhead sport fishery in California. The majority of angler effort is expended in river systems and coastal streams of the north coast, the central coast north of San Francisco Bay, and the Sacramento River system. Some rivers and streams of the central coast south of San Francisco still support a steelhead sport fishery, but these have become limited in recent years due to a decline in their populations. The steelhead fishery in southern California (south of San Luis Obispo) has been closed due to severe declines and extirpation of many of the runs and a listing of others under the federal Endangered Species Act (ESA). The San Joaquin River system presently supports a very limited fishery. The rest of California's steelhead sportfishery has instituted catch and release regulations since the ESA listing of naturally produced steelhead.

In 1993, California implemented the Steelhead Trout Catch Report-Restoration Card Program, which required that all steelhead anglers purchase a steelhead catch report card and record their catch. These data are used by the Department of Fish and Game (DFG) to generate catch statistics, including the number of steelhead caught and released. The report card has provided angler harvest information and funding for management, research, and habitat restoration projects. Current information indicates that approximately 69 percent of angler effort is expended on the north coast (north of the Mattole River), 15 percent on the north-central coast (between the Mattole River and the Golden Gate), four percent on the south-central coast (from the Golden Gate to Pt. Conception) and 12 percent in the Central Valley. In 1993, the total statewide steelhead catch estimated from report card data was 168,000 fish (but only 40,000 were kept). In 1994, estimated catch was 178,000, with 53,000 fish retained. These figures have not been corrected for non-response bias, however, so are likely overestimated. Even prior to the implementation of catch-and-release requirement for wild steelhead (see below), California steelhead anglers released approximately 70 percent of all steelhead caught.

Steelhead sport fishing is important not only for the recreation that it provides, but also for its economic benefits. A 1985 economic analysis of the anadromous sport fishery of the Sacramento-San Joaquin river system estimated that sales revenue generated from steelhead sport fishing in the Sacramento River and tributaries was over 7.2 million dollars. When non-fishing activities were included, Sacramento River steelhead generated over $9 million annually.

Status of Biological Knowledge

Steelhead are the anadromous form of rainbow trout, a salmonid native to western North America and the Pacific coast of Asia. In North America, steelhead are found in Pacific Ocean drainages from southern California to Alaska, and in Asia in coastal streams of the Kamchatka Peninsula. Spawning populations in California are known to have occurred in coastal streams from Malibu Creek (Los Angeles County) to the Smith River near the Oregon border, and in the Sacramento and San Joaquin river systems. Southern California streams south of Malibu Creek appear to support at least occasional spawning and production, but it is unknown if these coastal streams currently support steelhead populations. The present distribution and abundance of steelhead in California has been greatly reduced from historical levels.

Steelhead are similar to Pacific salmon in their ecological requirements. They spend most of their lives in the ocean where they grow to relatively large size, and then return to fresh water to spawn. Unlike Pacific salmon, steelhead do not necessarily die after spawning. Repeat spawning is common; however post-spawning survival rates are generally quite low (10 to 20 percent). Steelhead do not necessarily migrate to sea at a specific age. Some individuals remain in a stream, mature, and even spawn without ever going to sea; others migrate to sea at less than a year old. Although most spend two to six years at sea, some return to freshwater after spending less than a year in the ocean. The well-known Klamath River "half-pounders" are sexually immature steelhead that return to fresh water after spending only a few months at sea. These fish do not spawn, but return to the ocean and eventually ascend the river in a second upstream migration as a larger, mature steelhead.

In California, peak spawning in most runs occurs from December through April. Steelhead generally spawn in small tributaries where cool, well-oxygenated water is available year-round. Like salmon, the female steelhead digs a nest, or "redd," deposits eggs while an attendant male fertilizes them, then covers the eggs with gravel. The length of time it takes for eggs to hatch largely depends on water temperature. Steelhead eggs hatch in about 30 days at 51º F. Fry usually emerge from the gravel four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature all influence the timing of emergence.

The newly emerged fry move to shallow, protected areas associated with stream margins where they establish feeding stations that they defend. Juveniles mainly inhabit riffles, but they can utilize a variety of other habitat types. Relatively high fingerling densities occur in association with structural complexity, such as that provided by large woody debris. Juveniles also exhibit a preference for sites with overhead cover and appear to select positions in streams in response to low light levels.

The preferred depth for steelhead spawning is approximately 14 inches and ranges from six to 24 inches. In natural channels, water depth usually does not hinder adult migration because adult steelhead normally migrate during high flows. Depth can become a significant barrier or impedance in streams that have been altered for flood control purposes. It has been reported that seven inches is the minimum depth required for successful migration of adult steelhead, although the distance fish must travel through shallow water areas is also a critical factor.

Water temperature requirements for various life stages of steelhead have been well studied, although there are relatively few data specific to California. Egg mortality begins to occur at 56º F. Thermal stress has been reported at temperatures beginning at 66º F, and temperatures demonstrated to be lethal to adults have been reported at 70º F. In California, low temperatures are not as much of a concern as high temperatures, particularly during adult migration, egg incubation, and juvenile rearing. The ability of steelhead to tolerate adverse temperatures varies depending on stock characteristics, ecological conditions, and physiological conditions such as life stage.

The life history of steelhead differs from that of Pacific salmon in two principal aspects. First, juvenile steelhead rear in fresh water for longer periods of time (usually from one to three years). Because of this multi-year rearing requirement, water temperatures and other water quality parameters must remain suitable year-round. That is why steelhead typically migrate higher into watersheds to spawn than salmon. It is mostly in these upper tributaries that water quality - most importantly water temperature - remains suitable year-round.

The second principal difference between salmon and steelhead is the amount of time steelhead spend in fresh and salt water, which is much more variable. In a study of steelhead life history in central coast streams, it was found that the majority of adults returning to spawn had spent two years in fresh water and one or two years in the ocean. However, steelhead showing other life history patterns were not uncommon. Scale analysis of adults indicated that they typically spent from one to four years in fresh water and from one to three years in the ocean. Studies on Sacramento River steelhead also show this variability.

Steelhead have traditionally been grouped into seasonal runs according to their peak migration period. In California, there are well-defined winter, spring, and fall runs. This classification is useful in describing actual run timing, but is misleading when it is used to further categorize steelhead. Run-timing may be a characteristic of a particular stock, but by itself, does not constitute race or ecotype.

There are two principal steelhead ecotypes: 1) *stream-maturing* steelhead, which enter fresh water with immature gonads and consequently must spend several months in the stream before they are ready to spawn; and 2) *ocean-maturing* steelhead, which mature in the ocean and spawn relatively soon after reentry into fresh water. This corresponds to the accepted classification that groups steelhead into two seasonal "races" — summer and winter steelhead. Stream-maturing steelhead (summer steelhead) typically enter fresh water in spring, early summer, and fall. They ascend to headwater tributaries, hold over in deep pools until mature, and spawn in winter. Ocean-maturing steelhead (winter steelhead) typically begin their spawning migration in late fall, winter, and spring and spawn relatively soon after freshwater entry. Ocean-maturing steelhead generally spawn from January through April, but some spawning can extend into May and June.

Prior to the intensive water development of this century and the resultant loss of a considerable amount of holding habitat, stream-maturing (summer) steelhead were probably more common in California than they are today. There is some evidence that they were present in the Central Valley drainages, but were most likely extirpated with the construction of large dams that blocked access to the upper reaches on many of the major spawning tributaries. At present, summer steelhead are known to occur only in north coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity river systems. Ocean-maturing (winter) steelhead are also present in north coast drainages, and are also found in the Sacramento and San Joaquin river systems and central/south coast drainages.

The above classification scheme is based on behavioral and physiological differences and may not reflect genetic or taxonomic relationships. Genetic similarity appears to be a reflection of geographical relationships. For example, summer steelhead occupying a particular river system are more genetically similar to winter steelhead of that system than they are to summer steelhead in other systems. Similarly, little or no morphological or genetic differentiation has been found between steelhead and resident rainbow trout forms inhabiting the same stream system. Taxonomists conclude that *O. mykiss* cannot be separated taxonomically by immigration timing (fall-, winter-, spring-runs), ecotype (stream-maturing vs. ocean-maturing), or their migratory behavior (steelhead vs. resident forms). Rather, rainbow trout are taxonomically structured on a geographic basis. All steelhead in California belong to the coastal rainbow trout subspecies, *O. m. irideus.*

This taxonomic classification recognizes the extreme variability that occurs within rainbow trout populations. Rather than the different life-history forms comprising distinct populations, studies and observations provide evidence that coastal rainbow trout can form a single, interbreeding population in stream systems where there is access to the ocean. These populations are comprised of individuals with different life-history traits and a continuum of migratory behaviors, the two extremes being anadromy (strongly migratory) and residency (non-migratory). Recent research demonstrating that juvenile rainbow trout can adopt a life-history strategy that is different from their parents (*i.e.,* a steelhead can produce non-anadromous progeny and non-anadromous rainbow trout can produce steelhead progeny) provides further evidence.

This type of population structure and resultant flexibility in reproductive strategies allows a population to persist in the face of unstable and variable climatic, hydrographic, and limnological conditions that frequently exist at the margins of a species' range. For coastal rainbow trout, this includes stream systems in the Central Valley and those south of San Francisco Bay. Stream systems in California are subject to extreme variations in rainfall which can result in high volume, flash flood runoff, or droughts lasting several years. Natural stream flow in these streams can vary greatly, both seasonally and annually. It is not uncommon, even under unimpaired conditions, for the lower reaches of many streams to become interrupted during the dry season, restricting the population to the perennial headwaters, with these conditions persisting for years. The flexibility inherent in this type of population structure allows fish to complete their life cycles entirely in freshwater until conditions once again allow migration to the ocean, and this flexibility has allowed populations to persist in this marginal, frequently suboptimal environment. Having several different life-history strategies among a single population effects "bet-hedging" against extinction.

Status of the Populations

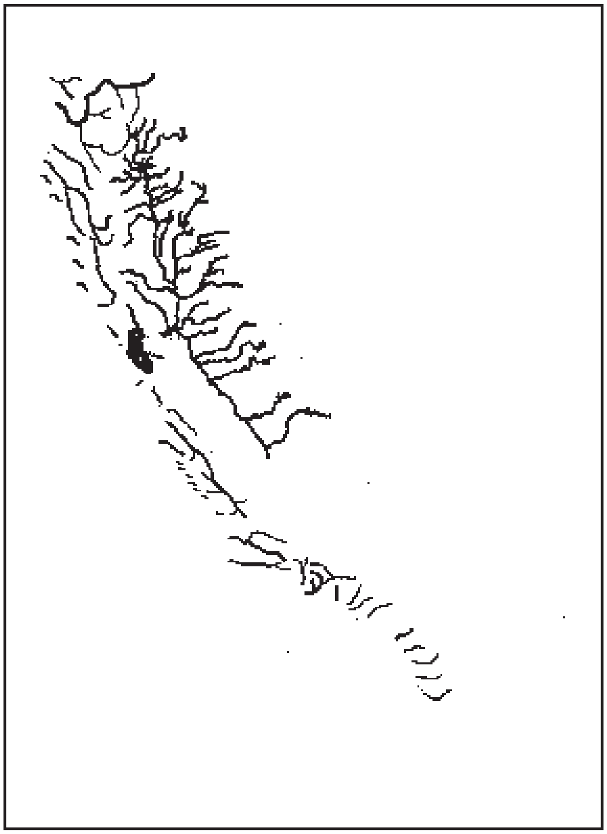
Because of the difficulty in assessing steelhead populations, we have limited estimates of adult numbers and a statewide population estimate is not available. Carcass surveys, a dependable method to estimate salmon spawning populations, are not useful for assessing steelhead spawning populations, because steelhead do not always die immediately after spawning. Counts made at weirs and fishways can be difficult because adult steelhead tend to migrate on high, turbid winter flows. Despite the lack of accurate numbers, other reliable indicators show that steelhead, like most other anadromous salmonid stocks in California, have declined significantly.

In October 1997, the federal government listed southern California steelhead as endangered and central and south Central Coast steelhead as threatened under the ESA. In May 1998, Central Valley steelhead were listed as threatened, and in August 2000, Northern California steelhead were listed as threatened. Consequently, all California steelhead populations south of the Klamath-Trinity River system are now listed under the ESA.

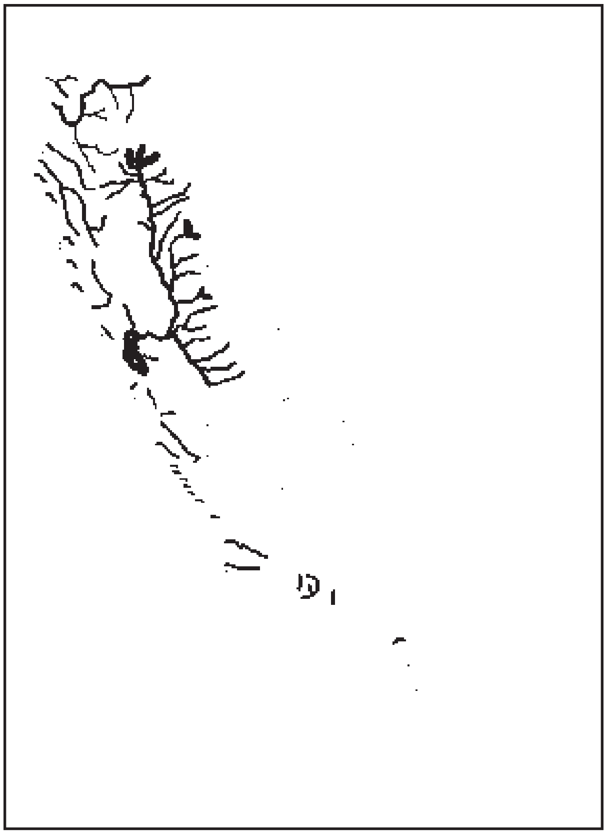
South Coast. The precipitous decline of steelhead on the south coast is well documented. Of 122 streams south of San Francisco Bay that were known to have contained a steelhead population, 47 percent had populations with reduced production from historical levels, 33 percent no longer supported steelhead populations, and only 20 percent had populations that had not declined significantly from historical levels. The percentage of streams with extinct populations ranged from zero percent in San Mateo and Santa Cruz counties in the north to 92 percent in Orange and San Diego counties.

Water development appears to be the primary cause of localized extinctions and decline in numbers. A recent study found that 35 percent of the southern steelhead populations reviewed were negatively impacted by water diversions, 24 percent by dams lacking functional fishways; 18 percent by artificial barriers other than dams (such as impassable culverts and bridge supports) and five percent from stream channelization. Overall, 21 percent of the 165 populations reviewed were impacted by blocked access to spawning and rearing tributaries due to main stem impediments. Other major impacts include urbanization and other land-use activities.

Southern steelhead stocks (those occurring south of Point Conception) are the most imperiled of all of California's steelhead populations, and are the only California steel-



The historical range of steelhead in California.
Only major streams within the range are depicted.



The present range of steelhead in California.
Only major streams within the range are depicted.

head that are listed under the ESA as endangered. The southernmost range of steelhead formerly extended to northern Baja California and they were present in streams and rivers of Los Angeles, Orange, and San Diego counties. At present, Malibu Creek in Los Angeles County is the designated southern extent of the steelhead range (in terms of the ESA listing). However, the recent discovery of a spawning population in San Mateo Creek in San Diego County has confirmed that steelhead are still present in streams south of Malibu Creek, and the federal government has recently proposed to extend the designated southern extent to include San Mateo Creek. It is not known if steelhead still occur in streams south of San Mateo Creek.

The historical run-size of the Santa Clara River is estimated to have been about 9,000 adults annually. In the past five years, several hundred steelhead smolts have been observed at fish screens at a diversion on the mainstem so it appears this population may be recovering, although only a few adult steelhead have been observed in the fishway in the diversion dam. A fishway on a small diversion dam on Santa Paula Creek, a major tributary to the Santa Clara River, was recently completed, so steelhead will now have access to some of their former spawning and rearing habitat.

The Santa Ynez River is reported to have had an annual run size from 12,995 to 25,032 adults in the 1940s. Although this was a cursory estimate, it does attest to the large size of this run, which was already reduced from former times because of forest fires and construction of dams in the upper watershed. The large size of this run is also indicated by a DFG rescue of 1,036,980 juvenile steelhead from the partially dry bed of the Santa Ynez River in 1944. Since the mid-1990s, a few adult steelhead have been observed every year, and juvenile steelhead have been observed in several tributaries.

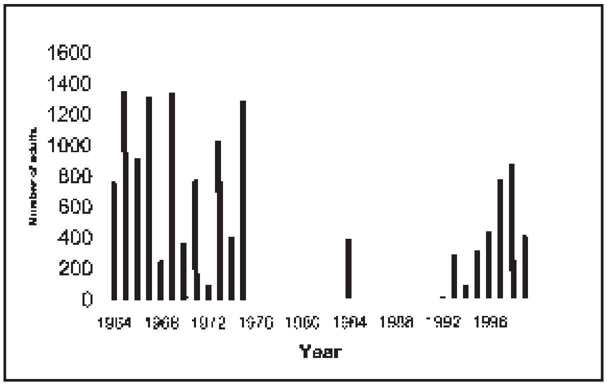
In the mid-1940s, DFG biologists reported that a minimum of 2,000 to 2,500 adults spawned in Matilija Creek, a tributary of the Ventura River, and they believed that this represented 50 percent of the total number of adults entering the Ventura River. There are recent anecdotal reports of adult steelhead in the lower Ventura River, and juvenile steelhead have been observed.

Much of the coastline of southern Monterey and San Luis Obispo counties is relatively undeveloped; hence, many of these small coastal streams still contain steelhead populations. Status of populations in these streams range from healthy in the relatively undisturbed streams in southern Monterey and northern San Luis Obispo counties, to severely depressed or extirpated in the Morro Bay/San Luis Obispo urban area. The largest populations of steelhead (on the order of hundreds of adults) in the south-central coast region are probably in the Little Sur and Big Sur rivers.

In the Carmel River from 1964 to 1975, the average annual run-size of steelhead was estimated to be 3,177 fish, about 25 percent of historical levels. The mean number of adults counted at the San Clemente Dam fish ladder during this 12-year period was 821 fish per year. During a three-year period from 1988 to 1990, the river never breached its sand bar at the mouth making the river inaccessible to upstream migrant adult steelhead. One adult was observed in the ladder in 1991, 14 adults in 1992, and 285 adults in 1993. In 1993, the Fish and Game Commission closed the lower Carmel River to all angling to protect the remnant steelhead run. With the cessation of the recent six-year drought, the Carmel River steelhead population appears to be recovering. The average annual run size for the five-year period beginning in 1995 was 590 adults. In recognition of the increasing health of the population, the river was opened to a limited catch-and-release fishery for steelhead in 1998.

With the recent occurrence of several years of ample precipitation, it appears that steelhead in this region may be starting to recover from the six-year drought of the late 1980s through early 1990s. Opportunistic observations confirmed the presence of steelhead in many small southern California streams that were not known to have contained steelhead populations for many years. Steelhead have been observed in Carpenteria, Maria Ygnacio, Gaviota, Mission, and Arroyo Hondo creeks in Santa Barbara County; Arroyo Sequit and Topanga creeks in Los Angeles County; and San Mateo Creek in San Diego County. Since the ESA listing, habitat restoration projects have increased in the past five years and include modification of grade stabilization structures to facilitate passage on Gaviota Creek, development and design of a fishway and screens on the Robles Diversion on the Ventura River, initial discussions on removal of Matilija Dam on Matilija Creek, construction of a new fishway at Harvey Dam on Santa Paula Creek, and various restoration projects in Topanga and San Mateo creek watersheds.

North Coast. The historical range of steelhead on the north coast (north of San Francisco Bay) has not been reduced to the extent it has in other areas of the state. Major dams that have blocked access to historical spawning and rearing areas are Iron Gate Dam on the Klamath River, Lewiston Dam on the Trinity River, Ruth Dam on the Mad River, Scott Dam on the Eel River, Coyote Dam on the Russian River, and Warm Springs Dam on Dry Creek (a tributary to the Russian River). All of these dams except the latter two are at elevations greater than 1,500 feet, so a considerable amount of habitat is still available downstream. The Russian River is the notable exception - dams block access to the headwaters and a major tributary.



Adult Steelhead Counts at San Celmente Dam on the Carmel River
Data show steelhead counted at the San Clemente Dam on the Carmel River between 1964 and 1999. Data not available for 1978-1983 and 1985-1987; no steelhead were counted at the San Celmente Dam during the years 1976-1977, 1989, and 1990.

The north coast rivers and streams have the largest area of steelhead habitat in the state and the most abundant populations of steelhead. The *California Fish and Wildlife Plan* of 1965 estimated an annual spawning escapement of 513,500 steelhead for this region. Because many of the spawning and rearing tributaries are largely undeveloped and fairly remote, the north coast runs are in better condition than other areas of the state. However, these populations have also had some declines.

In the 1960s, the Smith River was estimated to have a spawning escapement of 30,000 adult steelhead. There have been no recent spawning surveys done for steelhead and the population size is unknown at present. The Smith River is presently protected by federal Wild and Scenic River designation and has one of the most undisturbed watersheds in California. Steelhead populations appear to be healthy in this system and the habitat is relatively pristine. The Smith River is well known among anglers for producing trophy-size steelhead.

The largest population of steelhead in California inhabits the Klamath River system. The *California Fish and Wildlife Plan* estimated an annual run size of 283,000 adult steelhead for the entire Klamath River system. The size of the fall-run from the 1977-1978 to the 1982-1983 seasons ranged from 87,000 to 181,410 adults annually. The size of the winter steelhead population in this system in the early 1980s was probably about 10,000 to 30,000 adults annually, based on limited sport angler and Native American gillnet harvest data. The steelhead population of the Klamath River excluding the Trinity River has declined dramatically, most likely due to high summer water temperatures in the mainstem.

The most reliable population estimates for steelhead on the north coast are for the Trinity River, a major tributary of the Klamath River. DFG has operated several weirs in the system since 1977 to obtain steelhead run size, sport harvest, and spawning escapement estimates. Estimates for some years during this period are not available because of the difficulty in maintaining weirs in high water. Eight years of run size estimates for the Trinity River upstream of Willow Creek range from 7,833 to 37,276 and average 15,185 adults. The 1991-92 estimated run size for the Trinity River above Willow Creek was 11,417.

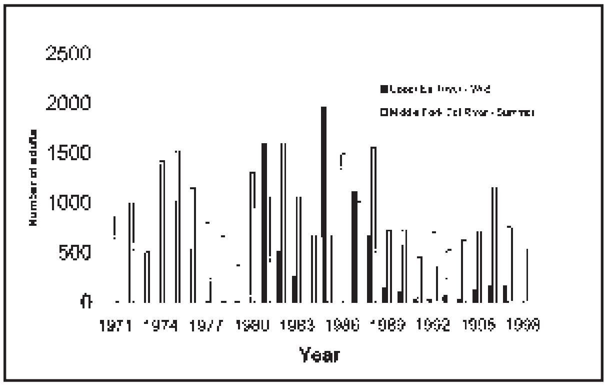
Steelhead runs in the Eel River system have declined significantly. Annual counts made at Benbow Dam on the South Fork Eel River show a decline from an average of 18,784 during the 1940s to 3,355 during the 1970s (counts were discontinued after 1975). Annual counts of adults at Cape Horn Dam in the upper watershed of the main stem Eel River declined from an average of 4,063 during the 1930s to 540 during the 1990s. Annual counts of wild steelhead at this location show an even greater decline: from an average of 893 in the 1980s to 82 in the 1990s. Recent anecdotal information indicates that steelhead populations also appear to have declined significantly in the South Fork Eel River, partly due to predation or competition from introduced Sacramento squawfish, which are now widespread throughout the system.

The *California Fish and Wildlife Plan* estimated an annual spawning escapement of 50,000 steelhead in the Russian River. Presently, escapement of naturally produced steelhead in this system probably ranges from about 1,750 to 7,000 adults. Historically, steelhead spawned throughout the Russian River system, but today many of the tributaries, including the East Fork, are now inaccessible due to dam construction.

Marin County tributaries to San Pablo and San Francisco bays have all sustained intensive urban development and anadromous runs in many streams have been extirpated. West Marin County tributaries to Tomales Bay and the Pacific Ocean still have steelhead with small population estimates. Steelhead escapement in Lagunitas Creek is probably about 400 to 500 adults annually.

There are four DFG hatcheries in the north coast area: Iron Gate Hatchery on the Klamath River, Trinity River Hatchery, Mad River Hatchery, and Warm Springs Hatchery on Dry Creek (tributary to the Russian River). Average annual production for these four hatcheries totals about 1,750,000 steelhead yearlings per year. The private, nonprofit Rowdy Creek enhancement hatchery on the Smith River releases approximately 125,000 steelhead smolts annually. Despite the significant number of hatchery smolts released, steelhead runs in north coast drainages are comprised mostly of naturally produced fish.

Since the early 1970s, systematic surveys have been undertaken on summer steelhead holding habitat to census adult summer steelhead. The most abundant populations are in the Middle Fork Eel and the North Fork Trinity rivers. The Middle Fork Eel River population has not fully recovered from the devastating 1964 flood which

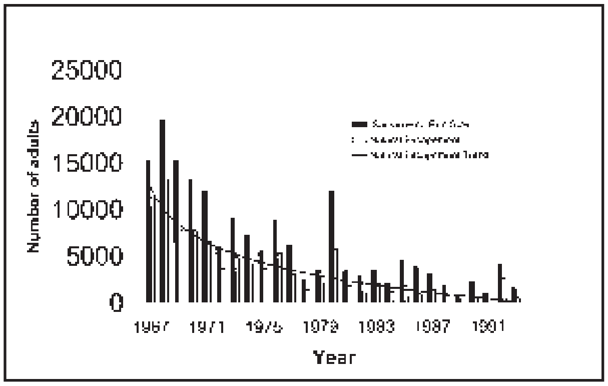


Eel River Steelhead Population Trends
Data shows steelhead population trends between 1971 and 1998 as counted for the Upper Eel River wild steelhead population and the summertime steelhead population (wild and hatchery) of the Middle Fork of the Eel River.

aggraded the river bed, filled-in holding pools, and smothered spawning gravels. The adult population has declined steadily since 1987 and is now about 500. The present estimated annual statewide abundance of summer steelhead is about 2,000 adults.

Major factors impacting north coast steelhead stocks are watershed disturbances due to logging, grazing, and road building, water diversions, and other agricultural impacts. Poaching is a problem, especially for summer steelhead, which must over-summer in fresh water, often concentrated in a few pools. This renders them susceptible to snagging and netting, especially if the pools are located in accessible areas. Urbanization of the watershed and gravel mining operations have caused serious problems on central coast streams.

Central Valley. Steelhead were historically well-distributed throughout the Sacramento and San Joaquin river systems, from the upper Sacramento/Pit river systems south to the Kings River (and possibly Kern river systems in wet years) and in both east- and west-side tributaries of the Sacramento River. Present distribution of steelhead in the Central Valley has been greatly reduced, mainly from construction of impassable dams that block access to essential spawning and rearing habitat. It is estimated that 82 to 95 percent of the historical steelhead spawning and rearing habitat in the Central Valley has been lost to dam construction/passage problems.



Adjusted Counts of Upper Sacramento River Steelhead at Red Bluff Diversion Dam
Data shows steelhead counted at the Red Bluff Diversion Dam between 1967 and 1993.

Naturally-spawning steelhead stocks are known to occur in the upper Sacramento River and tributaries, Mill, Deer, and Butte creeks, and the Feather, Yuba, American, Mokelumne, Calaveras, Stanislaus, and Tuolumne rivers. Naturally spawning populations could be more widespread, however, as indicated by recent implementation of monitoring programs that have found steelhead smolts in streams previously thought not to contain populations, such as Auburn Ravine, Dry Creek and the Stanislaus River. It is possible that naturally spawning populations exist in many other streams but are undetected due to lack of monitoring or research programs. A genetic evaluation by the National Marine Fisheries Service provides evidence that a native Central Valley steelhead stock still exists.

Until very recently, steelhead were considered to be extinct in the San Joaquin River system. However, this conclusion was based on little information and no field studies. The presence of steelhead in the San Joaquin River system has been confirmed by observations of steelhead smolts in the Stanislaus River and observations of steelhead adults and smolts in the Calaveras and Tuolumne rivers. Adult steelhead have also been observed in the Stanislaus River and in the San Joaquin River at its confluence with the Merced River.

The *California Fish and Wildlife Plan* estimated that there were 40,000 adult steelhead in the Central Valley drainages in the early 1960s. In the 1950s, the DFG estimated the average annual steelhead run size in the Sacramento River system above the mouth of the Feather River was 20,540 adults. Estimating steelhead abundance before extensive water development and habitat modification occurred is difficult given the paucity of historical information. However, an estimate can be made by comparing the relative abundance of chinook salmon and steelhead in other, relatively unimpaired river systems. These estimates show that steelhead abundance in these river systems is at least as great as chinook salmon abundance, and in some cases, is greater. It is estimated that chinook salmon escapement was one to two million spawners annually in the Central Valley prior to large-scale habitat changes, so a cursory estimate of the annual steelhead run size is one to two million adults

A cursory estimate of current steelhead abundance in the Central Valley, based on Red Bluff Diversion Dam (RBDD) counts, hatchery counts, and past natural spawning escapement estimates for some tributaries, is no greater than 10,000 adult fish. A more reliable indicator of the magnitude of the decline of Central Valley hatchery and wild stocks is the trend in the RBDD adult steelhead counts, which have declined from an average annual count of 11,187 adults for the ten-year period beginning in 1967, to 2,202 adults annually in the early 1990s. Natural spawning escapement estimates above RBDD for the period 1967 to 1993 averaged 3,465 and ranged from zero (1989 and 1991) to 13,248 (1968). Natural escapement has shown a more substantial decline than hatchery escapement. There are four steelhead hatcheries in the Central Valley: Coleman National Fish Hatchery on Battle Creek, Feather River Hatchery, Nimbus Hatchery on the American River, and the Mokelumne River Hatchery. Together, these hatcheries produce about 1.5 million yearlings annually.

Factors affecting abundance, persistence, and recovery have been identified for anadromous fishes in the Sacramento and San Joaquin River systems and these apply reasonably well to Central Valley steelhead. These factors include: water diversions and water management, entrainment, dams and other structures, bank protection projects, dredging and sediment disposal, and gravel mining. The primary impact to Central Valley steelhead is the substantial loss of spawning and rearing habitat due to dam construction at low elevations on all the major tributaries.

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Commercial Landings - Salmonids

Year	Chinook Pounds	Coho Pounds	Total Salmon [1] Pounds
1916	- - - -	- - - -	5,592,216
1917	- - - -	- - - -	6,085,997
1918	- - - -	- - - -	5,933,346
1919	- - - -	- - - -	7,208,382
1920	- - - -	- - - -	6,066,190
1921	- - - -	- - - -	4,483,105
1922	- - - -	- - - -	4,338,317
1923	- - - -	- - - -	3,736,924
1924	- - - -	- - - -	6,374,573
1925	- - - -	- - - -	5,481,536
1926	- - - -	- - - -	3,863,677
1927	- - - -	- - - -	4,921,600
1928	- - - -	- - - -	3,444,306
1929	- - - -	- - - -	4,033,660
1930	- - - -	- - - -	4,085,650
1931	- - - -	- - - -	3,666,841
1932	- - - -	- - - -	2,649,204
1933	- - - -	- - - -	3,657,661
1934	- - - -	- - - -	3,921,530
1935	- - - -	- - - -	4,773,112
1936	- - - -	- - - -	4,093,475
1937	- - - -	- - - -	5,934,996
1938	- - - -	- - - -	2,170,921
1939	- - - -	- - - -	2,238,755
1940	- - - -	- - - -	5,160,393
1941	- - - -	- - - -	2,946,030
1942	- - - -	- - - -	4,063,306
1943	- - - -	- - - -	5,285,527
1944	- - - -	- - - -	7,021,848
1945	- - - -	- - - -	7,912,754
1946	- - - -	- - - -	7,196,527
1947	- - - -	- - - -	8,104,297
1948	- - - -	- - - -	5,860,915
1949	- - - -	- - - -	5,531,021
1950	- - - -	- - - -	5,867,346
1951	- - - -	- - - -	5,849,530
1952	5,785,214	751,677	6,536,891
1953	6,335,634	800,589	7,136,223
1954	8,167,724	431,855	8,599,579
1955	9,245,882	411,114	9,656,996
1956	9,814,366	460,536	10,274,902
1957	4,640,709	536,200	5,176,909
1958	3,576,385	80,456	3,656,841
1959	6,543,223	225,476	6,768,699
1960	6,096,384	125,061	6,221,445
1961	8,100,964	536,943	8,637,907
1962	6,301,520	371,341	6,672,861
1963	6,829,048	1,019,642	7,848,690
1964	7,562,445	1,918,770	9,481,215
1965	8,102,205	1,571,469	9,737,674
1966	5,979,027	3,467,427	9,446,995
1967	3,866,374	3,375,944	7,401,729
1968	4,612,488	2,337,629	6,951,931
1969	4,895,322	1,234,529	6,150,906
1970	5,269,494	1,341,820	6,611,522
1971	4,925,826	3,183,830	8,116,878
1972	5,372,779	1,050,355	6,423,289
1973	7,586,832	1,993,863	9,668,984
1974	5,048,456	3,700,084	8,749,414
1975	5,781,321	1,128,304	6,925,172
1976	4,943,891	2,843,849	7,787,787
1977	5,637,016	283,222	5,929,542
1978	5,492,397	1,295,073	6,787,474
1979	7,547,752	1,197,983	8,749,498
1980	5,715,203	301,566	6,017,193
1981	5,534,833	477,237	6,040,353
1982	7,448,614	551,939	8,000,561
1983	2,144,365	266,412	2,410,783
1984	2,621,248	348,417	2,969,665
1985	4,519,174	80,396	4,639,296
1986	7,396,751	201,563	7,598,314
1987	9,047,150	245,608	9,296,162
1988	14,430,810	319,489	14,750,299
1989	5,489,796	230,581	5,724,836
1990	4,122,351	313,731	4,436,082
1991	3,238,000	459,000	3,697,000
1992	1,632,000	11,000	1,643,000
1993	2,536,884	- - - -	2,536,884
1994	3,103,104	- - - -	3,103,104
1995	6,633,463	- - - -	6,633,463
1996	4,113,403	- - - -	4,113,403
1997	5,247,792	- - - -	5,247,792
1998	1,847,102	- - - -	1,847,102
1999	3,845,762	- - - -	3,845,762

- - - - Landings data not available.

[1] Prior to 1958, a commercial salmon fishery in rivers and bays existed. This data is not shown.

Recreational Catch - Salmonids

Year	Chinook Salmon CPFV No. of Fish[1]	Chinook Salmon Skiff No. of Fish[1]	Coho Salmon CPFV[2; 3] No. of Fish[1]	Coho Salmon Skiff[2; 3] No. of Fish[1]	Total Salmon[4] No. of Fish[1]
1947	- - - -	- - - -	- - - -	- - - -	5,000
1948	- - - -	- - - -	- - - -	- - - -	11,200
1949	- - - -	- - - -	- - - -	- - - -	23,100
1950	- - - -	- - - -	- - - -	- - - -	56,300
1951	- - - -	- - - -	- - - -	- - - -	72,000
1952	- - - -	- - - -	- - - -	- - - -	86,500
1953	- - - -	- - - -	- - - -	- - - -	98,700
1954	- - - -	- - - -	- - - -	- - - -	119,900
1955	- - - -	- - - -	- - - -	- - - -	129,000
1956	- - - -	- - - -	- - - -	- - - -	114,500
1957	- - - -	- - - -	- - - -	- - - -	44,700
1958	- - - -	- - - -	- - - -	- - - -	52,700
1959	- - - -	- - - -	- - - -	- - - -	55,900
1960	- - - -	- - - -	- - - -	- - - -	37,900
1961	- - - -	- - - -	- - - -	- - - -	43,000
1962	85,700	33,900	1,900	11	121,511
1963	66,200	17,600	6,300	26	90,126
1964	77,300	24,600	14,700	25	116,625
1965	46,000	14,200	5,700	15	65,915
1966	62,700	10,900	7,500	25	81,125
1967	60,900	11,700	24,000	26	96,626
1968	113,600	40,600	14,000	26	168,226
1969	100,000	55,800	11,400	17	167,217
1970	93,000	54,800	5,300	9	153,109
1971	108,400	79,900	22,400	45	210,745
1972	139,800	60,700	11,800	33	212,333
1973	119,500	78,500	5,200	27	203,227
1974	91,700	65,800	16,200	60	173,760
1975	68,300	35,400	5,500	15,800	125,000
1976	50,600	30,400	15,300	42,600	138,900
1977	54,700	49,600	2,400	11,800	118,500
1978	42,000	34,100	3,600	41,000	120,700
1979	71,800	40,600	2,000	14,500	128,900
1980	62,900	22,500	1,700	20,400	107,500
1981	59,800	24,200	1,100	9,500	94,600
1982	91,500	47,200	3,900	22,800	165,400
1983	46,500	17,300	500	26,700	91,000
1984	68,200	19,600	800	18,200	106,800
1985	107,300	63,800	1,400	14,400	186,900
1986	86,500	55,100	2,200	16,500	160,300
1987	121,800	70,700	4,300	43,000	239,800
1988	109,100	62,300	3,500	31,200	206,100
1989	105,000	81,700	6,200	43,400	236,300
1990	78,300	61,600	10,200	41,500	191,600
1991	39,900	40,600	13,500	55,800	149,800
1992	42,400	31,100	1,000	10,500	85,000
1993	66,000	44,000	4,200	25,600	139,800
1994	99,100	84,100	(closed 5/1/94)	500	183,700
1995	182,000	215,200	(closed 5/1/95)	900	398,100
1996	72,900	91,200	closed	600	164,700
1997	122,400	106,600	closed	500	229,500
1998	59,700	62,300	closed	100	122,100
1999	40,000	47,700	closed	600	88,300

- - - - Landings data not available.
1 All data presented in number of fish.
2 Recreational fishing for Coho was allowed before May 1 between 1994 and 1995.
3 Recreational fishing for Coho was prohibited after 1996.
4 Total recreational salmon catch between 1947 and 1961 is derived from CPFV logbook data only.

California's Bay and Estuary Ecosystem

Principle Bays and Estuaries of California

Bay and Estuary Ecosystems

The bays and estuaries dotting California's coastline are truly the jewels in the crown of the state's marine environment. These partially enclosed bodies of water are protected from the full force of ocean waves, winds, and storms. Bays are wide inlets or indentations of the ocean, whereas estuaries are inlets containing the terminus of a river or stream. Many of the organisms described in this report spend part of their life in bays or estuaries. However, this section of the report focuses primarily on the plant and animal species that utilize the state's estuarine areas as their principal habitat.

California estuaries vary widely in shape and size, and are often referred to as lagoons, harbors, inlets, esteros, and sounds. The defining feature of an estuary is the mixing of fresh water from upland and riverine sources with oceanic salt water. The estuary ecosystem forms a zone of transition from land to sea and from fresh to salt water. The sheltered waters of California's estuaries support unique assemblages of plant and animal communities, varying by environmental conditions and location. Estuarine habitat types include shallow open waters, fresh and saltwater marshes, sandy beaches, tidal mud and sand flats, rocky shorelines, oyster-shell beds, river deltas, eelgrass meadows, and kelp beds.

California's estuarine environment sustains remarkably high levels of productivity. Often referred to as the "ocean's nursery," these waters support early life-history stages of such important organisms as California halibut, Dungeness crab, Pacific herring, starry flounder, and numerous surfperch species. Representative organisms typifying California estuaries include rails and stilts, harbor seal, Dungeness crab, surfperches, leopard shark, starry flounder, and clams and oysters. These animals are linked to one another and to an assortment of specialized plants and microscopic organisms through a complex food web, unique to estuarine environments. Tens of thousands of birds, mammals, fish, and other wildlife depend on estuarine habitats as places to live, feed, and reproduce. Additionally, the state's estuaries provide ideal locations for migratory birds in the Pacific Flyway to rest and forage during their journey. Due to their critical importance, the U.S. Environmental Protection Agency's National Estuary Project has identified San Francisco Bay, Morro Bay, and Santa Monica Bay as nationally significant estuaries, thus affording federal funding for research, management, and restoration efforts. This designation of three of the state's estuaries in no way diminishes the ecological importance of the other bay and estuarine ecosystems that dot the California coastline.

Besides serving as critical habitat for wildlife, the wetlands that fringe many of the state's bays and estuaries also provide other important ecological and human benefits. Wetland plants and soils act as natural buffers between land and ocean, absorbing flood waters, dissipating storm surge, and filtering sediments, nutrients, and other pollutants. The state's bays and estuaries are also cultural centers of coastal communities, serving as the focal point for local commerce, recreation, and cultural activities. The protected waters of California's bays and estuaries support important public infrastructure uses, serving as harbors and ports vital for the state's shipping, maritime, and industrial related economy.

Because of the complexity and fragility of estuarine ecosystems, they are imperiled by their proximity to intensive human activity and development. Sewage, industrial waste, dredging, filling of marshes and tidal flats, and oil development and spills typify the long-term degradation of many of California estuaries. As a result, 40 animal and 10 plant species that occur in or depend on the state's estuarine ecosystems, currently are listed by the federal government as threatened, endangered, or protected status. Additionally, environmental harm from nonindigenous, or invasive, species has increased exponentially in recent years. San Francisco Bay is considered by experts to be "the most invaded estuary in the world." Notable examples of deleterious nonindigenous species are the Chinese mitten crab, the Asian clam, and the European green crab. Such invaders are capable of wreaking extensive ecological and economic harm. As California's population grows, these impacts can be expected to increase. So too does the importance of protecting the state's estuarine resources for all of their natural, economic, and aesthetic values.

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Bay and Estuarine Invertebrate Resources: Overview

California's bay and estuarine invertebrate resources are myriad, and when most of us think of these resources, extensive mudflats come to mind, exposed at low tides and teeming with shorebirds and skittering crabs. The chapters in this section feature the molluscan bivalves we know as clams and the caridean shrimps known collectively as the bay shrimps. The latter are the object of targeted commercial trawl fisheries in San Francisco Bay for use mostly as live bait in the sport sturgeon and striped bass fisheries, while the edible clams have traditionally been largely the domain of recreational fishermen.

In recent decades, California's bays and estuaries have been under increasing assault from the introduction of exotic species, many of which are invertebrates. Some of these like the Asian clam have significantly altered the ecology of San Francisco Bay and can be found in densities as high as several thousand per square meter. The exotic green crab and Chinese mitten crab have also adversely impacted native species and their habitats. Green crabs can outcompete juvenile Dungeness crab in mudflat habitats while the mitten crab can burrow into and weaken levees along the San Francisco Bay Delta waterways. The problems caused by such alien species are discussed in another section of this publication.

California's coastal clam resources have been under attack from numerous other sources as well – from industrial waste and municipal sewage, to habitat loss and degradation, to exotic viruses hitchhiking on imported aquaculture seed stock, to over-harvesting and poaching. Bivalve mollusks dwelling in our embayments and estuaries by the luck of the evolutionary draw just happen to occupy those habitats most likely to be near high concentrations of human populations. In this respect, they have been our "canary in the coal mine" warning us when the consequences of under-regulated industrialization and human overpopulation have exceeded the carrying capacities of our bays and estuaries. Although wastewater treatment standards have significantly reduced the concentrations of some pollutants entering California's waters in recent decades, bioaccumulation processes still result in certain bivalve populations being unsafe to eat. For example, a potentially significant resource of Manila clams exists in San Francisco Bay, but water quality problems discourage public use in many clam beds. The accelerated silting-in of Morro Bay and Bolinas Bay and the deleterious effects of septic and agricultural runoff in Tomales Bay are just a few more examples of the challenges resource managers face in protecting our resources. Increasingly, as population pressures continue pressing on estuaries, especially near the large metropolitan areas in southern and central California, only remnant populations of harvestable bivalve mollusks will remain.

The law of unintended consequences and the complexity of human interaction within the natural world can work together in interesting and often unpredictable ways. The extirpation of the sea otter from most of California in the nineteenth century allowed populations of geoduck and pismo clams to flourish in the absence of this major predator. Under the protection of the federal endangered species act, sea otter populations have reoccupied their historical range in central California and as a consequence, have reduced geoduck and pismo clam populations in the Morro Bay and Monterey Bay regions to a point below the level of harvestable surplus.

The multiple threats of habitat destruction, pollution, exotic invasions, and the re-establishment of sea otter populations could mean the end of California's bay and estuarine resources as we have known them unless California's fishery managers, resource scientists and political leaders can work together to find timely solutions to these problems.

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California Department of Fish and Game

Bay Shrimp

History of Fishery

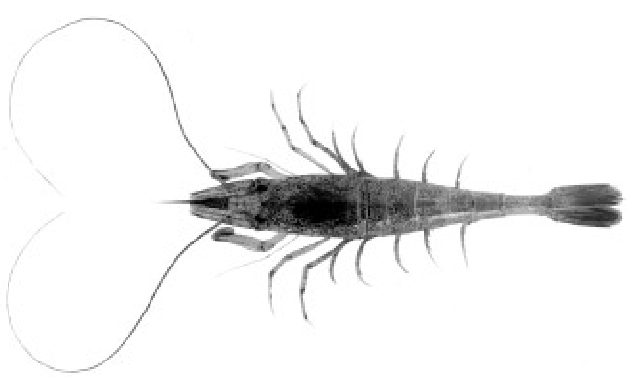
The commercial fishery for bay shrimp in San Francisco Bay began in the early 1860s, with some accounts indicating that the earliest participants used small-meshed bag seines. By 1871, Chinese immigrants established fishing camps along the shores of the bay and exported large quantities of dried shrimp meal (dried heads and shells) to China. These fishermen introduced what is now known as the Chinese shrimp net, a funnel-shaped net that is anchored in place and relies upon the tide to carry shrimp into the net. Fishing camps also existed in Tomales Bay between 1890 and 1895. At the height of the fishery in the 1890s, as many as 26 fishing camps operated up to 50 nets each in San Francisco Bay with daily landings of 400 to 8,000 pounds of shrimp, and annual landings exceeding five million pounds. Studies were required by the California Fish and Game Commission between 1897 and 1911 to address concerns that many young fish, particularly striped bass, were killed in the shrimp nets. The results of these studies prompted a May to August season closure and a prohibition of Chinese shrimp nets in 1911. The legislature modified this decision in 1915 allowing Chinese shrimp nets to be used in south San Francisco Bay. About this time, beam trawl nets began to be used by commercial shrimp harvesters in northern San Francisco Bay and San Pablo Bay. Annual landings gradually increased over the next two decades and peaked at 3.4 million pounds in 1935. Following this period, landings steadily declined in response to a decline in demand for fresh and dried shrimp as food. By the early 1960s, average annual landings declined to 1,500 pounds, and in 1964 no shrimp were landed.

The current commercial fishery for bay shrimp developed in 1965 to supply live bait for sturgeon and striped bass sport fishing with a small percentage of the catch reserved for human consumption. Regulation changes in the 1980s eliminated fishing in most of Suisun Bay due to high incidental catch and associated mortality of small striped bass in shrimp trawls. Currently, neither a quota nor season closure is in effect for the commercial fishery, and landings are influenced primarily by demand. Regulations also allow for the catch of yellowfin (Oriental) goby, long jaw mudsucker, and staghorn sculpin with a commercial bay shrimp permit. Sport regulations allow the use of hand-powered shrimp trawls no greater than 18 by 24 inches at the mouth and a daily bag limit of five pounds. Any finfish caught in the sport fishery must be returned to the water. From 1965 to the present, the commercial fishery for bay shrimp has exclusively used beam trawls. These trawls are spread by either a wooden or galvanized steel pole, are 20 to 25 feet wide, and use a mesh of 7/8 inch to one inch in the cod end. Live tanks are used on all vessels, and shrimp are transported to local bait shops by truck in either live tanks or iced-down wooden trays with burlap linings.

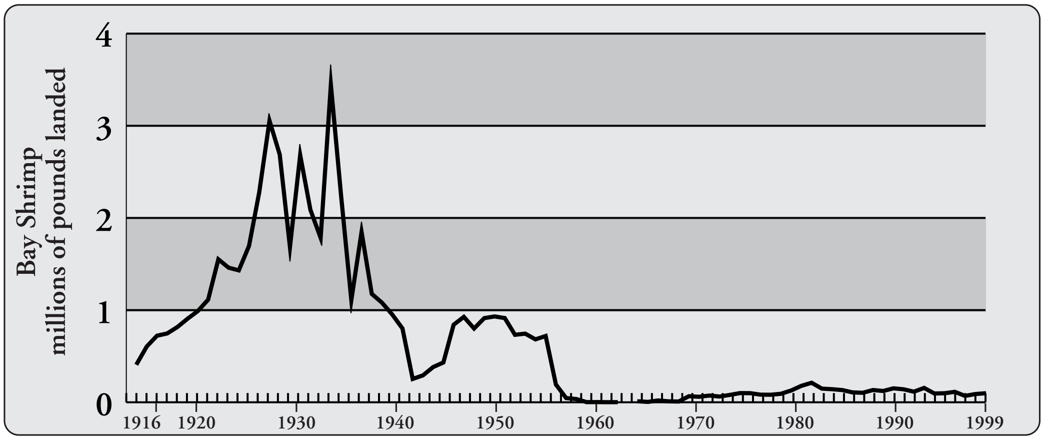
Since 1985, annual landings of bay shrimp have averaged 120,000 pounds and have ranged from 75,000 to 150,000 pounds. In 1999, 11 boats participated in the bay shrimp fishery. Eight of these boats fished exclusively in north San Francisco Bay and three fished exclusively in south San Francisco Bay. However, the total weight of bay shrimp landed was almost twice as high in the south San Francisco Bay versus north San Francisco Bay due to higher catch per boat, and higher catch per hour trawled. Primary fishing locations are Alviso Slough and Redwood Creek in south San Francisco Bay, north San Francisco Bay, northern San Pablo Bay, Petaluma Creek, and Carquinez Strait. Fishing generally occurs in waters less than 20 feet deep in channels of the estuary's shallow reaches.

The bay shrimp fishery exhibits a distinct seasonal pattern both in pounds landed, and catch-per-unit (CPUE) of effort as measured in pounds caught per hour trawled, with fluctuations typically on the order of five to eight-fold for both variables. Since 1996, March and April have had the lowest average monthly landings at 3,000 pounds as well as the lowest CPUE. Peak CPUE and total catch typically occurs in the months of June through November. Peak monthly catch for the past four years ranged from 10,000 to 12,000 pounds. Such seasonal variations in CPUE are most likely a result of fluctuations in salinity. However, seasonal variations in total pounds landed may reflect corresponding fluctuations in demand for bay shrimp by sport anglers.

The current value of bay shrimp landed each year is approximately $350,000, with the average pound of bay shrimp selling for $3.50 ex-vessel price. Additionally, over the past decade the bay shrimp fishery has caught between 9,000 and 2,000 pounds of staghorn sculpin and yellowfin goby per year at a total value ranging between $4,000 and $25,000.



California Bay Shrimp, *Crangon franciscorum*
Credit: DFG



Commercial Landings 1916-1999, Bay Shrimp
Data Source: DFG Catch Bulletins, log books, and commercial landing receipts.

Status of Biological Knowledge

The bay shrimp (grass shrimp) fishery is composed of four species: the California bay shrimp (*Crangon franciscorum*), the blacktail bay shrimp (*Crangon nigricauda*), the blackspotted bay shrimp (*Crangon nigromaculata*) and the oriental shrimp (*Palaemon macrodactylus*). The crangonid shrimp ("crangonid" is a taxonomic family) are easily distinguished from other shrimp by a very short rostrum that usually does not extend beyond the eyestalks, a dorsally flattened body, and poorly developed chelipeds. All four species prefer a soft substrate such as mud or sand, but can occasionally be found over rocky substrates and in the rocky intertidal.

The California bay shrimp, is the primary component of commercial shrimp landings. It is the dominant caridean shrimp ("caridean" is a taxonomic group between order and family) in most Pacific Coast estuaries, and the most common species in the San Francisco estuary. The California bay shrimp ranges from Alaska to San Diego to a depth of at least 180 feet. It is the largest of the bay shrimp species. Adult females and males may reach total lengths of 3.2 inches and 2.4 inches, respectively, in California, while a maximum size of 4.3 inches has been reported in the Columbia River. Life span varies by estuary. In the San Francisco estuary, males are estimated to attain a maximum age of 1.5 years and females may live up to 2.5 years. This species has been reported to be a protandrous hermophodite, with males changing to females.

Their larvae develop into the post-larvae stage in about 30 to 40 days. Both sexes reach maturity in about nine to 12 months. Males mature at approximately 1.3 to 1.5 inches, while females mature at about 1.9 to 2.1 inches. Though gravid females have been observed in all months of the year, they are most abundant in December through June. Spawning occurs near the mouth of the estuary in the summer months. During winter and spring, spawning takes place in nearshore areas outside of the estuary. During fertilization, female California bay shrimp, and other crangonid shrimp, extrude their eggs into their brood pouch (on their abdominal region). The fertilized eggs are held in the brood pouch throughout development (approximately 8 to 12 weeks) until they hatch.

California bay shrimp tolerate a wide range of salinity and temperature. During a 17-year interagency study in the San Francisco estuary, 90 percent of collected specimens were found in waters with salinity ranging from 2.8 to 25.9 parts per thousand (ppt) (mean 13.9 ppt). In the same area, mean temperature was 64.8˚F with 90 percent collected between 55.8 and 70.3˚F. Juveniles may be found throughout the estuary where salinity is greater than one part per thousand, although they prefer shallow (less than 16 feet), low salinity waters and migrate to deeper, higher salinity waters as they grow. The annual abundance of juveniles is strongly correlated with fresh water outflow in the winter and spring; lowest abundance occurs in years with low outflow.

Like other members of the genus, they are considered opportunistic feeders, and primary prey items may change with size of the shrimp. Smaller California bay shrimp (< 1.2 inches total length, TL) consume mostly foraminiferans, ostracods, and copepods; intermediate size shrimp prey upon amphipods and bivalves, and larger shrimp (> 2.4 inches TL) consume mostly bivalves, caridean shrimp, and polychaetes. Myoid shrimp are some common prey items in parts of the San Francisco estuary. Little is known about the ecology of larval and postlarval crangonids. However, diatoms and small zooplankton such as copepods are probably an important part of the larval diet.

The blacktail bay shrimp, ranges from Alaska to Baja California and is found in estuaries and nearshore ocean areas to a depth of at least 190 feet. This species is less tolerant of low salinities than California bay shrimp. In the San Francisco estuary, 80 percent of collected specimens were found in waters with salinity ranging from 18.0 to 31.7 ppt (mean 25.9 ppt). In the same area, mean temperature was 60.6˚F with 80 percent collected between 51.3˚ and 66.7˚F. Juveniles tolerate lower salinities and higher temperatures than adults. Adult females and males may reach total lengths of 2.5 and 2.4 inches, respectively. Males may live up to one year and females may live up to 1.5 years. Both sexes are reported to mature by the end of the first year; males are thought to spawn once and die. Male blacktails mature at approximately 1.1 inches, while females mature at about 1.5 to 1.6 inches. Juvenile shrimp usually peak in abundance from May through August, but in some years there is a second fall-winter peak. Blacktail bay shrimp feed mostly on amphipods.

The blackspotted bay shrimp is a very minor component of the catch. It ranges from the Gulf of the Farallones to Baja California, and is more common in the nearshore ocean area than in estuaries. It is found on sandy bottoms at depths ranging from 15 to 575 feet and reaches a maximum size of 2.8 inches TL. Females mature at about 1.7 inches and males mature at about 1.1 inches. Blackspotted bay shrimp tolerate a smaller salinity range and lower temperatures than the other two common crangonids. They are generally limited to areas with high salinity and cool temperatures, with 80 percent of the specimens collected at salinities ranging from 25.9 to 31.9 ppt and temperatures ranging from 51.6˚ to 64.0˚ F in the long-term interagency study. Abundance increased during the 1987-1992 drought. The Oriental shrimp, was introduced to the San Francisco estuary from Asia in the 1950s and is now a significant component of the commercial catch. This species reaches a total length of about 3.0 inches and appears to complete its entire life-cycle in estuarine waters. It is common in lower salinity areas, including south San Francisco Bay and areas upstream from San Pablo Bay. The center of its distribution is either Suisun Bay or the west delta. It is more tolerant of lower salinity than the crangonid shrimp and is abundant over a broad range of salinities. In San Francisco Bay, 80 percent of collected specimens have been found in waters with salinity ranging from 1.9 to 28.1 ppt (mean 13.5 ppt) and temperatures ranging from 54.1˚ to 71.˚ F (mean 64.4˚ F). Abundance of oriental shrimp did not appear to be affected by the 1987-1992 drought. Gravid female oriental shrimp occur most frequently from May to August, with larvae hatching during summer and early fall.

An additional species of *Crangon, C. munitella*, has been collected on rare occasions within the estuary. For example, from 1980 to 1996 the DFG's Bay-Delta Project caught more than 2.2 million California bay shrimp in otter trawls, while observing only 26 *C. munitella*.

A sixth species of bay shrimp, *Exopalaemon carinicauda*, was reported from San Francisco Bay in 1993. This species seems to have been introduced accidentally from Korea. It is distinguished from other shrimp by its long, toothed rostrum, large chelae, and dorsal ridges. Its abundance and distribution in the estuary, and the impact of this species on the ecosystem are unknown.

Bay shrimp are an important component in the diets of nearshore and estuarine fishes. Twenty-four predator species have been identified in the estuary and 20 in the adjacent ocean environment. Major predators include green and white sturgeon, striped bass, leopard shark, brown smoothhound shark, big skate, white croaker, staghorn sculpin, starry flounder, English sole, pile and rubberlip surfperch, Pacific tomcod and brown rockfish.

Status of the Populations

The absolute abundance of bay shrimp has not been estimated nor has the impact of commercial fishing on these populations. However, annual abundance indices of bay shrimp indicate that abundance can vary widely from year to year. For example, annual abundance indices of adult California and blacktail bay shrimp varied by more than a factor of 10 from 1980 to 1996. Studies indicate that the abundance of California bay shrimp increases with increased river inflow to the estuary, probably because of the increased low-salinity habitat which is favorable for the rearing of juveniles. In contrast, abundance of blacktail bay shrimp increased during years of low river inflow, although not to levels capable of replacing California bay shrimp in abundance.

Management Considerations

See the Management Considerations Appendix A for further information.

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Pacific Razor Clam

History of Fishery

The Pacific razor clam (*Siliqua patula*) is one of the tastiest food clams in California and is diligently pursued by sportsmen on the beaches where it is abundant. The best California beaches for razor clams are in Del Norte and Humboldt counties. Before 1949, a small commercial fishery existed, but only a few pounds of clams were ever sold. Commercial fishing for razor clams is presently prohibited.

There were no seasonal restrictions on razor clamming until 1953. Due to a decline in the numbers of larger clams at that time, Clam Beach in Humboldt County was divided into a north (Mad River to Strawberry Creek) and south beach (Strawberry Creek to Little River) to limit fishing effort seasonally. The south beach was open to clamming only in odd-numbered years, while the north beach was open during even-numbered years. A similar restriction went into effect for the razor clam bed at Crescent City in Del Norte County in 1955.

A 1960 study on Clam Beach concluded that the alternate-year closures were responsible for a decline in older and larger clams on the south beach due to of the concentration of clammers there. As a result, all of Clam Beach was opened to clamming from 1971 to 1973. During that three-year period, catch and effort were monitored, and public reaction noted. It was found that instead of being evenly distributed, 86 percent of the clamming effort took place on the north beach. The high pressure on the north beach resulted from a combination of easier access to the north beach, and the much greater clamming success there. There was also a strong sentiment among clam diggers to return to alternate year closures because of the declining average size of clams. In 1974, the alternate year fishing pattern was reinstated with the north beach open during odd-numbered years and the south beach open during even-numbered years. In the years immediately following the reinstatement, the catch-per-digger and the average clam size increased significantly.

A daily bag limit of 30 razor clams was changed to 20 in 1963. In addition, all clams dug were required to be kept regardless of size or broken condition.

Status of Biological Knowledge

The Pacific razor clam ranges from western Alaska to Pismo Beach, California, and is generally found on flat or gently sloping sandy beaches with a moderate to heavy surf. Razor clam shells are long and thin, with fragile, shiny valves – not what one would expect in a surf-loving animal. An excellent burrower, it depends on digging speed for protection from wave shock. Individuals laid on top of the sand have buried themselves completely in less than seven seconds. A digger must work quickly to capture a clam before it burrows to depths that are difficult to reach. At the surface of the sand, the clam assumes an almost vertical position with only siphons exposed. Water is drawn into the inhalant siphon by a current set up by the action of cilia lining the mantle cavity. As water is passed across the gills, planktonic food organisms are guided by cilia and a pair of palps to the mouth. Respiratory exchange takes place as the water passes over the gills, and waste products are passed out in the water through the smaller exhalant siphon.

The life-cycle of the razor clam is typical of most clams. Sexes are separate, fertilization is external, and free-swimming larvae develop three or four days after fertilization. Approximately eight weeks later, the larvae settle into the sand and the juvenile phase of life begins. Sexual maturity in razor clams may be related to size as well as age. While maturity is commonly achieved at a length of about four inches, the age at maturity varies with geographic location; usually at the age of two years in California. Razor clams usually spawn in May and June in California, mid-May to July in Washington, and as late as August in Alaska. The optimum temperature for razor clam spawning is around 55° F.

Razor clams attain their maximum rate of growth during their first year of life. The growth rate remains high through the second or third year, after which it slows markedly. The largest razor clam on record in California was a seven-inch specimen taken from Clam Beach in 1979.

The mortality rate of razor clams on Clam Beach increases rapidly after the third year of life, with few clams living to be seven years old. In the northern part of the range, the maximum age is greater. Razor clams in Alaska live 18 or 19 years, but the typical life-span is shorter.

Pacific Razor Clam, *Siliqua patula*
Credit: DFG

Status of the Population

There are only three areas along the coast of California that have had significant populations of Pacific razor clams. The Pismo Beach-Morro Bay area supported a very small sport fishery, which has diminished over the years. Currently, this population is quite small and seems to consist mostly of individuals ranging from one to two inches in size. The Clam Beach and Crescent City fisheries are similar to each other in several respects. Both beds are divided into north and south beaches with alternate-year closures in effect. In both areas, the northern beach was more heavily fished and more productive than the southern beach for many years. However, the southern beach in Crescent City saw an increase in effort and in catch-per-digger during the early 1980s. A decline in razor clam abundance was seen in the coastal states of Washington, Oregon, and California following the 1982-1983 El Niño. A previously unknown disease, nuclear inclusion X (NIX), caused the closure of the razor clam fishery in Washington in 1984 and 1985. Mortality appeares to depend on the intensity and prevalence of infection. The prevalence and intensity of NIX decreased both north and south of central Washington beaches. In Oregon, prevalence was high, but intensities were low enough that little mortality was seen. Little information exists for NIX in California, but large declines in razor clam abundance were noted in the late 1980s and into the mid-1990s for beaches in northern California. A major source of mortality, especially for young razor clams, is the scouring effect of winter storms. The El Niño events of the past two decades have had large storms associated with them and this may have had some impact on northern California razor clam populations. The razor clam population in the Crescent City area is recovering, but the Clam Beach population is still much diminished from former levels.

No current population estimates are available for any of California's razor clam beds. Beginning in 1974, a sampling program was initiated to provide estimates of total catch and effort for Clam Beach. Estimates of annual catch, number of diggers, and annual catch-per-digger were made for the years 1974 through 1989 for North and South Clam Beach and for the years 1980 through 1989 for Moonstone Beach (Little River to bluffs). Estimates of annual clam catch for North Clam Beach ranged from 1,100 to 116,400; for South Clam Beach the range was from zero to 45,500; and for Moonstone Beach the range was from zero to 74,800. The annual estimated number of diggers ranged from 880 to 12,670 on North Clam Beach, from 220 to 6,900 on South Clam Beach, and from 50 to 5,510 on Moonstone Beach. Annual catch-per-digger for North Clam Beach, South Clam Beach and Moonstone Beach ranged from 1.3 to 9.5, 0.0 to 6.6 and 0.0 to 13.9 clams, respectively. Catch, effort and catch-per-digger exhibited no particular trends but fluctuated over time.

Management Considerations

See the Management Considerations Appendix A for further information.

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Gaper Clams

History of the Fishery

The fishery for the gaper clams, the Pacific gaper (*Tresus nuttalli*) and the fat gaper (*Tresus capax*), is almost exclusively sport, however, the Fish and Game Code allows these clams to be harvested commercially in Humboldt Bay for daily restaurant or market orders. For the 20-year period from 1950 to 1970, annual commercial landings for Humboldt Bay averaged 1,000 pounds with a maximum annual landing of 6,000 pounds and a minimum of 200 pounds. More stringent public health regulations concerning the marketing of shellfish and the retirement of a long-time commercial clammer essentially eliminated the commercial clam fishery in the early 1980s.

The Pacific and fat gaper are the object of a heavy sport fishery that takes place in intertidal areas of bays with sand and mud bottoms. Humboldt Bay, Bodega Bay, Tomales Bay, Drakes Estero, Elkhorn Slough and Morro Bay are popular digging areas. At Tomales Bay, which is one of the major producing areas, as many as 1,200 people have been counted during one low tide on the two emergent sand bars. These popular areas, Clam Bar and Seal Bar, can be reached only by boat. In the past, a commercial ferry provided transportation to the two sandbars allowing as many as 11,000 people to dig there each year. With a legal limit of 10 gaper clams per day, clammers were taking about 55,000 clams per year. However, the commercial ferry service has recently been permanently discontinued and the annual sport take of clams has fallen by almost 75 percent.

Sport take of gaper clams is also quite popular in Humboldt Bay. A survey in 1992 estimated an average of 4,300 sport clammers per year for the previous 10-year period with an estimated annual take of 56,000 gaper clams. Current effort by clammers is estimated to be about the same or slightly higher. Since the discontinuance of the Tomales Bay clam ferry, Humboldt Bay is the largest gaper clam fishery in the state.

In the past, Morro Bay had been considered a good location for sport take of gaper clams. However, settlement of small gaper clams has been poor since the early-1990s for unknown reasons and that factor coupled with foraging by sea otters has reduced abundance of gaper clams, resulting in greatly reduced effort by clammers in the 1990s.

Utilization of gaper clams has increased through the years, and it appears that it will continue to increase in proportion to population growth in the coastal counties where these clams occur. There is no season or size limit, but there are bag limits set for sport and commercial harvesting. An angler may take 10 clams per day throughout the state, except in Elkhorn Slough where the limit is 12 clams per day and in Humboldt Bay where a take of 25 clams per day is allowed. The fact that gaper clams have relatively thin shells, which do not close tightly enough to maintain their moisture, restricts the commercial use of these clams to a fairly local market.

Diggers generally use skiffs to get to the better clam digging areas. Shovels are used to dig the clams, which may be as deep as four feet in sand or mud. In muddy areas, three-foot lengths of PVC pipes about 12 to 15 inches in diameter are often used to prevent the hole from caving in, enabling clammers to reach deeply buried clams.

Gaper clams generally are used in clam chowder or fried and served as a main dish.

Status of Biological Knowledge

Gaper clams are found from Alaska to Scammon's Lagoon, Baja California. Both the Pacific and fat gaper live in fine sand or firm sandy-mud bottoms in bays, estuaries, and more sheltered outer coast areas. They are found from the intertidal zone to depths of at least 150 feet. The Pacific gaper is the most commonly taken gaper clam in California. A closely related species, the fat gaper, is the predominant gaper clam taken in Humboldt Bay, where it is very common in the intertidal zone. Further south, the fat gaper occurs mostly subtidally but can make up to five percent of the catch taken in the intertidal zone at Tomales Bay.

Reproduction occurs year around in central California but is predominant during spring and peaks in the months of February and April. Upon completion of a free-swimming larval stage, the young gaper clam settles down to a fixed position and comparatively inactive existence. The only movement is downward as the clam grows older and increases in size. After reaching a size of about three inches, little downward movement occurs.

Age and growth studies reveal that most gaper clams taken in central California range from about three to eight years old. For the first four years, the clams average about one inch of growth in length per year. The growth rate

Pacific Gaper Clam, *Tresus nuttalli*
Credit: Windy Montgomery, University of California

appears to slow down after this period. Gaper clams live to a maximum age of 17 years and can attain a length of 10 inches with a weight of approximately five pounds.

The gaper clams reach sexual maturity and spawns at about two to three years of age. At this time, they are two to 2.75 inches in size. Spawning appears to begin in the spring, coinciding with the seasonal water temperature minimum.

Gaper clams are suspension feeders, feeding on suspended particles, which include phytoplankton and detritus. In intertidal beds, feeding occurs during the high tide period.

Status of the Population

Although densities of gaper clams in areas of certain bays have been determined, complete statewide intertidal and subtidal population estimates have not been made. However, both the intertidal and subtidal resource appears to be in a healthy state where most clamming effort is located. Subtidal populations are relatively unavailable and unused by sport clammers and provide a spawning refuge. In general, spawning stock reserves seem adequate to sustain the population. Gaper clams occur in densities of up to 20 clams per square foot, with a density of two clams per square foot considered commercially viable. Intertidal siphon counts by biologists using a stratified random sampling design on Clam Bar in Tomales Bay supplied data for estimating intertidal population sizes of 540,000 gaper clams in 1968 and 430,000 in 1969.

Management Considerations

See the Management Considerations Appendix A for further information.

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DFG biologists showing off gaper clam catch from Tomales Bay
Credit: DFG

Washington Clams

History of the Fishery

The Washington clam fishery is almost exclusively a sport fishery. The *Fish and Game Code* allows commercial fishing in Humboldt Bay by daily market or restaurant order and by special bag limits. These clams are highly perishable and are dug as required and consumed locally. From 1954 to 1963, commercial landings averaged 5,000 pounds per year, with a high of 11,000 pounds in 1956 and a low of 2,000 pounds in 1960. Landings decreased following this period due to more stringent public health regulations pertaining to the marketing of shellfish. By the early 1980s, commercial landings of Washington clams ceased with the retirement of a longtime commercial clammer.

Two principal species of Washington clam are harvested in California. The Washington clam (*Saxidomus nuttalli*) is the principal species sought, and the best yielding localities are Humboldt Bay, Bodega Bay, Tomales Bay, Drakes Estero, and Elkhorn Slough. Bolinas Lagoon and Morro Bay have historically been good yielding localities. However, in the past decade clam populations in these two areas have declined significantly. The second popular Washington clam, the butter clam (*Saxidomus giganteus*), formerly known as the smooth Washington clam, is seldom taken south of Humboldt Bay. In only one California locality, near Fields Landing in Humboldt Bay, is this clam common enough to support a minor fishery. Results of a sport clamming survey of Humboldt Bay, from 1975 through 1989, produced a mean estimated total take of both clam species of 42,000 per year.

The Washington clam catch is considerably less than that of gaper clams, primarily because the latter are more predominant in most bays, and the Washington clam siphon holes are more difficult to locate. The recent Humboldt Bay survey found that the Washington clam and the butter clam comprised 20 percent and 13 percent, respectively, of the total estimated harvest of all species taken in that bay. In Bodega Bay, Washington clams are the predominant take, comprising an estimated 30 to 40 percent of the total clam harvest, with an occasional butter clam also taken.

Sport clammers may take 10 Washington clams per day throughout the state except in Elkhorn Slough, where the limit is 12 in combination with gaper clams, and in Humboldt Bay, where the limit is 50 in combination with no more than 25 gaper clams.

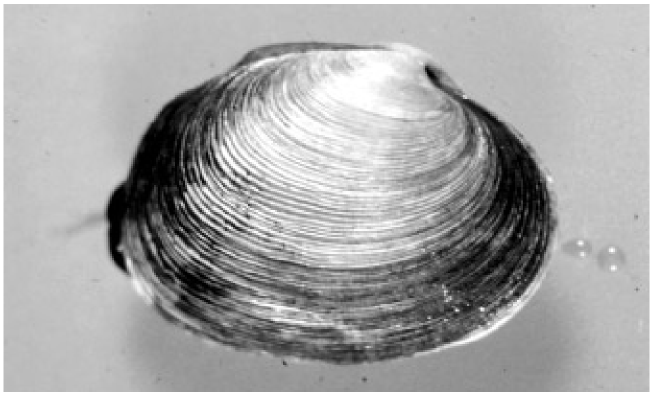
Skiffs are used to transport diggers to intertidal areas where these clams occur, but some locations have populations accessible by foot. The clams are dug by shovels to a depth of 12 to 18 inches near the low tide line. Washington clams have excellent flavor and texture and may be used in clam chowder, or fried and served as a main dish.

Status of Biological Knowledge

The range of the Washington clam is from Humboldt Bay, California, to San Quentin Bay, Baja California. This species lives at depths of 12 to 18 inches in mud, sandy mud or sand of bays, lagoons and estuaries. Its shell is thick and firm, oval in outline, and roughened on the outer surfaces by numerous concentric ridges. Inside, the shells are shiny white with dark purple markings at the posterior end. Though the harvest is from bottoms exposed at low tide, this clam also occurs subtidally in the same general area.

The butter clam ranges from Sitka, Alaska, to San Francisco Bay, California, but is infrequently taken south of Humboldt Bay. Its shell is thick and firm, oval in outline, but more rounded than that of the Washington clam. The interior of the shell is entirely white with no purple markings. This clam lives at depths of 10 to 14 inches in mud or sandy mud of bays, lagoons and estuaries in areas that are usually exposed at low tide.

Spawning occurs during a period from spring to fall, presumably as a result of warmer water temperature. A study of the Washington clam in British Columbia revealed that about half of these clams spawned at the end of their third year. The larvae appeared as bivalve veligers in two weeks and, at the end of four weeks, when less that 0.2 inches long, settled to the bottom. Tidal currents play an important role in the distribution of these animals due to their pelagic larvae life-stage. Successful spawning and settlement may be somewhat sporadic, with a period of years between settlements of consequence. Upon completion of a free-swimming larval period, both species settle down to a fixed position and a comparatively inactive existence. About the only movement is downward as the clams grow older and increase in size. Age studies reveal that most Washington clams harvested in central California are from four to eight years old. Occasional individuals of both species up to 10 years old are found in California, while some butter clams over 20 years old have been



Washington Clam, *Saxidomus nuttalli*
Credit: Windy Montgomery, University of California

found in British Columbia. The Washington clam grows to a length of nearly seven inches and attains a weight of about two pounds. The butter clam may attain a length of five inches.

Paralytic shellfish poisoning (PSP) is of widespread concern to consumers of shellfish. Both the Washington clam and the butter clam have been shown to retain high levels of paralytic shellfish toxin in the viscera and in the dark colored tips of the siphons for long periods of time after a PSP event. California clammers can call a toll-free biotoxin hotline at 1-800-553-4133 to obtain recorded information on PSP events and areas with posted biotoxin warnings.

Status of the Population

Densities and distributions of these clams have been determined for some of the more frequently used bay and estuarine intertidal areas, but knowledge is lacking about subtidal densities and distribution. Estimates have not been made of the total population size of the Washington clam resource in California, however, the present level of harvest can be easily sustained.

Management Considerations

See the Management Considerations Appendix A for further information.

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Geoduck

History of the Fishery

The geoduck clam (*Panope generosa*) fishery is entirely a sport fishery in California. Geoduck clams are the largest burrowing clam in the world and also the deepest-dwelling clam in California. The geoduck is an important sport and commercial species in Washington state and British Columbia. It is considered uncommon throughout California but is found in Humboldt Bay, Bodega Bay, Tomales Bay, and Drakes Estero. In the past, Bolinas Lagoon and Morro Bay had beds of geoducks which supported a sport fishery; however, geoduck and other clam species have declined significantly in abundance in these locations over the past decade.

Very few clammers in California take a sport limit of geoducks. Their rarity in most California bays and estuaries usually causes them to be taken incidently when clamming for gaper clams. As with gaper clams, they are often located on the mudflats by the streams of water they shoot several feet into the air. They differ from the gaper clams by not having chitinous flaps or pads at the siphon tip, no fringing tentacles on the inner edge of each siphon, and are a light brown in color. Clammers can check undisturbed clams by their siphons at the surface for this feature. The bulk of the geoduck population is subtidal which makes it harder to locate a geoduck. Only the lowest tides provide the chance of encountering many geoducks. In Tomales Bay, less than one percent of the catch consists of geoducks; about one out of three hundred clammers takes a geoduck while clamming in this location.

Geoducks can reach a weight of 10 pounds or more. Because of their size, a limit of three clams is considered an adequate bag limit throughout the state. Geoducks are one of the finest food clams in California. They are highly esteemed for their fine flavor and large size and are considered a trophy clam to sport diggers.

Skiffs are generally used to transport clammers to intertidal areas where these clams live buried in sandy mud at depths of four feet or greater. Lengths of PVC pipe or metal tubes, approximately 12 to 15 inches in diameter and about three feet in length, are needed to shore up the sides of the deep holes required to take these clams.

Geoduck clams may be ground for use in fritters or clam chowder, or pounded and fried and served as a main dish.

Status of Biological Knowledge

Geoduck clams are distributed from Forrester Island, Alaska to Scammon's Lagoon, Baja California and in the northern Gulf of California. They are found from the lower intertidal zone to depths of 360 feet in bays, estuaries, and sloughs, in bottom types ranging from mud to pea-sized gravel, but mostly in unshifting mud or sand.

Shells are whitish and covered with a dull, yellowish-brown periostracum, which is often badly eroded in large clams. Shells are sculptured with a number of unevenly spaced, concentric growth lines. Siphons are united to form a tube, extremely long and impossible to withdraw into the shells. Valves gap widely on all sides except on the hinge area. Flesh exposed between the gaping valves is covered with a heavy reddish-brown epidermis or skin.

Geoducks are long-lived and slow growing. Growth is rapid for the first four years then greatly decreases. In prime habitat in Washington state, geoducks can reach an average weight of 1.9 pounds in five years. Both male and female geoducks are usually sexually mature by age five. Maximum shell size is over nine inches, with a total body length (from foot to extended siphon) of 59 inches, and a weight of over 20 pounds.

The sexes are separate and spawning takes place in late spring to early summer. Fertilization is external and takes place in the water column. Larvae remain in the water column for several weeks before metamorphosing into juveniles and settling to the bottom. Larval clams eat phytoplankton while juveniles and adults filter-feed on plankton and detritus.

Predators include moon snails and spiny dogfish, which prey on small individuals. Juveniles and adults are eaten by pink seastars , sunstars, and various crab species. Sea otters are a major predator on geoduck clams within their range in California. Siphon tips are eaten by cabezon and starry flounder.

Status of the Population

While larvae of geoduck clams experience extremely high mortality, resulting in a low recruitment rate, the natural mortality rate of adults is low. Information on distribution and density of these clams comes from studies in Washington state and British Columbia, where com-

Geoduck Clam, *Panope generosa*
Credit: Windy Montgomery, University of California

mercial and sport fisheries exist; very little is known about geoduck beds in California. These studies showed that geoduck clams are contagiously distributed or clumped. In a Washington state study, the average geoduck density was 1.4 clams per square yard with a range of zero to 18 clams per square yard. In British Columbia, clam densities as high as 31 clams per square yard were found. Intertidal clam densities in California would be expected to be considerably less than one clam per square yard. Fluctuations in population size result from natural mortality and appears not to be influenced by sport clammers, whose take is very low. Geoduck populations in California will be impacted by the expansion of the southern sea otter over its historic range.

Management Considerations

See the Management Considerations Appendix A for further information.

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Littleneck Clams

History of the Fishery

There are seven species commonly known as "littleneck clams" or "chiones": banded chione (*Chione californiensis*), smooth chione (*Chione fluctifraga*), wavy chione (*Chione undatella*), rough-sided littleneck (*Protothaca laciniata*), common littleneck (*Protothaca staminea*), thin-shelled littleneck (*Protothaca tenerrima*) and Manila clam or Japanese littleneck (*Tapes philippinarum*). They are grouped here because they are regulated by an aggregate bag and size limit. All are members of the family Veneridae (Venus clams) and all but the Manila clam are native to California. The Manila clam is a native of the Orient and was introduced unintentionally into California waters in the 1930s.

Although seven species have been aggregated for regulating molluscan resources, only four (smooth chione, wavy chione, common littleneck and Manila clam) are of major importance; they comprise more than 95 percent of the littleneck clam harvest in California. Since commercial clammers are restricted to the same daily bag and size limits as sport fishers (50 clams, all species combined; minimum length 1.5 inches), it is not feasible for them to make a living harvesting these bivalves. Thus, most exploitation is by sport diggers.

All digging is by hand (with rake, shovel, garden hand fork, or trowel) and is carried out in intertidal areas during daylight hours, generally at low tides of 0.0 feet or less.

Status of Biological Knowledge

The three species of chiones occur south of Point Conception on mud and sand flats of sloughs and bays, primarily in the intertidal zone. Banded and wavy chiones may, however, occur subtidally to a depth of 165 feet.

Thin-shelled and rough-sided littlenecks are both uncommon in California except in Alamitos Bay (Los Angeles County) where the latter species is abundant. Thin-shelled littlenecks occur throughout the state in firm, sandy mud of bays, in the low intertidal zone, and offshore to a depth of 165 feet. They occupy burrows up to 16 inches deep. Rough-sided littlenecks occur in California from Monterey Bay south to the Mexican border in sand or muddy sand in bays, the low intertidal zone, and in adjacent shallow subtidal areas. Larger individuals may burrow up to 12 inches below the surface. The locally abundant population in southern California is in water too deep for stand-up diggers, and the underwater visibility is too poor for skin divers to harvest them.

The common littleneck occurs throughout California in bays, coves and cobble patches along the outer coast in the middle and low intertidal zones. This species generally occurs within six inches of the surface and deep digging is not required for harvesting. Clam beds known to resident sport diggers receive relatively heavy exploitation during minus tides. Other clam beds remain underutilized due to difficulty of access or lack of public awareness. This is one of the most abundant clams on the West Coast and is highly esteemed for food.

The Manila clam continues to expand its range on the West Coast and now occurs from southern California to British Columbia. It is particularly abundant in San Francisco Bay and other estuaries to the north in the intertidal zone. It is easily dug, as it generally occurs within two inches of the surface. It prefers a substrate of coarse, sandy mud with a mixture of larger gravel and cobbles and may attach itself with byssal threads to any suitable substrate, including broken glass or ceramics. It also occurs sub-tidally in the extensive oyster shell beds of south San Francisco Bay.

Maximum length of the three species of chiones is approximately 2.5 inches. Of the four types of littlenecks, the thin-shelled is the largest, attaining a length of 4.3 inches. The other three species reach approximately three inches in length.

Of the seven species, life history information is best known for the Manila clam population in San Francisco Bay. By examining the length-frequency distribution of a strong year class over time, minimum legal size was estimated to be reached in two and a half to three years. This was verified by examining internal and external growth rings on the shells formed each year in the fall as growth slows down or ceases. Maximum age is estimated to be eight or nine years.

Manila clams have a three-week planktonic larval period. They are first recognizable in the substrate at about 0.04 inch. At 0.75 to 1.0 inch, they are capable of reproducing and are repeat spawners. The primary spawning period is late spring to early summer, and they are known as dribble spawners, releasing eggs and milt over a prolonged time period. A secondary spawning period is thought to

Common Littleneck Clam, *Protothaca staminea*
Credit: DFG

occur in the winter. Sexes are separate, as they are in all littleneck clams.

Natural mortality of sublegal Manila clams may be as high as 50 percent per year. Known predators include bat rays, mud crabs, lined shore crabs, *Cancer* crabs, channeled whelks and scoter ducks. Large clams are capable of movements of up to three feet during a single tidal cycle, although marking studies have shown virtually no net movement over a several-month period.

Common littleneck clams have a similar early life history and are capable of reproducing at about one inch in length. In southern California, they may reach the minimum legal size in one to 1.5 years. External growth checks are prominent on the shell, but these are not annual rings. The spawning season in southern California is generally from March through July.

Meat yield from harvested littleneck clams has been estimated. A limit of 50, 1.7-inch common littlenecks yields 9.5 ounces of meat, while a limit of 2.5-inch clams would provide 24.5 ounces. In contrast, a limit of 50 Manila clams from San Francisco Bay with a typical mean length of 1.6 inches would yield 6.4 ounces of meat.

In the past, littleneck clams have been cultivated and transplanted. Aquaculturists have reared the Manila clam from 0.25 inches to 1.5 inches in 10 months with 64 percent survival. Manila clams were transplanted in 1953 from San Francisco Bay to several southern California bays and sloughs. Many of the transplants survived for more than a year, but there was no natural reproduction.

Status of Population

In 1981, population estimates of Manila clams were derived for beds in San Francisco Bay. In the 10 most important beds, the peak estimate in the summer was 19.3 million clams with 3.4 million of legal size. One bed in south San Francisco Bay, covering approximately 75,000 square feet, was surveyed annually for several years in the 1980s; population estimates have ranged from 80,000 to 1,525,000. For the highest estimate, only two percent of the population was of legal size. Maximum density of legal-sized clams in this bed was 2.5 per square foot. Densities of juvenile Manila clams may exceed 100 per square foot in the most productive intertidal beds. Typically, intertidal densities in San Francisco Bay range from 20 to 40 per square foot during years of good recruitment. In the subtidal shell beds, density averages one-tenth of that in the intertidal zone.

Surveys of clammers in San Francisco Bay in 1981 resulted in an estimated annual total effort of 900 user days. However, water quality problems have limited and still limit recreational harvest opportunities.

Small beds of common littleneck clams are generally the rule in northern California. One bed in San Mateo county has sustained an annual harvest estimated to exceed 10,000 clams. San Onofre, in southern California, contains an intertidal cobble bed over one mile in length and at least 115 feet wide. A 1967 population estimate yielded 4.5 million legal-size clams; however, the bed had never been open to the public before the survey. In terms of legal limits, this bed could have furnished 90,000 user days of recreation.

The cobble beach at San Onofre probably is the most productive bed of littleneck clams in the state. However, the population is unstable and fluctuates greatly even when unexploited. Heavy runoff from a nearby creek in 1969 caused expansive sanding-in of the cobbles and destroyed much of the bed. Recovery time was estimated at five years.

Little is known about the populations of the other littleneck species. The smooth chione is in danger of extinction in areas where harbors are being developed. Habitat loss or degradation, particularly by man-induced or natural siltation, can cause permanent population reductions. Extreme variations in physical conditions, such as rainfall, can depress populations dramatically.

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Commercial Landings - Bay and Estuarine Invertebrates

Year	Bay Shrimp[1] Pounds
1916	411,847
1917	605,004
1918	722,178
1919	747,023
1920	817,091
1921	907,467
1922	990,349
1923	1,113,358
1924	1,551,086
1925	1,460,234
1926	1,431,511
1927	1,697,365
1928	2,280,871
1929	3,054,748
1930	2,687,831
1931	1,684,763
1932	2,681,807
1933	2,087,952
1934	1,783,663
1935	3,445,091
1936	2,240,849
1937	1,108,761
1938	1,847,926
1939	1,175,979
1940	1,080,190
1941	952,152
1942	800,958
1943	253,215
1944	291,974
1945	382,147
1946	432,145
1947	841,086
1948	926,707
1949	800,441
1950	913,181
1951	931,323
1952	913,908
1953	732,308
1954	744,768
1955	682,731
1956	718,968
1957	192,814
1958	45,955
1959	35,011
1960	1,580
1961	2,050
1962	1,075
1963	1,225
1964	----
1965	10,765
1966	4,165
1967	19,771
1968	10,465
1969	8,041
1970	65,761
1971	59,721
1972	73,067
1973	62,308
1974	79,797
1975	99,708
1976	98,789
1977	82,797
1978	81,715
1979	92,213
1980	127,968
1981	178,363
1982	211,697
1983	148,115
1984	142,012
1985	132,578
1986	107,304
1987	103,088
1988	132,951
1989	122,599
1990	151,382
1991	140,725
1992	114,923
1993	155,891
1994	95,328
1995	98,053
1996	113,398
1997	69,231
1998	89,348
1999	98,086

---- No landings data available.

[1] Presented data represents the commercial landings from San Francisco Bay

Bay and Estuarine Finfish Resources: Overview

Finfish species utilizing California's bays and estuaries include the sturgeons, gobies, cow sharks, smelts, striped bass, Pacific herring, and California halibut. Many of these fish move between bays and estuaries and open Pacific waters. Several are dependent on bay and estuarine systems for their entire life histories. While numerous fishery resources, such as salmonids, Dungeness crab, and many of the marine mammals also occur in or utilize the state's bay and estuarine habitats, only the species that are principally dependant on this ecosystem for reproduction, or life stage development are discussed in this chapter. Surf and night smelts, which are not dependent on bay and estuarine habitats are included in this chapter due to the layout of the document which combined true smelts into a single paper. Coastal finfish species which utilize bays and estuaries as nursery grounds or for other purposes, but are discussed elsewhere in this document, include the salmonids, leopard shark, bat rays, some of the croakers, many of the surfperches, brown rockfish, and several flatfishes.

Bay and estuarine species support important commercial and/or sport fisheries. It is estimated that California's striped bass sport fishery has an annual economic value of more than $45 million. Add to this, the commercial value of fisheries for Pacific herring and the commercial passenger fishing vessel fleet targeting shark and other bay and estuarine species, and the overall annual value of fisheries specific to California's bays and estuaries range into the hundreds of millions of dollars. On the basis of economics alone, California's bay and estuary finfish species are very important resources.

In addition to being a food source and financial resource for human populations, many of the finfish species included here are an important food source for a diverse group of foraging marine fish, birds and mammals. Herring spawning, in particular, provides a highly utilized opportunity for feeding by other marine organisms. As herring move into shallow bay waters to spawn, a feeding frenzy often occurs which can last for several days. Gulls, cormorants, pelicans and other marine birds, California sea lions and harbor seals, a variety of fish, including sturgeon, and invertebrates feast on the adult herring and the developing embryos. Fish species such as Pacific herring and many of the smelt are a principal food source for marine organisms at the higher trophic levels. Fluctuation in the health and abundance of these higher trophic level species often can be traced to the population fluctuations of plankton feeders such as herring and smelt.

The finfish species found in the state's bays and estuaries serve as an index of the overall health of these important ecosystems. California's estuaries are heavily influenced by urbanization. While the more severe human impacts of such urbanization (filling of wetlands, for example) can be seen throughout the bay and estuarine ecosystems, the more subtle impacts tend to be chronic. Some of the chronic impacts are identified though long-term studies of specific indicator species. For example, while some impacts of increased diversions of water from the San Francisco Bay Delta to the state and federal water projects during the 1970s, could be determined through a decrease in freshwater outflow through the estuary, the impacts on fish were not immediately known. However, studies by the California Department of Fish and Game noted a decline in annual striped bass sports catch rates from over 750,000 in the early 1960s to approximately 52,000 fish in 1994. The DFG determined that the reduction in adult striped bass population was due to reduced recruitment of young fish and a decline in adult survival rates. This decline also correlated directly with the increase in Delta pumping. By 1998, catch rates had rebounded to approximately 295,000 fish, most likely as a result of increased fish abundance and renewed interest in the fishery. In recent years, recruitment has continued to increase as a result of improved survival of striped bass between the ages of zero and three.

Other measures of bay and estuarine health can be inferred through analysis of bioaccumulation of chemicals in fish species such as white sturgeon. Although this chapter does not directly address contaminant concerns, it remains that the overall health and abundance of bay and estuarine finfish species can serve as a looking glass into this often troubled environment.

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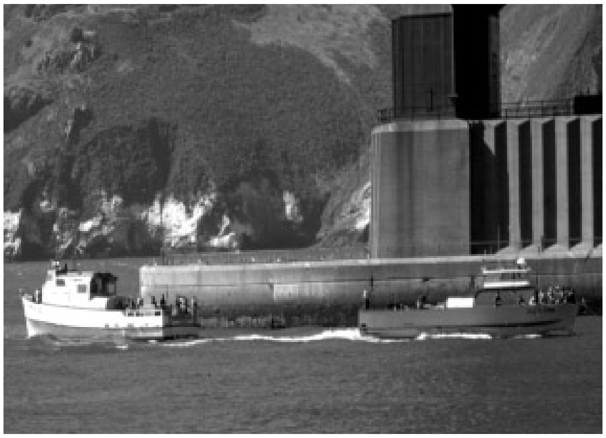


Sportfishing at Golden Gate Bridge for striped bass.
Credit: Chris Dewees, California Sea Grant Extension Program

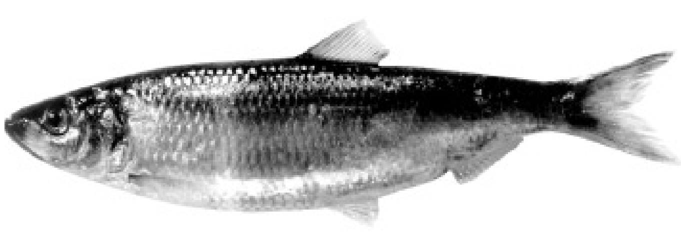
Pacific Herring

History of the Fishery

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

In 1973, sac-roe fisheries along the West Coast of North America from Alaska to California developed to supply the demands of the Japanese market. This occurred after domestic Japanese stocks crashed and Japan and the Soviet Union agreed to ban the harvest of sac-roe herring in the Sea of Okhotsk. The ban was enacted after these stocks were depleted by overfishing. The Japanese government also liberalized import quotas, which opened the sac-roe market to United States and Canadian exporters. Since then, herring in California have been harvested primarily for their roe, with small amounts of whole herring marketed for human consumption, aquarium food, and bait.

Herring ovaries (commonly referred to as "skeins" by those in the fishing indusrty) are brined and prepared as a traditional Japanese New Year's delicacy called "kazunoko." Brined skeins are leached in freshwater overnight and served with condiments or as sushi. Most herring taken in California are trucked from the port of landing to a processing plant for removal of skeins and brining and grading. Skeins are graded by size, color and shape, packed in plastic pails, exported for sale, and auctioned. Some herring are frozen and exported to China for processing where labor costs are low. Herring skeins from San Francisco Bay are typically smaller in size than those produced in British Columbia and Alaska but are highly valued for their unique golden coloration.



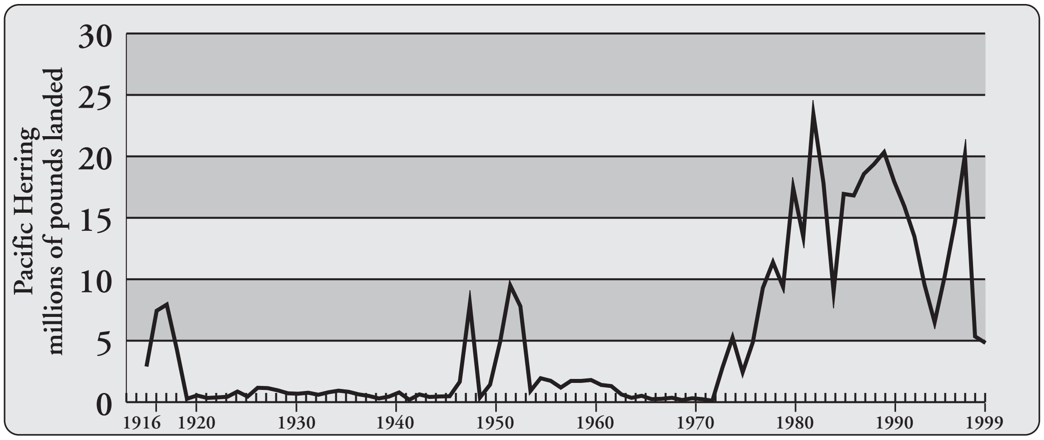
Pacific Herring, *Clupea pallasi*
Credit: DFG

California sac-roe herring landings peaked in the 1996-1997 season at 23.6 million pounds, and then fell to a record low harvest of four million pounds the following season. Ocean conditions due to the 1997-1998 El Niño produced herring in poor condition which were less susceptible to gillnet gear resulting in reduced landings. In addition, herring may have been displaced by changes in ocean currents, which are also attributed to El Niño, resulting in downswings of stock size. Stocks showed signs of rebuilding in the 1998-1999 season but declined again in 1999-2000 in spite of favorable La Niña conditions. Landings increased, however, to 6.8 million pounds in 1999-2000 season due to much improved physical condition of fish from the previous season.

The sac-roe fishery is limited to California's four largest herring spawning areas: San Francisco Bay, Tomales Bay, Humboldt Bay, and Crescent City Harbor. San Francisco Bay has the largest spawning population of herring and produces more than 90 percent of the state's herring catch. The four spawning areas are managed separately by the California Department of Fish and Game (DFG); catch quotas are based on the latest population estimates from acoustic surveys and spawning-ground surveys. Quotas are adjusted annually and are generally set at about 15 percent of the amount of herring expected to return to spawn at each spawning area. Since quotas are set before the start of the spawning season, they are conservative and allow for potential declines in herring biomass. If the herring biomass declines, and spawning escapement is less than expected, the landings may approach the department's recommended maximum harvest rate of 20 percent.

The sac-roe fishery is managed through a limited-entry system, which was implemented in the 1973-1974 season with 17 permits issued. Since 1983, only five new permits have been issued, and the number of annual herring permits has stabilized at just over 450. Approximately 400 of the permits are for the San Francisco Bay fishery in which an estimated 120 vessels participate. During the 1979-1980 season, the Fish and Game Commission decided not to issue any new round haul permits for the San Francisco Bay fishery with the intent of converting the sac-roe fishery to gillnet only by attrition. When it was clear that the number of round haul permits would not decline further due to the transferability of permits in 1988, the DFG developed a five-year conversion plan, which was implemented in the 1993-1994 season. The 1997-1998 season marked the completion of the San Francisco Bay sac-roe fishery conversion to a gillnet only fishery.

The sac-roe fishery, like many quota fisheries, is extremely competitive among fishermen and buyers for a share of the catch. Competition tends to breed innovation, especially with respect to gear, boats, and fishing practices



Commercial Landings 1916-1999, Pacific Herring
Data Source: DFG Catch Bulletins and commercial landing receipts.

in this potentially lucrative and high-pressure fishery. One of the more noticeable changes has occurred in boat design. The composition of the San Francisco fleet slowly evolved from converted wooden and fiberglass stern picking salmon trollers to fast state-of-the-art welded aluminum bow pickers, many outfitted with multiple jet drives and the latest in fish finding electronics. One piece of equipment that increased the efficiency of the gillnet fleet was the net shaker, a hydraulically driven drum with fins, working in concert with the net drum. This device shakes the net free of fish, eliminating the need to shake the net by hand. As a result of these and other changes, the sac-roe fleet has become very efficient.

Herring buyers pay fishermen based on the percentage of ripe skeins in the catch. This is calculated from several random 10-kilogram samples per landing taken by roe technicians. Each fish sampled is sexed and ripe skeins are extracted, placed on a scale and weighed. The total weight of the ripe skeins is then divided by 10 kilograms, resulting in the "roe count" or roe percentage. A typical "roe count" for the San Francisco fishery in January is 13 to 14 percent. The ex-vessel price paid is based on 10 percent yield, and is adjusted for percentage points above or below. A yield of 10 percent or higher is considered the minimum acceptable by the sac-roe buyers. In the year 2000, the base price for California herring with 10 percent roe yield was an estimated $500 per ton of whole fish. The base price for 10 percent roe count fish peaked at an estimated $2,000 per ton in 1979, when landing values reached as high as $4,000 per ton when adjusted for roe percentage. In recent years, the base price has ranged between $500 and $2,000 per ton. Since 1980, the ex-vessel seasonal value of the sac-roe catch in California has ranged from two million to 19.5 million dollars.

Another aspect of California's herring industry is the roe-on-kelp fishery. Beginning in 1965, scuba divers harvested species of algae with herring eggs attached from Tomales and San Francisco Bays. In the 1984-1985 season, a sac-roe permittee received a permit on an experimental basis to harvest roe-on-kelp using unenclosed floating rafts from which fronds of giant kelp are suspended. This product known as "komochi kombu" or "kazunoko kombu" is also a Japanese delicacy and prepared similarly to kazunoko. There are 11 roe-on-kelp permits for the 2000-2001 fishery in San Francisco Bay. Permits are available to permittees willing to trade their sac-roe permits for roe-on-kelp permits.

Currently, giant kelp is harvested from the Channel Islands off southern California or Monterey Bay, brought to San Francisco Bay, suspended from floating rafts or longlines hung beneath piers. Rafts are positioned in locations where herring spawning is expected to occur and then anchored. Once spawning has commenced, suspended kelp is left in the water until egg coverage is sufficient, or spawning has ended. In some instances, suspended kelp is harvested prematurely with less than optimum coverage because freshwater surface runoff may cause product deterioration.

Preliminary roe-on-kelp product grading is conducted by the permittee prior to harvest to determine if coverage is ample enough to warrant harvesting. Once the product is harvested, grading criteria such as the dimensions of the kelp blade, uniformity of egg coverage, thickness or number of egg layers, kelp condition, presence of eyed embryos, and the presence of silt are all used to determine the price paid to the fisherman. Roe-on-kelp has a per pound value much higher than herring roe. Ex-vessel prices range from $4 to $20 per pound.

Herring regulations changed yearly as the fishery expanded and new conflicts or issues were addressed. Management concepts new to commercial fishing in California were introduced as the herring fishery developed, such as limited entry, permits issued by lottery, individual vessel quotas, quota allocation by gear, the platoon system used to divide gillnet vessels into groups, the transferability of sac-roe fishery permits, and the conversion of round haul permits to gillnet permits. Many of these were controversial management decisions, but they have proven to be effective solutions to socioeconomic conflicts in a congested fishery.

Status of Biological Knowledge

Pacific herring occur within the coastal zone (waters of the Continental Shelf) from Baja California to Alaska and across the Pacific rim to Japan and China. Known spawning areas in California include San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor. California's largest spawning population of herring utilizes San Francisco Bay. Most spawning areas are characterized as having reduced salinity, calm and protected waters, and spawning-substrate such as marine vegetation or rocky intertidal areas; however, man-made structures such as pier pilings and riprap are also frequently used spawning substrates in San Francisco Bay.

Results of tag and recovery studies from Canada indicate that 25 percent of the herring may stray between adjacent spawning areas in British Columbia. The problem of stock identification has not been resolved in California, and it is not known whether adjacent spawning areas contain genetically distinct stocks. However, each spawning area in California where herring fishing is allowed is managed on the assumption that its spawning population is a separate stock.

During the spawning season (November through March), schools of herring enter bays and estuaries, where they may remain up to three weeks before spawning. School size varies but can be as large as tens of thousands of tons and miles in length in San Francisco Bay. Salinity is an important factor in the success of fertilization and embryonic development, and reduced salinity may act as a cue for spawning. When a school is ready to spawn, male herring initiate spawning by releasing milt. A pheromone in the milt triggers spawning by females which lay their adhesive eggs on suitable substrate. Fecundity is 220 eggs per gram of body weight, and a large female herring may lay 40,000-50,000 eggs. Female herring come in contact with the substrate while spawning, extruding a strip of adhesive eggs that is two to three eggs wide. Repeated passes by thousands upon thousands of females can build the eggs up to a thickness of four to five layers. Spawn depth distribution generally is shallower than 30 feet deep, but has been found to a depth of 60 feet in San Francisco Bay. A large spawning run may last a week and can result in 20 miles or more of the shoreline being covered by a 30-foot-wide band of herring eggs.

During the incubation period (about 10 days) embryos are vulnerable to predation by marine birds, fish, and invertebrates. They may also die from desiccation or freezing if exposed during low tidal cycles. Normally, between 50 and 99 percent of herring embryos die before hatching. Human induced causes of mortality at this stage include smothering caused by suspended sediments from dredging, and anti-fouling agents such as creosote.

Herring embryos hatch into larvae, which eventually metamorphose into juvenile herring. The distribution of larval herring in bays and estuaries is not well known, but juvenile herring from San Francisco Bay have been found as far inland as the Delta Pumping Plant at Tracy. Juveniles may remain in the bay until summer or early fall, when they migrate to the open ocean.

Some herring reach sexual maturity at age two when they are about seven inches in length; all are sexually mature at age three. California herring may live to be nine or 10 years old and reach a maximum length of about 11 inches, although fish older than seven are rare. Adult herring leave the bay immediately after spawning, and their distribution while in the ocean is not well known. Herring are sometimes caught in Monterey Bay in the summer, and are also caught by groundfish trawlers off Davenport (north of Santa Cruz) just prior to the spawning season.

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

Status of the Population

The size of herring spawning populations in Tomales and San Francisco Bays is estimated annually from hydroacoustic and spawning-ground surveys. Abundance fluctuates widely due to variations in recruitment (the first appearance of young fish, primarily two-year-olds, in the spawning population) caused by environmental factors that affect primary productivity, especially El Niño events. Since 1979, the San Francisco Bay herring biomass has ranged from a high of 99,050 tons to a low of 20,000 tons, with peaks occurring in 1982 (99,600 tons), 1988 (68,900 tons), and 1996 (99,050 tons). The lowest biomass estimates have occurred during or just after El Niño events – 40,800 tons in 1984, 21,000 tons in 1993, and 20,000 tons in 1998. The lack of upwelling and associated warm water conditions that occur during El Niño events reduces the production of food for herring, which can affect their condition and survival. It also may displace herring to areas of colder water. San Francisco Bay's population has not yet recovered from the affects of the 1997-1978 El Niño; spawning biomass was estimated at 27,400 tons in 2000.

The Tomales Bay spawning biomass estimates have ranged from a high of 22,163 tons in 1978 to a low of 345 tons in 1990 with a 26-year average of 4,671 tons per season. The season following the 1983 El Niño spawning biomass declined about 90 percent suggesting the herring population had not escaped the effects of that strong oceanic event. The next four years the population remained unstable with spawning escapement in Tomales Bay alternating between average and very poor. During the California drought, which lasted from 1987 to 1992, the herring spawning population severely declined in Tomales Bay. Consequently, the department closed the Tomales Bay commercial herring fishery from 1990 through 1992 to hasten the recovery of the stock. Spawning biomass in Tomales Bay averaged approximately 2,817 tons per season from 1993 through 1997; however, during the intense 1997-1998 El Niño, spawning biomass dropped to 586 tons. Although the Tomales Bay population rebounded to near normal levels the following season, the spawning biomass fell to 2,011 tons in 2000. Preliminary aging of Tomales Bay herring, caught during the 1999 and 2000 seasons, shows five- and six-year-old herring under represented in the spawning population. Because the Tomales Bay herring fleet has had a very low exploitation rate since the 1997-1998 season, the scarcity of older fish in the population is most likely related to oceanic conditions – not overfishing.

Humboldt Bay's spawning population has not been assessed since the 1990-1991 season, when 400 tons was estimated to have spawned. This population supported a small, but successful fishery with a 60-ton quota for many years. However, over the last 12 years fishermen have observed a decline in the spawning population, and in the last five years fishing effort has also declined. Only one of the four permits issued for Humboldt Bay has been used to fish in the last three seasons. It has been suggested that aquaculture impacts to eelgrass, the primary spawning habitat for herring in Humboldt Bay, may have contributed to the observed decline.

Individual spawning runs have been estimated in Crescent City Harbor, but no seasonal population estimates have ever been made for the area. The success of the small fishery that occurs there depends on the size of schools that appear. Because of the fishing methods used and large local populations of harbor seals and sea lions, it is very difficult for fishermen to catch fish from small schools.

Management Considerations

See the Management Considerations Appendix A for further information.

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Striped Bass

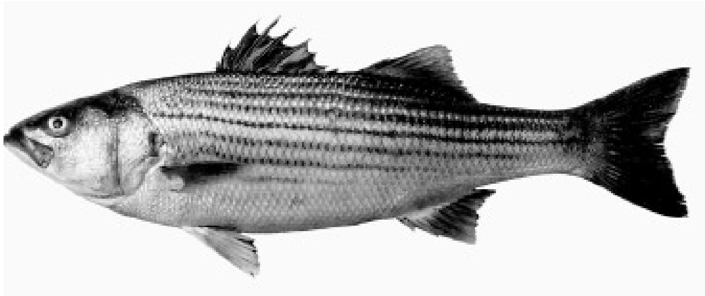
History of the Fishery

In 1879, 132 young striped bass (*Morone saxatilis*) from the Navesink River, New Jersey were released into the San Francisco Bay estuary at Carquinez Strait. A second plant of 300 fish from the Shrewsbury River, New Jersey followed in 1882. Shortly after these introductions, striped bass experienced a population explosion in the estuary. Commercial harvesting started in the early 1880s, and by the turn of the century, exceeded one million pounds annually. The greatest recorded commercial catch, over two million pounds, occurred in 1903. Subsequently, annual catches declined due to increased restrictions on the fishery.

In 1935, the commercial fishery for striped bass was closed, although the stock was not depleted. The closure stemmed largely from a social conflict between sport and commercial fishing interests which culminated in the closure of the commercial gillnet fisheries for chinook salmon and American shad in 1957. Thousands of striped bass that could not be legally marketed were killed annually in nets fished for these two species. Closure of the salmon and shad fisheries reduced fishing mortality for striped bass, but the magnitude of the reduction cannot be estimated because the precise extent of the incidental harvest is unknown. Some illegal netting continues today.

The striped bass sport fishery has become the most important fishery in the San Francisco Bay estuary and one of the most important fisheries on the Pacific Coast. From 1969 to 1996, a general decline in catch was associated with a decline in striped bass abundance. Over this period, the annual catch varied from about 444,000 fish in 1975 to 52,000 fish in 1994. During the early 1960s, the annual catch of striped bass was even larger, probably around 750,000 fish. In 1985, an economist estimated the annual value of the striped bass fishery to exceed 47 million dollars.

Striped bass angling occurs year-round, but fishing localities vary seasonally in accordance with the striped bass migratory pattern. Tag recoveries indicate that many adults inhabit salt water San Pablo Bay, San Francisco Bay, and the Pacific Ocean in the summer. The proportion entering the ocean varies from year to year. These fish begin returning to the delta in the fall.



Striped Bass, *Morone saxatilis*
Credit: DFG

The distribution of fishing effort and catch has changed substantially over the years. Before the late 1950s, little fishing occurred in San Francisco Bay and the Pacific Ocean. Most of the catch came from San Pablo and Suisun bays, the delta, and rivers upstream. From the late 1950s to early 1980s, however, post-spawning striped bass generally migrated farther downstream and stayed there longer. Thus, fishing improved in San Francisco Bay and the Pacific Ocean and declined in the delta. Also, the use of the Sacramento River as a spawning area appeared to have increased, improving fishing there in the spring. In the 1980s and much of the 1990s, the migrations shifted upstream again with Suisun Bay and the delta providing the bulk of the catch. However, in 1998 and 1999, fishing once again improved substantially in San Francisco Bay and the ocean. While significant environmental changes have occurred, data are insufficient to develop conclusions regarding causes of these changes in striped bass migrations.

Based on tag returns, in the 1970s private boat anglers accounted for about 63 percent, shore anglers for 19 percent, and commercial passenger fishing vessels for 18 percent of the annual striped bass catch. By the 1990s, the private boat portion of the catch changed little (64 percent), but the commercial passenger fishing vessel portion decreased to nine percent and the shore catch increased to 27 percent of the total.

Striped bass are generally caught by bait fishing or trolling, although under some conditions fly-fishing or casting plugs or jigs is effective. Common dead baits include threadfin shad, anchovies, cut sardines, staghorn sculpins (bullheads), gobies (mudsuckers), shrimp, blood worms, and pile worms. Drift fishing with live anchovies or shiner perch is popular in San Francisco Bay and the Pacific Ocean, and live golden shiner minnows or theadfin shad are sometimes are used in the delta. Trolling methods are specialized. Many types of plugs, jigs, and spoons are used in trolling, frequently in double combinations.

Present fishing regulations include an 18-inch minimum length and a daily bag limit of two fish. From 1956 to 1981, the minimum length was 16 inches and the bag limit was three fish. Prior to 1956, regulations were more liberal. A 12-inch minimum length and five-fish bag limit generally was in effect.

Exploitation rates have been estimated almost annually since 1958. They have varied from nine percent (1989, 1992, and 1994) to 28 percent (1963) except for an unusually high 37 percent in 1958. Exploitation in the San Francisco Bay estuary is lower than for historic exploitation on commercially fished Atlantic Coast stocks, which were exploited at rates as high as 50 to 70 percent annually before a severe population decline in the 1980s led to very restrictive regulations, included fishing moratoriums.

While the primary California population of striped bass is located in the San Francisco Bay estuary, striped bass also have been introduced into many other areas including the lower Colorado River, several reservoirs, and the Pacific Ocean in southern California. Conditions are generally not suitable for striped bass spawning in the reservoirs or in marine waters off southern California, so those fisheries usually depend on maintenance stocking from hatcheries. However, at least two reservoir populations, Millerton and New Hogan, do reproduce successfully. A striped bass fishery also has developed in reservoirs which are part of the State Water Project (SWP) and the federal Central Valley Project (CVP), such as San Luis Reservoir, O'Neill Forebay, and Pyramid and Silverwood lakes. These reservoirs are unintentionally stocked by young bass contained in water diverted from the Sacramento-San Joaquin Delta, and their fisheries have also declined in response to the decline of the "source" San Francisco Bay estuary population.

Status of Biological Knowledge

Spawning and Early Nursery Period. Striped bass begin spawning in the spring when the water temperature reaches 60˚ F. Most spawning occurs between 61˚ and 69˚ F, and the spawning period usually extends from April to mid-June. They spawn in fresh water where there is moderate to swift current. The section of the San Joaquin River between the Antioch bridge and the mouth of the Middle River, together with the other channels in the area, is one very important spawning ground. Another is the Sacramento River from Sacramento to Colusa. About one-half to two-thirds of the eggs are spawned in the Sacramento River and the remainder in the San Joaquin River system. Female striped bass usually spawn for the first time in their fifth year when they are 22 to 25 inches long. Many males mature when two years old and only about 11 inches long. Most males are mature at age three.

Stripers are very prolific. A five-pound, five-year-old female may spawn as many as 250,000 eggs in one season, and a 12-pound, eight-year-old fish is capable of producing over a million eggs. Some striped bass live for more than 20 years; these fish may exceed 50 pounds in weight and spawn several million eggs. Because of this great reproductive potential, striped bass were able to establish a large population within a few years after their introduction in California.

Striped bass typically spawn in schools at night during periods of warm weather when water temperatures rise. On one occasion, DFG biologists observed several thousand striped bass at the surface along the bank of the Sacramento River above Knights Landing. Small groups of from three to six bass were observed splashing and churning in the main current of the river in the act of spawning. At times, five or more groups of bass were observed spawning at one time. Usually a large female was accompanied by several smaller males.

During the spawning act, eggs and milt are released into the water. The milt contains microscopic sperm cells that penetrate the eggs and cause them to begin to develop. While the eggs are still in the female they are only about 0.04 inch in diameter, but upon their release they absorb water and increase to about 0.13 inch in diameter. At this time, they are so transparent that they are virtually invisible.

Striped bass eggs are only slightly heavier than water; so a moderate current will suspend them while they develop. Without any water movement they sink to the bottom and die. The larval bass hatch in about two days, although the length of time depends upon the temperature. Development is faster when the water is warmer.

The newly hatched bass continue their development while being carried along in the water. At first, the larval bass subsist on their yolk, but in about a week they start feeding on tiny crustaceans, which are just visible to the naked eye. After several weeks, they begin feeding on larger invertebrates, such as opossum shrimp and amphipods. At this time, they generally inhabit the delta and Suisun Bay. By late July or August, the young bass are about two inches long.

Status of the Population

Young Striped Bass Abundance

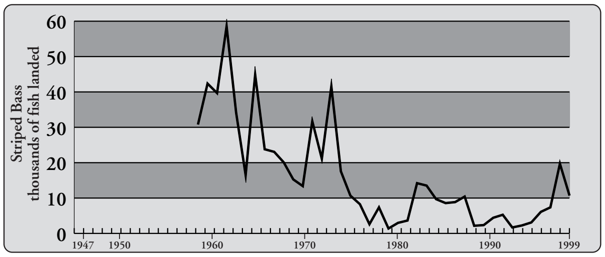
Reduced juvenile production was the principal cause of the adult striped bass population decline between the early 1970s and the early 1990s. Since 1959, the DFG has sampled young-of-the-year striped bass each summer (except 1966). An extensive survey is conducted every second week from late June to late July or early August throughout the nursery habitat. The fish are measured, and when their mean fork length reaches 1.5 inches, a young-of-the-year index is calculated on the basis of catch-per-net-tow and the volume of water in the areas where the fish are caught.

Young-of-the-year striped bass abundance has suffered an erratic but persistent decline from high index levels sometimes exceeding 100 in the mid-1960s to the all time low of only 1.4 in 1998. From 1959 to 1976, average abundance of young striped bass was more than three times the subsequent average abundance.

Substantial effort has gone into evaluating factors controlling young striped bass production. Initially (1959-1970), annual fluctuations in young bass abundance could be explained by a simple model based on delta freshwater outflow which indicated that young bass production was much greater in years with high spring-early summer flows than in years with low flows. The mechanism causing the most abundant year classes to occur under high flow conditions was unknown. However, one potential explanation was that when flows were high, a lower percentage of the flow to the delta was diverted by the combination of major water projects (CVP and SWP) and local delta agriculture. Hence, under those conditions, fewer young bass would be entrained in diverted water and removed from the estuary. Other potential explanations for the greater abundance in high flow years included: 1) expansion of the nursery area resulting in greater habitat availability and less competition; 2) higher food production; 3) dilution of toxicity; and 4) reduction in predation losses due to more turbid conditions.

In the early 1970s, production of young bass began to fall below the levels expected based on the initial models, and this decline was most acute in the delta portion of their nursery. During this period the SWP and CVP substantially increased their water export from the delta, resulting in greater diversion rates being associated with any particular flow. Minimum estimates of losses, which do not include fish smaller than 0.8 inches, in these water exports were approximately 10 to 30 million young striped bass annually. Maximum loss estimates approached or exceeded 100 million young bass in some years. Contrasting these losses with estimates of abundance at the 1.5-inch stage of about 15 to 30 million fish indicates that significant population impacts could be expected. Potential effects were taken into account by developing a new model which considered the delta and Suisun Bay separately and included both outflow and diversion terms in the delta portion of the model. This model yielded reasonable predictions of young bass abundance from 1959 to 1976 and provided additional evidence that losses of young fish to diversions were an important factor regulating striped bass abundance.

However, since 1977, abundance of young striped bass has been considerably lower than predicted by the 1959-1976 model. Scientists representing various interests, including the DFG, water user groups, universities, and the Oak Ridge National Laboratory, have extensively evaluated potential causes of this decline in abundance, and generally agree that reduced egg production by the smaller population of adults likely is part of the explanation. However, consensus has not been reached on the relative importance of various factors that may be at the root of the problem. These factors include losses of young fish to water exports, shortages of important food organisms possibly limiting survival of young bass, toxic chemicals and trace metals inhibiting reproduction and reducing survival, and a shift in global climate possibly resulting in adults straying from the estuary. It has also been suggested that the effect of water exports and adverse factors associated with salinity encroachment may be reduced by density-dependent mortality after the first summer.



Recreational Catch 1947-1999 , Striped Bass

CPFV = commercial passanger fishing vessel (Party Boat); Recreational catch from CPFV Logs for Ocean and San Francisco Bay (Sacramento-San Joaquin Delta catches are not included until 1964), CPFV catch was not reported prior to 1960.

Adult Striped Bass Abundance

The decline of the striped bass fishery in the San Francisco Bay estuary between the early 1960s and the present is a direct result of a substantial decline in the striped bass population. The California Department of Fish and Game (DFG) has measured adult (larger than 18 inches, about three years old) striped bass abundance with mark-recapture (tagging) population estimates since 1969.

According to the estimates, the striped bass population averaged about 1.7 million adults between 1969, when the estimates began, and 1976. Abundance declined to as little as 600,000 adults in the early 1990s, but had increased to about 1.3 million in 1998. A combination of much greater catches by the fishery and tag returns suggest that the striped bass population had about three million adults in the early 1960s. The reduction in the adult stock through the early 1990s was principally due to reduced recruitment of young fish. Increased abundance in the late 1990s is unexplained, but may be due to factors allowing greater survival of young fish until they are recruited to the fishery.

Fishery Restoration

As a result of the initial decline in estimated legal-sized striped bass abundance in the late 1970s, and also in response to public pressure for supplementation stocking, the DFG began a hatchery program starting with the 1980 year class that were stocked as yearlings in 1981. The number of fish stocked increased from about 63,000 for the 1980 year class to almost 3.4 million for the 1990 year class.

The hatchery program changed substantially in 1992 as the result of concern over potential predation by striped bass on threatened and endangered species, such as Sacramento River winter-run chinook salmon and delta smelt, and all stocking of hatchery-reared striped bass was suspended (age-one fish from the 1991 year class were not stocked in the estuary). Instead, 22,000-284,000 fish obtained from fish screens in the southern Sacramento-San Joaquin Delta and reared in floating pens have been stocked annually, beginning with the 1992 year class released as yearlings in 1993. Most years, a fraction of the stocked fish have been externally marked or coded-wire tagged to allow estimation of their contribution to the population.

Hatchery fish have contributed measurably to the population of each year class in the estuary, especially at the higher stocking levels. Estimated percentage of hatchery-reared striped bass in each year class increased from about one percent for the 1981 year class to about 31 percent for the 1989 year class. More recently, fish reared in floating pens have contributed about four percent of the 1994 year class and about 13 percent of the 1996 year class.

Greater stocking of age-one and age-two striped bass (up to 1.275 million age-one equivalents) reared in hatcheries and pens began in summer 2000. This stocking is the focus of a Striped Bass Management Conservation Plan prepared according the federal Endangered Species Act requirements. It is designed to maintain the striped bass population and sport fishery at the present level and to be consistent with recovery of listed species.

Due to the greater genetic diversity of naturally produced fish, the DFG's priority is to stock fish salvaged at the SWP and CVP fish screens in the southern delta and reared for one or two years in net pens floating in the estuary. However, it is unlikely that numbers of salvaged fish will consistently be sufficient to fully support the program, so in most years, net-pen-reared fish will be supplemented with fish produced by aquaculture.

Striped bass spawn primarily during May, but salvaged fish are not available until late May through July. Thus, each year, the number of salvaged fish available for pen rearing will not be known until after artificial spawning would have to occur. The DFG will attempt to ensure sufficient availability of fish each year by contracting with private aquaculturists to begin raising sufficient fish for most of the allotment. After the number of salvaged fish is known, excess aquaculture fish would be disposed of, or perhaps used elsewhere by the DFG or aquaculturists (*e.g.*, reservoir stocking or food market). However, past experience suggests that in spite of efforts to ensure a sufficient supply of fish, stocking goals will not always be met.

Sufficient quantities of these stocked striped bass will be marked to allow evaluation of their contribution to subsequent adult populations and the relative benefits of: 1) conventional aquaculture and pen rearing; and 2) stocking age-one and age-two fish.

Other actions by the DFG include: 1) working through the CALFED Bay-Delta program to plan and implement ecosystem restoration measures that will benefit a spectrum of species, including striped bass; 2) negotiating for mitigation from owners of power plants in the estuary for losses caused by power plant operations and for mitigation from the California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) for losses at their pumping plants; and 3) increasing study effort to improve understanding of processes controlling striped bass abundance, with study funding coming from several sources including the DWR, USBR, State Water Resources Control Board, Federal Aid to Sport Fish Restoration funds, and sales of striped bass stamps required of all striped bass anglers.

Management Considerations

See the Management Considerations Appendix A for further information.

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Green Sturgeon

History of the Fishery

Historically, the green sturgeon (*Acipenser medirostris*) resource has been of minor importance to Californians, although they may have been more important to American Indians in the north coast area. An early commercial fishery developed for sturgeon in the San Francisco Bay estuary between the 1860s and 1901, stimulated by a growing acceptance of smoked sturgeon and caviar on the East Coast of North America. However, green sturgeon probably were a minor component of that fishery, as they were considered to be of inferior quality and were actually claimed by some people to be poisonous. The commercial fishery was closed in 1901, then reopened from 1909 to 1917. Commercial sturgeon fishing in California ceased in 1917.

Sport fishing for green sturgeon was legalized in 1954, with a 40-inch total length minimum size limit and a one fish per day per person creel limit. In 1956, snagging for sturgeon was outlawed and the minimum size limit was raised to 50 inches through 1963. The sport fishery for green sturgeon in California is small, being overshadowed by the sport fishery for white sturgeon in the San Francisco Bay estuary and its tributaries and by the tribal green sturgeon fishery in the Klamath River. Exact sport catch data are not available. However, concern about potential over-harvest of white sturgeon in the late 1980s led to angling regulation changes starting in 1990 that instituted a 72-inch maximum size limit and increased the minimum size limit by two inches per year until a new minimum size of 46 inches was reached in 1992. These regulation changes have also benefitted green sturgeon.

Status of Biological Knowledge

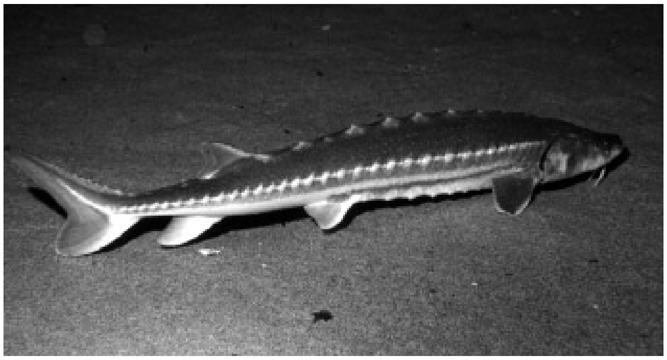
Green sturgeon are generally found in marine waters from the Bering Sea to Ensenada, Mexico. However, spawning populations have been found only in medium-sized rivers from the Sacramento-San Joaquin system north; spawning has not been documented in either the Columbia or Fraser rivers. Green sturgeon apparently spend much less time in the San Francisco Bay estuary than white sturgeon, either as young or adults. Adult green sturgeon probably enter the estuary and move up the Sacramento River in early spring. Spawning occurs as far upstream as the area above Red Bluff Diversion Dam, which is now open to allow fish passage during part of the green sturgeon spawning period. Anecdotal evidence suggests that spawning may also occur in the Feather River but has not yet been documented there. Almost all recoveries from a tagging program in the San Francisco Bay estuary have come from outside the estuary, primarily from rivers and coastal areas in Oregon and Washington.

California green sturgeon grow rapidly when young, probably reaching 12 inches fork length in one year. Juvenile green sturgeon raised in captivity grow substantially faster than white sturgeon raised under similar conditions. Relatively rapid grow continues until they reach 51-55 inches in about 15-20 years. Maximum size in the Klamath River in recent years has been about 90 inches and about 180 pounds, but historical accounts report fish up to 350 pounds. Like white sturgeon, their growth is likely affected by water temperature and dissolved oxygen concentration. The largest recently captured fish from the Klamath River were estimated to be about 40 years old.

Compared with most freshwater or anadromous fishes, green sturgeon are quite old (15-20 years) when they become sexually mature. Fecundity varies with female size, ranging from 60,000-140,000 eggs per female. These values are lower than for white sturgeon, both because green sturgeon are smaller than white sturgeon and because green sturgeon eggs are larger than white sturgeon eggs.

Spawning occurs in the Sacramento River between March and June; it may extend slightly longer, into July, in the Klamath River. Water temperature during spawning is likely 50° to 70°F. Little is known about spawning behavior. Spawning occurs in deep, fast water. The fertilized eggs are slightly adhesive and hatch after four to 12 days. Larvae stay close to the bottom and appear to rear primarily in rivers well upstream of estuaries. Under hatchery conditions, larval green sturgeon remain near the bottom and do not move up into the water column where they could be transported downstream. Most young green sturgeon migrate from river to ocean when they are one to four years old, which may partly explain their relative scarcity in the San Francisco Bay estuary.

Green sturgeon feed on a variety of bottom-dwelling animals. Sturgeon feed by suction with their ventral, protrusible mouths. Dense aggregations of taste buds on their four barbels presumably assist in identification of food on the bottom. Young sturgeon (eight inches) feed pri-



Green Sturgeon, *Acipenser medirostris*
Credit: DFG

marily on small crustaceans such as amphipods and opossum shrimp. As they develop, they take a wider variety of benthic invertebrates, including various species of clams, crabs, and shrimp. Larger green sturgeon diet includes fishes.

Little is known about predators on green sturgeon. Smaller fish are undoubtedly taken by various fish and bird predators, although the five lines of sharp, bony scutes along their bodies probably make them less desirable prey than most other species. Information from the Columbia River suggests that total mortality of green sturgeon is less than for white sturgeon.

Status of the Population

Because green sturgeon spend most of their lives in the ocean and are not readily available to the sport fishery or sampling programs in estuaries or rivers, their population status is difficult to determine. Although green sturgeon have never been abundant, limited evidence suggests that the overall population may have declined in California. This is supported by the apparent extirpation of the species from some rivers, such as the Eel and South Fork Trinity, leaving the Sacramento, Klamath, and mainstem Trinity rivers as the only documented spawning streams in California, along with the Rogue and Umpqua rivers in Oregon. However, abundance estimates in the San Francisco Bay estuary, based on mark-recapture estimates of white sturgeon abundance and the ratio of white to green sturgeon in tagging catches, do not suggest that the population has declined in that system. Additionally, the recent opening of the Red Bluff Diversion Dam gates during much of the spawning period has provided green sturgeon with access to additional spawning area upstream of Red Bluff. Catches of juvenile green sturgeon during sampling for downstream-migrant chinook salmon smolts at the dam in midsummer indicates that they have taken advantage of this additional spawning habitat. The number and size distribution of green sturgeon caught incidental to a commercial salmon fishery in the lower Columbia River leads Oregon biologists to suggest that "tens of thousands" of green sturgeon inhabit the ocean offshore of Oregon and Washington.

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White Sturgeon

History of the Fishery

Historically, the white sturgeon (*Acipenser transmontanus*) resource has been very important to Californians. Sturgeon scutes and skull plates are found in Native American middens in the San Francisco Bay, Sacramento-San Joaquin delta, and Elkhorn Slough areas, indicating that these large fish were important sources of tribal nutrition. An early commercial fishery developed for white sturgeon between the 1860s and 1901, stimulated by a growing acceptance of smoked sturgeon and caviar on the East Coast of North America. The California harvest was concentrated in the San Francisco Bay and delta. Fishing gear included gillnets, longlines, and multiple unbaited hooks for snagging sturgeon. The commercial catch peaked at 1.65 million pounds in 1887, declined to 0.3 million pounds in 1895, and to 0.2 million pounds in 1901, when the commercial fishery was closed. Small commercial catches in a reopened fishery from 1909 to 1917 indicated that white sturgeon populations were still low, and commercial fishing ceased in 1917.

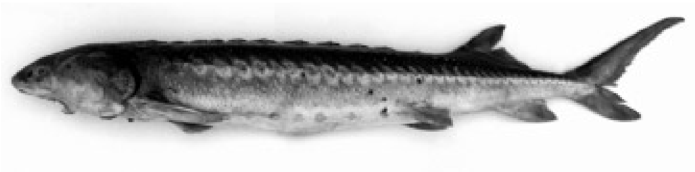
Sport fishing for white sturgeon was legalized in 1954, with a 40-inch total length minimum size limit and a one fish per day per person creel limit. In 1956, snagging for sturgeon was outlawed and the minimum size limit was raised to 50 inches through 1963. The small sport fishing catch increased dramatically in 1964 when the minimum size reverted to 40 inches and bay shrimp were discovered to be effective bait. By 1967, 2,258 sturgeon were landed by party boat anglers. Possibly due to reduced stocks of other estuarine and coastal marine species such as striped bass, angling for white sturgeon has become very popular. Although exact sport catch data are not available, the California Department of Fish and Game (DFG) estimates that the harvest rate during the 1980s was 40 percent greater than it was during the previous two decades. In 1990, a 72-inch maximum size limit became law and the minimum size limit was increased by two inches per year until a new minimum size of 46 inches was reached in 1992.

Status of Biological Knowledge

White sturgeon are generally found in estuaries, and their range extends along the Pacific Coast of North America from Ensenada, Mexico, to the Gulf of Alaska. However, spawning populations have been found only in large rivers from the Sacramento-San Joaquin system north. Indeed, most California white sturgeon are found in the San Francisco Bay estuary. Some white sturgeon move into the delta and lower Sacramento River during late-fall and winter. Some of these fish move up the Sacramento River to the Knights Landing-Hamilton City area to spawn. Spawning may also occur in the Feather River, but has not yet been documented there. A small number move up the San Joaquin River. The Klamath River supports the other California subpopulation of white sturgeon. Although most recoveries from a tagging program in the San Francisco Bay estuary have come from the estuary and its tributaries, a few fish (less than one percent of total recoveries) have moved along the Pacific Coast and been recovered in Oregon and Washington.

California white sturgeon grow rapidly when young, reaching 12 inches fork length in one year. This rapid growth slows thereafter and they reach the present minimum legal size of 46 inches after nine to sixteen years. Subsequently, they grow one to 2.5 inches per year. Ages and growth rates of field-caught fish have been determined from the number and spacing of annular rings, visible in sections of first pectoral fin rays. Laboratory experiments have shown that young-of-the-year white sturgeon growth is affected by water temperature and dissolved oxygen concentration. They grow significantly faster at 68°F than at 59°F, but an increase to 77°F does not significantly increase growth rate. When dissolved oxygen concentrations drop to 56 percent of air saturation at any of these three temperatures, juvenile fish show a significant decrease in growth rate, presumably due to reduced food consumption. The white sturgeon's rapid growth rate has attracted the interest of some California aquaculturists, who grow sturgeon in freshwater tanks which have consistently moderate temperatures and high dissolved oxygen concentrations.

The largest sturgeon were caught before 1900 when size records were vague. However, the largest of these fish was probably more than 13 feet long and weighed more than 1,300 pounds, making white sturgeon the largest freshwater-inhabiting fish in North America. This fish may have been 100 years old. The largest white sturgeon captured in California waters during the past 40 years was a 468-pound fish caught by a sport angler in Carquinez Strait in 1983. This fish is the present world record sport-caught white sturgeon. In a University of California, Davis (UCD) study of white sturgeon during the 1980s, many fish were caught, measured, examined for sex and stage of maturity, and released. Median male size was 3.6 feet and median female size was 4.6 feet in San Francisco Bay.



White Sturgeon, *Acipenser transmontanus*
Credit: DFG

Compared with most freshwater or anadromous fishes, white sturgeon are quite old when they become sexually mature, but they evidence impressive fecundity at this large size. In the UCD study during the 1980s, sexually mature males were 3.6 to 6.0 feet long (nine to 25 years old), whereas mature females were generally 4.6 to 6.6 feet (14 to 30 years old). However, high natural variability in the size at sexual maturity was noted, especially among females. For example, the smallest pre-spawning female white sturgeon weighed only 25 pounds, whereas a 120-pound female was caught which, from gonadal analysis, was determined to have not yet spawned. Studies suggest that white sturgeon females do not spawn every year. Several years may lapse between successive spawnings in an individual female. In the study on San Francisco Bay fish, approximately 50 percent of the males captured were approaching spawning condition for that year, compared with only about 15 percent of the captured females. Fecundity varies with female size. Smaller females (under five feet) contain about 100,000 eggs, whereas a 9.2-foot, 460-pound female contained 4.7 million eggs.

Spawning occurs in the Sacramento River between mid-February and late May when water temperatures are 46° to 72°F. Little is known about spawning behavior. White sturgeon spawn their eggs onto deep gravel riffles or rocky holes in the Sacramento River. The fertilized eggs are very adhesive and hatch after four to 12 days on the bottom. Larvae stay close to the bottom and rear in both the river and the estuary downstream. Rearing location is at least partly determined by river flow; more larvae are washed into the estuary when freshwater flows are high. Young juvenile sturgeon become increasingly tolerant of brackish water as they grow and develop.

White sturgeon feed on a wide variety of bottom-dwelling animals. Sturgeon feed by suction with their ventral, protrusible mouths. Dense aggregations of taste buds on their four barbels presumably assist in identification of food on the bottom. When their mouths are blocked by food, white sturgeon can ventilate their gills by flushing water in via the dorsal part of the gill slit and out via the ventral part. Young sturgeon (eight inches) feed primarily on small crustaceans such as amphipods and opossum shrimp. As they develop, they take a wider variety of benthic invertebrates, including various species of clams, crabs, and shrimp. Larger white sturgeon diet includes fishes and, during winter in San Francisco Bay, herring roe.

Little is known about predators on white sturgeon. Smaller fish are undoubtedly taken by various fish and bird predators, although the five lines of bony scutes along their bodies probably make them less desirable prey than other estuarine species. Anglers undoubtedly mount the largest predatory effort on adult fish.

Status of the Population

The 19th century history of white sturgeon fishing in California waters shows this species' vulnerability to overfishing. Delayed sexual maturity and infrequent spawning by the females exacerbates this vulnerability compared to many other fishes. DFG tagging studies indicated that angler harvest was high during the 1980s and new size limits (including initiation of a first-ever maximum size limit in 1990) reflect DFG's management concerns. Annual harvest rate estimates indicate that the angling regulation changes begun in 1990 have had the desired effect: harvest rates have been reduced by at least half from the levels of the mid- to late 1980s

Adult (at least 40 inches total length) white sturgeon abundance, as estimated from tagging studies, varied greatly between 1967 and 1998. The abundance estimate reached its highest level (142,000) in 1997. This abundance pattern is largely the result of irregular recruitment to the adult population by highly variable year classes. Strong year classes are produced in years with high spring freshwater outflows from the Sacramento-San Joaquin Delta, so much of the present high white sturgeon abundance is attributable to the very wet 1982-1983 period.

Unfortunately, the severe drought that gripped California from 1987 to 1992 will soon begin to affect the adult white sturgeon population, because reproductive success was low in most of those years. The strong year classes from the early 1980s were recruited starting in about 1994 and, by 1997 and 1998, few fish smaller than the minimum size limit of 46 inches were caught. Thus, the population should decline substantially as recruitment almost ceases and growth and mortality reduce the abundance of fish now in the fishable population. However, another cycle of strong recruitment can be expected when fish from a series of wet years starting in 1993 begin to enter the fishery late in the next decade.

The present low exploitation rates, past rapid recoveries from population lows in the mid-1970s and early 1990s, and current protection of the most fecund females by the 72-inch maximum size limit suggest that no further angling restrictions are needed at this time.

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Angler holding a white sturgeon
Credit: DFG

Cow Sharks

History of the Fishery

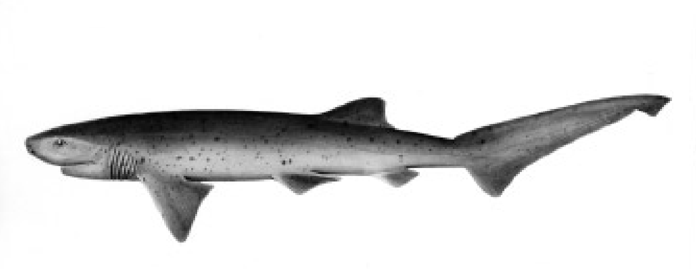
Two species of cow sharks (Family Hexanchidae) occur along the California coast, the sixgill shark (*Hexanchus griseus*) and sevengill shark (*Notorynchus cepedianus*). Sevengill sharks were among the most common species taken during shark fisheries of the 1930s and 1940s. Even after this fishery collapsed, these sharks were taken in considerable numbers during fishing competitions in San Francisco Bay in the 1950s and 1960s. The popularity of *Jaws* movies in the mid-1970s brought renewed interest in shark fishing. Several operators in the San Francisco Bay area targeted their charters on sevengill sharks, and as recently as the mid-1980s, these sharks were still the object of a popular sport fishery in San Francisco Bay. This fishery declined in the late 1980s and early 1990s, as charter boats began to target other species. Although caught primarily by recreational anglers, sevengills are caught incidentally in commercial fisheries for other species.

The sixgill shark is also an incidental catch, especially in trawl and gillnet fisheries. It frequently appears in fish markets and at dining establishments, but exact data on the extent of this fishery is lacking. Both species are typically either discarded or sold as "shark, unidentified," making it difficult to quantify landings.

Status of Biological Knowledge

The sevengill shark is a fairly common coastal species that frequently enters bays and, although rarely occurring below depths of 330 feet, is found occasionally to depths of over 660 feet. It seems to be most abundant where the water temperature lies between 54˚ and 64˚F. It tends to prefer rocky reef habitats where kelp beds thrive, though it is commonly caught over sandy and mud bottoms. Although relatively common at times of the year in Humboldt and San Francisco bays, very little is known about movement patterns along the open coast.

In the eastern North Pacific, sevengill sharks range from southeast Alaska to the Gulf of California, with their distribution becoming sporadic south of San Francisco Bay. The sevengill shark has a worldwide distribution in most temperate seas, the only notable exception being its absence from the temperate waters of the North Atlantic.



Sixgill Cow Shark, *Hexanchus griseus*
Credit: DFG

Sevengill sharks are ovoviviparous, with 80 to 100 young being born per pregnancy. The young are born during the spring following a two-year reproductive cycle. Humboldt Bay and San Francisco Bay serve as important pupping and nursery grounds. The young remain within the vicinity of these nursery grounds for the first few years of life, before ranging afield upon entering adolescence. Males mature between five and six feet, and grow to a maximum size of 8.25 feet. Females mature between 7.25 and 8.25 feet and grow to at about 10 feet. The size at birth is between 14 and 18 inches.

Juvenile sevengills grow quite rapidly during the first two years of life, more than doubling their length. This rapid growth rate by juveniles in the nursery ground enhances their chance of survival since a sevengill over 28 inches has fewer predators than a newborn half its size. In contrast to the rapid growth of juveniles, once maturation begins their growth rate slows down considerably.

The sevengill shark is an active predator that feeds at or near the top of the food chain. The main prey items include other sharks, skates, rays, bony fishes, and marine mammals. Sevengills have been observed to employ a variety of foraging strategies when hunting for food. As a solitary hunter, they will use stealth to ambush smaller prey items, but while hunting larger prey, these sharks will hunt cooperatively in packs to subdue seals, dolphins, other large sharks and rays. White sharks are one of the few known predators on adult sevengill sharks and have been observed to attack them on occasion. In most areas where it occurs, the sevengill shark is displaced only by the white shark and killer whale as the top nearshore marine predator.

The sixgill shark is one of the widest ranging of all shark species, with a circumglobal distribution from northern and temperate areas to the tropics. In the eastern North Pacific, this species occurs from the Aleutian Islands to southern Baja California. This is a deepwater shark; adults are found along the continental shelf and upper slopes down to at least 8,250 feet deep. They are known to move up to a thousand feet off the bottom, occasionally coming to the surface. Juveniles are often caught close inshore, including enclosed bays such as Humboldt and San Francisco, while adults are normally taken in deeper water. These sharks seem to associate themselves with areas of upwelling and high biological productivity.

Sixgill sharks are ovoviviparous with observed litters of 47 to 108. Adult females move onto the continental shelf during the spring to drop their litter following a two-year reproductive cycle. Young sixgills usually remain on the shelf and uppermost slopes until they reach adolescence, at which time they move further down the slope and into deeper water. It is the newborns and juveniles that typically seem to stray close inshore and occasionally occur in bays and harbors. Adult males typically remain in deeper water, where mating and courtship takes place. Males mature at about 10 feet, while females mature at about 14 feet. This is a large shark with males reaching at least 11.5 feet and females at least 15.8 feet. The size at birth is between 24 and 29 inches. Little is known about their growth rate, although juveniles held in captivity will grow quite rapidly, nearly doubling their size in the first year of life.

The sixgill shark is a large, active, powerful predator that feeds on a wide variety of prey species including other sharks, rays, chimaeras, bony fishes, and marine mammals. Larger sixgills will actively forage on quite large prey items including swordfish, marlin, dolphinfish, seals, and dolphins. They have also been observed to consume whales as carrion. Juveniles held in captivity have a voracious appetite.

Status of the Population

The main concentrations of sevengill shark populations in California appear to be in Humboldt and San Francisco Bays, both of which serve as nursery grounds for newborns and juveniles. Damage to either of these areas could have an adverse effect on the population. Outside these bays there is very little reliable information regarding the status of sevengill shark populations.

There is no information on the population status of the sixgill shark.

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U.S. Abalone

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True Smelts

General

The true smelts of the family Osmeridae are small fishes found in cold coastal, estuarine, and freshwater habitats in the Northern Hemisphere. The term "true smelt" identifies these fishes from similar-looking species of the silverside family (Atherinopsidae, recently changed from Atherinidae) whose common names often include the word "smelt" (such as jacksmelt, or topsmelt). Smelt life history strategies range from completing all life stages in freshwater, migrating from marine or estuarine habitats to freshwater to spawn (anadromous), or living entirely in the marine environment and spawning in the surf or subtidal zone. Like salmonids, the true smelts have an adipose fin and some have a curious cucumber odor.

Most of the 12 species in the family support either sport or commercial fisheries due to their highly prized delicate flavor. They are also a major forage fish for marine mammals, birds, and predatory fishes such as salmon and cod. Seven of the 12 species occur in California: delta smelt, found only in the upper portions of the Sacramento-San Joaquin estuary; surf smelt, commonly known as day smelt, found along most of California's coast but spawning only from Santa Cruz northward; wakasagi, a Japanese freshwater species introduced into California reservoirs which has also taken up residence in the Sacramento-San Joaquin estuary; night smelt, found from Pt. Arguello, northward; longfin smelt, an estuarine species found mainly in the Sacramento-San Joaquin estuary; eulachon, an anadromous species found mainly in the Klamath River; and whitebait smelt, a rather uncommon marine species ranging from San Francisco Bay northward, about which little is known.

The six native smelts have all supported commercial fisheries in the past, but only surf and night smelts contribute significantly to the fisheries today. The combined fisheries vary from year to year, with catch ranging from 0.5 to 2.1 million pounds per year (1970 to 1999). In 1995, for example, over 2.0 million pounds of smelt were landed, with a wholesale value of over $600,000. The average wholesale price per pound ranges from $0.20 to $0.30. Smelts are sought commercially not only for human consumption but also as feed for marine mammals, birds and fishes in aquariums, and as bait for fishing.

Unfortunately, most of the historical commercial landing records for smelt, gathered by the California Department of Fish and Game (DFG), were lumped together, so the relative importance of each species in the past fisheries cannot be determined. The catch records for 1916 through 1969 are for "smelt" and "whitebait smelt." The term, "smelt" included not only surf smelt but jacksmelt, topsmelt, and grunion. After 1969, the silverside catch was removed from the "smelt" statistics and all smelts except whitebait and night smelt were lumped into the category "true smelt." However, it is unlikely that whitebait smelt were ever harvested in very large numbers. Furthermore, "whitebait smelt" was the only smelt category available to fish processors who filled out the required DFG pink slips on which catch is recorded. Therefore, it is quite likely that "whitebait smelt" in the historical fisheries statistics includes all species of smelt harvested (but mainly surf and night smelt).

Since 1977, landings of smelts have been recorded in their own species categories; however up to one third of the landings were still reported as "true smelt" and not identified to species. After 1989, the percentage of landings reported in the "true smelt" category has averaged less than 0.5 percent of the total landings. Therefore, while the total smelt catch can be estimated for the past several decades, landings by species can only be determined since 1990.

In addition to commercial landings, there is a large, but largely unreported, sport fishery for surf smelt and night smelt. The Marine Recreational Fishery Statistical Survey (MRFSS), established by the National Marine Fisheries Service (NMFS) in 1979, estimates the impact of recreational fishing on marine resources. Estimates of annual recreational smelt catches (1980 to 1998), based on phone and intercept surveys, range from nearly 200,000 pounds in 1998 to less than 5,000 pounds in 1983. Nearly all of these recreational catches are reported as surf smelt.

Delta Smelt

History of the Fishery

In the 19th century, delta smelt *(Hypomesus transpacificus)* and longfin smelt were the object of a commercial fishery that supplied markets in San Francisco. Much of the market seems to have been for dried fish for the Chinese community. In the 20th century, delta smelt have not been the target of a fishery, however other bait fisheries in the Sacramento-San Joaquin estuary (*e.g.*, shrimp, threadfin shad) often collect delta smelt as bycatch.

Status of Biological Knowledge

Our understanding of delta smelt life history has increased dramatically just prior to and since the delta smelt was listed as a threatened species in 1993 by both the federal government and the state of California. Since then, it has been the target of focused research to determine the factors affecting its abundance and to develop water management strategies to protect it. It is endemic only to the Sacramento-San Joaquin estuary, which also serves as the major water conduit for two-thirds of the state's human population. Hence, under protections set forth in both the federal and state endangered species acts, the condition of the delta smelt population can play a major role in how water is managed throughout the state. The delta smelt is considered environmentally sensitive because it resides mainly in the brackish water portion of the estuary, is primarily an annual fish (*i.e.,* completes its life cycle, for the most part, in one year), is exclusively planktivorous and dependent on a zooplankton community that has been greatly altered by exotic species, has a very low fecundity for a fish with planktonic larvae, is fragile and easily stressed, and is a very poor swimmer.

The delta smelt is one of the smaller smelts. It reaches adult sizes at two to three inches and rarely lives more than one year. It is translucent with a silvery steel-blue streak along its sides and it exudes a strong odor of cucumbers. Most of the year, it resides in the open surface waters of the low salinity portions of the estuary where fresh and salt water mix. They are usually found at salinities between two and seven parts per thousand (ppt) although are not uncommon in salinities between zero and 18 ppt. Delta smelt migrate to freshwater areas of the estuary that are under tidal influence to spawn from late winter to early summer. Spawning usually takes place in shallow water where the eggs are demersal and attach to the substrate. Females produce between 1,200 and 2,600 eggs depending on size. Most adults die after spawning, however a few survive to a second year. In recent years, fewer smelt have survived to a second year and the average size of the first-year fish has significantly decreased. Larger fish may contribute significantly more to the egg supply and may be responsible for better success of the population when environmental conditions are favorable.

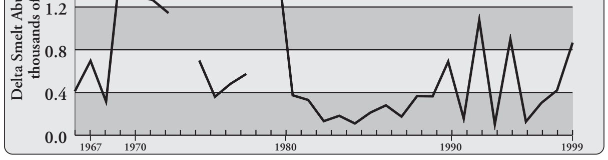
Delta smelt feed primarily on planktonic copepods, cladocerans, and amphipods. Recent dramatic shifts in the zooplankton community, both in terms of species invasions and total abundance, may affect delta smelt survival. Historically, the most common food item was the euryhaline copepod, *Eurytemora affinis;* however, this copepod has since been replaced by *Pseudodiaptomus forbesi,* as the primary prey item, although *E. affinis* is still strongly preferred. In recent years, the exotic Asian clam, *Potamocorbula amurensis,* has greatly reduced zooplankton densities in the estuary.

Genetic studies indicate that delta smelt are more closely related to surf smelt than to wakasagi even though they look more like the latter. Many of the traditional external characteristics used to identify different species (e.g., fin ray counts) overlap between delta smelt and wakasagi; however, the number of melanophores on the mandible (delta smelt has zero or one, wakasagi usually has five to many) is often used to separate the species. Hybrids between delta smelt and wakasagi, as well as delta and longfin smelt hybrids, have been observed in the estuary. Since the wakasagi has become established in more brackish portions of the estuary, the potential for interbreeding as well as for increased competition for food, spawning areas, etc., has increased and may pose a significant threat to delta smelt recovery.

Unlike many fishes with similar life histories in the estuary, delta smelt abundance is not strongly affected by freshwater outflow or by the position of the low salinity zone; however, population levels are only high in years with moderate to high outflows. Distribution, however, is strongly related to freshwater outflow. In low outflow years, the population is concentrated above the confluence of the Sacramento and San Joaquin rivers in the narrow channels of the delta where it becomes more vulnerable to entrainment in water diversions, predation, pollutant exposure, and competition with wakasagi and other planktivorous fishes. Delta smelt do not exhibit a strong stock-recruitment relationship that would be expected for a near annual fish, therefore, environmental factors may strongly contribute to population success

Status of the Population

Delta smelt were once one of the most common fishes in the estuary. Historically, delta smelt abundance fluctuated from year to year, but from the early 1980s to the mid-1990s, the population was consistently low. In recent years, abundance has varied dramatically even though stringent measures are now in place to provide better habitat conditions for delta smelt. The causes of the delta smelt decline are multiple and synergistic and vary from year to year. These include: reductions in freshwater outflow caused by drought and by the diversion and upstream storage of large amounts of water by the state and federal water projects, entrainment losses to water diversions, high outflows in extremely wet years, exposure to toxicants, disease, competition, predation, and loss of genetic integrity.



Fall Midwater Trawl Abundance Indicies
1967-1999, Delta Smelt
Data Source: DFG Central Valley Bay-Delta Branch. Indices for 1974 and 1979 were not available.

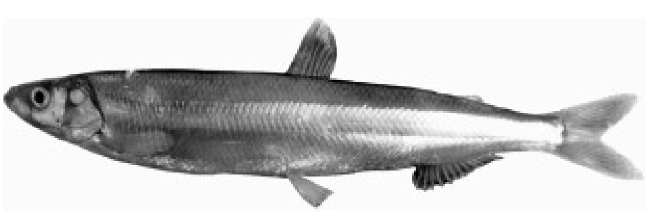
Surf Smelt

History of the Fishery

The fact that surf smelt *(Hypomesus pretiosus)* spawn on selected beaches at predictable times of the day and year has made them a favorite sport fish. The standard A-frame dip net used to catch this smelt is based on one used by American Indians in the aboriginal fishery. It consists of a three- to four-foot long triangle of netting with poles on two sides and bag at the apex, into which, fish can be flipped by tilting the net upwards. About 95 percent of all commercial landings are taken with this gear. The other five percent are captured using purse seines, trawls, or beach seines. This species was thought to be the dominant species in the commercial smelt catch; however, since all species categories have been reported, surf smelt average only one third (33.0 percent) of the smelt catch (1990 through 1999). Landings averaged 478,000 pounds between 1990 and 1999 with 70 percent being reported from Eureka and Arcata. Another 25 percent of the landings were reported in the Crescent City area. Surf smelt (and night smelt) are sold fresh in the coastal markets or sold to aquariums as feed for fish and marine mammals.

The sport fishery primarily uses techniques and A-frame nets similar to the commercial fishery. Beach seines ("jump nets") up to 20 feet long (with mesh sizes of at least 7/8 inch) are also legal in the sport fishery, as are cast nets (Hawaiian throw nets). The sport catch limit for smelt is 25 pounds per day, a regulation that has been in place for many years.

Unfortunately, we have no historical records of the recreational catch, although it was estimated to be 400,000 pounds, roughly four million smelt, in 1958. Since 1980, the MRFSS estimate of recreational surf smelt landings in California averages 86,000 pounds and ranges from 4,500 pounds in 1982 to 197,000 pounds in 1998. These recent estimates are less than half the 1958 estimate, perhaps suggesting that either changes in recreational effort or changes in surf smelt abundance has occurred. It should be noted that surf smelt was the only smelt to be reported in any numbers and very few night smelt landings were reported. This is unusual since night smelt currently make up over 50 percent of the commercial fishery.



Surf Smelt, *Hypomesus pretiosus*
Credit: DFG

Status of Biological Knowledge

Surf smelt are the most widely distributed smelt in California but are only common north of San Francisco Bay. They are schooling, plankton feeding fish that can reach 10 inches in length. Females typically grow the largest and live the longest (up to five years), while males rarely live longer than three years. Females are mature, however, in one to two years, producing 1,300 to 37,000 eggs. In California, most spawning occurs in June through September, in the surf zone of beaches, especially during high tides. The spawning smelt congregate in the surf during the day, usually while the tide is falling. The biggest congregations occur when high tide is in the late afternoon. The fertilized eggs adhere to sand and pebbles. The most favored spawning beaches are those made up largely of coarse sand and pea-sized gravel, with some freshwater seepage. During periods of heavy spawning, some beaches are literally coated with eggs. The eggs hatch in two to three weeks. Little is known about their larval life or of the habits of juvenile and adults in the ocean environment. They presumably spend their lives in waters close to shore, however, as smelt are a common bycatch in the shrimp fishery.

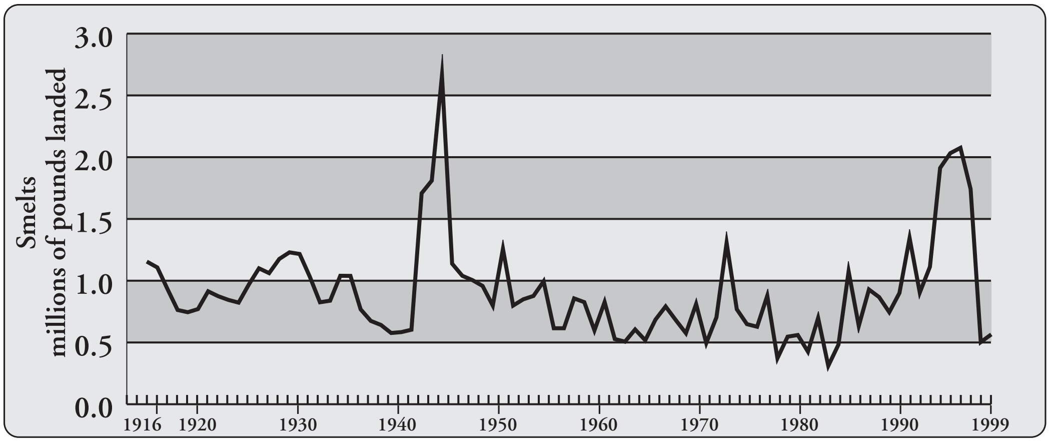
Status of the Population

The fishery for surf smelt may be decreasing while landings for night smelt have increased. Landings have dropped from over 800,000 pounds (1995 to 1997), to 100,000 pounds in 1998, to just over 12,000 pounds in 1999. Environmental factors such as seawater temperature changes (*e.g.*, El Niño) may dramatically affect population levels. However, given their short life-cycle, excessive fishing could cause smelt populations to plummet in just two or three years. Heavy recreational use of the beaches may also compact gravels and crush recently spawned eggs. It is also possible that the developing eggs may depend on water percolating through the gravels from above, so alterations of inflowing streams or lagoons may affect the suitability of the spawning habitat for egg survival.

Wakasagi

History of the Fishery

In Japan, wakasagi *(Hypomesus nipponensis)*, are a favored food fish, supporting a highly specialized fishery. Intensive commercial fishing and reduced catches stimulated the development of artificial propagation techniques that led to large-scale aquaculture facilities producing millions of wakasagi annually. This long history of artificial propagation of wakasagi is what made it so easy to transport them to California.



Commercial Landings 1916-1999, Smelts
Commercial landings include the combined landings of smelts and white bait smelts for 1916 through 1969 and the combined landings of true smelts, surf smelts, white bait smelts, and night smelts for 1970-1999.
Data Source: DFG Catch Bulletins and commercial landing receipts.

Status of Biological Knowledge

The wakasagi was imported from Japan to California in 1959 by the Department of Fish and Game as a forage fish for salmonids in lakes and reservoirs. At the time, it was believed to be the same species as delta smelt. It was apparently easier to ship wakasagi eggs from Japan than it was to collect and transport live delta smelt from the Sacramento-San Joaquin estuary. Its current range in California is from Shastina Reservoir, Siskiyou County, in the northern part of the state to San Luis Reservoir and parts of the California Aqueduct in the central part of the state. An initial introduction in southern California at Big Bear Lake, San Bernardino County, apparently did not survive. It is common in Lake Oroville on the Feather River and Folsom Lake on the American River, two large water storage facilities in which water is released in large amounts for transport down the Sacramento River to the water diversions in the southern delta. Since 1995, wakasagi, in small numbers, have been widely distributed throughout the Sacramento-San Joaquin estuary.

The wakasagi has been well studied in Japan due to its demand as a favored food item, but little was known about it in California until recently. Once the wakasagi became established in the estuary and its potential as a threat to delta smelt realized, research on the species increased dramatically. In Japan, it can be either anadromous or resident in fresh water. In California, it has been well established in cold-water reservoirs and now appears to survive in estuarine conditions as well as in the warm-water reservoirs of the California Aqueduct. Wakasagi are able to tolerate a wider range of salinities and temperatures than delta smelt. They are also faster swimmers and are much more tolerant of stressful conditions.

Wakasagi are opportunistic planktivores, feeding mainly on planktonic copepods. In the Sacramento-San Joaquin estuary, they feed on the same food items as delta smelt and represent a competitive threat to the delta smelt's limited food supply. In Japan, most individuals from anadromous stocks apparently live one year, spawn, and die, while some freshwater populations may live up to four years. In California, wakasagi can live at least two years and may reach lengths of up to five inches. They usually spawn from February to May. The presence of hybrids in the estuary indicates that wakasagi can interbreed with delta smelt; however, no backcrossed individuals have been observed. The high degree of genetic divergence between the two species suggests that the hybrids may be infertile.

Status of the Population

The wakasagi is still expanding its range in central California and the consequences of this introduction may not yet be fully realized. It is a threat to delta smelt not only because it can interbreed; it may also compete for the same food items and spawning locations, and possibly prey on its larvae. The first known observation of a wakasagi in the estuary was in 1974. Since then, the number of observations of individuals has increased although large densities of wakasagi are still rare.

Now that wakasagi are firmly established in the estuary, protective measures for delta smelt have become much more difficult to manage due to the physical similarity of the two species, particularly at small sizes. Regular accounting of delta smelt catch is required of projects that export water out of the delta so they do not exceed a "take limit" (*i.e.,* allowable number of delta smelt that can be killed which is established to limit project impacts). At the state and federal water diversions, which may draw in and kill tens of thousands of young-of-the-year smelts (delta smelt, wakasagi, longfin smelt) daily in the spring, "real time" identification of small smelt becomes nearly impossible. Regulated water diversions are allowed until the established take limit is exceeded. Then diversions are further restricted reducing the amount of water that is exported. Thus, timely identification of delta smelt is a necessity since reductions in exports may be very costly.

Night Smelt

History of the Fishery

Night smelt *(Spirinchus starksi)* are also taken in large numbers, both in the commercial and sport fisheries, in much the same ways as surf smelt. Although night smelt are smaller in size and spawn only at night, they represent over 50 percent of the total commercial smelt landings valued at over two million dollars in the 1990s. Landings averaged over 1.2 million pounds annually from 1994 to 1996. Like surf smelt, night smelt are caught mainly with A-frame dip nets. Most are caught in the area around Eureka, which accounts for about 60 percent of all commercial smelt landings. Crescent City landings make up an additional 33 percent. Night smelt are either sold for consumption as fresh fish or shipped to aquariums for consumption by fish, birds, and mammals.

Catches of night smelt in the sport fishery, as reported in the MRFSS data, are surprisingly small since they now make up the bulk of the commercial smelt catch. This may be due to limited angler contact at night when the majority of landings takes place. The largest catch estimate was 131 pounds in 1986, less than one-tenth of one percent of the total sport smelt catch for that year.

Status of Biological Knowledge

Night smelt range in distribution from Point Arguello in central California to Alaska. Like surf smelt, night smelt are schooling, plankton-feeding fish that are important prey for other fishes as well as marine mammals and birds. They rarely exceed six inches in length or three years in age.

Spawning has been recorded from January through September on the same beaches as those used by surf smelt. Much of the spawning takes place earlier in the season than the spawning of surf smelt; so it is likely that most of the smelt catch before June is night smelt, with surf smelt the predominant species in the summer. However, both species have been observed using the same beaches on the same day, with night smelt spawning at night and surf smelt spawning during the day. Peaks of spawning occur between dusk and midnight on outgoing tides, although night smelt spawning seems much less tied to tidal height than is the spawning of surf smelt. A distinguishing feature of night smelt spawning aggregations is the prevalence of males close to shore (and in the shore fishery). The male to female ratio early in the season is eight-to-one, but by the end of the season it is nearly 100-to-one. The ratio is close to one to one in offshore catches of smelt. Females apparently spawn repeatedly during the season, dashing in to release their eggs among crowds of eager males. The fertilized eggs stick to the gravel and hatch in about two weeks.

Status of the Population

While night smelt has become the predominant smelt in the commercial landings in the 1990s, averaging over 800,000 pounds per year, we know very little about the status of the population. Given the short life-cycle, excessive fishing could cause smelt populations to plummet in just two or three years. Heavy recreational use of the beaches may also compact gravels and crush recently spawned eggs. It is also possible that the developing eggs may depend on water percolating through the gravels from above, so alterations of inflowing streams or lagoons may affect the suitability of the spawning habitat for egg survival.

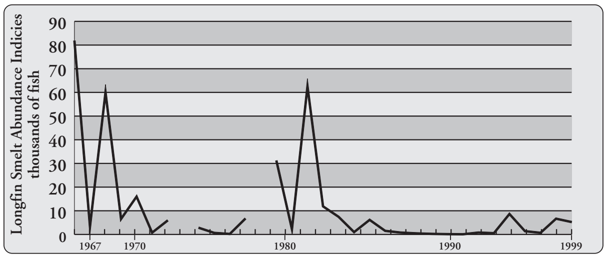
Longfin Smelt

History of the Fishery

Longfin smelt *(Spirinchus thaleichthys)* were once harvested along with delta smelt in the Sacramento-San Joaquin estuary for Chinese markets in San Francisco. There is currently no longfin smelt fishery in California, however it is often bycatch in the bay shrimp fishery.

Status of Biological Knowledge

The longfin smelt is a pelagic, estuarine fish, which ranges from Monterey Bay to Alaska. In California, it has historically been collected in the Sacramento-San Joaquin estuary, Russian River estuary, Humboldt Bay, and the Eel, Klamath, and Smith rivers. It is also often collected in the coastal waters of the Gulf of the Farallones particularly during late summer and fall.



Fall Midwater Trawl Abundance Indicies
1967-1999, Longfin Smelt
Data Source: DFG Central Valley Bay-Delta Branch. Indices for 1974 and 1979 were not available.

In the Sacramento-San Joaquin estuary, longfin smelt are widely distributed in the brackish parts of the estuary ranging in salinities from 14 to 28 ppt. Adults feed mainly on the opossum shrimp, while juveniles prefer copepods. Longfin smelt live up to three years and reach lengths of six inches, but most spawning adults are two years old and about four inches in length. Longfin smelt are anadromous and spawning takes place in the freshwater or slightly brackish portions of the estuary from December through April. Females produce between 5,000 and 24,000 eggs, which are adhesive and attach to the substrate. Hatching takes place in up to 40 days depending on the water temperature. This winter to early spring spawning period results in larvae hatching at times when freshwater outflows out of the estuary are highest. Early-stage larvae are surface oriented and are transported long distances by surface currents generated as these high freshwater flows mix with more saline water. As larvae mature, they move to lower portions of the water column at salinities of about 15 ppt where they can maintain their position in the estuary. Potential predators of longfin smelt include striped bass and inland silversides (eggs and larvae).

The annual abundance of longfin smelt in the Sacramento-San Joaquin estuary is significantly and positively correlated with the amount of freshwater outflow during spawning and larval periods. Potential mechanisms for this strong relationship include a reduction in predation during periods of high flows, increased habitat availability which may increase survival by reducing interspecific competition, and increases in nutrient levels which are transferred up the food chain.

Hybrids between longfin and delta smelt have been collected in the Sacramento-San Joaquin estuary. However, it is unlikely that offspring are fertile since these species are not closely related and no genetic introgression has been observed. Under certain hydrologic conditions longfin and delta smelt apparently overlap in their spawn times and locations. However, it appears that these circumstances are rare since only a few of these hybrids have been observed.

Status of the Population

Longfin smelt was once one of the most common fishes in the Sacramento-San Joaquin estuary; however, abundance reached an all time low in 1992, following seven years of drought. In the late 1990s, population levels have increased as hydrologic conditions have become wetter and freshwater outflows have increased, however population levels have not fully recovered to expected levels based on the abundance-outflow relationship. Additional factors potentially affecting abundance include reductions in outflows through water exports, entrainment losses to water diversions, climatic variations, toxic substances, increases in predation, reductions in food availability subsequent to invasions by exotic species.

Resident populations in coastal estuaries along the northern coast of California have declined dramatically or all but disappeared since the 1970s. Once common in Humboldt Bay, longfin smelt have only been observed in very small numbers in the mid-1990s. In addition, sporadic collections of longfin smelt from the Eel River estuary and the Klamath River occurred in the mid-1990s. There have been no recent observations in the Smith River. Although the causes of these declines in these northern estuaries are not known, they may be similar to the causes of the decline in the Sacramento-San Joaquin estuary.

Because of the severe decline in abundance of longfin smelt in California in the early 1990s, the USFWS was petitioned to list the longfin smelt as a threatened species. The petition was denied in 1993, largely on the basis that the California populations were not genetically distinct from abundant and stable populations found in Washington.

Eulachon

History of the Fishery

The eulachon *(Thaleichthys pacificus)* is the largest of smelts found in California. It is also known as candlefish, because they are so oily that American Indians once dried them to burn like candles. They are highly prized as a food fish, being considered one of the tastiest of the smelts. Until the mid-1970s or so, eulachon supported a fairly consistent river sport dipnet fishery, as well as a dipnet fishery by American Indians. The commercial catch in California has apparently never been large (maximum reported landings are 3,000 pounds in 1987), but eulachon are important commercially in British Columbia.

Status of Biological Knowledge

Eulachon range from central California to Alaska. In California, they are found along the coast as far south as Monterey Bay and seem to prefer the outer continental shelf, where they school at depths of 150 to 750 feet. They reach a length of up to twelve inches and may live to be five years old. They feed mainly on euphausid shrimps, copepods, and other crustaceans and can reach maturity in two to three years. They are a very important food for predatory marine animals, including salmon, halibut, cod, and sturgeon.

Eulachon are anadromous, spending most of their life in the open ocean then migrating to lower reaches of coastal streams to spawn in fresh water. The principal spawning run in California is in the Klamath River, but runs have also been recorded in the Mad and Smith Rivers and Redwood Creek. They spawn in gravelly riffles close to the stream mouths, rarely ascending more than six or seven miles. Most eulachon die after spawning, but a few apparently live to spawn a second time. Each female lays about 25,000 eggs which stick to the gravel and hatch in two to three weeks.

Status of Population

In recent years, eulachon numbers seem to have declined drastically; so they are now rare or absent from the Mad River and Redwood Creek and scarce in the Klamath River. However, the eulachon and its fishery have been largely ignored in the past, and so we do not known if the fish are at a low point in a natural population cycle or if they have been reduced by human related factors.

Whitebait Smelt

History of the Fishery

Although about half the commercial smelt catch was called "whitebait smelt," the species itself *(Allosmerus elongates)* is apparently uncommon throughout its range or only locally abundant and so it probably infrequently taken in the fishery.

Status of Biological Knowledge

One indication of the scarcity of whitebait smelt is that comparatively little is known about its biology. Like other smelt, they live in large schools and are voracious feeders on zooplankton. They tend to favor productive inshore areas and bays; however they are only rarely caught in estuaries or coastal waters. They are collected sporadically in San Francisco and San Pablo bays primarily during winter and spring. Spawning is thought to take place in sandy, subtidal areas. The Sacramento-San Joaquin estuary does not appear to be a spawning area since only post-larval to adult individuals have been collected there. Young-of-the-year remain translucent and are considered "post-larval" until they are almost three inches in length. They live one to three years and reach lengths of seven inches. The succession of even year classes in San Francisco Bay may suggest a two-year maturity schedule.

Status of Population

This species seems to be locally abundant and rarely enters the fishery. However, we have no idea if it was more abundant in the past or whether current populations are stable or not.

Discussion

California smelts provide examples at two ends of the spectrum of California fisheries. At one end are the surf smelt and night smelt, which together support a fairly large commercial and sport fishery. Although the fishery is one of the largest in California in terms of numbers and pounds of fish caught, its value is relatively low. It is also a fishery about which surprisingly little is known and could conceivably decline or collapse from a combination of overexploitation and alterations to the 19 or 20 principal spawning beaches, which are receiving increasingly heavy recreational use. At the other end of the fisheries spectrum are delta smelt, longfin smelt, eulachon, and whitebait smelt, all species, which once supported fisheries but that are now in relatively low numbers. One of these species has been listed as a threatened species, another was petitioned to be listed, and the other two we know so little about that we do not know if these populations are in trouble. Three of these species require fresh water for spawning and their declines are probably all related to alterations of the spawning and rearing habitats. It is clear that we need to know much more about all of California's smelt, so that they can be managed for fisheries of the future and to maintain their important roles in coastal and estuarine food webs.

Management Considerations

See the Management Considerations Appendix A for further information on all the true smelts.

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Bay and Estuarine Finfish

Commercial Landings

Year	Pacific Herring Pounds	True Smelts[1] Pounds
1916	2,928,591	1,153,306
1917	7,435,997	1,107,349
1918	7,938,280	932,841
1919	4,289,899	762,895
1920	274,364	744,865
1921	542,124	770,302
1922	341,621	914,147
1923	383,950	874,198
1924	435,620	844,395
1925	862,974	822,637
1926	453,607	968,680
1927	1,168,321	1,100,070
1928	1,139,682	1,061,302
1929	957,563	1,176,214
1930	717,634	1,229,582
1931	685,759	1,216,305
1932	765,724	1,032,756
1933	601,445	825,453
1934	801,601	838,173
1935	933,285	1,039,825
1936	840,530	1,038,969
1937	631,330	768,247
1938	504,884	674,585
1939	302,242	641,819
1940	453,193	576,809
1941	789,753	583,841
1942	190,815	603,197
1943	630,358	1,707,640
1944	422,255	1,810,469
1945	460,465	2,660,732
1946	481,776	1,137,813
1947	1,654,850	1,039,926
1948	8,002,692	1,004,595
1949	379,311	957,380
1950	1,425,351	798,575
1951	4,923,655	1,257,719
1952	9,495,386	798,794
1953	7,801,928	849,408
1954	911,906	876,508
1955	1,946,521	994,730
1956	1,735,776	615,153
1957	1,188,080	615,072
1958	1,726,966	856,669
1959	1,727,013	826,353
1960	1,800,672	597,757
1961	1,401,248	827,117
1962	1,305,569	527,855
1963	630,087	506,536
1964	349,270	605,254
1965	516,319	517,547
1966	241,973	684,716
1967	271,902	791,669
1968	357,869	681,123
1969	170,532	574,910
1970	315,968	811,364
1971	240,936	495,153
1972	115,748	703,656
1973	2,813,267	1,307,180
1974	5,252,676	768,844
1975	2,433,676	648,325
1976	4,858,113	627,416
1977	9,301,000	878,206
1978	11,387,000	372,317
1979	9,373,600	546,843
1980	17,447,200	560,437
1981	13,442,600	425,506
1982	23,433,040	698,396
1983	17,825,400	310,726
1984	8,973,600	482,563
1985	16,943,800	1,075,513
1986	16,816,400	633,716
1987	18,569,200	928,798
1988	19,369,600	867,271
1989	20,339,200	745,147
1990	17,944,200	900,527
1991	15,942,800	1,345,154
1992	13,476,400	903,908
1993	9,552,200	1,112,876
1994	6,496,600	1,912,447
1995	10,256,600	2,032,352
1996	14,551,200	2,075,415
1997	20,117,400	1,741,649
1998	5,347,200	503,118
1999	4,834,400	563,369

[1] True smelts includes the combined commercial landing categories of smelt and white bait smelt for 1916 through 1969 and the combined commercial landing categories of true smelts, surf smelts, white bait smelt, and night smelt for 1970 through 1999.

Recreational Catch

Year	Striped Bass No. of Fish[1,2]
1960	30,856
1961	42,357
1962	39,682
1963	58,551
1964	34,163
1965	16,488
1966	44,869
1967	23,794
1968	23,058
1969	20,091
1970	15,269
1971	13,381
1972	31,690
1973	21,120
1974	41,561
1975	17,561
1976	10,677
1977	8,263
1978	2,609
1979	7,370
1980	1,391
1981	2,985
1982	3,646
1983	14,206
1984	13,524
1985	9,686
1986	8,572
1987	8,858
1988	10,415
1989	2,167
1990	2,356
1991	4,427
1992	5,274
1993	1,687
1994	2,247
1995	3,102
1996	6,096
1997	7,368
1998	19,720
1999	10,774

[1] All data presented in number of fish caught.
[2] Ocean and San Francisco Bay recreational catch; Sacramento-San Joaquin Delta receational catches are not included until 1964.

Bay and Estuarine Plants: Overview

From a biological perspective, no other complex is more important to bay and estuary ecosystems than their plant communities. Whether discussing tidal wetlands, shallow subtidal habitat, or marine algae, plant communities and the habitats they form are vital to the function and health of bays and estuaries. Two important plant components within the bay and estuary setting are the tidal wetland, and the subtidal eelgrass (*Zostera marina*) and *Gracilaria spp.* communities. While these two plant groupings are small fractions of the bay and estuarine plant assemblage and do not occur in all bays and estuaries of the state, they are significant contributors to the overall productivity and species diversity of these ecosystems. Other commonly occurring bay and estuarine plant communities, such as phytoplankton, algal mats, and sea lettuce are not addressed by this report, but are important food contributors and principal components of these ecosystem carbon budgets.

Bay and estuary ecosystems are the probably the most impacted and altered environments of the California coastline. Most of the state's bay and estuary ecosystems are intensively urbanized, serving as centers for industry, agriculture, and commerce. The impacts of such anthropogenic activities are acutely evident within the bay and estuarine plant communities. The loss of tidal and subtidal wetland habitats on a statewide level is substantial. Where once vast mosaics of tidal wetlands predominated, agriculture, housing, or other developments have been formed from lands diked from the bay or filled. Similarly, losses of subtidal plant communities are accelerating worldwide. In southern California, it has been estimated that as little as ten percent of the historical distribution of eelgrass remains. In the majority of cases, once bay and estuary plant communities are destroyed they are lost forever. Some restoration has occurred throughout the coastal region of California with significant efforts focused on southern California, particularly within Mission and San Diego bays and the reopening of Bataquitos Lagoon to tidal flow. However, in most cases, the goal remains one of preservation.

Bay and estuary plant communities provide critical habitats, which support a diverse array of fish and wildlife including species that are in danger of extinction. The diverse structure of bay and estuarine plants also helps to improve water quality, protect lands from flooding, provide energy to the marine and estuarine food web, and stabilize shorelines against erosion. Studies have found that subtidal plant communities are also principal contributors to primary productivity within bay and estuary ecosystems.

The economic value of bay and estuarine wetlands and subtidal habitats is considered to be among the highest of all natural resources. Such habitats support commercial harvests of fish and shellfish and provide millions of days of recreational fishing and waterfowl hunting each year. On a global level, such plant communities help stabilize available nitrogen, atmospheric sulfur, carbon dioxide, and methane. In the crowded urban environment, where many remnant populations of bay and estuary plant communities exist, such habitats contribute to open space and are a valuable aesthetic asset. A recent economic assessment of California's wetlands conducted by the California Coastal Commission established annual benefits valued at between $6.3 billion and $22.9 billion.

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Coastal Wetlands - Emergent Marshes

General Description

Wetlands are broadly defined as the transitional lands that occur between the terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. There are five major systems of wetlands — marine, estuarine, riverine, lacustrine (lake), and palustrine (freshwater marsh). This paper discusses California's marine and estuarine wetland systems. However, it should be noted that all five systems occur in the state, all of which serve important roles as fish and wildlife habitat and in many ways are ecologically tied to one another.

One of the most widely used and comprehensive wetland classification system was developed for the U.S. Fish and Wildlife Service and is referred to as the Cowardin definition. This classification system defines wetlands as having one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. Although this system is commonly used to classify wetlands, regulatory agencies such as the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and other public agencies use varying definition when regulating the discharge of dredged or fill material or other alterations to wetland areas.

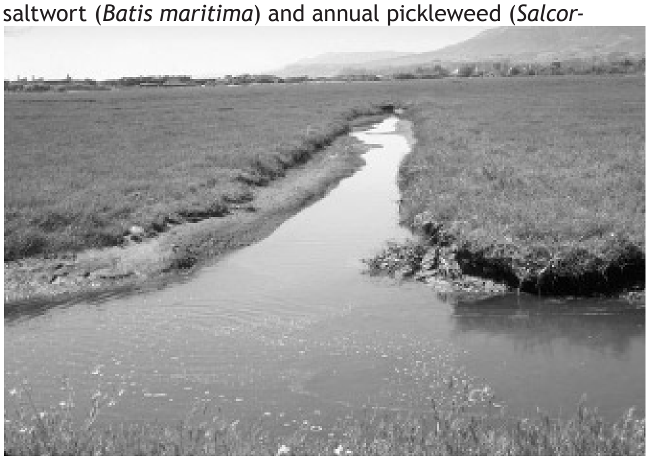
The term "tidal wetland" refers to areas that are covered with shallow intermittent tidal waters. Coastal tidal wetlands in the California include a number of natural communities that share the unique combination of aquatic, semi-aquatic, and terrestrial habitats that result from periodic flooding by tidal waters, rainfall, and runoff. These coastal wetlands, also referred to as salt marshes, provide a vital link between land and open sea, exporting nutrients and organic material to ocean waters. Wetlands also help to improve water quality, protect lands from flooding, provide energy to the estuarine and marine food webs, and help stabilize shorelines against erosion.

Tidal wetlands are dominated by a community of plants that are tolerant of wet, saline soils, and are generally found in low-lying coastal habitats which are periodically wet and usually saline to hypersaline. In fact, no other feature defines a salt marsh better than the plant communities that form there. The location of plant species within a salt marsh is defined by zone, with cordgrass (*Spartina foliosa*) forming the most seaward edge of the emergent marsh plant community. Of the thousands of plant species in North America, only cordgrass thrives in the lowest zone of a salt marsh. This lower marsh zone occurs from approximately mean sea level to the line of mean high tide.

The middle zone of a tidal marsh occurs from approximately the line of mean high tide to the mean higher high tide line and is characterized by the occurrence of pickleweed (*Salcornia sp.*). Pickleweed is less tolerant of tidal inundation than cordgrass, but is the most dominant plant of California tidal wetlands. Jaumea (*Jaumea carnosa*) also occurs, but to a lesser extent within the middle zone of California's coastal marshes.

The upper zone of a tidal marsh is defined by the line of mean higher high tide to extreme high tide. This upper zone of a salt marsh may only be inundated infrequently, in some locations as little as once or twice annually. Such inundation usually occurs during the spring tide cycle (highest annual tides) and during severe storm events. The upper zone of the tidal marsh is characterized by the dominance of salt grass (*Distichlis spicata*) which tolerates only occasional tidal inundation. This upper area of marshes contains the largest plant species diversity of the three zones. Species such as fat hen (*Atriplex patula*), sand spurrey *(Spergularia marina*), marsh rosemary (*Limonium californicum*), brass buttons (*Cotula cornopifolia*), can be found within the upper zone of salt marshes throughout California. In the southern portion of the state, species such as Australian salt bush (*Atriplex semibaccata*), sea-bite (*Suaeda californica* and *Suaeda fruticosa*), shoregrass (*Monanthochloe littoralis*), and salt marsh bird's beak (*Cordylanthus* sp.) can be found within the upper salt marsh zone.

The zonation of marshes in southern California is somewhat more complex than that described above. Southern California salt marshes lack expansive stands of cordgrass; instead they are dominated by succulents. Within the Mugu Lagoon, Anaheim Bay, Newport Bay, Mission Bay, San Diego Bay, and the Tijuna River estuary, zones of saltwort (*Batis maritima*) and annual pickleweed (*Salcor-*



Carpinteria Salt Marsh, Santa Barbara Co.
Credit: USEPA, 1995

nia bigelovii) integrate with cordgrass in the lower zone and perennial pickleweed (*Salcornia virginica*) and other middle zone plant species occur at higher than normal elevations in these and other southern California marshes.

In addition to the plant communities, other defining characteristics often associated with California's tidal wetlands include mudflats, tidal creeks, intertidal channels and sloughs, salt flats, and shallow pannes. Fresh water inflows are also often found in many of the state's coastal wetland areas, adding to the diversity of habitat types and associated species use.

Many of California's coastal wetlands are estuarine salt marshes. These salt marshes, associated mudflats, and eelgrass beds develop along the shores of protected estuarine bays and river mouths, as well as in more marine-dominated bays and lagoons. Overall, the state's tidal and estuarine wetland ecosystems provide some form of food, shelter, or other benefits to nearly a thousand species of fish, amphibians, reptiles, birds, mammals, and a multitude of invertebrates. During peak annual migration periods, hundreds of thousands of birds migrating along the Pacific Flyway descend upon the state's estuarine wetlands in search of refuge and food.

California's tidal wetlands also provide habitat for an array of endangered species, including the salt marsh harvest mouse, California clapper rail, certain runs of salmon, and wetlands plants such as a species of salt marsh birds peak. Wetlands produce an abundant yield of vegetation, which in turn provides the basis for a complex food chain nourishing a rich assortment of living organisms. The diversity and abundance of organisms in coastal wetlands is remarkable, given the often extreme and variable conditions that can occur. Bacteria, protozoa, algae, vascular plants, invertebrates, amphibians, fish, birds, and mammals can all be found within the state's coastal wetland ecosystems, and together comprise the biotic community of the wetland. Many of these organisms are dependent on the wetland for their existence, either spending their entire lives in the wetland, or spending a critical portion of their life cycle in the wetland.

Region	Estimated Original Acreage	Estimated Remaining Acreage	Estimated Percent Reduction
Northern Coast	unknown	31,300	unknown
Central Coast	unknown	3,800	unknown
San Francisco Bay	200,000	93,000 (tidal and mudflat)	54%
Southern Coast	53,000	13,100	75%
Statewide	**5,000,000**	**450,000**	**91%**

Historic Losses of California Coastal Wetlands
Source: Procedural Guidance for the Review of Wetland Projects in California's Coastal Zone, California Coastal Commision.

Status of Biological Knowledge

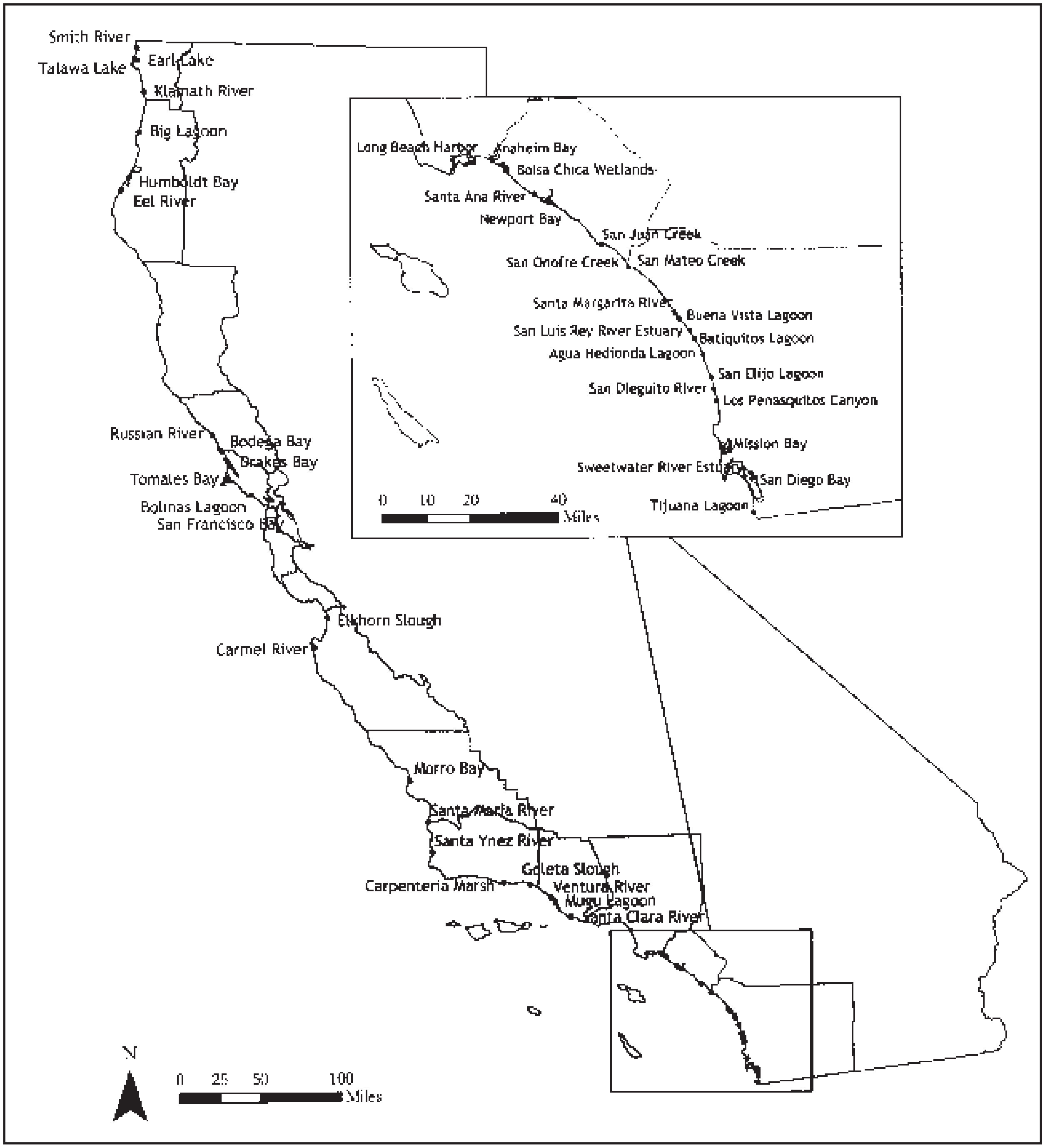
Literature on wetland science addresses a broad range of topic and setting, and much has also been written specific to California's estuarine and coastal wetlands. Programs such as the San Francisco Bay National Estuary Project, San Francisco Bay Baylands Ecosystem Habitat Goals Project, and organizations such as the Pacific Estuarine Research Laboratory, state and private universities, and numerous state and federal resource agencies have contributed extensively to the knowledge base of California's coastal wetland ecosystems. This is not to say that questions do not remain about the functions and science of the state's coastal wetlands.

Scientific study in the field of wetland science is ongoing. The role that the state's coastal wetland habitats play in the support of fish and wildlife resources is an area of extensive research, particularly in the effects of, and techniques for enhancement and restoration. Many of the coastal wetland restoration projects undertaken within the state include research and monitoring aspects within the project designs. Such analyses are vital to the overall knowledge base of wetland science and are critical to the improvement of subsequent wetland restoration activities.

Status of the Habitat

Human influence along California's coastline has a long history. The effect of this history is evidenced by the profound alteration of the natural environment, most pronounced of which are the modification of the shallow-water habitats within the state's bays and estuaries and the staggering loss of coastal wetlands. The total loss of California coastal wetlands is estimated at five million acres. This represents some 91 percent of the historic wetland acreage present before 1850. Although the entire coastline of the state has experienced losses of coastal wetland habitat, the largest losses are believed to have occurred in the San Francisco Bay estuary and along the southern coast of the state.

A variety of activities have contributed to the dramatic loss of California's wetlands. These include diking, filling, draining, and vegetation removal for agricultural uses; diking and filling for residential, commercial, and industrial development; placement of fill material for road and pad construction associated with oil and gas exploration and development; filling and other associated construction for roads, highways, and railways; dredging and filling for port and marina development; and channelization and filling for flood control purposes. Coastal wetland losses, including those historically occurring within bays and estuaries, throughout the state are primarily attributed to urban development. Although state and federal regula-



Principle Coastal Wetlands of California

tions, as well as social pressures have reduced activities that cause wetland losses, many are still occurring. Much of the current loss of wetlands is attributed to a lingering legacy of past development, such as continued use of wetland areas for agriculture, or expansion of existing urban and industrial complexes within wetland habitats. Secondary or indirect impacts also have contributed to the continued loss of coastal wetlands, including point and non-point source storm and wastewater discharges, and alteration of natural fresh and salt water inflows to the state's estuaries and wetland areas.

The Bolsa Chica wetlands in the Huntington Beach community is a site of recent controversy over wetland development and is an example of one of southern California's continuing struggles with the preservation of remnant coastal wetlands. The Bolsa Chica wetlands are the largest stretch of unprotected coastal marshland south of San Francisco, and provide 1,100 acres of wetland habitat, supporting many species of plants, fish, and wildlife, including several endangered species of birds, such as the California least tern, light-footed clapper rail, Belding's Savannah sparrow, and peregrine falcon. Southern California once had over 53,000 acres of coastal wetland areas. This number is now down to approximately 13,000 acres. Such wetland losses have contributed to a decline in California's wintering bird population. Once estimated to be about 60 million, flyway populations now fluctuates between two and four million waterfowl, one and two million shorebirds. For the Pacific Flyway as a whole, there has been some improvement in recent years, partly because of the end of a multi-year drought in the northern breading areas, but also because of the efforts made at restoring California's coastal and inland wetlands.

In many ways, the degree and type of tidal wetland habitat losses within the San Francisco Bay estuary reflect what has occurred in the state. Early reclamation activities resulted in the draining and diking of tidal, freshwater, and brackish marshes in the San Francisco Delta, as well as around Suisun Bay and San Pablo Bay. Much of this reclaimed land was cultivated for agricultural purposes. Additionally, the construction of salt production facilities resulted in the conversion of thousands of acres of tidal marsh to permanent salt pond operations. At the end of World War II, urbanization of the San Francisco Bay Area resulted in the conversion of intertidal and subtidal habitats to urbanized uplands. As a result of these wetland conversion activities, it is estimated that 95 percent of the estuary's tidal marshes have been leveed or filled. Some of the converted wetland areas, such as salt ponds and diked lowlands, remain as wetland habitat, but of a different type, offering substantially altered functions than that which existed before conversion. At present, it is estimated that less than 38,000 acres of tidal wetlands remain in the San Francisco Bay estuary, with an additional mudflat habitat of approximately 65,000 acres, diked seasonal wetland habitat of approximately 58,000 acres, and salt ponds and salt crystallization facilities of approximately 36,500 acres of non-tidal wetland habitat.

Losses and alteration impacts of tidal wetland habitat associated with coastal inlets and riverine estuaries along the California coast have also been great. Many of the state's historical wetland areas of this type have been lost or reduced in size due to direct impacts such as channelization, dredging and continued breaching of outer sandbars for flood control, and marina and harbor construction. However, off-site activities including water diversion and sediment inputs associated with watershed alterations including logging and agricultural cultivation also have significantly impacted California's coastal tidal wetlands.

California's remaining coastal wetlands are highly valued as habitat for the multitude of species that depend on them, and as aesthetic, functional, environmentally necessary elements. In fact, tidal wetland protection and restoration activities have become front-page news in many areas of the state and funding sources, once unobtainable, are now becoming increasingly available. Even with such changes in the political, economical, and environmental settings, much work needs to be done to recapture and protect California's tidal wetland habitats. Additional research and continued monitoring of existing wetland restoration projects are needed to build and contribute to the database on how best to address and undertake these activities. Additionally, methods need to be developed to address problems which could lead to the further loss of coastal wetland areas due to the anticipated rising sea-level, and other factors such as invasive species. Further public education, community involvement, and political action are needed.

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Submerged Aquatic Plants

Eelgrass

Introduction

Worldwide there are more than 50 species of vascular plants capable of inhabiting the shallow saline waters of the estuarine environment. The most common of these species, occurring in full-strength seawater, are the seagrasses. One of the most studied seagrasses in temperate and tropical regions is eelgrass (*Zostera* spp.). The eelgrass commonly found in North America, *Z. marina,* is widely distributed in the temperate zones of both coasts. Along the U.S. Pacific Coast, *Z. marina* occurs from Alaska to Baja California. Another species, *Z. asiatica*, is also found in a number of locations on the west coast of North America including offshore of the Santa Barbara area in California at depths up to 45 feet.

Eelgrass beds are generally regarded as highly productive habitats that support a rich assemblage of fish species and provide a refuge area for larval and juvenile fishes. Eelgrass habitat is also a very important resource for a variety of birds. It is associated with rich bottom fauna important to waterbirds, especially diving birds and mollusc-eaters. In California's bays and estuaries north of Monterey Bay, eelgrass provides spawning habitat for Pacific herring. Large numbers of waterbirds such as scoters, bufflehead, scaup, goldeneyes, American coots, eat eggs deposited onto eelgrass by Pacific herring during the mid-winter spawn. In addition, many birds such as surface-feeding ducks and other waterfowl, including the black brant, feed directly on eelgrass.

The location, abundance and health of eelgrass appear to be highly sensitive to changes in environmental conditions. For example, in the decade of 1935 to 1945, eelgrass beds on the north coasts of America and Europe suffered a substantial decline in abundance. The cause of this decline remains unknown but has been ascribed to a variety of causes ranging from parasitic infection by slime mold and fungus to greater than normal changes in rainfall or seawater temperature. A population decline in a wide variety of marine organisms dependent on eelgrass habitat was also seen during this period. Additionally, changes in bottom topography occurred in the affected eelgrass bed areas as currents and wave action reworked formerly stable bottom sediments. Recovery occurred slowly, due to the diminished and scattered distribution of individual plants resulting in reduced vegetative propagation and seed production.

Aside from its interaction in the marine and estuarine food webs, eelgrass assumes an important role in cycling nutrients. Organic material from natural decomposition processes or human influences are filtered and collected by eelgrass leaves and turions, providing a nutrient source for the eelgrass bed community. Nutrients that otherwise would accumulate in the sediments or be flushed out to sea may thereby be retained and recycled within the estuarine ecosystem.

The decline in eelgrass communities during the 1930s and 1940s encouraged the initiation of studies to gain a better understanding of this vital estuarine habitat. In recent years, the importance of eelgrass communities has resurfaced as a significant measure of the health of bays and estuaries. Some protection of this ecosystem has been afforded over the years through management practices that protect it through disturbance avoidance or in-kind replacement mitigation. In southern California further protection as also been provided by the implementation of the multi-agency Southern California Eelgrass Mitigation Policy of 1991 which is routinely included within permit conditions of both the U.S. Army Corps of Engineers and California Coastal Commission. While this policy was specifically designed to address eelgrass impacting projects in southern California, its principals have, at times, also been applied permit conditions for projects occurring in

Eelgrass, *Zostera marina*
Credit: DFG

northern California. The continued decline of important fish species may serve to offer additional protection for the state's eelgrass communities by designation of this habitat type as critical habitat under federal laws, administered by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.

Status of Biological Knowledge

The recognition of the importance of eelgrass within the bay and estuarine ecosystem has provided a focus of scientific research and resource management for several decades. Early last century researchers on both coasts collected an array of information on water and air temperatures along with plant data over a several year period. Additionally, measurements of eelgrass standing stock have been conducted throughout the Northern Hemisphere including the West Coast of North America.

The distribution of eelgrasses within bay and estuarine ecosystems is dependent on a variety of parameters, including light, temperature, salinity, substrate, waves and currents, nutrients, and availability of seed. Most commonly, estuarine seagrasses are found in soft sediments of semi-sheltered areas where depth and turbidity conditions allow sufficient light. The typical depth distribution of eelgrass is throughout the inter- and subtidal-zones. The maximum standing crop occurs just below mean low water. Maximum biomass occurs at depths corresponding to 20 to 30 percent surface-light intensity. Distribution and abundance of eelgrass also appear to be influenced along the land-sea axis of estuaries by the relative abundance of nutrients. Nutrient availability is higher at the riverine end of an estuary. However, the mixing zone within estuaries also tends to be more turbid. Thus, the relationship between light penetration and nutrient availability acts with other factors to define the areas within estuaries where eelgrass beds become established and thrive.

Eelgrass is a flowering marine plant that grows from rhizomes in soft sediment. The establishment and expansion of eelgrass beds occur through seed production and asexual rhizome propagation. Although their roots and rhizomes help to stabilize sediments where they are established, eelgrass beds are highly susceptible to anthropogenic disturbances, particularly substrate disturbances and reduced light penetration. Eelgrass beds are also susceptible to adverse impacts from non-native invasive species. Studies looking at the response of eelgrass to a non-indigenous mussel (*Musculista senhousia*) found that eelgrass beds showed a negative response to colonization of this invasive bivalve, particularly where the eelgrass bed was sparse or fragmented, or in beds that had been reestablished. The recent discovery of the invasive algae *Caulerpa taxifolia* (Mediterranean strain) in Agua Hedionda Lagoon in southern California has also demonstrated the ability of an invasive species to displace eelgrass.

Once disturbed, eelgrass bed recovery or recolonization is slow and may not be possible without reestablishment of favorable growth conditions. The decline of seagrass and related aquatic vegetation has reached and alarming state worldwide. Studies show documented plant losses in the United States that have approached or exceeded three-quarters of the historic distribution. Further, the importance of genetic distribution in the population dynamics of aquatic plants has in the past largely been ignored in restoration and conservation efforts. Studies in southern California found significantly reduced genetic diversity in eelgrass beds that were reestablished through transplants or that otherwise became established in previously disturbed locations. Reduced genetic diversity in the transplanted sites corresponded in general to a smaller size and younger plant age than in undisturbed sites, although this characteristic effect on the eelgrass community is not fully understood. However, there was no evidence that genetic diversity increased in transplanted sites over time. It is likely that this genetic diversity problem occurs in many areas of the state where eelgrass bed disturbances commonly take place.

Status of the Beds

Along the Pacific coastline of California, eelgrass is found to some degree in all of the larger bays and estuaries, from the Oregon border to San Diego, including Humboldt Bay, Tomales Bay, San Francisco Bay, Monterey Bay, Morro Bay, and San Diego/Mission Bay. Additionally, eelgrass is well established in several of the smaller open estuarine embayments along the state's coastline. The historical presence of eelgrass along the California coast was much greater than it is today. Although few records exist that measure the areal extent of eelgrass within the state's small coastal estuaries, the condition that existed prior to human disturbances in many of these locations were no doubt favorable to eelgrass bed communities.

Humboldt Bay

Measurements of eelgrass standing stock in Humboldt Bay were conducted in 1972. Distribution was determined by mapping the eelgrass beds through field surveys and light aircraft. Eelgrass standing stock values determined through density analyses ranged from 3.1 million pounds dry weight in April 1972, to 15.2 million pounds dry weight in July 1972, with South Humboldt Bay accounting for 78 to 95 percent of the total eelgrass stock. These results were similar to an earlier assessment in 1962.

The differences in densities between the north and south bays appear to be persistent. A wet-weight density range (depending on location) of 0.06 to 0.43 pounds per square foot for Humboldt Bay winter eelgrass was estimated in 1979. The study attributed eelgrass density differences between the two regions of the bay to variations in sediment composition, and dredging activities in North Humboldt Bay associated with the commercial cultivation and harvest of oysters, rather than light availability or tidal flushing. Localized eelgrass bed density surveys conducted by the Department of Fish and Game in an effort to evaluate the biomass of Pacific herring utilizing Humboldt Bay eelgrass beds for spawning substrate also noted significantly lower eelgrass densities in North Humboldt Bay compared to South Bay during the 2000-2001 commercial herring season. Total eelgrass coverage within Humboldt Bay was determined to be 3,053 acres in 1984. Since that time, a detailed bay-wide eelgrass survey has not been conducted. However, the California Department of Fish and Game, U.S. Fish and Wildlife Service, Humboldt State University, and others have proposed initiating biannual bay-wide eelgrass surveys to begin during the summer of 2001.

Small North Coast Estuaries

It is likely that at one time eelgrass predominated along the seaward edge of many of the small estuaries at the mouth the north coast river systems. Today, due to human alterations, such as channelization, dredging, and upstream disturbances that cause increase turbidity and siltation, eelgrass is limited to but a few such ecosystems. Remnant populations are documented within the North Coast estuaries that remain open to seawater influence year-round, such as the Big River estuary where eelgrass forms large beds along muddy banks within the first three miles of the estuary, and the Albion River Estuary, which also has a well-established eelgrass community.

Tomales Bay

Eelgrass is the most abundant marine flora in Tomales Bay. Surveys conducted by the California Department of Fish and Game in 1985, determined the areal extent to be 965 acres. Although eelgrass distribution is relatively stable from year to year in Tomales Bay, densities of eelgrass beds are highly variable within and between individual beds seasonally. The density and distribution of eelgrass within Tomales Bay are determined annually by the California Department of Fish and Game as part of the seasonal herring spawning-ground surveys. Extensive eelgrass beds are located within Tomales Bay throughout the intertidal and subtidal areas, generally in waters less than 12 feet mean lower low water between Sand Point and Nicks Cove, and around the immediate bay perimeter on both shorelines to the vicinity of Millerton Point.

The general locations of the Tomales Bay eelgrass beds appear to have been consistent since the early 1970s, although there is some annual fluctuation. The density of eelgrass during the winter of 1987-1988 was 0.04 0.55 pounds per square foot. Similar densities were observed 1973 and 1976. Such densities represent between 70 and 100 percent bottom-coverage. The long-term evaluation of Tomales Bay eelgrass beds indicates that one bed near the mouth of the estuary is more ephemeral than any other.

San Francisco Bay

San Francisco Bay, the largest of California's estuaries, is also the most impacted by human development. An estimated one third of the historic extent of the bay has been lost to fill and development. While estuarine systems are by nature highly turbid, poor water clarity within San Francisco Bay is further exacerbated by human activities including direct treated industrial and wastewater discharges, non-point source runoff, urban-associated atmospheric deposition, and riverine inflow containing urban and agricultural discharges. Data on the historic areal extent of eelgrass within San Francisco Bay are limited, although it is believed that it supported extensive eelgrass meadows in the past. Reduced light penetration due to extremely high bay turbidity has been found to limit the development of eelgrass and may be the principal cause of its decline in San Francisco Bay. Eelgrass beds in the bay today are limited to relatively small patches located in the central bay, Richardson Bay, and the eastern northern-most portions of the south bay. In 1989, the areal extent of eelgrass beds in San Francisco Bay was estimated to be 316 acres. Since that time, some eelgrass beds have increased in size and new patches have been sited.

Eelgrass densities are far lower than those of the larger, healthier beds found in Tomales and Humboldt Bays. Although the eelgrass beds appear to be stressed, they have remained persistent in the bay and are heavily utilized by estuarine organisms.

Southern California

The eelgrass communities found south of San Francisco are more heavily impacted by human alteration than those in northern California. Historical records suggest that eelgrass was a predominant plant species in the state's south coast estuaries. However, the majority of southern California's remaining eelgrass habitat exists primarily due to replanting or recolonization of eelgrass beds in new or historic locations. Patchy eelgrass communities found within the Monterey Bay Area and Morro Bay are two exceptions. The eelgrass beds within the Monterey Bay Area are limited to the estuarine environment of Elkhorn

Slough and its entrance to the bay. These areas make up a total of approximately 50 to 75 acres of eelgrass habitat.

Eelgrass remains the dominant plant in the beds of Morro Bay. The beds there are the largest and least impacted of any in the southern portion of the state. Nevertheless, there are wide fluctuations in areal extent. By 1997, eelgrass distribution reached a historic low of 50 total acres. Further studies in 1998 showed an improvement in eelgrass distribution ranging from 81 to 120 acres, depending on the season of survey.

Eelgrass bed communities also exist in Los Angeles Harbor, Huntington Harbor, and in adjacent coastal areas. Many of these have been established through transplant activities associated with specific development mitigation requirements. Due primarily to suitable light conditions, many of the reestablished areas have met their intended mitigation goals. However, some reestablishment attempts have been unsuccessful. A complete survey of the areal extent of eelgrass and associated density assessments within this location of the state has not been conducted. The National Marine Fishery Service and other state and federal resource agencies have conducted cursory surveys of eelgrass in these locations. While formal surveys and reports have not been completed, areas that support eelgrass have been identified.

The eelgrass bed communities within San Diego County coastal areas have been heavily impacted by urbanization. All of the bays in this area of the state have been intensively modified. Attendant stresses are evidenced by very low eelgrass densities. Additionally, many of the eelgrass communities in San Diego County coastal areas have been derived through reestablishment efforts or, as in Mission Bay, through natural colonization of dredged sediments. The most comprehensive survey conducted for eelgrass in the San Diego Bay was completed in 2000. This survey followed an early bay-wide survey conducted in 1994. Similar surveys have been completed for Mission Bay, Batiquitos Lagoon, and Agua Hedionda. The location of eelgrass present within Oceanside Harbor has also been documented by the National Marine Fishery Service.

Management Considerations

See the Management Considerations Appendix A for further information.

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Gracilaria and Gracilariopsis

History of Harvest

Although species in the red algal genera *Gracilaria* and *Gracilariopsis* have been harvested throughout the world for agar production and as a food source for humans and cultured shellfish, only small amounts have been harvested from the wild in California during the last few decades. Between 1965 and 1970, several applications were made to the Fish and Game Commission for permission to harvest Pacific herring eggs deposited on edible seaweeds for export to Japan, where it is considered a luxury food item. In 1970, Department of Fish and Game divers conducted a survey to determine the quantity and composition of the aquatic vegetation in Tomales Bay. The commission decided to establish one five-ton harvest permit each for Tomales and San Francisco bays. However, siltation, which occurs in both bays during the winter months, lowered the market quality of a large portion of the eggs-on-seaweed harvest; as a result, the five-ton quota was never reached in either bay. The harvest of herring eggs on wild edible seaweed in Tomales and San Francsico bays is now prohibited.

Status of Biological Knowledge

Gracilaria pacifica and *Gracilariopsis lemaneiformis* are commonly found in California's bays and estuaries. Both species have numerous brownish-red thin branches loosely connected to the substrate by a small holdfast and grow to a maximum height around three feet. Because they are so similar in appearance and frequently found growing in the same area, they are often difficult to distinguish. *Gracilaria pacifica* is commonly found in sheltered intertidal to subtidal locations from Alaska to the Gulf of California, Mexico. *Gracilaria lemaneiformis* occurs in areas exposed to ocean currents as well as protected intertidal and subtidal areas from Vancouver Island, British Columbia, Canada, to Santa Catalina Island in the Southern California Bight. Both species are fast growing and, when detached from the substrate, often form large dense mats in estuarine areas protected from strong currents. In Tomales and San Francisco bays, where annual vegetation density studies are conducted in conjunction with Pacific herring spawning surveys, *Gracilaria* and *Gracilariopsis* densities fluctuate considerably from year to year.

Little is known about the significance of these species in bay and estuary ecosystems. One study conducted in Jarvis Bay, Australia, found relatively low numbers of fish and decapod species inhabiting drifting *Gracilaria spp.* beds when compared to adjacent seagrass beds, suggesting that these beds may not be a critical habitat for estuarine macrofauna. However, *Gracilaria* and *Gracilariopsis* appear to be among the preferred spawning substrates for Pacific herring in California waters and may be essential to herring when other aquatic vegetation is not available. These beds with herring eggs are an important feeding area for a variety of marine animals.

Management Considerations

See the Management Considerations Appendix A for further information.

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Aquaculture: Overview

The commercial culturing of marine species in California is limited primarily to the production of shellfish such as oysters, mussels, and abalone. While the culturing of finfish for enhancement purposes is well established in California, commercial culturing has been limited in scale and remains focused on solving technical questions through research. The commercial production of most cultured shellfish has declined from recent peaks. Oyster production is down from a peak in 1994; abalone production is down from a peak in 1996; and mussel production is down from a recent peak in 1997. In several instances, demand exceeded production and the declines reflected several ongoing challenges faced by these industries in their efforts to maintain production. More information on production levels can be found in the specific sections that follow.

Developing and maintaining production of cultured marine species is still influenced by technical problems, in some cases in spite of a well-established production history. Fledgling industries, such as those engaged in scallop and finfish production, face technical challenges in developing breeding and rearing techniques. The well-established industries, such as oyster and abalone culture, face technical challenges in maintaining production when faced with environmental change or disease impact. Human-caused changes in water quality, for example, present significant challenges to culture facilities that are sited in bays and estuaries. In order to address product safety concerns in these areas, the production of mussels, oysters, and clams are often subject to closures or depuration requirements. The presence of a shellfish aquaculture facility in an area can, as a consequence, provide a contamination early-warning system for sport-harvest of shellfish and an assessment of the biological conditions in the general area. With the exception of concerns related to the accumulation of biotoxins, changes in water quality do not present significant technical challenges in the culturing of scallops because of the tendency in that industry to site in offshore areas. Natural changes in water quality have also hampered shellfish production. Much of the recent decline in production can be attributed to El Niño-related impacts, particularly in the culturing of mussels and abalone. A broader discussion of these technical challenges can be found in the specific sections that follow this overview.

Development of a technical response to disease, and conforming to regulatory requirements related to disease control have both influenced production in the oyster and abalone industry and have influenced the success of white sea bass enhancement efforts. Oyster production in Tomales Bay, for example, continues to be influenced by a significant summer-time mortality of unknown cause. Abalone production has been influenced by mortality from withering syndrome and hampered by regulatory requirements intended to prevent the spread of an exotic parasitic worm. Large numbers of juvenile white seabass have been destroyed to address disease concerns. In each instance, the industry made positive contributions to cooperative efforts among resource agency disease-management researchers.

Taken as a whole, the industry has ardent entrepreneurial support, has great economic potential, and has been a source of significant positive societal benefit. If not conducted in a resource-sensitive manner, aquaculture can also cause negative environmental impacts, by introducing exotic species, by introducing or contributing to the spread of disease, or by altering the natural systems within which production facilities are located. The key to achieving the positive aspects of aquaculture while minimizing negative ones rests in how effectively the industry, the research community, and regulatory agencies can work together. Industry leaders are now focusing on developing best management practices to ensure that shellfish culture does not impact the health of ecosystems upon which they depend. A common goal will be to ensure that the industry achieves its successes in resource sensitive ways without having to do so under an undue regulatory burden. Our ability to achieve that goal may hinge on developing trust through effective communication.

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Culture of Abalone

History

Pioneering efforts to mass cultivate abalone in California began about 35 years ago. Three abalone species, the red (*Haliotis rufescens*), the green (*H. fulgens*), and the pink (*H. corrugata*) have been farmed, and research into cultivation techniques has been conducted on the black (*H. cracherodii*) and white abalone (*H. sorenseni*). The red abalone, however, is the mainstay of the industry and comprises more than 95 percent of total production. Abalone are grown in either land-based tanks or in cages suspended in the water column. The cages are typically tethered from a raft but have also been suspended beneath a wharf. Aquaculturists that operate these in-water systems typically obtain small seed abalone from land-based hatcheries for grow-out.

In a typical hatchery operation, ripe brood stock abalone are induced to spawn using hydrogen peroxide or ultraviolet light treated seawater. Fertilized eggs that successfully develop to the veliger swimming stage are transferred to through-flowing larval rearing tanks. In about six days at 59° F, larvae are ready to settle from the planktonic to the benthic stage. They are transferred to nursery tanks, and commence to feed on diatoms. After six months of growth, half-inch abalone are then transferred to plastic mesh baskets suspended in larger tanks. At this point, the abalone begin feeding on macroalgae. An additional six to eight months are required before they reach the size where they are transferred to grow-out tanks or in-water systems. After growing in these tanks or in-water systems for 20 months or longer, they attain the typical three- to four-inch shell length preferred by the market.

The number of participants in this industry and their total production have increased through time, peaking in 1996. In 1991, 15 registered abalone aquaculturists in California produced an estimated 175,000 pounds of abalone in the shell. By 1996, 27 registered abalone aquaculturists produced over 292,000 pounds of product. Participation and production then declined slightly through 1998 when 22 aquaculturists produced 162,000 pounds of product valued at $2.4 million. Only 13 of the 22 abalone aquaculturists registered in 1998 were actively producing abalone and most of the production came from four or five growers.

Red abalone being grown out on plastic substrate.

The decline in participation and production since 1996 is attributable, at least in part, to disease impacts exacerbated to some extent by a significant El Niño event. Until recently, cultivated abalone had been considered relatively disease-free. The bacterium *Vibrio sp.* infected larval cultures, but it was typically suppressed by using filtered, ultraviolet treated seawater. That perspective changed with the introduction of a parasitic sabellid polychaete worm from South Africa. By the mid-1990s, the parasite had spread to virtually every abalone aquaculture facility in the state. The worm induces the infested abalone to form a tube for it out of nacreous material. With heavy infestations, the abalone shell is brittle and very deformed and abalone growth is stunted. Impacts to the industry included loss from voluntary stock destruction and reduced income from marketing deformed product. Cooperative efforts by the industry, the Department of Fish and Game (DFG), and Sea Grant sponsored university researchers have almost completely eradicated the worm from California.

Unfortunately, the industry also started experiencing elevated losses of cultured product from withering syndrome (WS) during this same time frame. This disease, caused by a rickettsia-like prokaryote, is characterized by a drastic shrinkage of the abalones' foot and is always fatal. However, red abalone can be infected by the bacterium without showing clinical signs of disease. Research suggests that a stress trigger is necessary to induce clinical signs of the disease in this specie. The only recognized stress trigger is elevated water temperature. With the El Niño event, many facilities experienced elevated water temperatures that triggered WS, resulting in elevated mortality in their cultured stock.

The dedicated entrepreneurs at the core of this industry have achieved their successes despite these challenges and interest in abalone aquaculture remains high, prompted in part by the closure of the commercial abalone fishery in 1997. Presently, abalone are available to meet market demands only through importation or the purchase of cultured abalone. Consequently, there is a high market demand and a good price to growers for the farmed product.

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

Status of Biological Knowledge

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

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

The DFG's Marine Region shellfish pathology laboratory in Bodega Bay has expanded our knowledge of the biology of the parasitic sabellid worm that has contributed significantly to the success that has been achieved in the cooperative eradication efforts. That laboratory also identified the causative agent for WS and has conducted extensive research into questions related to transmission and control of this pathogen.

Two principle areas for research, nutrition and genetics, may provide significant benefits to the industry in the future. Prepared diets have been developed and are being used widely for juvenile stages. However, most prepared feeds are expensive and not readily accepted by adult abalone in comparison to giant kelp. Less progress has been made in genetics research. Most growers use a selection process where brood stock is selected based on growth rates. Wild broodstock is also used to maintain genetic diversity in cultured stocks. Some research has been done with triploidy as a means of enhancing abalone growth rates. While encouraging, the results have not been applied broadly within the industry.

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US Abalone

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Culture of Mussels

History

Mussels of the genus *Mytilus* have fluctuated in importance in California's commercial and sport shellfish fisheries for food and bait since the early 1900s. Experiments in culturing wild seed stock and in developing hatchery and grow-out methods in the 1980s have increased the economic potential of mussels, particularly *Mytilus galloprovincialis* (the Mediterranean mussel), which occurs primarily in southern and south-central California.

A related species, *Mytilus trossulus* (the "foolish mussel") is sport-harvested in northern California and hybrids of *M. trossulus* and *galloprovinciallis* are commonly found between Cape Mendocino and Monterey Bay.

The sea mussel, *Mytilus californianus*, is of minor economic importance in California at present, though it is taken by sport harvesters and it is periodically sold by a southern California harvester to restaurants. It is primarily used as bait along the West Coast, but in the 1980s, wild harvested sea mussels, highly esteemed by gourmet chefs in Oregon, were sold to fine restaurants in Portland and still may have a future in California.

Between 1916 and 1927, a total of over 470,000 pounds of mussels, ranging from 9,000 to 69,000 pounds per year, were landed in California. After 1927, most areas were closed to harvest by the California Department of Health Services due to a major outbreak that year of paralytic shellfish poisoning. Mussel landings declined to 1,610 pounds in 1928 and stayed depressed until 1972, when a record 111,000 pounds were landed, primarily for bait. Bait sales continued to be the most significant commercial activity for California mussels until improved methods of harvesting wild stocks were developed, new culture methods were adopted, and West Coast markets began developing for this tasty shellfish in the early 1980s.

Research on harvesting wild-set Mediterranean mussels from offshore oil-production platforms for food was initiated in the Santa Barbara Channel in 1979. Divers routinely removed fouling organisms from the submerged support structures of offshore platforms at considerable expense to oil companies. An ecological consulting firm, hired to suggest ways to control the biofouling, found that various stages of the succession of organisms included settlement and growth of edible mussels, both *M. galloprovincialis* and *M. californianus*. Recognizing the potential for food production and increasing market demand for high quality shellfish, the owners of the firm contracted with various offshore oil companies to test the feasibility of harvesting and marketing the mussels.

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

In 1985, approximately 104,000 pounds of mussels were harvested, primarily from offshore platforms, but by this time a farm in Tomales Bay also had begun to utilize European longline methods to grow mussels. Over the next seven years, three to five other Tomales Bay oyster growers diversified into mussel production. These growers utilized wild-caught and hatchery reared seed, with the latter being relied upon more in the late 1980s, as natural recruitment during this period was often erratic and unreliable. After a brief period of expansion, several Tomales Bay growers ceased all but minimal production in the mid-1990s to concentrate on oyster culture. By the fall of 2000, only one company was producing commercial quantities of mussels. These are sold exclusively to local restaurants around Tomales Bay. At least three other growers have the capability to produce commercial quantities and may scale up their operations again if market conditions improve.

On the north coast, an oyster grower operating in Mad River Slough, Humboldt County, began farming mussels in 1992 using the floating raft culture method. Seed mussels, attached to a line inside flexible plastic mesh netting, are suspended from the raft during grow-out. Cultured mussels from Humboldt Bay were initially used, but since the mid-1990s, wild juvenile mussels collected from the bay have been the primary source of seed. The mature mussels are sold locally at farmers' markets and restaurants. One other Humboldt Bay operation began experimenting with mussel grow-out in 2001, using wild seed stock and following the raft culture method used in Mad River Slough.

The total state mussel production tripled in 1986, reaching more than 334,000 pounds, with over 90 percent harvested from platforms in the Santa Barbara Channel and the remainder from Tomales Bay. Statewide production dropped slightly in 1987 to approximately 286,000 pounds and decreased further in 1988 to 151,000 pounds, due to major winter storms, which dislodged market-ready mussels from platform structures. Production jumped to over 300,000 pounds in 1989 but dropped to 130,000 pounds in 1990 when the Carlsbad firm ceased production, continuing a slide in 1991 to a low of only 47,000 pounds. During the next six years (1992 through 1997), with the Carlsbad firm back in production, increasing harvest from offshore platforms in the Santa Barbara Channel, and steady production in Tomales Bay, the statewide total rose from 187,000 pounds to 471,000 pounds. Strong winter storms following warm El Niño seawater conditions in the fall of 1997 caused havoc to mussel production throughout the state the following year. An economically devastating drop in production of nearly 50 percent, to 256,000 pounds, occurred in 1998. One of the large southern California growers stated that spawning and recruitment were both affected by these events. A colder water regime in 1999 - 2000 improved the recruitment situation and has been encouraging to growers.

Mussels harvested during the five years between 1986 and 1990 provided a return of $1.17 million to California growers. Steady expansion of production during the following five years between 1991 to 1995 increased statewide returns to $2.06 million. Return to growers dipped in 1996 and 1997 to about $500 thousand per year with a critical drop in 1998 to $280 thousand.

The wholesale price has not changed significantly over the past 15 years still ranging from $1.10 to $1.25 per pound. Retail/restaurant prices have increased slightly from $2.00 in 1990 to $2.25 in 2000. Direct sale prices to the public at farmers markets and retail shellfish farms has increased, varying between $2.50 per pound in southern California and $4 per pound in the Tomales and San Francisco Bay area. The retail/restaurant price in Humboldt County is slightly higher at $2.50 per pound and direct sales at farmers' markets are intermediate at $3.00 per pound.

California growers continue to face stiff competition from mussels imported from eastern Canada, New Zealand, Maine, and Washington due to the advent of low cost air transport of fresh shellfish and individual flash freezing methods. Competing on the world market is a challenge to California producers, because of massive production of mussels in China, Korea, New Zealand, Australia, and other Pacific Rim countries. Expansion of the industry is dependent on the maintenance of clean growing areas, a supportive regulatory environment, aggressive marketing, and dependable sources of seed. Climatic and oceanographic events have also had significant impacts on the economic health of this industry.

Until 1986, all mussels grown commercially in California were set or collected as wild or natural seed. In 1985, a cooperative effort was initiated by a Humboldt County shellfish nurseryman to produce the first commercial quantities of hatchery-reared mussel seed on the West Coast. Growers utilized a variety of substrates and set the spat at different densities. A wide range of results, from zero survival to excellent survival and growth were reported. The methods of growing out seed evolved and matured in Tomales Bay and in the Puget Sound area of Washington state but were not proven on a commercial scale in south-central and southern California as growers continued to utilize natural seed.

The five participating growers in Tomales Bay purchased larger (0.5-1.0 inch) seed, which could be grown to market size in six to nine months. Excessive predation on maturing mussels by scoter ducks and on small natural-set seed by schools of perch over time proved burdensome to most of the shellfish growers who were concentrating on oysters as their primary product. All but one company in Tomales Bay ceased or minimized their mussel operations, citing competition from low-cost imported mussels as the reason.

Southern California mussel companies also face stiff competition from imports, and also must cope with water quality fluctuations, especially in nearshore areas or embayments. One south-coast aquaculturist has built a depuration system for bivalve shellfish, one of the first in California. The grower has been able to use a protected lagoon to grow mussels, which are relayed to the onshore depuration system prior to sale. By utilizing seawater treated with ultraviolet violet light to eliminate harmful bacteria, he can produce wholesome, high quality mussels.

Status of Biological Knowledge

Genetic studies utilizing protein electrophoresis in the late 1980s showed that there were two distinct forms of *edulis*-like mussels on the West Coast that are morphometrically similar. One of these forms is electrophoretically indistinguishable from *M. galloprovincialis*, the Mediterranean mussel, which is known to have recently colonized many disparate shores around the world. The other form is also distinct from the Atlantic *M. edulis* and was designated *M. trossulus*, the Pacific Northwest mussel. It was found from Alaska to central California. The two forms occur together and are reported to hybridize with one another. Several genetic studies in the late 1990s have confirmed that *M. galloprovincialis* is found principally south of the Monterey Peninsula and *M. trossulus* is found primarily north of Cape Mendocino. A zone of hybridization has been documented between these two distinct coastal features.

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

Spawning in *M. californianus* occurs throughout the year at a very low level, with peaks in July and December. The spawning and recruitment of *M. galloprovincialis* also occurs year round, although it is heaviest in February, March, and April and again in September and October in southern California. Mussels reaching 1.6 inches are found to have gonads in various stages of development and are able to spawn.

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

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

Growth rates of both *M. galloprovincialis* and *M. californianus* have been reported to be at least 0.25 inch per month and as high as 0.5 inch per month in the Santa Barbara Channel. Growth rate is influenced primarily by the quantity and quality of food, rather than temperature, and mussels achieved a two-inch shell length in six to eight months.

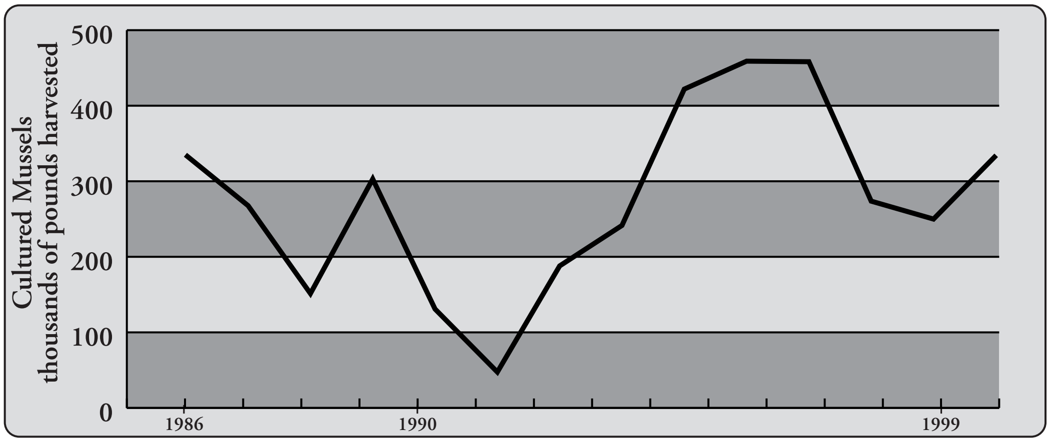
Food consumed by mussels includes dinoflagellates, organic particles, small diatoms, zoospores, protozoa, unicellular algae, bacteria, and detritus. Phytoplankton is considered to be the main food item providing energy for rapid growth.

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

Predators of California mussel species are abundant. They include two sea stars, five species of muricid gastropods, and three crabs. Scoter ducks, the black oyster- catcher, shiner perch, and the sea otter are also important predators in coastal waters.

An invasive species of algae, *Caulerpa taxifolia*, recently found in a southern California lagoon is another concern of both mussel growers and resource managers. Known for its progressive smothering of the Mediterranean seafloor, the alga is the focus of an intensive effort by state and federal regulators to eradicate the species before it spreads.

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



Commercial Harvest 1986-1999, Cultured Mussels
Annual pounds of cultivated mussels landed by State aquaculture producers. Harvest data for 1997-1999 include only mussels cultivated in Tomales Bay and Drakes Estero. Data Source: California State Tax records (royalties reports) and DFG Aquaculture Harvest Survey Database.

Management Considerations

See the Management Considerations Appendix for further information.

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Culture of Oysters

History

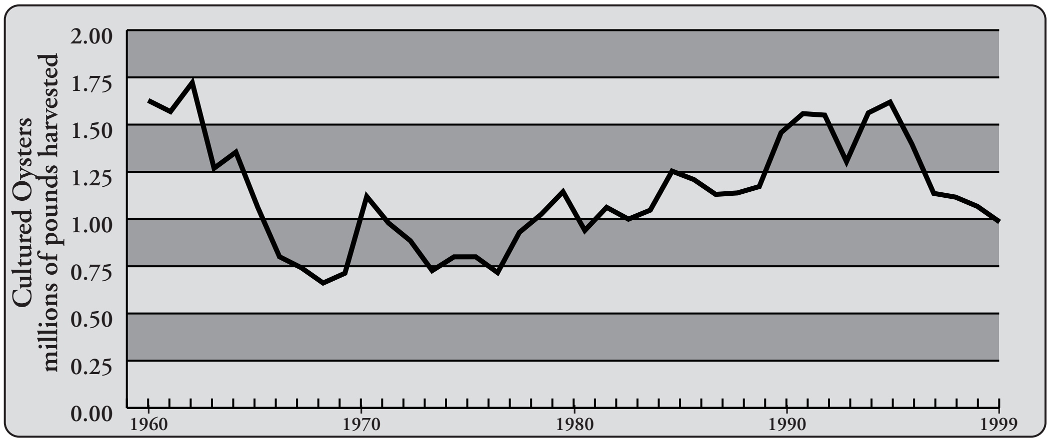
California's oyster fishery and oyster aquaculture industry have had a rich and colorful tradition. American Indians harvested the oyster resource for thousands of years before Spanish, Tsarist Russian, and European settlers occupied the West Coast. A substantial commercial oyster fishery began in the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

Growing Oysters in Tomales Bay
Credit: Fred Conte

Transcontinental trade for Eastern oyster seed was fully established by 1875. Small, one-inch seed was transplanted in San Francisco Bay for further growth. The Shoalwater Bay trade for Olympia oysters was gradually terminated, and from 1872 until the early 1900s California's San Francisco Bay Eastern oyster industry was the largest oyster industry on the West Coast. Maximum production was reached in 1899 with an estimated 2.5 million pounds of oyster meat.

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

Boxes containing oyster shell with attached young oysters (spat) were transported by ship in wooden crates kept moist with seawater. With the influx of seed oysters, the industry began its recovery in California and on the West Coast. The DFG lifted its restriction on Pacific oyster seed in Humboldt Bay in 1953, and in the next 30 years, the California industry showed rapid growth with production



Commercial Harvest* 1960-1999, Cultured Oysters Annual pounds of cultivated oysters harvested by State aquaculture producers. Data Source: California State Tax records (royalties reports) and DFG Aquaculture Harvest Survey Database. * Packed weight is estimated to be 15.5 percent of live weight for *C. gigas* and 10.9 percent for *C. virginica*. Shucked gallons are calculated as 8.6 pounds/gallon for *C. gigas* and 8.5 pounds/gallon for *C. virginica*. Cultchless oysters, *C. sikamea* and a large portion of *C. gigas* are sold as shellstock.

centered in Humboldt Bay, Drakes Estero, Tomales Bay, Elkhorn Slough, and Morro Bay.

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

Another hatchery product is cultchless oyster seed that are grown out as individual oysters exclusively for the half shell market. Cultchless seed are produced by setting the larvae on sand or finely crushed oyster shell, resulting in unattached, individual oysters. Many California growers purchase cultchless seed from California-based advanced seed producers. These producers receive 3.0 to 5.0 mm cultchless seed from a hatchery, then use floating upweller systems (FUS) to hold the seed in flow-through containers receiving bay water containing algae. The oyster seed increases in size and is more easily handled in mesh bags used by the end producer. Individual growers are also adopting and expanding their own land-based FUS and downwellers to cut the cost of seed and assume the responsibility of early seed growth. All oysters grown in California currently are produced from hatcheries located in Washington, Oregon and Hawaii.

The hatchery systems primarily produce two species of Pacific oysters; the Pacific oyster (*C. gigas*) and the Kumamoto oyster (*C. sikamea*) which also originated in Japan and does not reproduce in California's cooler summertime water. Other less prominent species produced by hatcheries have included the European oyster (*O. edulis)* and some Eastern oyster (*C. virginica*). The ability to ship oyster larvae long distances and set the spat at the growout areas has significantly reduced the cost of seed. The last shipment of Japanese seed to California was in 1989.

The level of oyster production within the various bays has fluctuated throughout the years, primarily because of water quality, the bay's ability to produce good standing crops of algae on which oysters feed, the adequacy of selected sites, and the financial viability of the various oyster operations. All growing areas are classified and certified by the California Department of Health Services (CDHS) based on health-related water quality standards established and regulated by the Interstate Shellfish Sanitation Conference (ISSC) and the National Shellfish Sanitation Program (NSSP). Water-bottom and offshore growout areas are leased from the state through the Fish and Game Commission, harbor and recreation districts, or belong to private corporations.

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

California oyster production is currently centered in four areas, Arcata Bay located in the North Humboldt Bay complex, Drakes Estero, Tomales Bay and Morro Bay. Morro Bay oyster production has declined in recent years, but techniques have included bottom, rack-and-bag, and stake culture. Shellfish producers in the Santa Barbara Channel have used a system of longlines with attached bags of European oysters suspended from offshore rafts in the deep waters, but have discontinued production in recent years. Shellfish producers also cultured cultchless oysters in Agua Hedionda Lagoon, located north of San Diego, but have switched to mussel production which was considered more suitable to the area.

Humboldt Bay growers use a variety of oyster culture methods, but the predominate method has been bottom culture of Pacific oysters. In bottom culture, cultch with attached spat is spread over leased areas in the bay, the oysters are grown to about four inches and are then harvested by hand picking and hydraulic dredge. Most of California's shucked oyster product is from bottom culture in Humboldt Bay. Because of environmental concerns and the impact of hydraulic dredging on eelgrass, growers are currently changing about 85 percent of their bottom culture production over a period of about three years to off-bottom, longline culture of the Kumamoto oyster. The Kumamoto oyster derives a higher market price as non-shucked shellstock, and the remaining bottom culture will be targeted for the peak shucked-oyster market in November and December. Environmental and economical studies are being conducted to determine the impacts of these changes on both the health of the bay and the economic health of the industry.

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

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

Tomales Bay growers also use a variety of off-bottom techniques including rack-and-bag, stick and bag, and bag and longline culture. Rack-and-bag culture uses cultchless seed that is first grown in trays, upwellers and downwellers, or floating, rotating, mesh cylinders. After initial growth, the small oysters are transferred to a series of different sized mesh bags positioned on low racks in the bay. Bag and longline culture use cultchless seed in mesh bags attached to an anchored line which suspends the bags vertically in the water or secures the bags on a stable, hard bottom, intertidal area. Bags can also be maintained horizontally at the surface using floats. To maintain the prime oyster shape for the half shell market, the bags must be moved frequently to prevent the individual oysters from growing together and resulting in an irregular shape.

Total annual oyster production for California has fluctuated throughout the industry's history, reflecting cyclic shellfish mortalities ("Summer Mortality Syndrome", SMS), availability of seed oysters, economic conditions, and the financial stability of individual companies. With the advent of hatchery technology and remote setting of oyster seed, the industry demonstrated significant growth from the mid-1980s to a second post-1960s peak in the mid-1990s. Reduced production after 1994 directly reflects several industry setbacks, which include financial restructuring after the 1990s recession, extended bay harvest closures due to sanitary degradation and oil spills, and recurrence of cyclic SMS. Several of these factors have been resolved, and production increases are expected. The data represents a conversion of all oyster products to a common denominator of shucked pounds of oysters expressed as packed weight. Total production in recent years is primarily Pacific and Kumamoto oysters. Annual Eastern oyster production has been 20 pounds or less for the past three years.

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

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

Status of Biological Knowledge

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

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

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

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

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

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

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

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

The adult Pacific oyster ranges from about four to six inches in length. The shell is coarse, with widely spaced concentric lamella and ridges. The shell is thinner than that of Eastern oysters yet more deeply cupped. The Kumamoto oyster is smaller but is prized for its deeper cup. It spawns in the fall in nature and grows more slowly than the Pacific. The Miyagi is the principal variety of Pacific oyster grown on the West Coast. The Pacific oyster's shape may be highly variable and greatly influenced by environmental conditions. The upper, flat, right valve is smaller than the left, and the inner surface of the valves is white with a faint purple hue over the muscle scar.

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

Oyster diseases on the West Coast most frequently occur in hatcheries, but a few significant oyster diseases have been reported from the field. Hatchery conditions are artificial environments which can stress oysters and render them susceptible to an array of infections. Hatchery-associated oyster diseases are usually confined within the hatchery. When identified, the stocks are destroyed and systems disinfected. This is a protective measure for the natural resource and considered the most economically practical approach by the industry.

Field-associated oyster diseases are not common, but they do occur. Two examples of the most significant of these diseases for the West Coast are "Summer Mortality Syndrome" (SMS) of Pacific oysters, and "Bonamiasis" of European oysters. Summer mortality of Pacific oysters was first reported in the 1960s with mortality levels as high as 65 percent of adult Pacific oysters. Oyster losses attributed to SMS have fluctuated over the years, and studies have addressed the initiating agent as possible unknown pathogens, environmental factors and impacts, and stressors such as the combination of depleted energy reserves and attempted gonadal maturation. SMS was researched for decades without resolving the cause. In 1993 and 1994, summer mortalities of Pacific oyster seed in Tomales Bay reached 52 and 63 percent respectively, and were associated with elevated water temperatures above 20˚C and a dinoflagellate bloom. Pathological examination and histology suggested that these mortalities were related to environmental causes and not an infectious agent. SMS appears to be cyclic, may be related to decadal cycles, and is the most significant mortality-related event experienced on the West Coast of the United States. In addition, as the losses are a "syndrome" and are not caused by a specific pathogen, multiple etiologies may result in oyster deaths during the summer. The type of stress that results in losses may also fluctuate over time, making diagnosis of the cause(s) and management of losses difficult. Growers are attempting to circumvent the problem by not planting Pacific oyster seed during the warmer months from May to October. However, seed availability during the cooler months has been a problem. Growers report that cooler bay water temperatures in 1999 appear to have moderated the mortality rate from that experienced previously.

Bonamiasis of the European oyster, caused by a parasite, has impacted the oyster industry to the same extent as SMS, as it has contributed to the inability to establish European oyster culture in California. The parasite infects the oyster's blood cells, destroys its immune system, and impacts other physiological processes.

Of recent concern is the 1980s discovery in California of a haplosporidium similar to that which causes MSX or Delaware Bay Disease on the East Coast. West Coast producers have not experienced the cyclic, catastrophic haplosporidia diseases that have occurred on the East Coast, despite movement of Eastern oysters between the coasts. It has been confirmed that the organism is the causative agent of MSX of Eastern oysters. The organism is found among Pacific oysters in one bay in California but is not associated with significant mortalities. Morphologically similar haplosporidians have also been reported from Washington state. Recent studies suggest a common ancestry for the organism on both coasts and that the haplosporidian was not endemic to the East Coast but originated in Pacific oysters from Japan. Hypotheses for the introduction of the disease to Eastern oysters include importation of infected Pacific oysters to the East Coast, ballast water containing the infective agent, or introduction of an unknown intermediate host. In any event, the ultimate result has been catastrophic for the Eastern oyster and the East and Gulf coast industries. The result of these studies demonstrates the first molecular confirmation of the introduction of an exotic marine pathogen and emphasizes the need to adhere to strict importation guidelines as established by the International Council for the Exploration of the Seas (ICES).

Shellfish and the Environment

One of the more significant challenges to aquaculture in the next decade will be the industry's ability to position itself within the environmental framework and philosophy of natural resource management. Environmental issues are a concern nationally and are paramount in California.

Immediate environmental concerns relative to shellfish culture are the potential biological and physical impacts of culture technology on sensitive components of the marine ecosystem. These sensitive components include eelgrass as essential habitat for salmonid and other finfish, and the invertebrate assemblage present on and within the substrate that is essential to the food web of birds and other marine species. Also included are the impacts on the life habits of birds and marine mammals and on the physical structure of the bay. It will be essential that shellfish technology not have significant impact upon the health of the ecosystem on which it also depends. Shellfish culture and our living marine resources depend upon excellent water quality and a healthy environment and, therefore, these concepts are not mutually exclusive.

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

Future Trends

Oyster hatchery and production seed technology has rapidly expanded in the past ten years. This has included application of remote setting of oyster seed as an industry standard, and the production and use of triploid (3n) oysters containing an extra set of chromosomes. The 3n condition prevents the onset of maturation and results in oysters characterized by year-round production of high quality meat. Although triploid production was a positive technical breakthrough, the sterile 3n oyster does not reproduce and therefore can not be improved through genetics. To overcome this, the industry now applies high pressure following fertilization to retard both polar bodies. The resultant tetraploids (4n) are then artificially crossed with diploids (2n), thereby producing sterile triploids (3n) that are used as production oysters while maintaining a viable genetic line in the diploid broodstock. This technology, coupled with the more recent establishment of broodstock genetic programs, will be a major industry thrust.

Oyster genomic research is an industry priority and a regional cooperative effort involving university and industry geneticists and oyster hatchery managers.

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

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

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

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Culture of Salmon

History

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

Land-based tank operations maintain all of the fish at the facility until harvest. Fish are kept in tanks made of concrete, fiberglass, or other materials. Round tanks are often in the range of 30 to 40 feet in diameter. Water is pumped through the tanks to maintain good water quality, and growth comes from manufactured feed provided by the aquaculturist.

Net pen facilities use young fish produced in hatcheries, which are then placed into pens where they are fed until grown to market size. The pens are made from flexible netting material suspended from floats and are generally a few hundred square feet at the surface. Pens are often linked together to form large units of up to many acres. The net-pens are usually placed in sheltered salt-water areas where protection from ocean storms is provided and good water quality is maintained by natural currents.

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

In California, land-based tank operations were tried in the 1980s and 1990s, and accounted for some limited private aquaculture production of salmon. Most commercially produced salmon were from tank-rearing operations located in northern California, where cold water suitable for salmon culture is more readily found. Fish were grown to market size in tanks using either fresh or salt water. Steelhead trout (*Oncorhynchus mykiss*) were produced from domestic brood stock maintained by California aquaculturists, whereas coho salmon (*Oncorhynchus kisutch*) and Atlantic salmon (*Salmo salar*) eggs or fingerings were imported from out of state to California farms. Salmon culture has not been a major component of the state's private aquaculture sectors and never contributed as much as five percent to the total value of the industry's production.

Conversely, public salmon hatchery operations play a key role in the management of California's natural resources. Hatcheries are built and operated to supplement natural salmon resources or to mitigate for the loss of natural production that occurs when water and power generation projects eliminate salmon spawning habitat. Thus, hatcheries help provide for the multiple beneficial use of the state's water resources. Public hatcheries produce approximately 40 million fish each year and are critical to maintaining the state's sport and commercial salmon fisheries. Over ninety percent of California's salmon harvest comes from south of Point Arena, where hatchery-produced fish generally make up over half of the catch.

Public hatchery production of salmon in California dates back to 1872 with the establishment of Baird Hatchery on the McCloud River in the upper Sacramento River drainage. Several other salmon hatcheries and egg taking stations also began operations in the late 1800s and early 1900s. Baird originally operated as an independent hatchery, then as an egg collecting station for salmon and trout reared at Mount Shasta Hatchery (then called Sisson Hatchery). After the construction of Shasta Dam, Mount Shasta Hatchery and the upper Sacramento spawning grounds were separated from the lower Sacramento River and the Pacific Ocean. Coleman National Fish Hatchery was built in 1942 to mitigate for those losses. It replaced many of the early hatcheries, including most of the salmon operations at Mount Shasta. Coleman Hatchery is on Battle Creek, a tributary of the Sacramento River at Anderson (south of Redding). It is the only federally operated fish hatchery in California.

Today there are seven California Department of Fish and Game-operated salmon mitigation hatcheries and two state-operated salmon restoration and enhancement hatcheries. All nine of these state-operated hatcheries have been built since 1955. The mitigation hatcheries are located on central valley and north coast rivers downstream from dams constructed for water or power development.

Hatchery	Location
Iron Gate	On the Klamath River below Copco Lake
Trinity	On the Trinity River below Clair Engle Lake
Feather River	Below Lake Oroville
Mokelumne River Fish Installation	Below Camanche Reservoir
Nimbus	On the American River below Folsom Lake
Van Arsdale Fisheries Station	On the Eel River below Van Arsdale Reservoir
Warm Springs	On a tributary to the Russian River below Lake Sonoma

The DFG's two restoration and enhancement hatcheries are the Mad River Hatchery near Eureka and the Merced River Fish Installation below Lake McClure. There is also a non-profit salmon and steelhead enhancement hatchery in California on the Smith River. The Rowdy Creek Fish Hatchery is located in the town of Smith River and began in 1967 as a Kiwanis Club project. It operates under an individual category in the California Fish and Game Code.

In addition, public or privately funded nonprofit salmon restoration and enhancement projects use a variety of habitat improvement, artificial spawning, and rearing techniques to improve runs of wild fish or to contribute additional fish to the fishery. Most are located on coastal streams in northern and central California. Saltwater pen-rearing operations have been located at Tiburon, Port San Luis, and Ventura. In 1998-1999, a total of twelve projects planted an average of 30,000 fish per project.

Status

Currently, there is no private for-profit aquaculture production of salmon in California. Nationally, and internationally, net pen rearing of salmon has proven to be the most successful method of private aquaculture production of salmon for the seafood market. The only net-pen rearing of salmon in California has been some small sport fishing salmon enhancement projects. Commercial net-pen rearing is not prohibited, in part because no suitable sites have been identified or developed which do not conflict with other established uses.

Every private aquaculture operation in California is required to register with the Department of Fish and Game. Before approving an application for registration, the department must determine that each facility will not cause significant negative impacts on adjacent native fish and wildlife. Private salmon culture may be permitted throughout California where negative impacts will not result, except that commercial salmon farming is prohibited from the Smith River watershed.

The lone California commercial salmon ranching project (Davenport Landing) is required to operate under an annual permit from the Fish and Game Commission. Commission authority to issue the salmon ranching permit is granted by the California Legislature. The legislature reviews the authorization periodically and in 1995 extended authority to issue the permit to January 1, 2001. While the project does not have a current permit, it historically has been authorized to ranch chinook salmon, coho, and steelhead.

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

Public hatchery production remains relatively constant; therefore, years of low natural production result in harvests with a larger proportion of hatchery fish. Depending upon the success of each year's natural production, Department of Fish and Game biologists estimate that hatchery-produced fish generally contribute from 50 to 60 percent of California's sport and commercial salmon harvests.

Most of the public hatchery production of salmon in California is intended to mitigate for the loss of habitat caused by construction of dams for water and power development. The concept of providing mitigation for losses to fish and wildlife caused by the building of a government project was originally established by the U.S. Congress when it enacted the Fish and Wildlife Coordination Act of 1934. The need to replace the natural fishery resources eliminated by these projects continues to have high priority with the people of California.

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Weighing and spawning of Chinook salmon at Rowdy Creek Hatchery, a community-run hatchery near Crescent City.
Credit: CA Sea Grant Extention Program

Culture of Marine Finfish

History of Finfish Culture

The impetus to develop marine aquaculture in the U.S. is strong. In 1998, the U.S. imported $8.2 billion in edible fishery products. During the past 15 years, production of food fish by capture fisheries reached a plateau of 66 million tons per year. Similarly, FAO statistics report that 60 percent of marine fisheries are fully or over-exploited. Under these conditions, and with a growing human population, it is estimated that aquaculture production will have to increase by 140 percent from 1995 levels by the year 2025.

Marine finfish farming in California and the United States is in its infancy. In California, with the exception of anadromous species, no marine finfish are being produced on a commercial scale. In the United States, specifically Texas, only red drum are cultured in large numbers. However, the red drum fingerlings being produced are used primarily for stock enhancement and not grown out and marketed for direct human consumption. Like the Texas stocking program for red drum, California has been evaluating the efficacy of marine stock enhancement since the early 1980s. This research has been conducted largely under the auspices of the Ocean Resources Enhancement and Hatchery Program (OREHP). In recent years, the stock enhancement research has lead to projects designed to evaluate the feasibility of commercial growout in nearshore cages. The two primary species that have been investigated in California are the white seabass (*Atractoscion nobilis*) and the California halibut (*Paralichthys californicus*). Giant sea bass (*Stereolepis gigas*) have also been studied but to a much lesser extent.

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

The OREHP began in 1982 and has since been reauthorized with minor modifications. This program funds research through the sale of recreational and commercial marine enhancement stamps for all saltwater anglers south of Point Arguello. The California Department of Fish and Game manages the OREHP with the assistance of an advisory panel that consists of academic and management agency scientists, representatives of both commercial and recreational fishing groups, and the aquaculture industry. Since 1995, OREHP has supported operation of the Leon Raymond Hubbard, Jr. Marine Fish Hatchery in Carlsbad, California. This research facility is dedicated to improving our understanding of marine fish culture.

The species described in this chapter are native to California and have historically represented important fisheries to the region. Detailed descriptions of the natural history and fisheries for each are provided elsewhere in this volume.

Culture, Facilities and Systems

In California, land-based research facilities (hatcheries) are used for broodstock holding and maturation, and for larval rearing of marine finfish. Juvenile culture has been conducted on a limited scale for white seabass in cages, pools and raceways, and with California halibut in raceways. Seawater is pumped into land-based facilities from nearshore areas, (typically lagoons, harbors, or embayments) where water quality may be highly variable.

Broodstock maturation systems are typically recirculated so that water temperature can be controlled and used to induce spawning. Pool volumes range from 5,000 to 11,500 gallons. Egg hatching and early larval rearing systems require fine control over water quality parameters. Low flow requirements make flow-through systems practical, but recirculating systems are generally recommended. Pool volumes for egg hatching and early larval rearing range from 80 to 450 gallons. Juvenile growout has been conducted in flow-through systems (pools and raceways) up to 8,000 gallons in volume and nearshore cages up to 145,000 gallons.

California's OREHP maintains one of the largest breeding populations of a single species of marine finfish, white seabass, in the world. More than 250 adult fish are maintained in captivity either in breeding pools or support facilities. The need for this large number of individuals stems from the stock enhancement objectives of the program and the desire to ensure genetic diversity of released animals. However, the large broodstock population also results in a surplus of egg production that could help support a developing commercial culture industry.

Spawning of marine finfish, including white seabass and California halibut is often allowed to occur naturally or is induced semi-naturally using photo-thermal manipulation. That is, seasonal cycles are either natural (ambient water temperature and photoperiod) or controlled to promote spawning out of season. Hormone-induced spawning has not been investigated thoroughly and the few attempts to induce spawning have been largely unsuccessful. The disposition and general hardiness of California halibut and giant sea bass makes them potentially better suited to the extra handling required for hormone injections, while white seabass are not.

Female white seabass and California halibut are reported to mature in the wild at four to five years. For white seabass, this represents a size of 27 inches and for California halibut, 18.5 inches. Eggs from each of these species are pelagic. Females are batch-spawners, with each batch typically yielding hundreds of thousands to more than a million eggs.

Growth of each of these species is highly dependent on water temperature. White seabass and California halibut are physiologically adapted to estuarine conditions as juveniles and therefore can tolerate (and may prefer) higher temperatures (71-81° F) associated with embayments. Furthermore, the southern range for these species near Magdelena Bay in Baja California, Mexico where water temperatures can be expected to be even warmer than those in California.

White seabass have been cultured in raceways to a size of 3.3 pounds in two years at temperatures of 56-79° F. A similar growout period in cages yielded only a 1.75 pound white seabass, but water temperature was considerably lower (52-72° F). California halibut cultured in raceways exhibited slow growth, reaching a maximum of 0.9 pound in two years under conditions of 55-77° F. It should be noted that these data are preliminary and that growth will likely be improved as the nutritional requirements and the potential for selective breeding are investigated more fully.

White seabass begin feeding at an age of four to five days (post hatch). Their relatively large size allows them to feed successfully on newly hatched *Artemia*. California halibut and giant sea bass both require smaller prey items such as rotifers for the first week of feeding, before transitioning to *Artemia* nauplii. Beginning at 20 days, dry feed is offered to the fish along with the *Artemia*. In order to help the fish wean from a live prey diet to dry feed, frozen zooplankton (adult *Artemia*, krill or mysids) is also fed to the fish. The amount of live food (*Artemia* nauplii) and frozen feed is slowly reduced as fish begin feeding on the dry feed. Once on dry feed, the feed size is increased as the fish grow. The feed type, characterized by the protein and fat content, may also be adjusted to reduce costs and improve fillet quality.

Among the more common infectious diseases affecting white seabass and California halibut are: 1) protozoans; 2) bacteria; and 3) invertebrate parasites. Among these pathogens, the bacterium *Flexibacter maritimus* is the most common and difficult to eradicate. Infections by this organism occur frequently after handling the fish and may result in lesions and fin rot. Among the non-infectious diseases, gas bubble disease is often severe among white seabass cultured in shallow water systems that are not adequately degassed, including floating raceways in natural water bodies. Nutritional deficiencies are also likely in cultured marine fish, although the effects are not well understood.

Cannibalism can be a significant problem among younger life stages of marine fish before grading is practical. Cannibalism can be reduced by optimizing feeding and nutrition and by grading the fish. In outdoor rearing pools, birds such as herons are known to prey on cultured fish. These predators can effectively be excluded using inexpensive netting. In cages, marine mammals such as California sea lions and harbor seals can be a problem if given the opportunity. Birds, both diving and non-diving, can also prey on caged fish. To prevent predation on caged fish, extra netting (*i.e.*, in addition to the fish containment net) should be employed above and below the water.

Aquaculture Potential

The aquaculture potential for white seabass and California halibut should be excellent. The potential for giant sea bass culture appears to be less promising, although further research is warranted for this species. White seabass and California halibut are popular, high-value species. Wild white seabass are available seasonally and at a large size of more than six to seven pounds. Wild halibut are available year-round and there is a growing market for live fish.

In other regions, species similar to white seabass and California halibut are being cultured successfully -- in some cases on a truly commercial scale. Among some of the croaker species (related to white seabass), red drum, and seatrout are being cultured in the United States. Totoaba, corvina, and maigre (all members of the croaker family) are being evaluated for culture in Mexico, Argentina, and the Mediterranean, respectively. Several species of flatfish are also being cultured. On the East Coast of the United States, the summer flounder and southern flounder are being evaluated for culture. In Japan, a flounder has been cultured on a commercial scale for many years, and two species of flounders are being cultured in South America.

Conclusions

Aquaculture of marine finfish is in its infancy in the United States, and California has not contributed significantly to its development. With 1,200 miles of coastline, opportunities to farm the ocean should be readily available. Unlike the agriculture industry in California, which consistently ranks number one in the nation (greater than $26 billion in 1997), mariculture opportunities in California are impeded by competing uses for coastal resources and a restrictive regulatory environment. In addition to the typical burdens associated with bureaucracies, California regulatory agencies often overlap in authority, lack a clearly defined process, and are often poorly educated about the need for aquaculture and what is involved with mariculture activities.

There is a clear need for aquaculture development worldwide and California has access to the coastal resources and high value marine species necessary to compete in the world seafood market. A proactive approach is required to make this a reality.

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Invasive Species

History

Invasive species are the number two threat to rare, threatened or endangered species nationwide, second only to habitat destruction. Commercial fishermen nationwide are seeing significant impacts on local fish populations from invasive marine life. Indeed, coastal systems, including tidal flats and salt marshes, have been particularly susceptible, possibly because they are typically high-stress, species-poor environments. California water agencies have expressed alarm at the "potentially devastating" impacts that invasive species can have on California's waters. Unlike threats posed by most chemical or other types of pollution, biological pollution by invasive species normally will have permanent impacts, as they are virtually impossible to eradicate once established.

Specific environmental threats from invasive organisms include consumption of natives and their food sources, genetic dilution of native species through cross-breeding, alteration of the physical environment, introduction of non-native parasites and diseases, and poisoning of native species through bioaccumulation of toxics that are passed up the food chain. For example:

- In the former Soviet Union, a species of comb jelly was introduced into the Black and Azov Seas through ships' ballast and played a significant role in virtually destroying an entire fishery. Since the introduction of this species, fishing harvest in those seas dropped 200,000 tons in a five-year period.
- Microscopic neurotoxin-producing organisms called dinoflagellates have been transported in the sediments carried with ballast water and discharged into new regions of the world, where they have produced toxic red tides, including red tides in southern Australia that probably originated in ballast water.
- Scientists have warned that a non-native goby now found in the Great Lakes raises toxin levels in indigenous fish and could pose a serious health risk to humans who eat game fish.
- Microbial studies conducted in Canada on ships arriving in winter from Europe found that more than 50 percent of the ships carrying ballast water violated water discharge standards with fecal coliform bacteria. The authors surmised that ships arriving in the summer, or from Asian ports, would be likely to have substantially higher rates of contamination.

Here in California, numerous studies indicate that San Francisco Bay is already severely impacted by harmful non-native species. These studies have identified at least 234 nonindigenous plant and animal species that now live in San Francisco Bay. Moreover, the rate at which aquatic invasive species are becoming established in San Francisco Bay has increased from an average of one every 55 weeks before 1960, to one every 14 weeks between 1961 and 1995. Invasive species that have been positively identified as permanent residents of the Bay include Asian clam, the European green crab, the New Zealand sea slug, the Chinese mitten crab, and several species of sponges, jellyfish, fish, anemones, snails, mussels, clams, and barnacles. Indeed, San Francisco Bay is likely the most invaded estuary in the world.

The discharge of ships' ballast water from foreign ports is currently the single largest source of coastal, aquatic invasive species. A recent survey found that 53-88 percent of the aquatic invasive species introduced into San Francisco Bay in the last decade originated in ballast water discharges, and there is evidence that the number of ballast-related introductions of aquatic invasive species is steadily growing. According to estimates by the San Francisco Estuary Institute, between half a billion and a billion gallons of ballast water are discharged into the San Francisco Bay/Delta Estuary each year by ships arriving from foreign ports. Aquaculture, unintentional introductions via recreational vehicles, deliberate introductions (*i.e.*, to establish a fishery), and importation of live marine organisms for human consumption, bait, pets or research are other important vectors of aquatic invasive species.

Examples of Significant Invasive Species

Numerous invasive species threaten the health of marine life both directly and indirectly through alteration of coastal ecosystems and habitats. This section highlights three of the more significant species, which are a particular problem in the San Francisco Bay and surrounding areas, and reviews the status of invasions elsewhere in the state.

The European Green Crab (*Carcinus maenas*)

The green crab, native to the Atlantic coasts of Europe and northern Africa, occupies protected rocky shores, sandflats and tidal marshes. In 1989-1990, it was discovered in San Francisco Bay, and has since spread as far north as Washington and southern British Columbia and south to Morro Bay. It may have entered California through the discharge of ballast water from trans-oceanic ships, although spread is also possible through discard of seaweed packing material used in shipping live shellfish and the interstate transport of shellfish aquaculture products and equipment.

The green crab is a voracious predator that feeds on many types of organisms, particularly bivalve mollusks, polychaetes, and small crustaceans. The green crab is

European Green Crab, *Carcinus maenas*
Credit: DFG

capable of learning and can improve its prey-handling skills while foraging. The crab is quicker, more dexterous and can open shells in more ways than other types of crabs. In its native range, the green crab feeds heavily on mussels. On the East Coast, the crab is believed to have played a role in the demise of Atlantic soft-shell clam fisheries in the 1950s. In Bodega Harbor, California, records show a significant reduction in clam and native shore crab population abundance since the arrival of green crabs in 1993. Furthermore, laboratory studies show that the green crab preys on Dungeness crab of equal or smaller size. Dungeness crab spend part of their juvenile life in the intertidal zone, and may therefore be at risk from green crab predation. Besides its threat as a predator, the green crab may carry a parasite, the acanthocephalan worm, which can infect local shore birds.

The Chinese Mitten Crab (*Eriocheir sinensis*)

The Chinese mitten crab is native to the coastal rivers and estuaries of the Yellow Sea. It was first collected in the San Francisco estuary in 1992 by commercial shrimp trawlers in South San Francisco Bay and has since spread rapidly throughout the estuary. Mitten crabs were first collected in San Pablo Bay in fall 1994, Suisun Marsh in February 1996, and the delta in September 1996. The Chinese mitten crab now extends at least from north of Colusa in the Sacramento River drainage, east to eastern San Joaquin County near Calaveras County, and south in the San Joaquin River near the San Luis National Wildlife Refuge. The most probable mechanism of introduction to the estuary was either deliberate release to establish a fishery or accidental release via ballast water. In Asia, the mitten crab is a delicacy and crabs have been imported live to markets in Los Angeles and San Francisco.

The mitten crab is catadromous - adults reproduce in salt water and the offspring migrate to fresh water to grow. A single female can carry 250,000 to a million eggs. After hatching, larvae are planktonic for one to two months. The small juvenile crabs settle in salt or brackish water in late spring and migrate to freshwater. Young juvenile mitten crabs are found in tidal freshwater areas, and usually burrow in banks and levees between the high and low tide marks. In China and Europe, older juveniles have been reported several hundred miles from the sea. Maturing crabs move from shallow areas to the channels in late summer and early fall and migrate to salt water in late fall and early winter to complete the life-cycle.

Mitten crabs are adept walkers and readily move across banks or levees to bypass obstructions such as dams or weirs. They are omnivores, with juveniles eating mostly vegetation, but preying upon animals, especially small invertebrates, as they grow.

Mitten crabs pose several possible threats. Their burrowing activity may accelerate the erosion of banks and levees, disturbing local habitat. In addition, the crab can disrupt needed water deliveries to estuarine habitats by clogging the pumps that deliver the water. The mitten crab also has become a nuisance for commercial bay shrimp trawlers in south bay, who have reported mitten crabs damaging nets and killing shrimp. The crab may also compete in the delta with an exotic crayfish that is the basis for a small commercial fishery. The mitten crab may also be the secondary intermediate host for the Oriental lung fluke, with mammals, including humans, as the final host.

The ecological impact of a large mitten crab population is the least understood of all the potential impacts. It could reduce populations of native invertebrates through predation and change the structure of the estuary's fresh and brackish water benthic invertebrate communities.

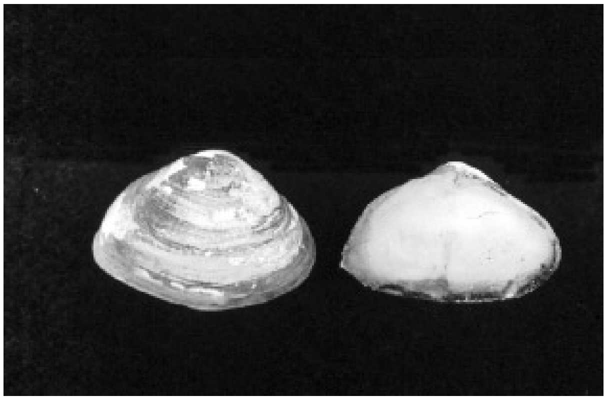
Chinese Mitten Crab, *Eriocheir sinensis*
Credit: DFG

An Asian Clam (*Potamocorbula amurensis*)

In October 1986, the first Asian clams found in California were collected in San Francisco Bay by a community college biology class. Just nine months later, the Asian clam had become the most abundant clam in the northern part of the bay, averaging over 2000 clams per square meter.

The clam is a highly efficient filter feeder, ingesting bacteria and small zooplankton as well as phytoplankton. At year 2000 densities in the bay, virtually the entire water column may pass through the filtering apparatus of these clams between once and twice a day. Since its arrival, the clam has eliminated annual phytoplankton blooms that had previously characterized this ecosystem, disrupted food webs, reduced the populations of native zooplankton species, and possibly increased the vulnerability of the ecosystem to invasions by exotic zooplankton, many of which have since occurred. This clam is also thought responsible for a reduction in particulate organic carbon. With less food available for larval and other benthic filter feeders, the relative populations of native species could shift.

The clam may also be acting as an accumulator of contaminants, concentrating selenium in bottom-feeding fish and birds at levels that are high enough to cause reproductive defects. This magnification of selenium concentrations in the food chain could also affect fish- and shellfish-eating marine mammals such as harbor seals, sea lions, and the sea otters, which are returning to the bay.



Asian Clam, *Potamocorbula amurensis*
Credit: DFG

A South African Sabellid Worm (*Terebrasabella heterouncinata*)

The South African sabellid worm is a parasitic polychaete worm that infests mollusks. It was introduced into California waters in the mid-1980s with abalone imported into a California aquaculture facility. The worm spread rapidly among abalone facilities through the transfer of infested seed stock and proved difficult to control once established. The worm infests only the abalone's shell, significantly reducing the growth rates of cultured abalone. A heavy infestation can cause shell deformation, elevate mortality as the shell becomes brittle, and reduce reproductive capacity as more energy is channeled into shell production.

Introduction in state waters is highly likely, given the species' broad host specificity. Sabellids have been detected in a native gastropod mollusk, in the intertidal zone adjacent to the discharge pipe from an abalone facility in central California. Attempts to eradicate this invasive species at this site and at culture facilities are ongoing.

The California Department of Fish and Game (DFG) has established inspection requirements for abalone stock transfers, required detailed clean-up plans from all infested aquaculture facilities, prohibited out-planting, and added the sabellid to the Fish and Game Commission's significant disease list. Such controls appear to be having some effect, as most abalone culture facilities report some level of control and eradication of this worm. However, there have been reports of re-infestation by abalone shipments that had been inspected and certified by the DFG. The inspection protocols used have been mathematically demonstrated to be unlikely to detect a low level of infestation in transferred abalone, such as one to five percent or lower. Moreover, the mesh on the screens of the discharge pipes of onshore culturing facilities are far too large to prevent the release of eggs or larvae, and the openings in offshore barrel and cage culture are even larger. Subtidal inspection of possible release sites for the sabellid worm has been very limited, and the locations of some of these possible release sites are simply unknown. Further work is needed to ensure that all infestations are removed and effective controls are in place to prevent reinfestation.

A Tropical Seaweed (*Caulerpa taxifolia*)

An invasive green algae dubbed the "killer algae," was discovered in the waters of southern California off Carlsbad in early 2000. Native to tropical waters, it became popular in the aquarium trade in the late 1970s and either escaped or was released into the Mediterranean Sea in the mid-1980s. It is now widespread throughout much of the northwestern Mediterranean. It appears that the algae found off southern California is a clone of the released Mediterranean plant, and can grow in deeper and colder waters than the tropical populations. Its impacts have been compared to unrolling a carpet of Astroturf across the sea bed. In areas where it has become well-established, it has caused economic and ecological devastation by overgrowing and eliminating native seaweeds, seagrass reefs, and other communities.

In southern California, the algae poses a significant threat to eelgrass meadows and other benthic environments that are essential to the survival of native invertebrates, fish and aquatic birds. If the algae spread from the coastal lagoons to the nearshore reefs, it could inhibit the establishment of juveniles of many species, including kelp and the biota associated with kelp beds. Efforts to destroy this patch of algae have involved tarping off the area and injecting chlorine under the tarp.

Other Invasives

Invasive species are present not only in San Francisco Bay but are common as well in other harbors and bays in California and along the Pacific Coast. For example, recent compilations list about 25 invasive species in Morro Bay in central California, and about 80 invasive species in the bays and harbors of southern California. One such organism is an Australasian isopod that significantly erodes the banks of salt marsh channels and marsh edges in San Diego Bay, resulting in reduction of already-limited coastal habitat.

Once established in one area, exotic organisms may quickly spread to another through either natural or anthropogenic transport. Invasive species initially established in bays may subsequently invade the open coast. A predatory New Zealand sea slug that was collected in San Francisco Bay in 1992 may have spread north to Bodega Bay and south to near San Diego, though further taxonomic work is needed to identify which of the two to four species of invasive sea slugs are involved and the locations of their spread.

Existing Regulatory Regime and Regulatory Gaps

National Invasive Species Act of 1996

Existing regulation of the major vector of invasive species introduction - ballast water discharges - is generally limited in its reach. The primary federal law regulating ballast water discharges, the National Invasive Species Act (NISA), calls primarily for voluntary ballast water exchange by vessels entering the U.S. after operating outside of the EEZ (mandatory ballast water exchange requirements exist only in the Great Lakes). Some of the limitations of NISA are that while it states that the voluntary program could become mandatory after several years, there are currently no criteria in the statute or accompanying regulations to guide that decision. Moreover, it addresses only vessels entering the U.S. from outside the EEZ, and ignores, for example, coastwise traffic from areas contaminated with problematic invasive species (such as the San Francisco Bay area).

NISA requires annual reporting to assess the ongoing effectiveness of the program. The first interim report by the National Ballast Information Clearinghouse, issued in October 2000, found that over the first 12 months (July 1999-2000) that the rule was in effect, only 20.8 percent of the vessels that entered U. S. waters from outside the EEZ filed the mandatory reports required under NISA and pursuant to U.S. Coast Guard regulations. For the entire U.S., compliance with reporting improved only slightly over the 12-month period, remaining between 23 percent and 29 percent from October 1999 through June 2000. Only for the West Coast of the contiguous U.S. did compliance with the reporting requirement increase markedly over time, primarily from an increase in California, which receives the most ship arrivals. This increase coincided with implementation of a 1999 California state law that requires submission of copies of the federal ballast water management reports to the State Lands Commission, authorizes monetary and criminal penalties for noncompliance, and utilizes an active boarding program that targets 20-30 percent of arrivals. As a result, compliance with reporting in California increased over the past 12 months to approximately 75 percent.

The report concluded that due to the poor nationwide reporting rate (20.8 percent), it is difficult to estimate reliably (a) the patterns of ballast water delivery and (b) the compliance with NISA's voluntary guidelines for ballast water management. Based on the information that was submitted, the report found that nationwide, approximately 42 percent (10.2 million metric tons) of the foreign water reported discharged into the U. S. had not been exchanged completely as requested in the voluntary guidelines. The report also noted that although it is clear that many vessels that discharge ballast water in the U.S. are not in compliance with voluntary guidelines, based upon their reports, the extent of non-compliance with these guidelines simply cannot be estimated accurately due to the very low rate of reporting.

Clean Water Act

The Clean Water Act prohibits the discharge of "any pollutant by any person" into waters of the United States, unless done in compliance with specified sections of the Act, including the permit requirements in Section 402. National Pollution Discharge Elimination System (NPDES) permits issued to discharges into the territorial sea also must comply with "ocean discharge criteria" specifically designed to prevent the degradation of those waters, pursuant to Clean Water Act Section 403.

Currently, an EPA regulation adopted in the 1970s specifically exempts ballast water from the NPDES permit program. In January 1999, a petition was made to the EPA by the Pacific Environmental Advocacy Center, on behalf of conservation groups, commercial and recreational fishing interests, American Indian tribes and California water agencies, to regulate ballast water discharges under the NPDES permit program in Section 402, arguing that the regulatory exemption adopted by EPA exceeded their authority and violated the mandates of the Clean Water Act. Moreover, the assumption that ballast discharges are harmless is clearly no longer the view of the EPA or other federal agencies. After two years of waiting, the petitioners filed suit against EPA in January 2001 to respond to the 1999 petition.

If a pollutant is threatening or impairing use of a water body, the water body violates water quality standards and must be listed under Section 303(d) of the Clean Water Act as "water quality limited" for that pollutant. EPA or the state then must establish the "total maximum daily load" (TMDL) of the offending pollutant that can be released into the water body and still ensure that the water meets water quality standards, within a "margin of safety." A water body whose use is impaired by aquatic invasive species could be "listed" under Section 303(d); if so, EPA or the state must identify the maximum load of problem aquatic invasive species that can be safely discharged into that water body. Given the significant and ongoing impacts associated with numerous aquatic invasive species, it may be difficult for the applicable agency to set a TMDL for aquatic invasive species other than zero and still meet Section 303(d)'s "margin of safety" requirement. Currently, many reaches of the San Francisco Bay are listed as impaired by invasive species under Section 303(d).

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires that federal agencies prepare an Environmental Impact Statement (EIS) for "major federal actions significantly affecting the quality of the human environment." NEPA may be used to require further examination of federal projects that may result in increased discharges of ballast water containing invasive species. At least one circuit court has recognized that NEPA requires federal agencies to evaluate a project's indirect impacts on the spread and introduction of aquatic invasive species.

Endangered Species Act

Under Section 7 of the federal Endangered Species Act (ESA), federal agencies must ensure that their actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species…" In addition, federal agencies must consult with the Secretary of the Interior and/or Commerce, as appropriate, "on any agency action which is likely to jeopardize the continued existence of any species proposed to be listed…or result in the destruction or adverse modification of critical habitat proposed to be designated for such species."

Section 7 of the ESA should be used to examine the impacts of a federal project that may result in increased discharges of ballast containing invasive species, where such discharges may affect endangered or threatened species.

Presidential Executive Order 13112

On Feb. 3, 1999, President Clinton issued an Invasive Species Executive Order creating a Cabinet-level National Invasive Species Council. The Council was charged with creating a National Invasive Species Management Plan that would address all types and sources of invasive species, including aquatic invasive species in ballast water. An Invasive Species Advisory Committee made up of a range of stakeholders has been working with the Council on a draft management plan. The draft management plan was released for review in October 2000 and was finalized in early 2001.

California Environmental Quality Act

The California Environmental Quality Act (CEQA) requires appropriate mitigation of projects that contain significant environmental impacts. A "significant" impact is a "substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the Project including land, air, water, minerals, flora, [and] fauna…" The documented adverse impacts associated with invasive species appear to fit this broad definition. In addition to meeting the general definition of "significant effect," the impacts associated with increased discharges of invasive species may require a mandatory finding of significance under CEQA, thus mandating feasible mitigation of those impacts or an alternative project.

California Porter-Cologne Water Quality Control Act

Under California's Porter-Cologne Water Quality Control Act "any person discharging waste, or proposing to discharge waste, within any region that could affect the quality of the waters of the state" must file with the appropriate Regional Water Quality Control Board a report of the discharge. Pursuant to the act, the regional board then prescribes "waste discharge requirements" related to control of the discharge. The act defines "waste" broadly and the term has been applied to a diverse array of materials. The San Francisco Bay Regional Water Quality Control Board has determined that "ballast water and hull fouling discharges cause pollution as defined under the Porter-Cologne Water Quality Control Act," raising the possibility that the act may be actively used to regulate such discharges.

California Fish and Game Code

State fish and wildlife laws contain provisions that relate to the control of aquatic invasive species from a variety of vectors. Some examples in the California Fish and Game Code include the following:

- Section 2271. "No live aquatic plant or animal may be imported into this state without the prior written approval of the department."
- Section 6603. "All fish, amphibia, or aquatic plants which the department determines are merely deleterious to fish, amphibia, aquatic plants or aquatic animal life, shall be destroyed by the department, unless the owner or the person in charge . . . ships them out of the state . . . ."
- Section 6400. "It is unlawful to place, plant, or cause to be placed or planted, in any waters of this state, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the state, without first submitting it for inspection to, and securing the written permission of, the department."
- Section 15200. "The commission may regulate the placing of aquatic plants and animals in waters of the state."
- Section 15600. "No live aquatic plant or animal may be imported into this state by a registered aquaculturist without the prior written approval of the department pursuant to the regulations adopted by the commission."

Public Resources Code

In 1999, California became the first state in the nation to enact legislation mandating exchange of ships' ballast water in an effort to control the introduction of invasive species. The Public Resources Code requires vessels carrying foreign ballast to exchange that ballast in open seas. It also requires specified state agencies to analyze the status of invasions, the effectiveness of the ballast exchange program, and alternatives for ballast treatment; sets penalties for noncompliance; and levies fees on regulated vessels to pay for the program. Washington state passed a mandatory ballast water exchange law modeled on California's law in 2000. California's mandatory law, clear penalties, and an active ship boarding program has resulted in its taking the lead in the nation on the control of ballast water, as the Clearinghouse report conclusively found.

Controlling the introduction of invasive species is well within the traditional police powers of the states. As long as the proposed legislation does not dictate the specific type of ballast water treatment techniques that vessels must use and does not favor "local" shipping over "foreign," then state ballast water management laws do not appear to be preempted by constitutional law or by NISA.

Local Application of State and Federal Laws

Place-based management of invasive species introductions can occur where agencies implement state and federal laws on a local level. For example, in response to a petition from conservation groups, the San Francisco Bay Regional Water Quality Control Board identified invasive species as "pollutant stressors" subject to Clean Water Act Section 303(d) in lower, south and central San Francisco Bay, Richardson Bay, Suisun Bay, San Pablo Bay, Carquinez Strait and the delta. The regional board ranked invasive species as a high priority for action in all affected water bodies. The listing was approved by the State Water Resources Control Board and U.S. EPA (see above discussion of TMDL requirements).

The regional board approved a resolution to transmit to U.S. EPA an Exotic Species TMDL Report on impairment of the San Francisco Bay estuary by invasive species. Among other things, the regional board asserts in its report that a water quality-based endpoint to achieve the estuary's water quality standards is no exotic species introductions. In other words, an acceptable TMDL of exotic species or organisms is zero.

Conclusions

The legal frameworks that apply, and may apply, to control of aquatic invasive species introductions are broad and varied. Many of these legal tools are just beginning to be utilized. As the costs associated with aquatic invasive species continue to mount, it appears likely that additional research and regulatory actions will be taken to reduce such discharges. To maximize the effectiveness of regulatory regimes, stakeholder input - from the conservation, shipping, port, fishing, utility and other communities - should be encouraged and carefully considered.

In spite of the significance of the impacts of invasive species, relatively little research has been done to date on the status of current invasions (particularly outside of San Francisco Bay). Research is also needed on the potential for new invasions and on methods for preventing and addressing invasions. California's 1999 ballast water exchange law requires the state to complete, by 2002, research and reports on existing coastal aquatic invasions, the effectiveness of ballast water exchange in controlling invasions, and the potential for other methods to control the discharge of invasives in ballast water.

The San Francisco estuary Institute, under an array of federal and state grants, is taking a lead on needed research. They have received funding to investigate and report on invasions in southern California marine waters and to sample ballast water coming into the San Francisco estuary for invasive species. They are examining ballast water treatment through two projects: one with the city and county of San Francisco and the University of California, Berkeley Department of Civil and Environmental Engineering to research treatment of ballast water in municipal wastewater systems, and one to analyze more generally the potential for onshore treatment of ballast water in municipal and industrial treatment plants and ballast-specific treatment plants.

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Marine Birds and Mammals: Overview

Using a loose definition of deriving some of their annual needs from the ocean, marine birds comprise an abundant and diverse group in California waters. Included would be about 70 regularly-occurring species: divers (loons and grebes), albatrosses, shearwaters, fulmars, storm-petrels, certain waterfowl (scoters, brant), phalaropes, skuas, gulls, terns, and auks (murres, puffins, guillemots, auklets, and murrelets). Infrequently occurring species would bring the total near 100. And that does not include any estuarine species, which certainly feed on "marine" fish and invertebrates (herons, egrets, curlews, godwits, plovers, and sandpipers). Peregrine falcons, bald eagles, and ospreys could also be considered as marine species as their prey often are marine organisms.

A true seabird never comes to land except to raise its young (incubate eggs, bring food to chicks), and most spend about 90 percent of their lives at sea. Using such a definition reduces the California species list of marine birds to a few dozen. Notable examples are albatross, storm-petrels, murres, and murrelets. Most divers, waterfowl, and gulls would drop from the list. Unlike most marine fish and invertebrates, true seabirds are long lived and produce very few offspring. They lay but one or two eggs each year or every other year, and guard them closely. Their strategy, unlike fish and invertebrates, is to take care of a few young for a long time until they become independent and have a pretty good chance for future survival. For many, care of young continues after departure from the nest. The reason for being so careful of young is that it is difficult for air-breathing vertebrates (including humans) to derive food from the sea.

Seabirds are highly evolved to exist at sea. They are among the most efficient flyers of all birds, and derive energy not just from food but also, in a way, from the winds. In fact, many species prefer to sit on the water if there is no wind. Using the wind, they can search huge expanses of ocean for prey and consume very little energy in the process. By and large, they take the most abundant and energy rich prey available, including small fish (anchovies, sardines, smelt, herring, and the juveniles of much larger prey: salmon, rockfish), squid, and crustaceans. For most species, the preferred prey are found in large schools near the surface. Some marine birds, however, can dive to depths greater than 300 feet (auks, loons). In their flights, marine birds seek areas where ocean processes concentrate their prey, for example where ocean waters of differing properties (warm *vs.* cold) meet (fronts).

Another unusual characteristic of seabirds is that they have almost no defense against land mammals. This is because they evolved using offshore islands for nesting; normally, such places provide easy access to the sea and have no naturally occurring land predators.

For as long as humans have lived along the California (or any) coast, seabirds have been important and are part of the culture. Initially, they were used as sources of food and clothing (feathers) during the short times annually when thousands gather to breed and lay eggs. Nowadays, most human uses are recreational although since seabirds find fish more quickly than humans do, their feeding concentrations serve as beacons to commercial fishermen. The slow reproductive rates of seabirds make them vulnerable to human factors that lead to mortality - especially of adults and subadults (pollution, entanglement in fishing gear). The fact that they mostly eat the same fish prey as humans makes them vulnerable to over-exploitation of fish populations, showing signs of prey depletion (reduced growth of populations) before humans do.

The marine mammals of California include cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, fur seals, and sea lions), and sea otters. Some are residents, while others pass along the coast during great migrations. Gray and humpback whales, for example, feed in Alaskan waters and migrate along the coast on their way to Mexican waters to breed and calf. Blue whales visit during summer to feed on rich concentrations of krill.

Marine mammals have been an important part of the coastal commerce off California for centuries. Native tribes used furs, teeth, and bones in different ways, and ate the flesh of various species of marine mammals. By the nineteenth and early twentieth centuries the harvest of seals, whales, and sea otters was such a profitable undertaking that many populations of marine mammals became depressed to levels from which some are still recovering. Off California, New England and Russian hunters captured sea otters for their furs until, on the brink

California Sea Lions, *Zalophus califonianus*
Credit: Lillian Smith

of extinction, the International Fur Seal Treaty protected them in 1911. Now they have repopulated most of the California coast north of Point Conception. For a number of years in the 1900s, whaling was a profitable business in parts of California, but the loss of whales and, subsequently, their protection made whaling unprofitable. Nowadays, boat excursions carrying enthusiasts to view whales are more profitable than direct exploitation in past days. As examples of current use of marine mammals, the passage of gray whales by the Point Reyes Headlands during early winter requires shuttle buses by the National Park Service to avoid the traffic jams that otherwise would ensue. The Año Nuevo State Reserve attracts many thousands of visitors annually to observe the elephant seal rookery there. Hundreds of tourists each weekend stop at turnouts along California Highway 1 to observe harbor seals hauled out nearby on Bolinas Lagoon mud flats, and other thousands observe sea lions at Pier 45 in San Francisco. Sea otter exhibits at such places as Monterey Bay Aquarium and displays of other marine mammals at Sea World are major attractions.

The Marine Mammal Protection Act of 1972 placed a moratorium on taking marine mammals. The act has since been amended several times to better define how it should function in concert with other legislation. The focus now is to reduce the incidental take of some species. In response to protection, many populations of marine mammals have increased to levels that existed prior to their exploitation. Some populations, while expanding, are still listed as endangered or threatened under the federal Endangered Species Act. The Guadalupe fur seal, believed until 1926 to be extinct, is making a very gradual recovery. Among baleen whales, the humpback, blue, and fin whales have shown little recovery and are listed. On the other hand, the gray whale was the first marine mammal species to be removed from the list of endangered and threatened wildlife. The sperm whale, the only non-baleen great whale is still listed as endangered.

Meanwhile, populations of some pinniped species have flourished from their protection to the extent that their interactions with humans again have become controversial. The state depleted their populations significantly during the early 1900s through direct slaughter. Now, the individual sea lion that feasts on the fisherman's catch and/or destroys gear can be shot only when caught in the act. Unintended entrapment or hooking of pinnipeds, sea otters, and porpoises has become a problem in some areas, where subsequently the use of gillnets has been restricted or stopped. The population increase and spread of sea otters have impinged on the fisheries for abalone and sea urchins, which are commercially profitable only in the absence of the otters. Whether or not the otter population will be allowed to recover further is a source of conflict that needs continual attention.

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Pinnipeds

History

There are six pinniped species inhabiting the California coast and offshore islands: the California sea lion (*Zalophus californianus californianus*), Steller (or northern) sea lion (*Eumetopias jubatus*), Pacific harbor seal (*Phoca vitulina richardsi*), northern elephant seal (*Mirounga angustirostris*), northern fur seal (*Callorhinus ursinus*) and Guadalupe fur seal (*Arctocephalus townsendi*). The ribbon seal (*Phoca fasciata*) and the hooded seal (*Cystophora cristata*) have been reported in California waters, but these were extremely rare events and they are not considered normal California visitors.

The California sea lion and Pacific harbor seal are probably the best known and most often seen pinnipeds in California waters. Californians and visitors from around the world enjoy watching the playful behavior of these animals cavorting in the water near shore or hauled out to rest on buoys, rocks, and other solid objects. They also enjoy seeing them in public display aquaria or as performers in animal shows at zoos and parks. Pinnipeds are amusing and intelligent entertainers, but there is another aspect of the pinniped story which is related to their diet of fish and their expanding populations.

In recent years, California sea lions and, to a lesser degree, Pacific harbor seals have gained notoriety by taking over portions of marinas, bathing beaches and by eating endangered or threatened salmon and steelhead moving upstream to spawn. Marina operators and boat owners consider them a major nuisance, and potentially dangerous. Some seals react aggressively when people approach. Some who fish commercially or for sport believe that pinnipeds compete for fish and are costly pests consuming tons of valuable fish, destroying valuable fishing gear and interfering with fishing operations. They complain that any sea lion is attracted to fishing operations and that the mere presence of a sea lion scares fish away from the fishing area. Research biologists speculate that most of those problems are caused by a relatively few "rogue" pinnipeds. The rogues have learned that a fish caught in a net or hooked on a line is an easier meal than a free-swimming fish, and some actually target these fisheries on a regular basis. A major concern is that this behavior will spread as the pinniped populations grow.

Resolving pinniped conflicts with human activities is a controversial issue. Faced with decreasing catches, increasing marine mammal populations, and increasing fishery interactions, some sport and commercial fishermen contend that some pinniped populations have reached the point where population control and management efforts should be implemented. This would include the lethal removal of nuisance animals. Others will argue for protection of pinnipeds in spite of the damage and economic losses they cause.

It is unclear whether foraging by pinnipeds is impacting the abundance of marine species harvested by man. Current research data are insufficient to answer this question. Ecological interactions between pinnipeds and fishery resources are complex and poorly understood. Food habits studies on California sea lions and Pacific harbor seals indicate a broad range of prey species are consumed. The opportunistic feeding nature of pinnipeds means food habits can change dramatically between areas and years in response to changes in the abundance of different prey species. Research in this area is difficult because of the great complexities of interactions. Though we do know their diets often include fish such as anchovies, mackerel, herring, hake, rockfish, salmon, and cephalopods, such as squid and octopus.

In the 1860s and 1870s, many pinnipeds were killed for their oil or body parts and many females were captured for displays or animal acts. Pinnipeds were hunted commercially until 1938, when California law gave them complete protection from hunting. Nevertheless, sport and commercial fishermen were free to kill sea lions and harbor seals that were destroying gear or otherwise interfering with fishing operations. In 1972, the Marine Mammal Protection Act was passed by Congress prohibiting the take (pursuit, harassment, capture, or kill) of marine mammals except under special permitted conditions. The act was renewed and revised in 1994. From its inception, the act specified that marine mammals should be protected as functioning elements of the ecosystem. The 1994 amendments to the act established a new system to reduce the injuries and mortality of marine mammals involved incidentally in commercial fishing operations to insignificant levels approaching zero.

Research has been conducted in the past on methods of reducing the impacts that pinnipeds have on certain fisheries (*e.g.*, various taste aversion substances and acoustic harassment devices), but with little success. In most cases, the animals appeared to acclimate to the deterrents, and sometimes used the purported scare devices as "dinner bells" signifying active fishing boats and an easy food source. Long-term solutions remain illusive.

Status of Biological Knowledge

California Sea Lion

The California sea lion ranges from British Columbia south to Tres Marias Islands off Mexico. Breeding grounds are mainly on offshore islands from the Channel Islands south into Mexico. Breeding takes place in June and early July

California Sea Lion, *Zalophus californianus*
Credit: Phil Schuyler

within a few days after the females give birth. The pups are weaned at six months to a year or more. Males and females reach sexual maturity between four and five years, although males normally do not achieve territorial status until age eight or nine. Males weigh between 500 and 1,000 pounds and reach seven to eight feet in length. Females weigh between 200 and 600 pounds and reach six feet. Adult males have a pronounced sagittal crest (a ridge on top of the skull extending from the forehead to the rear of the skull), a characteristic distinguishing this species from the Steller sea lion. Food of the California sea lion consists largely of squid, octopus, and a variety of fishes (anchovies, mackerel, herring, rockfish, hake, and salmon).

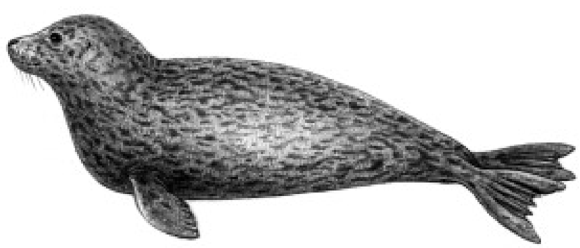
Steller Sea Lion

The Steller sea lion's distribution partially overlaps that of the California sea lion. It ranges from the Bering Strait off Alaska to southern California. Breeding grounds extend from the Pribilof Islands to Año Nuevo Island. The largest breeding colonies in California are at Point St. George, Año Nuevo, and the Farallon Islands. Breeding is in late June, after which the animals migrate northward. This species is a tawny or yellowish-brown color in contrast to the darker reddish color of the California sea lion. Grown males are 1,500 to 2,200 pounds and reach a length of 13 feet. Females usually weigh between 600 and 900 pounds and reach a length of nine feet. Food of the Steller sea lion consists primarily of squid and fish.

Steller Sea Lion, *Eumetopias jubatus*
Credit: Phil Schuyler

Pacific Harbor Seal

The Pacific harbor seal ranges along the northwest coast of America from the Gulf of Alaska to Cedros Island off Baja California. In California, harbor seals are abundant along the entire coast. Adult male Pacific harbor seals reach a length of six feet and weight of up to 240 pounds, while females reach 5.5 feet and 275 pounds (when pregnant). The coloration patterns of adults vary from black with white spots to white with black spots. Breeding season varies with latitude, starting in March to May on the Channel Islands of southern California and continuing later up the coast. Age at sexual maturity is three to four years for females and five years for males. Newborn pups are approximately 32 inches long and weigh about 22 pounds. They are weaned at five to six weeks at an average weight of 50 pounds. Adult females ovulate and mate at the end of weaning, with a two-month delayed implantation of the developing embryo. Their diet consists of fish such as flounders, herring, tomcod, hake, and lampreys, and cephalopods such as squid and octopus.



Pacific Harbor Seal, *Phoca vitulina richardsi*
Credit: Phil Schuyler

Northern Fur Seal

The northern fur seal is one of the best-known seals in the world because of its valuable fur, for which it was hunted to near extinction. Historical populations, centered on the Pribilof Islands, Alaska, are estimated at two million animals, but in 1911, when international treaties were established to protect and manage this species, there were fewer than 125,000 animals. San Miguel Island, off Santa Barbara, California, hosts a small breeding colony and is the southernmost extent of its range. It is a remnant of a much larger population that existed in California in the early 1800s. The peak breeding and pupping period is in July. After breeding, the males migrate out to sea where they spend as many as 10 months. The pups are weaned at four months of age and are left to travel in the northward migrations on their own. Fur seals are distinguished from sea lions by their pelage, composed of a very dense undercoat and a thinner, coarser layer of guard hairs, and by their relatively long flippers. The northern fur seal is closely related to the Guadalupe fur seal and is distinguished from its close relative by its very short muzzle. Males reach a length of eight feet and weigh up to 700 pounds. Females are only four to five feet long and weigh about 130 pounds. Sexual maturity is attained between three and seven years, with longevity reported to be up to 26 years.

Northern Fur Seal, *Callorhinus ursinus*
Credit: Phil Schuyler

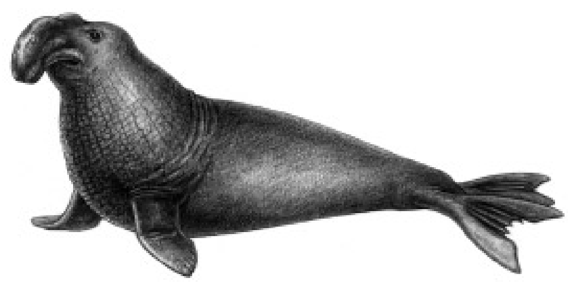
Guadalupe Fur Seal

The Guadalupe fur seal was presumed extinct until 1926, when a group of 60 animals was discovered on Guadalupe Island, Mexico. The population is recovering slowly from near extinction brought about by sealers in the last century. This is a rare pinniped in California waters, seen only occasionally at islands in the Southern California Bight and the Farallon Islands. They breed only on Guadalupe Island. They are identified by a "collie-like," long pointed muzzle. Males reach up to six feet in length; females are slightly smaller.

Guadalupe Fur Seal, *Arctocephalus townsendi*
Credit: Phil Schuyler

Northern Elephant Seal

The comeback of the northern elephant seal, the largest of all the seals, is one of the great success stories for an animal threatened with extinction. Male elephant seals reach a length of 15 to 16 feet and weight of about 4,000 to 5,000 pounds. Females reach a length of 11 feet and weigh about 1,700 pounds. The male develops a bulbous enlargement of the snout from which, along with its size, it gets its common name. Breeding colonies exist on San Miguel Island, Santa Barbara Island, San Nicolas Island, San Simeon Island, Año Nuevo Island, Southeast Farallon Island, and Point Reyes Peninsula. They have also begun hauling out at several other mainland sites where historically they did not haul out. The breeding season is from December through March. Breeding groups, or "harems," consist of one male and eight to 40 females. The gestation



Northern Elephant Seal, *Mirounga angurstirostris*
Credit: Phil Schuyler

period is about 11.5 months. Pups are weaned by four weeks but remain on the rookery another eight to 10 weeks, sleeping during the day and gradually starting to enter the water at night. Departure from the rookery occurs at an age of approximately three months. Females begin breeding as young as two years of age. Males reach sexual maturity at five years; but older, larger males prevent young and socially immature males from mating until they are at least eight or nine years old. Males and females both live about 14 years.

Elephant seals do most of their feeding at night and probably in deep water as evidenced by the fact that they have been caught in nets at 2,000-foot depths. Time-depth recorder experiments show that elephant seals can dive to 5,200 feet, and stay beneath the surface for up to an hour. Stomach content analyses indicate that they feed on small sharks, rays, ratfish, rockfish, and squid.

Status of the Populations

The Marine Mammal Protection Act recognizes marine mammals as components of the marine ecosystem and requires maintenance of stocks above levels at which they would lose their function in the ecosystem. In practice, marine mammal management is directed toward maintaining the optimum sustainable population size (OSP) for each species within its geographical range. To be optimal, the population size should be between the rate at which maximum growth occurs and the carrying capacity of the environment. A variety of procedures are used to assess population status.

California Sea Lion

California sea lions breeding on U.S. rookeries are assumed to comprise a single stock. The population of newborn pups is determined from an aerial census. The size of the entire population is estimated from the number of new births and the proportion of pups in the population. Their status was last assessed in 2000. At that time, the population size was estimated at 204,000 to 214,000 animals. Recent estimates place the population growth rate at 6.2 percent per year. Fishery mortality is increasing.

Steller Sea Lion

Population estimates for northern sea lions are based on counts of animals hauled-out during the breeding season. A decline of this species is occurring throughout its range, including the Gulf of Alaska and Aleutian Islands, which support 75 percent of the world's population. The current West Coast population of northern sea lions is estimated at 39,031 animals, which is less than half of the population level from 1956 to 1960. The dramatic decline in numbers of Steller sea lions throughout most of its range has prompted its listing as endangered under the Endangered Species Act and depleted under the Marine Mammal Protection Act.

Pacific Harbor Seal

From aerial census data, the harbor seal population along the California coast appears to be increasing, and concurrently, the number of occupied sites has increased. From the last aerial survey (1995), the population was estimated at 30,293 animals after using correction factors. The population appears to be growing and fishery mortality is declining.

Northern Fur Seal

The eastern North Pacific population of fur seals is estimated at over one million animals. The population at San Miguel Island was estimated in 1999 at 4,336 animals after correction factors. The San Miguel Island population has increased steadily since the 1970s. An annual increase of eight percent occurred from 1965 through 1996. However, the eastern North Pacific stock of fur seals is formally listed as depleted under the Marine Mammal Protection Act.

Guadalupe Fur Seal

The historical distribution and abundance of the Guadalupe fur seal are unknown because commercial sealers and other observers failed to distinguish between it and the northern fur seal in their records. This species, once thought to be extinct, has an estimated population of 7,408 animals. The population is growing at approximately 13.7 percent per year. Although the primary breeding colony is on Guadalupe Island, recent sightings of adult and juvenile seals on some of the Channel Islands suggest that recolonization of that area may occur in the future. The Guadalupe fur seal is listed as threatened under the Endangered Species Act and depleted under the Marine Mammal Protection Act.

Northern Elephant Seal

The exploitation and subsequent recovery of the northern elephant seal population is a remarkable story. Biologists estimate that only 100 to 500 animals were left on Guadalupe Island before protective legislation was passed. They claim that the entire current population may have originated from this small group of animals. Based on pup counts, the California breeding stock was estimated at 84,000 animals in 1996. The apparent growth rate since 1980 has been about eight percent annually. Annual surveys indicate that this species has reoccupied most or all of its historical rookeries and hauling grounds. The population is continuing to grow and fishery mortality is relatively constant.

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Whales, Dolphins, Porpoises

History

Marine mammals played an important role in shaping the early history of California. By the late 18th century, English whale ships had voyaged to the waters of California in search of sperm whales. Portuguese immigrants from the Azores and Cape Verde followed in the 1840s, manning and operating the first shore-based whaling industry. Shore whaling was distinct from nineteenth century Yankee pelagic whaling, because whales were pursued from a vessel launched from a nearby coastline. Deploying rowboats from shore and using harpoons, whalers typically pursued, captured, and towed whales back to the whaling stations. At shore-based whaling stations, workers extracted oil from the whale's blubber. The lure of gold and quick prosperity brought numerous crewmen from New England's whaling industry in the late 1840s and early 1850s. After the gold rush abated, many returned to their previous occupations on whaling ships. The early shore-based whaling industry in California primarily caught gray and humpback whales, because trips by shore whalers were limited to within 10 miles of the coastline. However, whalers occasionally took the right, blue, and fin whales, more highly prized due to the greater oil content of their blubber. Until 1901, at least 15 stations operated at various locations between Crescent City and San Diego.

After more than 40 years of whaling along the California coast, whale populations and the demand for expensive whale oil declined, and subsequently the whaling industry became less profitable in the late 1800s. Nevertheless, modern whaling vessels caught some gray whales and many humpback whales in California waters after the turn of the century. Powered by engines, modern whaling vessels hunted whales more efficiently through the use of explosives, mounted cannons, and grenades. Whalers would deliver carcasses to floating processing plants where the oil was extracted. Modern catcher boats originating from shore stations also periodically took whales during this period. The last remaining whaling station in the United States, near Richmond, California, closed in 1971.

In 1931, 50 nations, including the United States, agreed upon the International Convention for the Regulation of Whaling. This agreement was the first international effort to control the decimation of the world's whale populations. The primary protection measures included full protection for right whales and, for all other species, a ban on the killing of calves, suckling whales, immature whales, and females with calves. The agreement was ineffective, however, because the major whaling nations did not join. Several international agreements followed which attempted to improve upon this initial document. In 1946, the International Whaling Commission (IWC) was established, both to ensure the development of the whaling industry and to conserve the worlds whale stocks for the interests of future generations. For many years, the IWC concentrated its efforts on maximizing the level of removal of whales rather than on whale conservation. However, in recent years, the IWC has attempted to move towards whale conservation.

In 1972, the United States Congress enacted the Marine Mammal Protection Act (MMPA), which established a complex and comprehensive federal policy of marine mammal management. The MMPA made it unlawful to take (defined as kill, capture, pursue, or harass) marine mammals in the waters of the United States and it also prohibited U. S. citizens from taking marine mammals on the high seas. Under limited circumstances, exceptions may be authorized for the taking of some marine mammals, provided that the level of removal will not cause the population to decline below sustainable levels. For instance, marine mammals may be removed for public display and scientific research, or incidental to activities such as shipping and commercial fishing.

Current Management

Since the enactment of the MMPA in 1972, the focus of concern has shifted to the incidental capture of marine mammals during commercial fishing operations. Due to the rapid expansion of several of California's coastal fisheries, there has been an increase in the incidental capture of marine mammals in recent years. Nonetheless, in California, the level of take of cetaceans is lower than it is for other marine mammals (*e.g.,* pinnipeds). The National Marine Fisheries Service (NMFS) is currently implementing a management regime to govern the incidental taking of marine mammals in commercial fishing operations. Under this program, some marine mammal species may be incidentally taken during commercial fishing operations or during other human-caused activities so long as the level of take will allow the stock to reach and maintain its optimum sustainable population. Moreover, the California Department of Fish and Game (DFG) has developed regulations to help minimize the incidental take of marine mammals in the coastal gillnet fishery.

Due to the recovery of the gray whale population and accessibility of migrating gray whales along the California coastline, a large and diverse whalewatching industry has developed. Since the 1970s, commercial whalewatching has become an important recreational, educational, and economic activity. The 1983-1984 whalewatching season alone generated an estimated total gross income of

$2.6 million. This estimate did not include regional economic benefits from the sale of meals, fuel, lodging, whale paraphernalia and other whale-related activities. In 1985, the commercial whalewatching industry in California was the largest in the United States, with 74 boats in operation.

The rapid growth of commercial whalewatching, and increased interest by private boaters in observing and approaching whales in the wild, have been accompanied by concerns that these activities could cause adverse biological impacts to whales. In California, NMFS adopted whalewatching guidelines that established minimum approach distances (100 yards) for vessels and aircraft, as well as additional operational guidelines for vessels. Nevertheless, each year there are numerous reports of harassment of whales by commercial whalewatching vessels and private boaters. NMFS is currently developing regulations that will provide mechanisms to enforce minimum approach distances.

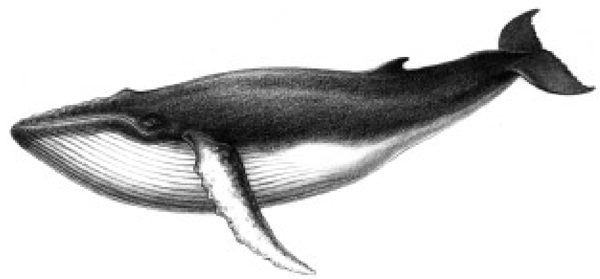
Partly as a result of the protection and management achieved from regulatory measures, and partly because of increased public awareness and appreciation of marine mammals, some populations have rebounded since the years of commercial exploitation. Marine mammals that inhabit the coastal waters of California now represent resources that enhance both the wealth and recreational benefits of the state. For many people, a commercial whalewatching cruise is their first contact with the marine environment. Thus, the value of observing marine mammals in the wild not only increases public awareness of these animals but also contributes to increased public appreciation of the diversity and abundance of other living marine resources.

The waters of California provide essential habitat to a large variety and abundance of whales, dolphins, porpoises, and other marine mammals. These animals play an important role in maintaining the balance of marine ecosystems. Consequently, protecting California's marine mammals is an integral part of the conservation of all living marine resources in California.

Status of Biological Knowledge and Populations

Humpback Whale

Humpback whales (*Megaptera novaeangliae*) are distinguished by their exceptionally long flippers up to 1/3 of body length, and robust body that may reach a length of over 45 feet and weigh up to 37.5 tons. There appear to be two distinct populations of humpback whales in the North Pacific. The Alaska feeding population migrates



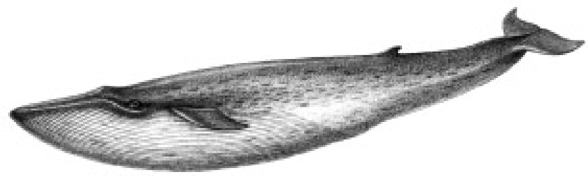
Humpback Whale, *Megaptera novaeangliae*
Credit: Phil Schuyler

to its breeding grounds in Hawaii and offshore islands in Mexico. The California, Oregon, and Washington feeding populations migrate to coastal Mexico and Central America to breed. During their seasonal migrations, humpback whales may frequently be seen along the California coast from April through November. Some individuals appear to remain in California year-round. In the Gulf of the Farallones, humpbacks may be observed feeding during May and November. Off southern California, humpbacks often migrate along submarine ridges (*e.g.,* Santa Rosa-Cortez Ridge) and occasionally enter the coastal waters of the San Pedro and Santa Barbara Channels. They obtain their food by straining krill (small shrimp-like crustaceans) and schools of small fish with their baleen. Humpback whales are well known for their complex songs, thought to be used in courtship or competition between males, and their leaping out of the water, or breaching behavior. The songs on their breeding grounds can last up to several hours.

Near the turn of the century, an estimated 15,000 humpback whales inhabited the North Pacific Ocean. Commercial whaling reduced this population to dangerously low levels, and in 1966 the IWC established a moratorium on harvesting them. With this protection, the population has recovered to a size of 8,000 individuals. The California feeding population is thought to consist of about 1,000 animals. The California population appears to be growing at about eight percent per year. The humpback whale has been listed as an endangered species under the United States Endangered Species Act (ESA) since 1970.

Blue Whale

Blue whales (*Balaenoptera musculus*) are the largest animals in the world, sometimes attaining a size of over 90 feet. An individual blue whale may consume up to eight tons of krill in a single day. The majority of the eastern North Pacific population spends the summer on feeding grounds between central California, the Gulf of Alaska and the Aleutian Islands. Like all baleen whales, the blue whale seasonally migrates to lower latitudes in the winter to calve and breed. Migratory routes generally follow the

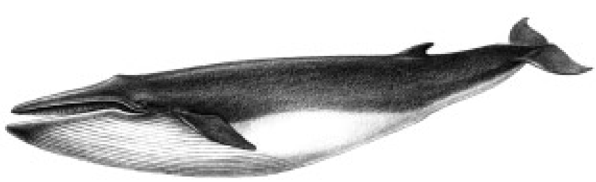


Blue Whale, *Balaenoptera musculus*
Credit: Phil Schuyler

continental shelf and slope, but blue whales are occasionally found in deep oceanic zones and shallow inshore areas. Blue whales are usually seen off the California coast traveling alone or in pairs, from May to January, although they have been observed in every month of the year. They frequently may be seen feeding in the Farallon Islands between July and October and occasionally are sighted in Monterey Bay and over deep coastal submarine canyons off central and southern California. Historically, the North Pacific population may have been comprised of over 5,000 individuals before its severe depletion by modern whaling operations. An estimated 1,700 to 1,900 blue whales currently inhabit the eastern North Pacific Ocean. It is estimated that the California feeding population is comprised of at least 1,700 whales. No information exists on the rate of growth of blue whale populations in the Pacific. The blue whale has been listed as an endangered species under the ESA since 1970.

Fin Whale

The fin whale (*Balaenoptera physalus*) is a common, large cetacean occurring off the California coast. Fin whales can reach a size of up to 87 feet and weigh up to 76 tons. These whales may be distinguished by the white coloration of their lower right lip and V-shaped head. They are distributed throughout the world's oceans, but



Fin Whale, *Balaenoptera physalus*
Credit: Phil Schuyler

little is known of their seasonal movements in the North Pacific. The North Pacific population reportedly winters between central California southward to 20° N latitude and summers from Baja California to the Chukchi Sea north of the Bering Strait. Fin whales have been observed in every month of the year in California. Approximately 1,000 fin whales are estimated to be off California. There is some indication that fin whales have increased in abundance in California coastal waters. This species uses its baleen to filter krill, capelin, sand lance, squid, herring, and lantern fish from the water. They have been listed as an endangered species under the ESA since 1970.

Minke Whale

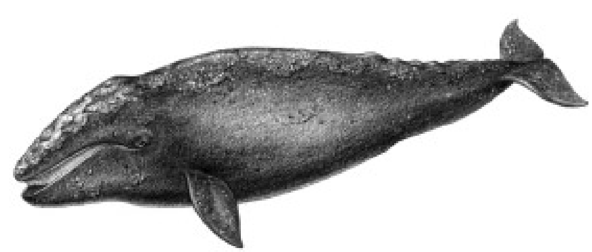
Minke whales (*Balaenoptera acutorostrata*) inhabit both the high seas and nearshore waters where they are known to enter bays, inlets, and estuaries. This species is the smallest of the baleen whales in California waters, attaining a size of up to 32 feet, and is distinguished by a transverse white band on its flippers and its relatively tall and falcate (hooked) dorsal fin. In the summer months, minke whales feed on krill, copepods, sand lance, and herring in the Bering Sea and Arctic Ocean. During the

Minke Whale, *Balaenoptera acutorostrata*
Credit: Phil Schuyler

winter months, they migrate south along the North America coastline to Mexico. There are some year-round residents off California. An estimated 400 minke whales live off California. Minke whales are occasionally seen from whalewatching and sport fishing vessels and from shore in California.

Gray Whale

Gray whales (*Eschrichtius robustus*) are distinguished by their mottled gray body, narrow head and absence of a dorsal fin. They can reach a length of over 45 feet. The gray whale undergoes one of the longest migrations in the animal kingdom. Perhaps the best known of the great

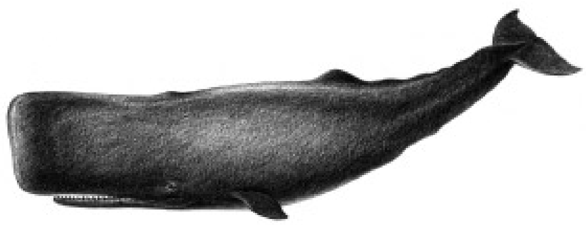


Gray Whale, *Eschrichtius robustus*
Credit: Phil Schuyler

whales off California, the eastern North Pacific gray whale migrates from its feeding grounds in the Bering Sea and Arctic Ocean to its calving and breeding areas in the subtropical lagoons along the west coast of Baja California. This population generally migrates along the coastline, often within a few miles of shore. The gray whale migration can be observed from several locations in California such as Point Loma, Point Vincente, Point Sur, and Point Reyes. They begin to enter California waters in late November and December on their southward migration. In mid-February, gray whales begin their return migration north, passing through southern California waters until late May or early June. Some immature whales reportedly remain in kelp beds to feed over the winter months off California. The northbound cow/calf migration usually occurs during April through June. Gray whales use their baleen to sift out crustaceans, molluscs, and other invertebrates, which they suck up from bottom sediments. The most recent population estimate is approximately 23,000 animals. In 1994, the gray whale became the first marine mammal species to be removed from the List of Endangered and Threatened Wildlife. The number of gray whales is above its unexploited stock size prior to whaling and is increasing at a rate of 2.5 to 3.2 percent per year.

Sperm Whale

Unlike the other great whales, the sperm whale does not feed with baleen, but is a toothed whale. It is the largest of the toothed whales with males reaching a length of

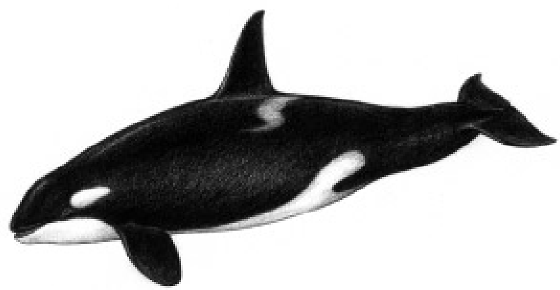


Sperm Whale, *Physeter catodon*
Credit: Phil Schuyler

60 feet and females 40 feet. Sperm whales are noted for their ability to make deep dives, which can last up to an hour and a half and can be as deep as two miles below the surface. They feed mainly on squid, including the giant squid. Sperm whales are widely distributed across the entire North Pacific and are found year-round in California waters. They reach peak abundance from April through mid-June and from the end of August through mid-November. Sperm whale abundance appears to be fairly stable with approximately 1,000 to 1,200 sperm whales estimated to be off the coast of California. The sperm whale has been listed as an endangered species under the ESA since 1970.

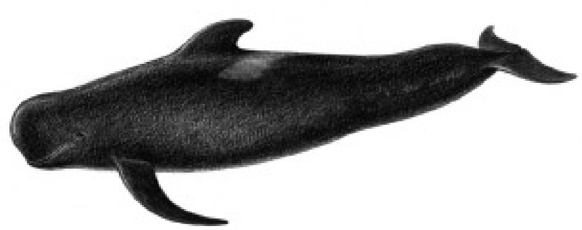
Killer Whale

Killer whales (*Orcinus orca*), actually the largest of the dolphins, are year-round residents in California. They have been seen entering kelp beds, bays, or inlets, but are more common offshore. The killer whale is widely known due to its popularity in oceanaria. It is recognized by its striking black and white color pattern and erect dorsal fin, which can be up to six feet tall in adult males. This spe-



Killer Whale, *Orcinus orca*
Credit: Phil Schuyler

cies may reach a length of nearly 30 feet. Killer whales are top predators in the ocean, using their sharp conical teeth for grasping and tearing prey. They have been observed attacking the largest animal on Earth, the blue whale, and there is one documented kill of a white shark by a killer whale. Killer whales were so named for their habit of attacking seals and whales; however, fish are the most important component of their diet. Small groups of sometimes-related individuals (pods) often hunt in a coordinated and cooperative manner. Some killer whale pods have strong social bonds, remaining in pods of five to 30 individuals for decades. There are 600 to 800 killer whales along the coast of California, Oregon and Washington. No information is available regarding trends in abundance of eastern North Pacific offshore killer whales.



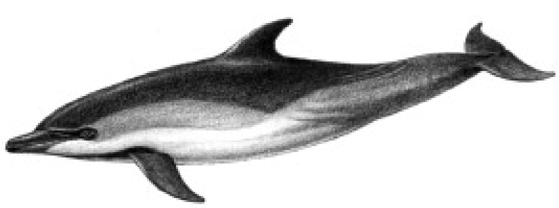
Shortfinned Pilot Whale, *Globicephala macrorhynchus*
Credit: Phil Schuyler

Shortfinned Pilot Whale

The shortfinned pilot whale (*Globicephala macrorhynchus*) can reach a size in excess of 17 feet, and is distinguished by its bulbous forehead and broad based slightly falcate dorsal fin. In California, these whales are commonly found south of Point Conception, but there have been sightings as far north as the Gulf of the Farallones off San Francisco. Following movements of local squid populations, shortfinned pilot whales may move seasonally nearshore in the winter and offshore during other times of the year. Before the El Niño event in 1982 and 1983, the number of shortfinned pilot whales was near 2,000 during peak periods off southern California. However their numbers declined during that El Niño, presumably due to emigration, and the population has not returned to its previous level. One hypothesis for the population's failure to rebound is that it was competitively excluded by the Risso's dolphin population in California. Currently, the population size is estimated to be between 700 to 1,000 individuals present in the nearshore waters of California. This species was the first "whale" displayed in captivity and is still seen occasionally in oceanaria around the world.

Common Dolphin

There are two different species of common dolphin in California waters. One is called the short-beaked common dolphin (*Delphinus delphis*) and the other is called the long-beaked common dolphin (*Delphinus capensis*). The long-beaked has a relatively longer beak and more muted coloration. It occurs from offshore southern California waters south to Islas Tres Marias and along the entire coast in the Gulf of California. The short-beaked has a relatively shorter beak, more contrasting coloration, and is more common offshore from Isla Cedros north.

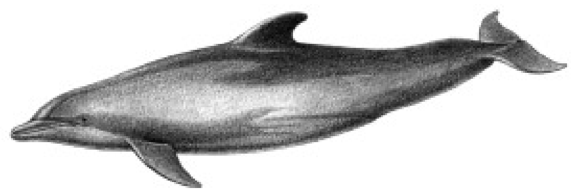


Common Dolphin, *Delphinus delphis*
Credit: Phil Schuyler

The common dolphin is the most abundant cetacean in California. Common dolphins can reach nearly eight feet in length and can be distinguished by the unique hourglass coloration on their sides which appears as a V-shaped black or dark gray saddle when they are observed at sea. Among the most gregarious of cetaceans, common dolphins often form groups of over 100 animals, sometimes numbering in the thousands. Population surveys estimate that over 350,000 common dolphins inhabit the waters off southern California between summer and autumn. Common dolphins frequently engage in bow-riding and aerial acrobatics.

Bottlenose Dolphin

Bottlenose dolphins (*Tursiops truncatus*) are readily recognizable by the public due to their antics on television, their performances in oceanaria, and because the coastal form is occasionally seen surfing in the waves along populated southern California beaches. This species may reach a size of over 12 feet and is distinguished by its gray coloration, lightly colored belly, and moderately tall and falcate

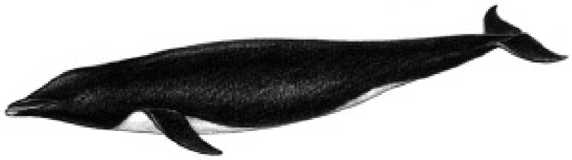


Bottlenose Dolphin, *Tursiops truncatus*
Credit: Phil Schuyler

dorsal fin. South of Point Conception, bottlenose dolphins are common, whereas few animals are encountered further north. In California, both coastal and offshore forms are found. The coastal form inhabits shallow water just beyond the surf zone, and is known to frequent bays and estuaries. Groups of 10 to 25 animals may travel together and make regular migrations along the coastline. There are reportedly seasonal shifts in their distribution northward to San Francisco County. It is estimated that the coastal form is comprised of approximately 160 animals. The population estimate for the offshore form is about 3,000 animals. This species often rides the bow wave of vessels, and swims in the wake of large whales.

Risso's Dolphin

Risso's dolphins (*Grampus griseus*) are known to reach a size of over 13 feet, usually have extensive scarring over their white to light-gray colored body, and lack a beak. The population is estimated to be about 29,000 Risso's dolphins residing off California. Since El Niño (1982-1983), their numbers are believed to have increased. Risso's dolphins normally appear in pods of 25 to 50 individuals and do not usually bow ride but will perform some acrobatics such as spy hopping and breaching. They are distributed widely, frequently being found in deep water areas with warm temperate to tropical water conditions. Risso's dol-

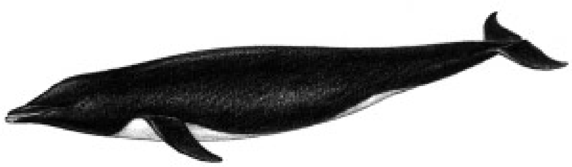


Risso's Dolphin, *Grampus griseus*
Credit: Phil Schuyler

phins are occasionally observed in central and northern California waters.

Northern Right-Whale Dolphin

Northern right-whale dolphins (*Lissodelphis borealis*) have no dorsal fin and have a very slim and graceful black body that may attain a length of 10 feet. They appear to prefer offshore, cold temperate waters and only occur inshore over deep submarine canyons. The northern right-whale dolphin is commonly found in the waters off central and northern California, although they also appear in winter

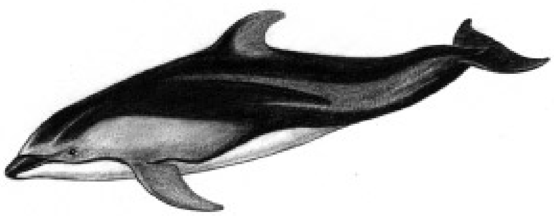


Northern Right-Whale Dolphin, *Lissodelphis borealis*
Credit: Phil Schuyler

and spring off southern California. There appears to be some seasonal north-south shift in their distribution as a result of water temperature changes and prey availability. Recent surveys indicate there are between 14,000 and 20,000 northern right-whale dolphins in California waters. This gregarious species sometimes occurs in large herds of up to several thousand and is noted for its fleetness. Northern right-whale dolphins rarely approach vessels.

Pacific white-sided dolphin

The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) has a short, thick beak, a falcate dorsal fin and

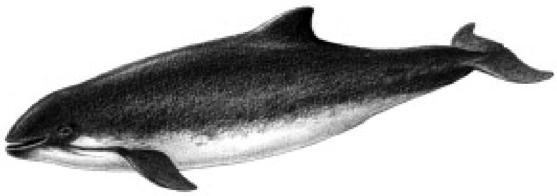


Pacific White-Sided Dolphin, *Lagenorhynchus obliquidens*
Credit: Phil Schuyler

may reach a size of at least seven feet. The species is thought to be the second most abundant dolphin off southern California, and the most common off northern California. The Pacific white-sided dolphin is seen year-round, frequenting the continental shelf and slope waters, sometimes appearing in Monterey Bay. They may occur in herds of over a few thousand individuals, but groups of several hundred are more common. Recent surveys indicate population sizes of 110,000 animals in California waters. This species is known for its acrobatic behavior and bow riding abilities. Pacific white-sided dolphins are occasionally displayed in oceanaria.

Harbor Porpoise

The harbor porpoise (*Phocoena phocoena*) is the smallest cetacean found in California waters, rarely reaching a length of over six feet. It may be distinguished by its lack of a beak and its triangular dorsal fin. Harbor porpoises frequent the cooler waters of central and northern California, seldom straying south of Point Conception. Locally abundant concentrations exist between Cape Mendocino and Point Reyes, and in Monterey Bay. They are not known to migrate extensively, but may move between inshore and offshore areas. The harbor porpoise occurs primarily in relatively shallow nearshore water and, thus, is vulnerable to human activities such as the coastal gillnet fishery in California. In response to the general increase in gillnetting, DFG has implemented several management mecha-

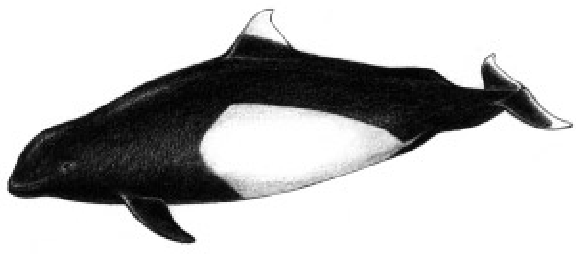


Harbor Porpoise, *Phocoena phocoena*
Credit: Phil Schuyler

nisms to reduce the incidental take of harbor porpoises. This species never approaches vessels or bow rides. The harbor porpoise population off California may consist of over 11,000 individuals.

Dall's Porpoise

The Dall's porpoise (*Phocoenoides dalli*) has a stocky shape, and the striking white pattern on its belly, flank, and tips of dorsal fin and tail, contrasts with its generally black body. This species may attain a size of over seven feet. The Dall's porpoise inhabits the cooler waters of the continental shelf in central and northern California, and also frequents a variety of other areas including nearshore deep-water canyons and the open sea. The Dall's porpoise can be found off northern California in autumn and winter, however individuals can also be found in southern California at this time. There appear to be near-shore-offshore shifts in their distribution whereby they remain inshore in autumn and move northward and off-



Dall's Porpoise, *Phocoenoides dalli*
Credit: Phil Schuyler

shore in the late spring. Dall's porpoises travel in small groups of 10 to 20 individuals and are known to bow ride often creating a rooster tail wake when traveling at high speeds. Recent surveys indicate populations of between 82,000 to 118,000 individuals inhabit the eastern North Pacific.

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National Marine Fisheries Service

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Sea Otter

History

Sea otters (*Enhydra lutris*) once ranged from extreme northern Japan through the Kuril Islands, southern Sakhalin Island, southern Kamchatka Peninsula, Commander Islands, Aleutian Islands, southern Alaska, British Columbia, Washington, Oregon and California, extending south to about the midpoint of the Pacific coast of Baja California, Mexico. Prior to 1741, human contact with sea otters was limited to native cultures through much of the range and to Spanish colonists in California and Mexico.

Commercial utilization of sea otters followed the Bering Expedition of 1741 to the mainland of southern Alaska and the Aleutian and Commander Islands. Reports of vast numbers of sea otters stimulated the fur trade and contributed to the eventual settlement and economic development of the west coast of North America by non-native people. Russian fur traders developed facilities at several locations on the North American coast, most notably at Kodiak Island and Sitka. The southernmost outpost, at Fort Ross, California, was established in 1812. Russian hunters worked at least as far south as the islands off Santa Barbara, but the Russian presence in California was contested by Spanish colonists. Spanish trade in sea otter pelts began in 1786 and was the most important industry in coastal California for several decades.

The early Russian otter traders utilized enslaved Aleut natives as hunters. The Aleuts worked from native canoes, hunting with spears and clubs. Later, American and European hunters entered the trade using firearms as primary tools of capture. By the 1840s, the sea otter population in California was greatly reduced as a result of overexploitation.

Sea otters were approaching extinction at the beginning of the twentieth century. Thirteen remnant populations, totaling perhaps 1,000 to 2,000 individuals, survived in the North Pacific in 1911. Sea otters were widely regarded as extinct in California by 1900, but scientists and game wardens were aware of a surviving group near Point Sur in Monterey County as early as 1914. Rough population estimates in the early 1900s ranged from less than 50 to about 100 sea otters in California. Other remnant populations were known to exist in 1911 in Mexico, Canada, Alaska and Russia. The remnant populations in Mexico and Canada were thought to be extinct by 1920.

The International Fur Seal Treaty was signed in 1911 by Canada (for Great Britain), Japan, Russia and the United States. The Treaty recognized the serious overexploitation of northern fur seals and sea otters and provided full protection for both species. State law has prohibited take or possession of sea otters or their pelts in California since 1913. With the termination of the trade in sea otter pelts, the California sea otter population began to grow in numbers and range. State Highway 1 was opened between Monterey and San Simeon in 1937, traversing a coastal segment previously not accessible by automobile. Highway access led to the much-publicized "rediscovery" of California sea otters by the general public at Bixby Creek in 1938. The sea otter population numbered roughly 300 individuals at that time. The state of California provided additional protection for sea otters by creating the Sea Otter Game Refuge, extending along 100 miles of coastline from the Carmel River, near Monterey, to Santa Rosa Creek, near Cambria.

Between the late 1930s and the late 1970s, the California sea otter population grew at an average annual rate of about five percent, extending its range to more than 200 miles of coastline from Santa Cruz to Pismo Beach. Whether this growth occurred smoothly or in pulses is not known. In the early 1980s, a cessation of population growth was recognized, and some argued that the population was declining in numbers. Studies by federal and state agencies determined that the nearshore set-net fishery for halibut was causing significant mortality of sea otters as a result of incidental entanglement and drowning. Estimates of annual mortality in nets ranged as high as 80-100 animals, a rate perhaps sufficient to account for the cessation of population growth. Legislation by the state imposed restrictions on set-net activity, greatly reducing incidental take of sea otters in nets. By the middle 1980s, it was apparent that population growth had returned to levels previously observed. However, in the mid-1990s population growth again ceased and by 1999 numbers had declined by more than 10 percent over a four-year period. The spring 2000 sea otter count erased most of the decline of the previous four years and raised hopes that the population had resumed expansion.

Sea otter pup
Credit: D. Varonjean

Status of Biological Knowledge

The subspecific status of various populations of the sea otter has been in dispute for many years. The most recent studies, based on skull morphology and DNA, suggest the California population is a separate subspecies. It is possible, if not likely, that subspecific differences have been magnified by separation of northern and southern populations brought about by near extermination. Definition of the subspecies of sea otters will likely remain controversial.

While sea otters in California occur predominantly along rocky shores supporting forests of the large kelps, in the past decade it has become apparent that significant numbers can maintain themselves off sandy shores. Along the mainland coast, the kelps typically form extensive surface canopies in waters less than 80 feet in depth where the substratum is rock. Sea otters commonly form resting groups, known as rafts, particularly in kelp canopies. Rafts typically contain up to 10 individuals, but under certain circumstances may include more than 100 otters. Most sea otters remain within one mile of shore, but in some situations, such as in Monterey Bay, Estero Bay and off Pismo Beach, otters are regularly seen foraging and resting more than two miles offshore. Juvenile males tend to range farther offshore than other age/sex categories. Records from the fur trade suggest that sea otters once were abundant in the soft-bottom habitats of San Francisco Bay.

Adult male sea otters in California typically weigh 60 to 75 pounds, reaching a length of four to 4.5 feet. Adult females typically reach a weight of 40 to 55 pounds and a length of four feet. The largest sea otter recorded in California was a male weighing 92 pounds.

Sea otter pelage includes outer guard hairs and dense, fine underfur. Density of sea otter fur is higher than that of any other mammal. Sea otter pelage provides the primary thermoregulatory barrier between the animal and the chilling effects of seawater. Most other marine mammals rely on subcutaneous fat or blubber rather than pelage for thermal protection. The effectiveness of the pelage as a thermal barrier depends on frequent grooming and consequent cleanliness. Soiling of the fur largely eliminates the insulative qualities, resulting in rapid heat loss. Food volume equivalent to 25 percent or more of individual body weight must be consumed daily to maintain the high metabolic rate typical of sea otters.

Male sea otters reach functional sexual maturity at five to six years. In California, adult males establish and defend territories in areas of high female density, seasonally in some areas and year-round in others. Younger males typically are excluded from breeding areas by territorial males. Female sea otters become reproductively mature at three to five years of age. Mature females typically come into estrus within a few days to a few weeks after weaning of pups. Gestation is four to six months and involves delayed implantation. After implantation, development to birth normally requires about four months. Virtually all births are single. Care of dependent pups is entirely maternal. The period of pup dependency averages six months in California, with a range of 4.5 to 9.5 months. Studies suggest that pre-weaning mortality rate for firstborn pups may exceed 50 percent. Survival of dependent pups improves with the experience of the mother. Most adult females produce one pup per year. In cases of premature death of dependent pups, females may come back into estrus and be reimpregnated within a few weeks after loss of the pup.

In California, rates of pup birth apparently peak in late winter, with a secondary peak in late summer or early fall. Some pupping occurs year round. Sea otters typically weigh four to five pounds at birth, and 20 to 30 pounds at weaning. In most sea otter populations, maximum longevity probably is in the range of 11 to 15 years. Captive animals are known to have lived as long as 28 years.

Known predators of sea otters include sharks, killer whales, eagles, coyotes and bears. While attack by white sharks probably occurs at a low rate throughout the California range, in areas north of Santa Cruz it accounts for a significant portion of the mortality. Predation generally is regarded as less important than food limitation in controlling the size of sea otter populations. Patterns of activity vary widely among sea otter populations and among individuals within sea otter populations. In California, most otters forage during morning hours, rest from late morning through mid-afternoon and resume foraging in late afternoon. Sometimes a third period of foraging occurs at night, between about 11 p.m. and 2 a.m. Juvenile females typically spend more time foraging than other age/sex categories, often feeding during hours when other otters are at rest.

In California, home ranges of adult males during the principal breeding season (summer and fall) have a mean coastline length of about a half mile and an area of about 100 acres. During winter the range approximately doubles for those individuals that remain in breeding territories. Long-distance movements among high-use areas range from 35 to 60 miles and often are seasonal. Males may remain within a high-use area for months at a time, but travel between such areas rarely requires more than a few days. Females follow the same general pattern as males, but high-use areas are typically 1.5 to two times larger for females than for males. Females also travel long distances in short periods, but such travel is much less frequent for females than for males. Substantial short-term movement of females among high-use areas often occurs in association with pupping. Juvenile males tend to utilize larger areas and travel greater distances than other age/sex categories. Various studies have shown that sea otters are capable of homing from distances as great as 300 miles.

Sea otters generally feed on large-bodied, bottom dwelling invertebrates obtained during dives. They are able to dive to at least 320 feet, but most foraging dives in California are in waters less than 80 feet deep. Dive duration may be as long as four minutes, but more typically, is 50 to 80 seconds. Individual otters typically feed on a relatively few species of prey. At the population level, however, sea otters are dietary generalists. More than 160 species have been reported as sea otter prey. Composition of sea otter diet relates to patterns of population growth. In California, diet is predominantly sea urchins, abalones, large crabs and large clams when otters have recently reoccupied a foraging area. As the period of occupation increases, preferred prey decline in availability and the diet diversifies. In cases of occupation by sea otters for more than a few years, the most common prey in California are crabs and small snails. Other frequent prey include octopus, mussels and clams, and at least some otters eat large quantities of market squid when available. Sea otters are well known for their abilities in using stones as tools while foraging. Stones may be used as hammers to dislodge prey from the substrate during dives and may be used as anvils for breaking shells of prey during surface intervals. Fish are common prey for sea otters at certain locations in Alaska and Russia. Consumption of fish by sea otters is rare in California.

Sea otters have important effects on the character of nearshore biological communities. In a number of circumstances, it has been reported that otters substantially reduce prey abundance and individual size. The best-known cases involve species such as abalones and sea urchins that are sought in commercial or recreational fisheries. Such interactions have provided grist for intensive political discord for many years regarding approaches to management of sea otter populations. Such conflicts first arose in regard to the central California abalone fishery in the 1960s. More recent conflicts involve sea urchins, Dungeness crabs and several species of clams. Human over-harvesting of shellfish populations sometimes contributes to management difficulties and political controversies associated with conflicts of sea otters and shellfisheries.

The control of herbivorous invertebrates by sea otters allows secondary development of dense algal populations, including kelps, which may substantially alter the structure and dynamics of nearshore ecosystems. Proliferation of algae as a consequence of growing sea otter populations has been reported at a number of locations throughout the range of the species.

The 1989 *Exxon Valdez* oil spill (EVOS) in Prince William Sound demonstrated the potential vulnerability of sea otter populations to catastrophic oil spills. As many as 781 spill related sea otter carcasses were recovered after the spill. Total mortality of sea otters resulting from EVOS was much higher. Over 350 sea otters, mostly oiled, were captured alive after the spill, but survival was less than 50 percent despite intensive efforts to treat and rehabilitate oiled animals. Oiled sea otters died primarily from hypothermia resulting from matted pelage, toxic effects of oil fumes inhaled, oil ingested during futile grooming efforts, and from stress.

To deal with potentially catastrophic oil spills impacting sea otters in California, the California Department of Fish and Game's (DFG) Office of Spill Prevention and Response (OSPR) built and maintains the Marine Wildlife Veterinary Care and Research Center in Santa Cruz. This facility can provide care for up to 120 sea otters as well as oiled birds and other marine mammals if necessary. It is part of the larger Oiled Wildlife Care Network (OWCN) run by the Wildlife Health Center at the University of California, Davis, under funding from DFG-OSPR. Smaller numbers of oiled sea otters may also be cared for at the Monterey Bay Aquarium, the Marine Mammal Center and Sea World, which are affiliated with the OWCN and OSPR.

Status of the Population

The sea otter population in California currently ranges along nearly 350 miles of coastline from approximately Half Moon Bay, San Mateo County to approximately Gaviota, Santa Barbara County. Determination of trends in the number of sea otters has been complicated by the variety of survey techniques used, differing in accuracy and precision. However, few would argue that since the late 1960s the population and range have more than doubled. In 1982, a standard survey method was adopted for assessments of the California population. The most recent count in California, in the spring of 2000, totaled 2,317 animals, 2,053 independent sea otters and 264 dependent pups.

Intensive investigation into the causes of sea otter mortality in California occurred throughout the 1990s and into 2000. Virtually every fresh dead sea otter received a detailed necropsy by a veterinary pathologist either from the National Wildlife Health Center or the DFG in partnership with the Veterinary Medical Teaching Hospital at the University of California, Davis. Several new disease agents and disease processes were described. Some of the more important diseases and parasites of sea otters in California include: 1) thorny headed worms of the genus *Profilicollis*, which when present in high numbers penetrate the gut wall causing peritonitis; 2) protozoal encephalitis; 3) bacterial septicemia; 4) biotoxin poisoning from certain "red tide" organisms; and 5) San Joaquin Valley fever. The prevalence of some of these pathogens may be influenced by human activities within and adjacent to the marine environment of sea otters. If these diseases are new to the sea otter population then serious consequences may be in store. However, these may be old diseases recently discovered. The influence of contaminants, immune system function, and malnutrition on patterns of disease and overall mortality are being investigated. Diseases and parasites of sea otters in California appear to be largely different from those of Alaskan sea otters.

The cessation of population growth centered around 1982-1983 and 1997-1998, both strong El Niño years, suggests to some, that long term cyclic environmental changes resulting in ups and downs in prey availability may be responsible. Others argue that increases in disease and/or parasite infection rates are primarily responsible for population dips. Still others suspect that bycatch of otters in net and trap fisheries may be the major factor. It is likely that all of these play a role in regulating population size. If long-term, more or less permanent, human caused and/or natural environmental change is occurring, then predicting the future for sea otter populations, or any living resource, is troublesome.

Current Management

Passage of the federal Marine Mammal Protection Act (MMPA) of 1972 provided new authority for protection of sea otters in all U.S. waters. With the passage of the MMPA, management authority for sea otters in California transferred from the state to the federal government. The managing agency is the United States Fish and Wildlife Service (FWS). Sea otters were conferred "threatened" status under the federal Endangered Species Act of 1973 (ESA) in 1977. The ESA directed the formation of a recovery team and the production of a recovery plan for California sea otters. A primary element of the plan, issued in 1982, was the establishment of a new colony of sea otters by translocation within California. The colony was to be well separated from the existing mainland range, thereby reducing the possibility that a single large oil spill or similar disaster could contaminate all the sea otters in California.

Between 1987 and 1990, 139 sea otters were translocated from the mainland range to San Nicolas Island (SNI), off southern California. The number of sea otters counted at SNI through most of the 1990s hovered around 15. The most recent survey of the island, in April 2000, found 23 sea otters (21 adult and two dependent pups). While over 50 sea otter pups are known to have been born at the SNI, the population strangely has remained small. The status and future of the sea otter colony at SNI remain uncertain.

The federal law (Public Law 99-625) that authorized the translocation of sea otters to SNI also created a management zone (aka the no-otter zone) as a concession to the shellfish industry for fisheries expected to be lost due to sea otter foraging. This management zone includes all California waters south of Point Conception except for those surrounding SNI. All sea otters found in the management zone were to be captured by FWS in cooperation with DFG and returned either to SNI or the mainland range. Over 20 sea otters were captured in the management zone between 1990 and 1993 and returned to the mainland range. However, shortly after, two separate otters captured from the management zone and translocated back to the Monterey area, were found dead. The FWS judged that the deaths might have been due to the stress of capture, transport and relocation. This brought an end to the "containment program," as it was called, because removals were to be by non-lethal means. Small numbers of otters remained in the management zone through 1997 with relatively little outcry from opponents of this outcome. Then in 1998, over 100 sea otters moved into the area south of Point Conception. Since that time the numbers counted in the management zone have seasonally vacillated from less than five to over 150. The count south of Point Conception in May 2000 was 79 sea otters. No action by FWS to remove sea otters from the management zone has occurred since 1993.

At this writing (June 2000) the FWS is being sued by the shellfish industry for failure to enforce the management zone as legally mandated by Public Law 99-625. Meanwhile, the Friends of the Sea Otter, a sea otter advocacy group, has vowed to sue the FWS if they attempt to enforce the management zone on the grounds that such action would violate the ESA.

The draft revised recovery plan for sea otters in California was made available for public review in the spring of 2000. The primary goal of the new Plan, like the old, is attainment of a sea otter population with sufficient numbers and range to eliminate the possibility of disasters such as the EVOS exposing all California sea otters to contamination and possible injury or death. Interestingly, the draft revised plan no longer views the process of translocation as a valuable tool to speed recovery, viewing natural expansion of the population to be the appropriate approach. According to the recovery team, it will require the average of three consecutive standardized spring counts to be 2,650 or greater for sea otters to be delisted under ESA (Friends of the Sea Otter is threatening to sue to increase this number).

If the sea otter population in California does increase to the level suggested for delisting, and should delisting occur, it will still, in all likelihood, be accorded "depleted" status under the MMPA. Removal from depleted status requires the "optimum sustainable population" be attained which is generally regarded as 60 percent of the "carrying capacity." If the historical statewide population size of 14,000 is used, then the count of sea otters in California necessary for removal from depleted status under the MMPA is 8,400. Only after this sea otter population size and associated range size are achieved will real zonal management (separation of sea otter and shellfishing areas), which would require lethal take, become a possibility. Unlimited expansion is the likely management option that will be pursued for the foreseeable future.

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Marine Bird Resources

Seabirds are a diverse assortment of bird species that inhabit salt or brackish water environments for most of their annual cycle, but this is no clear definition. Some seabird species (such as the double-crested cormorant) have populations that are both saltwater or freshwater year-round (even with populations spending part of their annual cycles in both environments). Other types of waterbirds found on salt water also include the classic waterfowl (ducks, geese, coots, and shorebirds) as well as those that live on sandy beaches and in coastal marshy areas or that nest in arctic tundra or inland lakes and marshes (such as loons, grebes, wading birds, and even the well-known seaducks). Loons and grebes are, in fact, unique in many ways. They may be encountered during their non-breeding seasons foraging and living miles at sea; yet, they nest inland in fresh water habitats. This discussion is, however, limited to those species of birds that have breeding populations on offshore islands, coastal rocks, headlands, and certain coastal old-growth forests and are part of the neritic (shallow marine waters less than 200m deep) and pelagic food webs. Our California seabird avifauna can also be further divided into resident (breeding) and non-resident (non-breeding) species. Birds in various ecological categories are very different in how they affect or are affected by the natural environment and human-related events offshore from our coast.

There are 29 species of seabirds (according to our definition) that breed in the state of California. Point Conception is generally considered a major area of transition between characteristically temperate (such as those found in the Gulf of Alaska and Washington) and subtropical seabirds (such as those found in the Gulf of California). North of Point Conception, marine waters are dominated by cold, nutrient-rich water upwelled along the coast. Waters south of Punta Eugenia, Baja California, are generally subtropical. Between is an area of transition that varies in marine climate depending on the temporal extent and timing of upwelling. For example, well-known El Niño conditions often extend warmer waters northward, while the opposite conditions known as La Niña often move relatively colder waters more southward. Ecologically, (and including both breeders and non-breeders) this makes California's marine birds among the most interesting and taxonomically diverse (for the amount of coastline and area of open ocean) in the Northern Hemisphere.

In California, many of our breeding seabirds, such as common murres, Brandt's cormorants, and Cassin's auklets (all primarily northern species) are concentrated at national wildlife refuges, for example, at the Farallon Islands (off San Francisco) and Castle Rock (near Crescent City). The Farallones are the most important single seabird-breeding site in California; these islands are monitored and studied each year by the Point Reyes Bird Observatory and U. S. Fish and Wildlife Service. Large seabird populations there are associated with a high availability of suitable and protected nesting habitat, coupled with strong and productive upwelling systems that provide for large prey resources in the same general area.

Many other species are concentrated on the Channel Islands, located south of Point Conception in the Southern California Bight. Most of these islands are within the Channel Islands National Park. The Channel Islands harbor important nesting colonies for some seabirds of northern affinity (such as Cassin's auklets), but also the state's entire nesting population of both brown pelicans (presently a recovering endangered species under the Endangered Species Act, ESA) and Xantus's murrelet (about to be proposed for endangered species listing; a petition has been recently submitted to the U.S. Fish and Wildlife Service for listing under the ESA). Both species have southern breeding distributions and also nest on islands off Baja California, but the brown pelican is of tropical affinity (origin), whereas the Xantus's murrelet is of subarctic affinity. Seabirds are monitored and studied each year in the Channel Islands by biologists from a number of government agencies, universities, and research groups (*e.g.*, University of California, Humboldt State University, U. S. Geological Survey, Channel Islands National Park, U.S. Minerals Management Service, California Department of Fish and Game, and California Institute of Environmental Studies).

Most of the remainder of important seabird breeding sites are protected by the National Park Service at Point Reyes National Seashore and by the U.S. Bureau of Land Management and State of California, which manage all offshore rocks as the new California Coastal National Monument. The marbled murrelet nests on public and private land, located within privately-owned forests.

The marbled murrelet, in fact, is one of the most unique and interesting breeding seabirds off central and northern California. It is a small seabird that nests inland on the branches of coastal, old-growth coniferous trees, often over a hundred feet above the ground. This little bird species, listed as threatened under the Endangered Species Act, is very likely to be still declining (our table lists it as unknown) because of the loss of its nesting habitat due to logging and mortality caused by oil spills and, previously, gillnet fishing. Fortunately, because of conservation measures, there has been no known mortality in gillnets for the past 15 or so years, so there is cause for optimism.

Usually by the end of summer (after the upwelling period), the California Current system experiences an immigration,

Table 1. Seabirds which breed off the California coast, their distributional status relative to areas north (Alaska) and south (Baja California) of California, the approximate sizes of their breeding populations in 1989-1991, and their probable status in the early 2000s (X indicates presence, 0 indicates absence).

1989-91 Distribution in: Common Name (Scientific Name)	Alaska	California[1]	Baja Calif.	Estimated CA Breeding Pop. in the early 2000s [2]	Current Status in CA
Forked-tailed storm-petrel *(Oceanodroma furcata)*	X	X	0	300	Unknown
Leach's storm-petrel *(Oceanodroma leucorhoa)*	X	X	X	18,300	Declining
Ashy storm-petrel [3] *(Oceanodroma homochroa)*	0	X	0	<10,000	Declining
Black storm-petrel *(Oceanodroma melania)*	0	X	0	150	Unknown
Brown pelican [3] *(Pelecanus occidentalis)*	0	X	X	9,000	Stable
Double-crested cormorant *(Phalacrocorax auritus)*	X	X	X	1,900	Stable/Increasing
Brandt's cormorant *(Phalacrocorax penicillatus)*	0	X	X	64,200	Stable/Increasing
Pelagic cormorant *(Phalacrocorax pelagicus)*	X	X	0	15,900	Stable/Increasing
Western gull *(Larus occidentalis)*	0	X	0	51,000	Increasing
Common murre *(Uria aalge)*	X	X	0	363,200	Stable/Increasing
Pigeon guillemot *(Cepphus columba)*	X	X	0	14,700	Stable
Marbled murrelet [3] *(Brachyramphus marmoratus)*	X	X	0	<10,000	Declining
Xantus's murrelet [3] *(Synthliboramphus hypoleucus)*	0	X	X	<10,000	Stable/Declining
Cassin's auklet *(Ptychoramphus aleuticus)*	X	X	X	131,200	Declining
Rhinoceros auklet *(Cerorhinca monocerata)*	X	X	0	400	Increasing
Tufted puffin *(Fratercula cirrhata)*	X	X	0	250	Stable/Declining
Number species in common	10	-	7		
Total breeding species	28 (30)	16 (29)	14 (22)		

1. Some species that breed in Alaska or Baja California are not listed above because they do not usually breed along the California coast; these species usually occur only as visitors, but in many cases can occur in very large numbers. Species in this category include white pelicans, black skimmers, at least four other species of gulls (Heerman's, laughing, ring-billed, and California), and seven species of terns (elegant, royal, Caspian, Forster's, gull-billed, least, black); numbers in parentheses indicate such additions for each area.
2. Indicates numbers of individuals.
3. Updated since 1991.

Note: The estimated total Alaskan breeding seabird population is about 40,200,000 compared to about 700,000 for California. These numbers represent approximate mean levels throughout the 1980s. Ten to 40 percent should be added to include non-breeders and immatures, a proportion that varies from year to year and species to species. Four species (common murre, Brandt's cormorant, Cassin's auklet, and western gull) comprise almost 90 percent of the total number of breeders. Population numbers given in this column are from the most recent statewide breeding surveys (see Carter et al. 1992).

emigration, and reshuffling of certain species of seabirds from the north, south, and within California. The abundance and diversity of seabirds increases immensely at this time. One of the most abundant seabird species in the world, the sooty shearwater, comes through California waters by the hundreds of thousands, mostly from New Zealand breeding colonies. Similarly, thousands of pink-footed and Bullar's shearwaters visit from Chile and New Zealand, respectively. During the summer and late fall, large numbers of black-footed and smaller numbers of Laysan albatrosses visit from their Hawaii nesting colonies. Occasionally, southern seabirds, such as boobies, red-billed tropicbirds, and magnificent frigatebirds, will provide the highlight of an offshore birding trip. Usually, beginning in July, several species arrive from the Gulf of California, Mexico, dispersing northward along the California coast; these include black-vented shearwaters, least storm-petrels, Heermann's gulls, elegant terns, and many more brown pelicans than nest in California. Especially during late fall and winter, we witness the arrival of northern seabirds, such as northern fulmars, horned puffins (plus other species of the "alcid" family), black-legged kittiwakes, and other species. Such diversity and abundance certainly adds to the overall richness and ecological value of California's total marine avian resources.

Table 2. Scientific names of birds mentioned in text but not included in Table 1.

Albatrosses	Family Diomedeidae
Black-legged kittiwake	*Rissa tridactyla*
Black skimmer	*Rynchops niger*
Black tern	*Childonias niger*
Black-vented shearwater	*Puffinus opisthomelas*
Boobies	*Sula sp.*
Bullar's shearwater	*Puffinus bullari*
California gull	*Larus californicus*
California least tern	*Sterna antillarum*
Caspian tern	*Sterna caspia*
Elegant tern	*Thalasseus elegans*
Forster's tern	*Sterna forsteri*
Gull-billed tern	*Sterna nilotica*
Heermann's gull	*Larus heermanni*
Horned puffin	*Fratercula corniculata*
Least storm-petrel	*Oceanodroma microsoma*
Magnificent frigatebird	*Fregata magnificens*
Northern fulmar	*Fulmarus glacialis*
Pink-footed shearwater	*Puffinus creatopus*
Red-billed tropicbird	*Phaethon aethereus*
Ringed-bill gull	*Larus delawarensis*
Royal tern	*Sterna maxima*
Sooty shearwater	*Puffinus griseus*

History and Utilization

Seabirds are the most conspicuous and familiar elements of marine communities and are a source of pleasure and enjoyment for people at sea or along the coast. They are unique and important biotic elements of marine ecosystems and in the practical sense are a good indicator of the general health of coastal offshore environments, yet people working or recreating at sea often know little about them. Although often omitted from marine resource reference works, seabirds require management and protection, just as other elements of marine ecosystems do.

Seabirds are prominent elements in the biodiversity of marine ecosystems. They perform what ecologist Paul Ehrlich calls ecological services, such as nutrient cycling and scavenging of biological waste materials and debris from waters and beaches. They often guide fishermen to fish. They are a pleasure to watch, and consequently, contribute significantly to eco-tourism. A small industry of offshore nature cruises has, in fact, developed in many ports along the California coast. Healthy seabird populations give us the justified feeling that all is well at sea, and a missing, sick, or oiled bird tells us that it might not be.

Like most marine wildlife, marine birds have historically suffered severe and relentless exploitations by man. In California this was especially true at the Farallon and other islands during and after the gold rush (from 1850 to about 1900), where common murres were heavily exploited for their eggs. There was no regulation of take and the murre populations declined severely. Numbers had declined by an order of magnitude by the 1900s, and only a few thousand individuals were left by the 1930s. The Farallon Islands murre population did not recover for several decades and even now is far below numbers of the 1800s. Exploitation of seabirds or seabird products is neither a local or recent phenomenon. Recall the ancient, managed harvest of guano by the Incas of Peru, or the harvest of guano for manufacturing gunpowder by the imperialistic navies of Europe in the 16th-18th centuries. Empires were won or lost over control of seabird islands. Early sailors and explorers often utilized seabirds or their eggs for food, driving some species to extinction. In general, however, there has been little success worldwide in utilizing seabirds for sustainable food or other product sources. The few exceptions include guano harvests in

Peru, harvest of eider down from seaducks in Iceland, and muttonbird (shearwater) harvests for food in New Zealand. There has been no successful sustainable harvest of seabirds or seabird products in California or along the West Coast. Since the early days of exploitation, management has usually involved putting the nesting islands into a protection system. This is the case for all islands off California.

After World War II, California's abundant seabird populations began to suffer from new problems. For example, populations were depleted as a result of offshore chemical pollutant discharges from industries in southern California. Most recently, populations have declined as a result of excessive mortality from entanglement in commercial gill-nets. Bird populations in central and southern California may have declined because of excessive sardine fishing. Most species of seabirds feed on or near the surface, schooling species that are also sought in commercial fisheries. The well-known decline of sardines off Monterey is thought to have had deleterious effects on some species of seabirds. It is not well known, however, how long it takes to bring about a population decline of seabirds from prey depletion. Some species are able to switch effectively to other prey species, but often there are no other appropriate prey species to switch to. Since the 1950s, large oil spills and chronic waste oil discharges

Adult Western Gull, *Larus occidentalis*
Credit: Paul Gorenzel, UC Davis

(such as slops and oily bilge waste-water) have become increasingly more frequent, and large numbers of seabirds have been killed. An outstanding example of seabird losses by oil spills is the "Point Reyes Tar Ball Incident" in which it is estimated that 10,000 to 20,000 seabirds died. Although acute oiling of seabirds from large oil spills receives a great deal more attention, chronic oil fouling of the offshore environment might cause the most damage to seabirds and other marine wildlife. Rehabilitation (washing and captive care) of oiled birds has so far not been very successful. Most birds die before rehabilitation can be attempted and many birds that receive care die anyway either before or after their release. It is not likely that most birds surviving rehabilitation will go on to breed. Thus, prevention of both oil spills and chronic oiling is the best solution. And, in stepping-up prevention activities, California has changed several factors to reduce the incidence and spread of spills: oil spill response schemes in all harbors, ship traffic control systems in all large ports, heavy fines of perpetrators of spills, and double-hulls required of all new tankers. In 1994, a multi-million dollar, statewide oil-spill rehabilitation network was initiated by the Office of Spill Prevention and Response, California Department of Fish and Game and Oiled Wildlife Care Network, University of California, Davis, to provide the immediate capability to clean oiled marine wildlife and to conduct research to improve rehabilitation techniques and survival success. Rehabilitation of individuals affected by diseases such as botulism or individuals that have been hooked or otherwise injured by fishing gear have proven to be much more successful. Unfortunately, funds to implement strategies to prevent birds from contacting oil during the spill response, such as wildlife hazing programs, have received limited support.

Population restoration and maintenance of populations into the future are ultimate goals of wildlife managers. Historically, most seabird conservation and management measures have been through protection of critical nesting, feeding, and roosting areas from human exploitation and disturbance, eradication of small populations of introduced predators, protection and recovery of prey species, and reduction of contaminants (*e.g.*, DDT and PCB compounds). Now, however, more proactive efforts are being utilized. For example, planned eradication of a large population of rats on Anacapa Island (by the Island Conservation and Ecology Group working with the Channel Islands National Park, USFWS, NOAA, and CDFG) will hopefully allow re-establishment of large populations of formerly-abundant crevice-nesting seabird populations. In another example, old-growth redwood forests have been preserved because of their importance as nesting habitat for marbled murrelets. Seabird recolonization is being achieved through social attraction techniques (using decoys, mirror boxes, and taped calls) to restore breeding populations of common murres along the central California coast. Using these methods, breeding-age individuals were attracted to Devil's Slide Rock in San Mateo County, the site of a previously extirpated breeding colony. Since the project was initiated in 1996 (by the USFWS, Humboldt State University, and National Audubon Society), a small breeding colony soon established itself and increased each year to over 100 pairs in 2001. Proactive restoration and conservation efforts will undoubtedly expand in the future.

Since seabirds are visibly affected when people misuse marine resources, the well-being of our seabird populations can tell us a great deal about the health of our oceans. Potential effects on seabirds from future development are often examined to help evaluate overall projected effects on the marine environment. Such activities include increased levels of offshore oil extraction and transport, mining of other ocean resources, development of other forms of energy, use of new fishing techniques, fish farming and fish ranching at sea, and new marine product development and exploitation. Additionally, "ecotourism," a rapidly growing industry, can itself lead to unregulated intrusion onto islands that are important as nesting sites for seabird populations. There is already a long history of disappearance of seabird colonies on islands visited too frequently by unsupervised tourists. Global warming may also have detrimental effects on fish resources and, ultimately, seabirds. This may be seen in the form of population declines, changes in behavior, and/or shifts in distribution. Often predictive models, based on current research, will be necessary to more adequately predict what changes might be expected from long-term and radical changes in environmental conditions due to global warming.

The heavy fines and natural resource damage assessments that can be imposed on polluters, as well as recognition of the importance of seabirds as environmental indicators and of the effects that human activities can have on them, has led to a surge of activity and interest in seabird conservation and management. In addition to many governmental agencies that are concerned or charged with seabird conservation, there are at least five "seabird groups" that are composed of interested professionals worldwide who have become organized to study, help conserve these important elements of marine wildlife, as well as to educate the general public as to the value of seabirds in the California area. The Pacific Seabird Group focuses on the Pacific Coast from Baja California to Washington, plus Alaska, Hawaii, British Columbia, other parts of Mexico, and Japan. In California, state and federal governmental agencies, sport and commercial fishermen, seabird biologists, and marine bird conservationists are beginning to work together, guided in part by the California Marine Life Protection Act, to help study, conserve, and manage marine wildlife. Trust funds established from natural resource damage assessments resulting from oil spills such as the *Apex Houston,* the *American Trader,* and the *Commend* oil spills has already resulted in major new initiatives for seabird conservation; restoration funds of about $12.5 million have been committed to these efforts. And for the first time, significant marine bird protection zones (mainly for nesting areas) are being considered along with marine reserves, which address primarily fishery resources.

Seabird Ecology

Almost all important adaptations in body form and behavior of seabirds reflect specialization for either breeding or feeding. Methods of marine bird feeding depend on types of foods and where these foods are found in the water column. Seabirds, therefore, are influenced by the environmental factors that influence the marine environment. During the breeding season, seabirds are confined to feeding within range of their nesting islands. In addition to providing suitable habitat, nesting islands must be free of predators and disturbances. Outside the breeding season, when not constrained to tending offspring, many seabird species are highly mobile and can move long distances to find food while some species may remain in areas of abundant and predictable food supplies, just like fishermen. At sea, distribution of seabirds is heavily influenced by physical oceanographic processes. For example, plankton feeders will be found where ocean currents favor growth and accumulation of planktonic species. Such areas, in turn, provide food for shoals of species such as northern anchovy, Pacific sardine, herring, mackerel, or juvenile demersal fishes such as rockfishes. These midwater and epipelagic fish in turn are preyed upon by fish-feeding seabirds.

Juvenille Western Gull, *Larus occidentalis*
Credit: Paul Gorenzel, UC Davis

Some seabirds feed at the surface and others fly or paddle underwater to extend their reach lower into the water column. Some California species can dive to a depth of 330 feet. Water clarity influences which type of feeding method will be most successful. For example, clear, tropical waters typically best support species that catch fish by plunge-diving (boobies and pelicans). In contrast, northern waters are usually too turbid for aerial plungers to see prey, but are better suited to underwater swimmers or flyers (like the murres, auklets, and cormorants).

While nesting, seabirds are largely bound to nest contents that requires protection from predators. The breeding season is the period of time it takes from courtship, nest-building, and egg-laying to the point of fledging, when young leave the nest or become independent. During breeding seabirds are strongly influenced by local food supplies (*i.e.*, prey available within the feeding range of nesting birds), which are dependent upon oceanographic and meteorological conditions. Reproductive success is influenced by the biomass, availability, and consistency of local food supplies. For instance, when El Niño weather patterns associated with reduced productivity occur, seabirds reproduce poorly or not at all because prey resources are less abundant and available. Decadal alteration of marine climate can also be important, for example, the warm, nutrient-depleted period that existed during the late 1800s and again in the last decades of the 1900s.

Since offshore islands with nearby, stable food supplies are in short supply for nesting seabirds in California, such birds are almost always found concentrated into tightly-packed nesting colonies, with different species usually segregated onto different kinds of micro-habitat. As a consequence, nesting colonies are vulnerable to destruction by mammalian predators such as foxes, raccoons, mink, and cats. Therefore, nesting islands must be free from both terrestrial predators and human disturbance to provide seabirds with successful nesting opportunities. Evolutionary development on islands lacking terrestrial predators has left many seabirds with no defenses against predators, except to abandon their colonies. Undisturbed roosting and loafing sites are also critical to seabirds. Tourism and introductions of rats, cats, dogs, pigs, goats, and other feral animals has repeatedly led to extermination of seabirds from islands that were formerly predator-free.

Brown Pelican, *Pelecanus occidentalis*
Credit: Paul Gorenzel, UC Davis

Management and Conservation

Traditionally (up until about 1990), responsible government agencies had expressed almost no interest in funding basic seabird conservation research. Official listing under various categories and laws (the most outstanding being both state and federal "endangered" species acts) forced agencies to expend some limited funds on such species as brown pelicans, least terns, and marbled murrelets. Impending offshore oil development prompted some federal agencies to begin basic surveys of marine birds and mammals at sea and on the California coastline. Recent damage assessments guided by the Oil Pollution Act of 1990 have stimulated new directions in seabird conservation and management. It is ironic that mainly because of impending threats to seabirds by various forms of oceanic pollution (Outer Continental Shelf developments and marine contaminants), only then have seabirds begun to receive adequate research and conservation attention. Relative to other categories of marine resources, however, marine wildlife research and conservation still has to be considered as minimal. Interestingly, the non-game program of the California Department of Fish and Game (under the leadership of Howard Leach) pioneered on a national basis, investigations of seabird resources in California. Also in the early-1970s, a non-profit research organization, the Point Reyes Bird Observatory, initiated important research on the Farallon Islands.

Many federal and state agencies are now involved in the management and conservation of marine birds, and many statutory and regulatory provisions contribute to their protection. In addition, California has one of the finest systems of sanctuaries and refuges for seabirds in the world, although coordination among the many agencies and organizations involved has proven to be challenging. However, our coastal wetlands now comprise only a small percentage of their former extent, and these habitats are critical to many species of seabirds. Offshore waters are becoming increasingly occupied and utilized by people, yet many offshore islands and rocks are as close to their natural states as one might reasonably expect in our modern world.

Nonetheless, some of California's seabirds have been designated as threatened or endangered (*e.g.*, California least tern, California brown pelican, and marbled murrelet), and others may already warrant such designations (*e.g.*, Xantus's murrelet and ashy storm-petrel). Brown pelicans may eventually be downlisted and delisted as an endangered species because its populations have shown strong recovery and are now self-sustaining; among seabirds this is one of the few true success stories of marine bird conservation in recent times.

Seabird populations have a number of characteristics in common, which make them susceptible to harm from environmental changes:

1) Resident seabirds concentrate their nesting efforts over several months at small areas, and they traditionally use the same nesting areas year after year.
2) Some seabirds (*e.g.,* pelicans, cormorants, and gulls) concentrate in roosts or resting sites. Night roosts provide protection from predators and disturbances and may have beneficial thermal characteristics. Day roosts are located closer to food supplies and may also have good plumage-drying properties, such as sunny, cold-wind protected surfaces.
3) Many seabirds depend on concentrated food supplies, often commercially valuable fisheries resources. Marine fisheries biologists are beginning to work with marine wildlife biologists to balance recreational and commercial fisheries with other wildlife needs.
4) Many seabirds tend to be long-lived with low annual reproductive rates. Thus, seabirds cannot usually recover very rapidly from large impacts on their populations.
5) Seabirds are often components of assemblages with interdependent elements, which means that they are closely allied to other species in their system. Disruption of one or more interacting elements may affect the entire assemblage in some way.

Seabird and Fisheries Interactions

Seabird-fisheries interactions have been categorized as follows: 1) direct competition, with negative population implications either for fish or seabird populations; 2) mutualism, where the interaction is beneficial, or commensalism, where there is neither benefit nor detriment to the interaction; and 3) physical injury, where birds are killed or injured by fishing activities, or bird activities affect operations or damage gear. Categories 1 and 3 describe conflicts in resource use that should be minimized. Extensive mortality of common murres and other seabirds in the 1980s and 1990s in gillnets has led to extensive fishing closures throughout most of California. Multi-species or ecosystem management instead of management that is single-species oriented may be the key to minimizing many conflicts. The management plan of the Pacific Fishery Management Council (PFMC) for northern anchovies was one of the first in the nation to consider the multiple uses of the anchovy resource, including prey for both seabirds and marine mammals and bait for sport fishermen. With recovering Pacific sardine populations (beginning in the late 1980s), the PFMC is revising its anchovy plan to include multi-species management of small pelagic fishes. Fishery management plans are beginning to include concepts such as forage reserves, multiple-needs, ecosystem balance, and thresholds of minimum resource abundance.

In recent years, there has been conflict between seabird needs for disturbance free nesting habitat and the market squid fishery in the Channel Islands. This fishery depends on the use of intense lighting during the night to attract squid. Much of the squid harvest occurs relatively close to the shorelines of islands where seabirds nest. As a result, smaller crevice-nesting nocturnal birds (*e.g.*, Xantus's murrelet and ashy storm-petrels) become highly vulnerable to predators (such as gulls and owls) while attending nest sites. These species are also attracted to light and can become disoriented and crash into the boats, potentially causing death or injury, or separating adults from their young on the water. Additionally, there is concern over the impacts of continuous light on the breeding success of diurnal species such as brown pelicans and cormorants. For these species, continuous light may affect hormonal levels, which in turn may alter behavioral patterns important in courtship, incubation, and chick care. Noise and disturbance generated from fishing activities may also affect breeding success of vulnerable species. Measures to resolve these conflicts are currently (in 2001) being considered and discussed by state and federal agencies together with seabird biologists and fishery managers, but at this time (summer of 2001) there are no assurances of a resolution.

Overall, the future of fishery-seabird interactions free of major conflicts is improving. For example, since gill-netting has been banned in many areas, some fishermen have switched to alternate fishing methods that do not harm seabirds. Situations are more difficult to control when commercial fishing occurs outside areas of state or federal jurisdiction, such as foreign waters where many of our migratory seabirds reside part of the year. Interactions between the recreational fisherman and marine wildlife also occur. While each individual interaction may involve only one angler and one bird (involving hook injuries, monofilament entanglements, and other injuries from handling and struggle), recreational fishermen as a group can have a significant impact on some seabird populations. In most instances the best management approach is still education.

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Because this report focuses on the status of marine fisheries, as required my the MLMA, the editors have had to limit the space devoted to birds. Since marine birds are an integral part of all the ecosystem divisions of this book we have included a comprehensive list of references.

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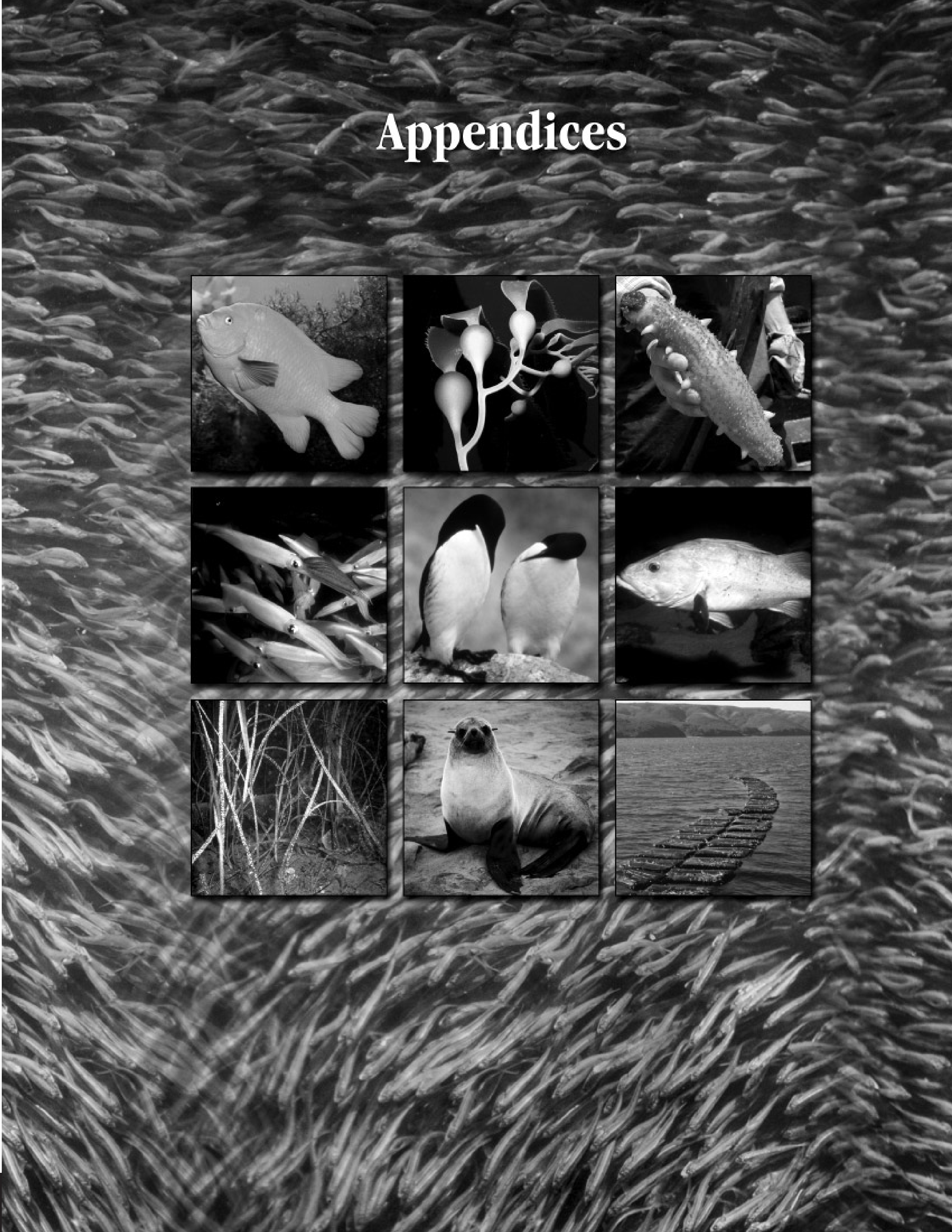
Appendices



Appendix A: Management Considerations

This appendix of Management Considerations is provided for informational purposes only. These views, submitted by the authors, do not necessarily represent the views of either the California Department of Fish and Game or the California Fish and Game Commission, and no endorsement of any of these views by these agencies is implied.

Abalone

DFG's goals for abalone include the recovery of the abalone resource throughout its historic range to sustainable levels, pursuant to the mandates of legislation (Abalone Recovery and Management Plan and the Marine Life Management Act).

For reasons discussed above, many historic abalone fishery management practices were ineffective in protecting the resource south of San Francisco. The state recognizes the value and importance of abalone resources, and has made abalone recovery and management a high priority. Future abalone management might likely include the following:

1. Marine protected areas that provide refuge and protection for breeding populations of abalones, and other long lived, broadcast-spawning invertebrates. Such areas need to have active and adequate enforcement. These areas are necessary early in the recovery phase to enhance reproductive viability.
2. Individual species management. The life history, habitat needs, and population levels of each species should be recognized and considered within the framework of ecosystem management. Knowledge of the age class structure, frequency and rate of recruitment, natural mortality rate, and growth is needed to model the fishery for each species and area.
3. Rapid response to environmental and human induced stresses is needed to adjust or stop harvests when unforeseen problems such as disease or unusual climatic events arise.
4. Fishery-independent data to determine the health and sustainable harvest rate of the resource.
5. An evaluation to identify the potential size of the fishery using biological data and an economic analysis to evaluate resource rent, *i.e.*, the amount necessary to cover the cost of research, management, and protection of the resource, in order to apply these costs to the fishery.
6. A constituent involvement process that assists in evaluating the best uses of the resource. Such a process would also enable information-exchange between the DFG and interested parties.
7. An evaluation of the consequences of reoccupation of the sea otter into southern California waters.

Albacore

Currently, North Pacific albacore fisheries are not subject to formal management measures, such as limited entry or total catch restrictions for the commercial fisheries, or size or bag limits for the recreational fisheries. However, more structured management of the albacore population is being considered by an international convention (Multilateral High-Level Conference (MHLC) on the Conservation and Management of Highly Migratory Fish Stocks in the western and central Pacific Ocean) that includes nations that historically have supported fisheries for the highly migratory stocks of the Pacific Ocean. It is likely that initial management approaches will include some form of limited entry intended to minimize the detrimental effects to the stock that commonly arise due to intensive fishing over extended periods of time. One of the most difficult tasks that the MHLC must address will be to develop a strategic plan (research and management goals) for the North Pacific albacore stock that is applicable to the population's entire range. Such a plan must be supported by each nation's albacore management institution and industry if it is to be successful.

Angel Shark

Though the angel shark fishery is currently very minor in California (it is growing in Mexico), it can serve as a valuable case study of an emerging fishery that grew to be one of the most valuable elasmobranch fisheries on the Pacific coast in the past 25 years. A number of fishermen, both gill-netters and trawlers, who continue to harvest angel sharks, have expressed interest in working with DFG biologists to reassess the 1987 minimum size limit. They cite the fact that the main angel shark habitat and population centers have been protected by the Proposition 132 area closures for over six years and that the Marine Life Management Act (MLMA) encourages "adaptive management" to review and amend regulations if stocks improve. Participation of experienced fishermen proved valuable in the cooperative life history and population studies conducted on the research vessel *Squatina* in the 1980s and the MLMA identifies collaborative research as a priority in obtaining cost-effective data for fisheries management. A future cooperative research study of the angel shark population could also shed light on the effectiveness of a large "no-take" marine reserve, at least on this single resident species.

Further studies on the genetic variability of geographically separated island and mainland stocks would provide resource managers with valuable information in developing a fisheries management plan. A review of the socio-economic impacts of the area closures on small scale fisheries, coastal communities, and local economies could also provide managers with tools to assess the pros and cons of incorporating marine reserves in future management strategies.

The fishing industry, university researchers, and resource managers might seek to initiate a cooperative program with Mexico to assure a sustainable angel shark fishery that can continue to supply both Mexican and U.S. markets.

Barred Sand Bass

This species seems to be a good candidate for the establishment of harvest refugia in some areas during peak spawning times.

Bay Shrimp

The current lack of catch limits, closed seasons or restricted areas is based upon the assumption that limited demand for bay shrimp maintains effort at levels far below the level that would threaten long-term sustainability of the fishery. Data is not available to test this assumption. Because of this, the following measures are suggested:

1. Continue the compilation of bay shrimp logbook data to get past and current catch per unit effort, as well as maintaining logbook requirements for commercial fishery participants.
2. Monitor species composition in bay shrimp landings. Currently, four species are known to be caught in the fishery with indications that a newly introduced fifth species may also be of importance. Long-term shifts in species landed by the fishery may be indicative of broader problems in the populations of each species.

Bocaccio

Bocaccio have been managed under the Groundfish Management Plan of the Pacific Fishery Management Council since 1982. The bocaccio population is now under a formal rebuilding program, requiring severe restrictions on fishing opportunities. The length of time needed to rebuild the population depends on the frequency of rare large year classes, but may require 40 years under conditions similar to those seen in recent years.

Bull Kelp

In order to ensure a productive future for California's bull kelp resource and the species dependent on it, the following considerations are offered:

1. Continue the present management system for the 300-series beds, including the harvest prohibition for beds 303-307.
2. Modify the present 15 percent harvest-limit on the leasable 300-series beds to require distribution of the harvest throughout the bed to minimize local impacts.
3. Prohibit harvest of bull kelp in beds where the bull kelp resource has been shown to be chronically diminished during the past several decades.
4. Encourage the use of alternative feeds, some of which have already been developed for cultured species such as red abalone.
5. Fund more regular assessments and more research to examine the impacts of various harvest strategies.

Cabezon

In recent years, federal groundfish management policy has resulted in drastic reductions in allowable take of many groundfish species due to the overfished status of some species such as lingcod, bocaccio, and canary rockfish. These reductions in turn have shifted effort to more lucrative markets, such as the live-fish fishery. For bocaccio and canary rockfish, the efforts required to rebuild stocks will restrict harvest levels for all associated species for several years, so fishing pressure on cabezon and other nearshore groundfish species is not likely to decrease, and may increase further, without some intervention. DFG developed interim management measures to further address increasing demands on these nearshore fish populations. Measures for cabezon include:

1. An increase in the minimum size limit.
2. A closed commercial and recreational fishery during spawning and nest guarding seasons.

In addition, the department is mandated to develop a Nearshore Fishery Management Plan, which will include cabezon and may be adopted by the Fish and Game Commission in January 2002.

Calico Rockfish

Calico rockfish are a minor component of commercial rockfish landings in California, but they may comprise a significant portion of the undocumented bycatch of the nearshore commercial fisheries that target other finfish or invertebrate species. The extent to which these nearshore fishing operations increase calico rockfish mortality is not known and requires further study, including onboard observation and sampling of the bycatch of nearshore commercial hook and line, trap, and trawl fishing vessels in southern and central California.

There is currently some onboard sampling of CPFVs in California as part of the ongoing coastwide Marine Recreational Fisheries Statistical Survey, but additional onboard sampling of CPFVs will be required to adequately assess the mortality that is caused by sport anglers to calico rockfish stocks. Angler education and enforcement efforts to reduce the sport angler practice of high-grading would also help conserve the stocks of calico rockfish.

California Barracuda

1. Establish equilateral regulations with Mexico based on collaborative research.
2. Maintain current commercial and recreational regulations.

California Corbina

1. Maintain the current sport fish regulations and the ban on commercial take of corbina.
2. Ascertain size and age structure of populations.

California Halibut

1. Maintain the current commercial and recreational regulations.
2. Protect nursery grounds in southern California's embayments and estuaries.
3. Prohibit dredging operations in embayments and estuaries during periods of peak abundance (March-May) of larval and newly settled halibut in southern California.

California Sheephead

Implementation of the minimal size (12 inches) for the sheephead may allow smaller females to reproduce prior to their entry to the fishery. However, larger, more fertile females are still at risk. Careful monitoring of catch and effort data, if possible, is needed to allow early detection of a problem. A better understanding of reproduction would help set a more realistic minimum size limit.

Coonstripe Shrimp

Information on biological parameters of coonstripe shrimp off California is limited. A precautionary approach to management should be employed until more is known about the impacts of commercial harvest on this resource. Given this lack of knowledge, the following management measures should be considered:

1. Restrictions on access.
2. Limit the number of traps used by each fisherman.
3. A season closure from November through April, during the predominant egg-bearing period.
4. A mandatory logbook.
5. Development of a fishery dependent and independent monitoring program to gather data on life history and population characteristics.
6. Since sport harvest of this resource may increase in the future, the issue of equitable allocation should be seriously considered.

Coastal Cutthroat Trout

Sportfishing regulations in many waters have been changed to catch-and-release, enabling sport fishing to continue, at reduced harvest levels.

1. Catch and release regulations should be continued.
2. Data on abundance and distribution of coastal cutthroat trout should be collected in the context of habitat conditions so that the relationship between the fish and ecological processes can be understood.
3. Programs should implement conservation measures and restoration of habitat to permit dispersal among populations and different strains of coastal cutthroat.

Dolphin

Continue to monitor the commercial and sport fisheries for catch and effort data. Work with the Pacific Fishery Management Council to implement the Highly Migratory Species Fishery Management Plan, which includes dolphin.

Eel Grass

1. Carry out and maintain a comprehensive eelgrass inventory for the state.
2. Revise the Southern California Eelgrass Mitigation Policy or develop and implement a new statewide eelgrass disturbance, avoidance, and mitigation policy that recognizes eelgrass as a vital living marine resource whose presence is critical in nearshore food web.
3. Evaluate the potential impacts of anticipated sea level rise and coastal erosion on remnant and re-established eelgrass bed communities. Because the natural, often gently sloping shorelines around many of California's bays have been replaced by revetments, a study of the potential loss of eelgrass habitat due to the lack of intertidal refuge from increased water depth and reduced light penetration should be undertaken. The results of such a study would then be added to the analyses of potential impacts and preparations for the anticipated rise in sea level.
4. Include maintaining plant stock genetic diversity as an important parameter within mitigation-based eelgrass re-establishment requirements.

Flatfish

The author of the 1992 arrowtooth flounder assessment recommended a conservative management approach, especially until new data and models could estimate absolute biomass and exploitation rates. Management of this species falls under the jurisdiction of the Pacific Fishery Management Council (PFMC). The Pacific halibut fishery is regulated by the International Pacific Halibut Commission, made up of members from the United States and Canada. For the other minor flatfishes, the most recent recommendations of the Groundfish Management Team of the PFMC suggest no change in the coastwide acceptable biological catch.

Because of tighter restrictions on the primary federally-managed groundfish species (notably members of the Sebastes complex and lingcod), it is reasonable to assume that more fishing effort may be placed on other species of fish in the immediate future as fishermen seek alternate fisheries, including the minor flatfishes. If so, it is imperative that this group of fish be included in fishery management plan development.

Gaper Clam

Present sport bag limits for locations with large sport clam fisheries seem adequate to protect the gaper clam populations in those areas and also in areas where declines in populations have occurred. Population declines in other areas are most likely not caused by over-harvest since there remains a subtidal portion of the population that acts as a spawning reserve. There are a number of reasons for reduced clammer success in formerly productive bay and estuarine areas, including decreased tidal flushing and increased sedimentation reducing gaper clam habitat; increased foraging on gaper clams within the range of southern sea otters; and environmental effects, both long-term and those associated with shorter-term El Niño events. Poor clammer success and take of small-sized clams tend to limit effort in areas where this occurs and should preclude the necessity of having a large number of differing bag limits for gaper clams throughout the state.

Geoduck Clam

The present sport bag limit is adequate to protect the resource from overharvest. In areas where foraging by sea otters has reduced populations, the extremely low sport take presents no threat to the populations, since reduced clam density usually leads to reduced clammer effort.

Giant Kelp

For the purpose of management, the kelp beds off California represent more than just a single species of interest. They represent an important nearshore ecosystem. Giant kelp forests provide essential habitat for a diverse assemblage of marine fishes and invertebrates and their loss would reduce the populations of many marine species. Kelp forests are also important to sport and commercial fishermen, kelp harvesters, recreational divers, photographers, and sightseers, and for their general aesthetic value. During the latter half of the 20th century, throughout California and in southern California in particular, kelp forests have been subjected to increasing environmental stresses. Some are natural, such as the warm water El Niños. Other stresses are clearly the result of human activity. These include sources of pollution and sedimentation resulting from coastal development and the increasing influences of human population growth. While the causes of decline are complex and are masked by seasonal fluctuations, there is general agreement that there is much less kelp along the southern California coast than there was when we first began conducting surveys, shortly after the turn of the century.

At least three areas of management offer some hope for reversing this trend of decline:

1. Reduce harvest rates of urchin predators. These include California sheephead and spiny lobster. The Southern sea otter may eventually return to southern California areas which would result in less dense populations of urchins.
2. Coastwide kelp photographic flights should be increased. The causes for the apparent declines in kelp beds, particularly in southern California cannot be thoroughly analyzed or understood without a better time series of data. Once gathered, the data should be incorporated into a statewide Geographic Information System (GIS). A similar database should be gathered on coastal development. Once established the GIS should be frequently reviewed for evidence of kelp bed damage tied to onshore activities.
3. Provide additional substrate (constructed reefs) over widespread areas for establishment of new kelp beds. These may also serve as spore sources for re-establishment of former natural kelp communities.

Giant Sea Bass

Although there has been recent interest in re-opening the recreational giant sea bass fishery, this does not seem prudent at this time given the lack of data and new evidence that suggest high body burdens of DDE and PCB in California giant sea bass. Research projects underway at this time are collecting detailed information on the movement, habitat use and behavior of this species. In a few years, we may have enough data to make informed management decisions regarding giant sea bass. Current management measures should remain in place.

Gracilaria

Baseline data on the extent and density for *Gracilaria* and *Gracilariopsis* in areas favorable for its growth are lacking. Little is known about its ability to capture and recycle nutrients, its invertebrate associates, and its value as a food source for macrofauna, especially the various avian species that over-winter in California's bays and estuaries. The California Fish and Game Code gives the commission authority to make regulations to insure the proper harvesting of kelp or other aquatic plants. If the worldwide market for *Gracilaria* and *Gracilariopsis* increases, the pressure on the commission to open up more of California's nearshore waters to wild stock harvesting of these and other agar-bearing marine plants will likely increase. However, until essential information is obtained on the role these seaweeds play in the ecology of California's bays and estuaries, a proactive management recommendation would continue to prohibit harvest of wild stocks of *Gracilaria* and *Gracilariopsis* species at this time.

Grunion

Proactive investigations to enhance knowledge of this species for future management should include estimates of relative abundance of spawning fish and human take along the sandy beaches of the Southern California Bight. This would reveal trends in abundance, distribution, beach preference, and fishing mortality. On-site observations at several locations, over several nights of each run, could add quantitative data on abundance and human take. This information would be valuable for resource damage assessment in the event of widespread petroleum spills during the spawning season.

The only current aspect of grunion management that should be a candidate for revision is the lack of a bag limit. The case for establishing a bag limit is not based on current harvest rates but on the potential impact of a constantly growing human population in California. A nominal bag limit of, perhaps, 50 fish would not restrict current legitimate recreational harvesting but could serve to prevent over harvest if grunion gathering became more popular. A bag limit also is valuable to insure that fish caught under the authority of a sport fishing license are not being harvested in large quantities for illegal sale.

Jack Mackerel

The jack mackerel population can probably continue to support the current level of fishing exploitation, but it is difficult to predict the effects of increased exploitation, due to the limited knowledge of the composition and behavior of the older segment of the population and to the limited knowledge of reproduction and recruitment in jack mackerel. Under the CPS FMP, jack mackerel are a monitored species unless landings exceed the ABC for two years. Should jack mackerel become actively managed, it will be important to know the contribution of older fish to the population and fishery.

Kelp Bass

It may be time to explore new conservation measures such as increasing the size limit, imposing minimum and maximum size limits (slot fishing), and/or promoting catch-and-release fishing.

Louvar

Biological requirements and worldwide distribution limit the ability of local fisheries to severely impact the louvar population. If a breeding or subpopulation is determined to exist off the California coast, a level of awareness through proactive management could be utilized to prevent over fishing and maintain optimum yield.

Monkeyface Prickleback

Due to the relative low utilization of monkeyface prickleback, specific management recommendations are not considered at this time. However, in view of the unique and limited habitat which this species occupies, a reduction in number (from the existing 10-fish recreational bag limit) and a minimum legal size (such as 14 inches) might be appropriate in the future. Most individuals are taken in the intertidal zone or in very shallow water, and the survival rate for those returned to the water would be expected to be high. However, based on their mode of feeding, hooking mortality might be a limiting factor and would preclude a size limitation.

Mussels

Improving and maintaining the water quality of California's coastal and estuarine waters is the most critical management issue affecting the continued survival of the mussel industry. Both sport and commercial utilization of all of the state's shellfish fisheries is impacted by increasing quantities of ocean-bound effluents produced by point and non-point sources in many areas of the state. Community-based education programs beginning in elementary school and emphasizing the linkages between our coastal watersheds, urban and ocean environments, and human health are a positive step in developing an informed public. DFG, the California Sea Grant Extension Program, California Water Quality Control Board, National Marine Sanctuary Programs and several other public and private groups have made progress in this effort, but persistence and determination are needed to slow and reverse the loss of our clean coastal waters.

Opah

Although commercial landings of opah are recorded by the department, opah is not presently a target species and their take is not managed. The impact of California landings on the species as a whole may be minimal, as the population is worldwide in temperate and tropical seas. However, since very little is known about the opah, it is difficult to determine the impacts of various fisheries worldwide.

Other Nearshore Rockfish

Concerns are increasing due to increasing demand on a limited resource; commercial size limits, commercial permits, and gear limitations have been implemented to address these concerns. Recent changes in federal management of nearshore species have resulted in very low allowable take, increasing the demand and thus the prices. DFG is currently mandated to develop a Nearshore Fishery Management Plan (NFMP), which uses the best available data, provides for significant public involvement in the process, and is peer-reviewed. The NFMP may be adopted by the Commission in January 2002. DFG has developed interim management measures to further protect this emerging fishery. Interim measures included control date for limited entry, reduced bag limits, season closures, gear limitations (rod and reel only), and adjustment of size limits. Increased sampling of landings, education of buyers to use proper market categories, and more fishery-independent sampling to assess stocks adequately are needed to effectively protect these resources.

Pacific Bonito

An assessed decline in bonito abundance coupled with a drastic reduction in the size of the fish harvested commercially, brought about a reduced bag limit and minimum size regulation in 1982. The status of the population has not been re-assessed since then. Also, this species is not covered under any current or proposed federal fishery management plan. Declines in both recreational and commercial landings in the 1990s indicate that this species should be re-assessed and appropriate management actions be taken. Such actions might include the initiation of discussions between the U.S. and Mexican governments on coordinating management of this transboundary stock.

Pacific Hake

Since implementation of the Fisheries Conservation and Management Act in the U.S. and the declaration of a 200-mile fishery conservation zone in Canada in the late 1970s, annual quotas have been the primary management tool used to limit the catch of Pacific hake in both zones by foreign and domestic fisheries. The scientists from both countries have collaborated through the Technical Subcomittee of the U.S.-Canada Groundfish Committee, and there has been informal agreement on the adoption of an annual fishing policy. However, overall management performance has been hampered by a long-standing disagreement between the U.S. and Canada on the division of the acceptable biological catch (ABC) between U.S. and Canadian fisheries. In 1991-1992, U.S. and Canadian managers set quotas that summed to 128 percent of the ABC, while in 1993-1998, the combined quotas were 112 percent of the ABC on average. Under the current management impasse there is a potential for overfishing of Pacific hake.

The current management of hake and the composition of the fishery may be affected by growth of tribal fisheries. At present, only the Makah Tribe of western Washington has initiated a fishery. However, two other Washington tribes have stated an interest in entering the hake fishery and NMFS has established preliminary quotas for these tribes. Other coastal tribes may also qualify for entry into the hake fishery. Non-Indian fishers are challenging allocation of hake to treaty tribes, but definitive court rulings on this matter have not yet been reached.

Hake remains the largest fishery on the West Coast. With the recent declines in salmon and the low abundance of rockfish, fishermen engaged in these fisheries are concerned about the bycatch of these species in the hake fishery. The hake fishery is one of the lowest bycatch fisheries in the U.S., but even the relatively low bycatch of salmon and rockfish is a large portion of the current low quotas for depleted salmon and rockfish. The hake fishery is currently faced with the challenge of developing fishing practices to minimize bycatch to the lowest level possible.

Pacific Herring

In general, the current management strategy used for California's herring fisheries has proven to be effective because it allows the department and commission to integrate new and comprehensive information. This strategy has several key components that have contributed to its effectiveness over the years:

1. Conservative harvest levels. Since the inception of the roe fishery, harvest quotas have been conservative and adjusted annually based on spawning population assessments for Tomales and San Francisco bays.
2. Annual population assessments. Each year, DFG assesses the status of the state's two largest spawning populations (San Francisco Bay and Tomales Bay) by collecting information on spawning biomass, age structure, and other biological data.
3. Limited entry. The expansion of the fishery was carefully controlled and has not increased since 1983.
4. Commission management authority. Unlike other commercial fisheries, which have been regulated by the legislature, the commission was given management authority for the herring fishery during the roe fishery's second year. This allows the regulations to be changed on an annual basis and new issues to be addressed as they arise.
5. Director's Herring Advisory Committee. This committee was established to seek valuable industry input on fishery-related matters.

The department is striving to incorporate an ecosystem approach to management of its marine resources. The harvest level used for Pacific herring to some extent takes into consideration this species' role in the marine food web and its connection to environmental factors, but these relationships are not well understood. Most aspects of herring biology and ecology are in need of further scientific research to improve existing herring management and further incorporate an ecosystem approach. The Humboldt Bay and Crescent City spawning populations need re-assessment and more frequent assessments in the future to improve harvest levels. Herring spawning habitat requirements need to be better understood so that they can be adequately protected.

One of the weakest aspects of current management is the inability to predict the number of two-year-old herring that will recruit to the spawning population each year because this age group has the largest impact on spawning population size. Research is needed to understand how environmental factors affect herring survival, particularly during early life history stages, so that we may better predict year-class strength.

Stock assessments and quota management will also improve with better understanding of the distribution and abundance of herring in the open ocean, and whether or not spawning populations are genetically distinct from each other.

Pacific Razor Clam

Current estimates for total catch and effort are needed for the Crescent City beaches and especially Clam and Moonstone beaches in the Eureka area. Little is known about the extent and importance of subtidal populations acting as brood stock for intertidal populations; dependance on these alone to repopulate the Eureka area beaches may be unwarranted. Closure of Clam and Moonstone beaches to intertidal take or reduction of the present bag limit may increase the rate of recovery for these fisheries. In other parts of the state, the present sport bag limit appears to be adequate to protect the resource since minimal digger effort is seen for razor clams.

Pismo Clam

Since 1948, DFG has managed the recreational Pismo clam fishery by the use of bag limits, size limits, closed seasons and closed areas. In 1976, an invertebrate reserve (closed to the commercial and recreational take of any invertebrates) was established in the Pismo Beach area to study the separate effects of recreational clamming and sea otter foraging on the Pismo clam population. In 1979, sea otters were first observed foraging on Pismo clams. By 1982, beach surveys found few clams either inside or outside of the invertebrate reserve.

1. There is no further need for the closed seasons or the five-inch size limit in San Mateo, Santa Cruz or Monterey counties since there is no recreational clamming.
2. It is suggested that a 4.5-inch statewide size limit be adopted to simplify regulations.
3. There is no further need for the invertebrate reserve established in California Code of Regulations or the various Pismo clam closed areas (known as clam preserves) because long term management of a recreational fishery in these areas is not likely to be needed.

Purple Sea Urchin

There are several gaps in basic knowledge concerning purple sea urchins. Although there are scattered studies of growth and survival in the literature, data have not been gathered together and synthesized in a manner suitable for setting harvest size limits. Studies of early growth and survival up to an age of one year are few and are needed to link settlement information with recruitment to the reproductive population. Linking sources of larvae with sites of settlement has not been done and is crucial to developing management plans that involve marine reserves. Because of ocean current patterns, not every region of coastline can be considered to be a suitable source of larvae for all marine species. Both fishery-dependent and -independent monitoring should continue in order to assess changes in stock condition. Fishery dependent monitoring of commercial landing levels and patterns should detect any trend toward large-scale harvests that might require more specific management measures. At present, the most comprehensive fishery independent data consists of the long-term monitoring of settlement patterns in northern and southern California. Continuing this monitoring should provide a measure of settlement supply, and an early warning of possible adverse effects of harvesting on recruitment.

Red Rock Shrimp

Information on the size and condition of the red rock shrimp population in California is mostly anecdotal. For this reason, the resource should be managed cautiously until its status is better understood. Fortunately, fishing pressure has historically been light, with only a few fishermen involved, mostly along rock jetties and breakwaters. In addition, these shrimp may have a low susceptibility to trapping. Large numbers of shrimp have been observed outside of traps while few, if any, were inside. In 1975, a small number of experimental traps were set in deeper water (20 to 70 feet) at locations including reefs and rocky shorelines. Red rock shrimp were known to be present at these locations, based on diver observation, but for unknown reasons, no shrimp entered the traps. Traps have also been observed with many shrimp climbing on the outside, but none entering the trap. These characteristics make it unlikely that the shrimp could be widely, or excessively, harvested with current gear. Regardless, it would be advisable to take the following precautions in managing this fishery:

1. Apply a closure during the egg-rearing period, most likely from May through July.
2. Regulate the size of openings in traps to allow small shrimp (< one inch) to escape.
3. Collect data from fishermen including bycatch and occurrence of females carrying eggs.

Red Sea Urchin

The red sea urchin fishery is fully exploited in California, and evidence from a variety of sources points to an overfished condition in northern and portions of southern California. Management measures developed and implemented collaboratively with the industry (minimum size limits, restricted access, temporal closures) have not been effective in reversing long-term declines in harvestable stocks. The following management-related actions may be needed to reverse this condition:

1. Expand existing fishery-dependent and -independent monitoring programs. Logbook data needs to be collected at a higher spatial resolution using GPS technology. Fishery-independent needs to be expanded to allow managers to assess density and size distributions. Fishery-dependent monitoring will detect trends in harvest, but is confounded by harvest levels, which are strongly affected by quality of urchin gonads and market conditions. Fishery-independent monitoring will allow managers to assess abundance of size classes and poor quality urchins not sampled within the fishery. Continuation and expan-

sion of long-term monitoring of settlement patterns is crucial to providing a relative measure of settlement supply and should be continued and expanded. Re-establishment of an industry-based revenue system would assist in funding these programs.

2. Develop a science-based red sea urchin fishery management plan for the Fish and Game Commission.
3. Conduct a capacity goal analysis. Consider reducing the permit goal to below the present level of 300 divers and explore methods for accelerating the attrition rate.
4. Continue to examine and consider the use of spatial management techniques (*i.e.*, marine protected areas, rotating harvest zones) in urchin management.
5. Expand collaborative monitoring and research with industry participation.

The following management measures could be implemented on an interim basis before a fishery management plan is in place:

1. Establish and monitor a maximum size limit to accelerate recovery of fished areas. A maximum size limit would be expected to protect animals with the greatest spawning potential and enhance the survival of juvenile urchins under the spine canopy.
2. Establish regional management zones for northern and southern California.
3. Establish annual harvest quotas based on the five-year average annual catch. This measure could ensure that a sudden increase in demand, as occurred in the mid-1980s, does not drive stock levels below their ability to recover.

Ridgeback Prawn

Recommendations for the management of ridgeback prawns closely follow that of spot prawns. Current regulations need to be evaluated for effectiveness. As mentioned above, no population estimates are available for ridgeback prawns in California; periodic assessments are necessary to determine whether the resource is robust and able to support a continuing fishery.

Rock Crabs

The rock crab fishery is currently one of the few remaining significant nearshore fisheries not subject to some form of restricted access limitation. Present open access and relatively low capital requirements for entry could result in large increases in effort for rock crabs as fishermen seek opportunities to diversify their fishing activities. The multi-species nature of the rock crab fishery also presents a number of challenges to implementing biologically meaningful management measures. Future management activities, which should be considered to help insure the future health of this resource and fishery include:

1. Establish a system for obtaining periodic fishery-independent data on rock crab abundance, species and size composition, recruitment patterns, and bycatch characteristics.
2. Begin to monitor the commercial fishery for species and size composition, geographic and temporal patterns in catch and effort, and bycatch characteristics.
3. Investigate the need to establish a restricted access program for this fishery.
4. Explore gear modifications to reduce bycatch.

Rock Scallop

The rock scallop is a valuable marine resource to the sport diver as well as a highly promising candidate for extensive cultivation in the sea by new methods of aquaculture. There will be an increasing demand for hatcheries to provide seed stock for population enhancement and for the developing aquaculture industry.

Salmon

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

1. Continue its efforts to improve, restore, and enhance freshwater and estuarine habitats for salmon, focusing on:
    a. Screening of water diversions
    b. Abatement of pollution sources, chemical and thermal
    c. Reductions in siltation and gravel compaction levels
    d. Elimination of gravel removal operations in important spawning and rearing areas

e. Reduction of vegetation encroachment into major spawning areas

f. Maintenance of suitable stream flows and temperatures

g. Control of diseases, particularly bacterial kidney disease in hatcheries.

2. Support studies to differentiate races of salmon, particularly in the Central Valley, where winter chinook and spring chinook are severely depressed.
3. Develop and implement plans addressing habitat and fishery management to reverse the status of depleted salmon stocks, winter-run and spring-run in particular.
4. Investigate the feasibility of constructing a salmon (and steelhead) hatchery within the San Joaquin basin to produce study fish needed to evaluate delta water management strategies.
5. Continue to work with the Klamath Fishery Management Council in negotiating harvest sharing agreements between ocean and river user groups, developing methods of adjusting fisheries on an a real time basis, and refining stock projection and fishery models.
6. Support studies to compare hooking mortality rates following release for sublegal and out-of-season salmon caught by trolling and mooching.
7. Operate hatcheries and rearing facilities and conduct fish stocking practices responsibly to minimize effects on natural production.

Sand Crab

Not all beaches are suitable for sand crab survival through the winter and must be colonized annually. For this reason, regulation of the fishery should focus on smaller management areas such as the Santa Monica Bay in southern California, where most of the historic catch has been taken.

Scorpionfish

Because there has been no assessment of California scorpionfish numbers, it may be prudent to set conservative quotas on both the recreational and commercial catches, in order to forestall the collapses seen in many other California fisheries.

Sea Cucumber

The dive and trawl fisheries target different species. In order to manage these fisheries, it is important to know the quantities of each species taken. Presently, both the dive and trawl landings of sea cucumber are lumped on commercial landing receipts under a single code for "sea cucumbers, unspecified." It is recommended that:

1. Individual species codes be assigned to both the California and warty sea cucumber. The logbook data also should be coded to species. This is especially important for dive logbooks, because it is possible for divers to target either species depending on where in the state they are fishing.
2. Limited entry regulations for the two fisheries be maintained.
3. Effort is needed to collect the field data necessary to perform stock assessments and generate biomass estimates for both the warty and California sea cucumber. The biological, catch, effort and catch per unit effort parameters derived from logbook data would be used to model the impact of different levels of fishing intensity.
4. Fishery-independent, as well as the fishery-dependent, information is needed to properly manage this fishery. Video surveys of fished areas, to compare with unfished areas, should be conducted.
5. Closed areas may need to be established to serve as controls in order to evaluate the impact of harvests on abundance in open areas.
6. Finally, if the limited entry restrictions do not adequately limit the take of sea cucumbers to sustainable levels, additional management options, such as individual or area quotas, may need to be considered.

Sheep Crab

The sheep crab fishery is presently unregulated. Additional biological information, including a better understanding of physiological and behavioral reproduction, is needed for the development of sound management policies. Nevertheless, limited recommendations can be made based on certain biological characteristics of the sheep crab.

1. The sheep crab undergoes a terminal molt upon reaching adulthood. Thus, the adult claws will not regenerate once removed indicating the claw fishery utilizes a non-renewable resource.
2. The terminal molt, as well as other characteristics, also has implications for management of the live, whole body fishery. For example, size limits would

likely need to include both an upper and lower limit, leaving the largest and smallest crabs to mate so as to maintain recruitment and intermediate sizes, as well as to protect large juvenile males which overlap in size with the adults.

3. Protection of seasonal spawning aggregations may need to be incorporated into a management plan for this species.
4. Use of abrasion stages may also provide a good tool for management. However, duration of the various abrasion stages and their association with gonadal development and reproductive success needs to be determined before considering this management strategy.

Shortfin Mako

The shortfin mako's uncertain status calls for increased investment in fishery-dependent and -independent research. Population assessments are needed, which require more research on fishing mortality, demographics, stock structure, and abundance. The state might consider reinstatement of its volunteer pelagic shark-tagging program. This program has provided information on the migration paths, biology, and ecology of mako sharks. Satellite pop-up tags may also prove useful in determining the distribution and biology of adult mako sharks.

Silversides

The only current aspect of topsmelt and jacksmelt management that might be a candidate for revision is the lack of a bag limit. The case for establishing a bag limit is not based on current harvest rates, but on the potential impact of a constantly growing human population in California. A nominal bag limit of, perhaps, 30 topsmelt (which are commonly used for game fish bait), including jacksmelt in a general provision such as "20 fish, no more than 10 of any one species," would not restrict current legitimate recreational harvesting but would serve to prevent overharvest if fishing for these species became more popular. A bag limit also is valuable to insure that fish caught under the authority of a sport fishing license are not being harvested in large quantities for illegal sale.

Skates and Rays

The continued removal of large numbers of skates and rays without additional management would be ill advised. More data are needed to produce an effective management plan for the species involved. The information needed includes:

1. Landing data on size, sex, and species composition of the sport and commercial catch.
2. Survival rates for released catch.
3. Life history parameters for many of the species involved.
4. Population dynamics including species movements. All of this information will help determine if increased landings of previously discarded catch are altering the impact to the species involved.
5. With skate landings increasing in California, Oregon, and Washington, it would be advisable to coordinate management among the three states.

Skipjack Tuna

Since skipjack tuna in the Pacific are considered under fished, management is not being considered. However, because skipjack tuna in the eastern Pacific are caught with yellowfin tuna, many of the recommended management measures applied to yellowfin tuna may impact skipjack tuna. Some of these include reduction of effort levels and reducing fishing on schools associated with drifting objects to minimize bycatch and the catches of small tunas.

Spiny Lobster

The limited entry program has had some beneficial results. An active fishermen's organization, the California Lobster and Trap Fishermen's Association, worked with the department to develop the current management program. In addition to formalizing a trap retrieval program for traps washed into the surf or onto the beach, the trappers regularly participate in the commission process to resolve industry problems or improve the current regulations.

The current logbook system needs to maintained, and a program needs to be initiated to determine the recreational take of spiny lobster. A formal review of the current limited access program should be scheduled to address issues such as permit transferability until a fishery management plan is produced.

Spot Prawn

The spot prawn fishery has undergone significant growth in the last 10 years in terms of the total pounds landed, numbers of participants and vessels. This pressure is not likely to ease given the worldwide demand for shrimp and prawn as well as the displacement of fishermen from other fisheries such as the groundfish fishery along the Pacific Coast and from the spot prawn fishery in Washington. Given these issues, the following management measures should be considered:

1. Limited entry for both the trap and trawl fleet.
2. Development of a coastwide spot prawn geographic information system (GIS) database, which would identify historic and current fishing areas as well as preferred habitats.
3. Coastwide fisheries-independent population survey of the spot prawn resource.
4. Evaluation of the effectiveness of the current management scheme.
5. Evaluation and establishment of a minimum and/or maximum roller gear size-limit.

Spotfin Croaker

1. Maintain the current sport fish regulations and the ban on commercial take of spotfin croaker.
2. Protect and enhance available bay and nearshore habitats.
3. Collect more complete data on age, growth and maturity.
4. Ascertain size and age structure of populations.

Spotted Sand Bass

Since they are not specifically targeted as a food fish and are mostly caught by recreational anglers adopting a catch and release policy might prove beneficial to this species.

Steelhead

Steelhead are rarely caught in the ocean and state laws and regulations require they be released. The management challenges for this species are almost exclusively in inland waters. In 1996, the Steelhead Restoration and Management Plan for California was published which identified the goals and objectives for management and research needs. The primary management focus for the department recovery of imperiled populations is through the restoration of freshwater habitat, particularly restoration of access to historical habitats that are still suitable but blocked by dams.

In 1999, the department implemented the north coast steelhead research and monitoring project to obtain information on status and life history of north coast steelhead stocks. A similar effort is needed for the Central Valley and south coast. More steelhead focused research and monitoring is needed to provide the necessary information to facilitate the recovery these stocks.

Striped Marlin

All Pacific billfish resources will soon be covered under new international conventions and a federal management plan for highly migratory species is currently being drafted for the Pacific Fishery Management Council. These management groups provide a great opportunity for effective long-term management and conservation of striped marlin and other highly migratory species. However, stock assessments for striped marlin are badly out of date and in need of re-examination. New assessments should include current fishery statistics, a clear definition of geographical limits, better understanding of age, growth and reproductive status, better indices of abundance and evaluation of the effectiveness of catch and release in the recreational fisheries.

Swordfish

Current assessments are based on old, incomplete and sometimes inaccurate data. New assessments using updated and standardized fishery statistics are necessary to determine stock condition and to validate existing levels for MSY. International and domestic conventions are currently being developed to improve reporting of fishery statistics from all fishing nations. These international management authorities need to establish comprehensive assessments to ensure precautionary exploitation, allocation, and conservation of the Pacific swordfish resource.

Smelts

Delta Smelt

Since the delta smelt was listed as a threatened species, modifications to provide better habitat conditions as well as restrictions on the timing and amounts of diversions from the estuary have been instituted. Large-scale habitat restoration projects to improve spawning and rearing habitat have also been planned. Monitoring of the population as well as research designed to determine mechanisms affecting abundance are needed to evaluate the success or failure of these modifications.

Eulachon

The eulachon populations in California need investigation in order to evaluate the status of these populations. It is unknown whether a fishery for this fascinating fish can be restored.

Longfin Smelt

Abundance trends of longfin smelt should be closely monitored since freshwater outflows out of San Francisco Bay estuary are highly regulated and other coastal estuaries are highly modified.

Night Smelt

The fishery for night smelt appears to be stable or increasing; however the fishery is in fact poorly regulated and monitored. Fisheries independent sampling, as suggested earlier, can verify whether apparent increases in fishing effort are over-exploiting the resource. An evaluation of the recreational impacts on spawning beaches should be done.

Surf Smelt

The apparent shift from surf smelt to night smelt as the most common smelt in the commercial fishery may reflect changes in effort or methods; however, the fishery should be monitored much more closely. Fisheries-independent sampling would also verify changes in abundance irrespective of changes in fishing effort. Any additional information, especially on life stages where little or no information is known, would greatly add to our understanding of surf smelt biology.

Wakasagi

Additional research is recommended in order to monitor the potential expansion of wakasagi distribution. The impacts of wakasagi expanding its range into southern California are unknown.

Whitebait Smelt

Since very little is known about the life history of this species, any research or information would add greatly to our understanding. Smelt catches should be constantly examined for the presence of this species.

Washington Clam

The greatest take of Washington clams occurs in Humboldt Bay and with the present level of effort unlikely to increase greatly. The current combination of Washington and gaper clam bag limits appears to be adequate. The present sport bag limits for the rest of the state also appear to be adequate at this time to protect Washington and butter clams from over-harvest.

Wavy Turban Snails

Further development of the fishery should follow procedures for emerging fisheries under the Marine Life Management Act. Thus, the department should identify and monitor new emerging fisheries and notify the commission of such fisheries. The commission can then adopt regulations that limit taking in the fishery until a fishery management plan is adopted and/or direct the department to prepare a fishery management plan for the fishery and regulations necessary to implement the plan.

Recommended interim regulations, based on current best scientific knowledge and slow growth rates, include:

1. A minimum legal size of four inches in shell diameter.
2. A fall and winter fishing season.
3. A temporary cap on the number of fishery participants.
4. Closed areas for study where snails can not be fished.

These interim regulations could be implemented while the department is developing and evaluating a fishery management plan and conducting population monitoring.

White Croaker

There are currently no limitations on catches of white croaker off California, with the exception of a small no-take zone off Palos Verdes. Future management considerations should include continual monitoring of the population size and the status of contaminant levels in areas of concern.

Yellowfin Tuna

The current IATTC management objective for yellowfin tuna in the eastern Pacific is to maintain the stock at levels capable of producing the average MSY. To attain this objective, the IATTC continues to recommend an annual catch quota. Future management issues for yellowfin tuna in the eastern Pacific will also include capacity reductions to maintain or reduce effort levels and reduced fishing on drifting objects to minimize the catches of small tunas and bycatch.

Yellowfin croaker

1. Retain current status as a recreational resource only and existing bag limit of 10 fish.
2. Collect basic life history information such as age and growth, size at first maturity, and fecundity.

Yellowtail

Given the current status of the yellowtail population, and recent enactment of a minimum size limit for sport caught fish, no further management measures are needed to protect the stock.

Appendix B: Glossary

ABC - See Acceptable Biological Catch.

Abyss - The deepest part of the ocean.

Acceptable Biological Catch (ABC)- A term used by a management agency which refers to the range of allowable catch for a species or species group. It is set each year by a scientific group created by the management agency. The agency then takes the ABC estimate and sets the annual total allowable catch (TAC).

Advection - Horizontal or vertical movement of water.

Allele - One of several variants of a gene that can occupy a locus on a chromosome.

Allozyme - A variant of an enzyme coded by a different allele.

Amphipod - Laterally compressed, planktonic or benthic crustaceans.

Anadromous - Fish that migrate from saltwater to fresh water to spawn.

Anaerobic - Living in the absence of oxygen.

Angler - A person catching fish or shellfish with no intent to sell. This includes people releasing the catch.

Annuli - Annual variations in the pattern of growth rings on fish scales.

Aquaculture - The raising of fish or shellfish under some controls. Feed and ponds, pens, tanks, or other containers may be used. A hatchery is also aquaculture, but the fish are released before harvest size is reached.

Artisanal fishery - Commercial fishing using traditional or small scale manually-operated gear and boats.

Ascidiacea - See Tunicate.

Bag limit - The number and/or size of a species that a person can legally take in a day or trip. This may or may not be the same as a possession limit.

Baitboat - Refers to a vessel that fishes with live bait. Examples of target catch for baitboats include albacore and other tunas.

Baleen - A specialized plate of horny material used by some species of whales (Mysticetes) to filter-feed.

Barbel - A slender flesh “chin whisker” found in many kinds of fishes. Barbels function primarily as sensory organs for locating food.

Bathymetry - The science of measuring depths in the ocean.

Batoid - A skate or ray.

Beam trawl - A conical-shaped net held open by an horizontal beam. At each end of the beam are iron frameworks that hold the net open in a vertical direction.

Benthic - Of, relating to, or occurring at the bottom of a body of water (including the ocean).

Berried - Bearing eggs.

Bight - A name for the water body found abutting a large indentation in the coast. A bight is less enclosed than a bay.

Billfishes - The family of fish that includes marlins, sailfish and spearfish.

Bioaccumulation - The build-up over time of substances (like metals) that cannot be excreted by an organism.

Biomass - The total weight or volume of a species in a given area.

Biosystematics - The study of relationships with reference to the laws of classification of organisms; taxonomy.

Biota - Refers to any and all living organisms and the ecosystems in which they exist.

Biotoxin - Substances produced by organisms that can seriously impair living processes and in some cases cause death.

Bioturbation - Disturbance of soft sediments by the movements and feeding activities of infauna (animals that live just beneath the surface of the sea bed).

Bivalve - A mollusk with the shell divided into two halves; e.g. clams, mussels.

Brachiopod - A bivalve mollusk distinguished by having, on each side of the mouth, a long spiral arm, used to obtain food.

Brackish water - Water of reduced salinity resulting from a mixture of freshwater and seawater.

Brail net - A small dip net used to scoop out portions of the catch from the main net and haul these portions aboard. Brail nets are used to transfer tuna, salmon, and sometimes menhaden from the purse seine to the boat’s hold.

Broken and burnt otolith method - Otoliths are broken and burned, revealing more accurate information about the age of a fish.

Bryozoa - A group of sessile colonial animals that are colonial invertebrates and live on hard surfaces.

Bycatch - The harvest of fish or shellfish other than the species for which the fishing gear was set. Bycatch is also often called incidental catch. Some bycatch is kept for sale.

CEQA - California Environmental Quality Act.

CPFV - Commercial passenger fishing vessel.

CPS - Coastal pelagic species.

CPUE - See Catch Per Unit of Effort.

Calanoid copepod - A crustacean zooplankton that has a barrel-shaped body, is found in all oceans of the world, and is an important food source for many fishes.

Calcareous - Made of calcium carbonate.

Capelin - A small silvery fish, most common in the North Atlantic.

Caridean - An infraorder of the decapod crustaceans. Examples include many shrimps and prawns.

Catadromous - Refers to fish that migrate from fresh water to saltwater to spawn.

Catch - The total number or poundage of fish captured from an area over some period of time. This includes fish that are caught but released or discarded instead of being landed. The catch may take place in an area different from where the fish are landed. Note that catch, harvest, and landings are different terms with different definitions.

Catch Per Unit of Effort (CPUE) - The number of fish caught by an amount of effort. Typically, effort is a combination of gear type, gear size, and the length of time gear is used. Catch per unit of effort is often used as a measurement of relative abundance for a particular fish.

Caudal fin - Tail fin.

Caudal peduncle - The tapered, posterior fleshy part of a fish just in front of the tail fin.

Cephalopod - Organisms belonging to the phylum Mollusca that are nearly always carnivorous and are characterized by complex behavior, a well-organized nervous system, a circle of grasping arms, and a powerful beak. Examples include squid and octopus.

Cetacean - A member of the order of marine mammals that includes whales, porpoises, and dolphins.

Chimaera - A member of a group of bottom-dwelling, invertebrate-feeding fishes. Distinctive characteristics include an operculum that covers four gill openings, an upper jaw fused to the skull, teeth consisting only of a few large, flat plates, and no scales.

Chitin - A horny substance forming the hard part of the outer skeleton of crustacea.

Chiton - Mollusks found commonly on hard substrates that are ovalshaped and flattened, have eight dorsal plates which cover the dorsal mantle, and are herbivores.

Chum - To attract fish to a hook by throwing whole or chopped fish or shellfish into the water.

Cilia - Hair-like structures used for locomotion, and in some species, for feeding.

Cladogenesis - The branching of an ancestral lineage to form equal sister taxa (species, genera, families, etc.).

Cladocera - Planktonic crustacea with a bivalved outer skeleton.

Clupeid - A member of the Clupeidae family of fishes. Clupeids include herrings, shads, sardines, and menhaden. They can be readily recognized by their keeled (sawtooth) bellies and silvery, deciduous scales.

Codend - The end of a trawl net. Fish are eventually pushed into the codend as the net is dragged along.

Cohort - A group of fish spawned during a given period, usually within a year.

Coliform - A bacteria commonly associated with food poisoning.

Community - An ecological unit composed of the various populations of micro-organisms, plants, and animals that inhabit a particular area.

Congener - A member of the same genus.

Convergence - The contact at the sea surface between two water masses converging, one plunging below the other.

Copepod - A group of small planktonic, benthic or parasitic crustaceans. Copepods that spend their entire life in the water column are usually the numerically dominant group of zooplankton captured by nets in most marine areas.

Coriolis effect - The deflection of air or water bodies, relative to the solid earth beneath, as a result of the earth's eastward rotation.

Creel - A container used by anglers to hold fish.

Crustacean - A group of freshwater and saltwater animals having no backbone, with jointed legs and a hard shell made of chitin. Includes shrimp, crabs, lobsters, and crayfish.

Ctenophore - Gelatinous zooplankton having eight longitudinal rows of fused cilia ('ctenes') used in swimming.

Cultch - Material (as oyster shells) laid down on oyster grounds that furnish points of attachment for the young oyster.

Cycloid - A round, flat, and thin fish scale found on fish such as trout, minnow, and herring.

Davit - A fixed or movable crane that projects over the side of a boat or over a hatchway. It is used for hauling nets, anchors, boats or cargo.

Demersal - Describes fish and animals that live near water bottoms. Examples of demersal fish are flounder and croaker.

Density - dependent factors - Factors, such as resource availablilty, that vary with population density.

Depuration - Cleansing of bivalve shellfish by moving them from polluted waters to clean waters.

Detritivore - An organism that feeds on detritus.

Detritus - Any loose material produced directly from rock disintegration.

Diatom - One-celled phytoplankton with an external skeleton of silica.

Dinoflagellate - Unicellular plankton having two flagella and, in some species, a cellulose test.

Doliolaria - The second stage of the echinoderm (which include starfish and sea urchins) larvae.

Dorsal fin - An unpaired fin on the dorsal or upper side of the body, between the head and the tail.

Dory - A flat-bottomed boat with high flaring sides, a sharp bow, and a deep V-shaped transom.

Downwelling - The sinking of water.

Drum seine - Similar to a purse seine but the seine is stored on a large drum mounted at the stern. The drum is particularly successful in handling shallow nets.

EPA - Environmental Protection Agency.

ESA - Endangered Species Act.

Ecosystem - A group of organisms that interact among themselves and with their nonliving environment

Effort - The amount of time and fishing power used to harvest fish. Fishing power includes gear size, boat size, and horsepower.

Ekman circulation - Movement of surface water at an angle from the wind, as a result of the Coriolis effect.

El Niño - Condition in which warm surface water moves into the eastern Pacific, collapsing upwelling and increasing surface-water temperatures and precipitation along the west coast of North and South America.

Elasmobranch - Describes a group of fish without a hard bony skeleton, including sharks, skates, and rays.

Electrophoresis - A method of determining the genetic differences or similarities between individual fish or groups of fish by using tissue samples.

Embayment - Formation of a bay. Also, the portion of water or coast that forms a bay.

Endangered species - A classification under the Endangered Species Act. A species is considered endangered if it is in danger of extinction throughout a significant portion of its range.

Entrainment - Mixing of salt water into fresh water, as in an estuary.

Epipelagic zone - The upper region of the sea from the surface to about 200-300 meters depth.

Epiphyte - A plant that grows on another plant.

Epipodium - A ridge or fold in the lateral edges of each side of the foot of certain gastropod mollusks.

Escapement - The percentage of fish in a particular fishery that escape from an inshore habitat and move offshore, where they eventually spawn.

Estuary - A partially enclosed body of water having a free connection with the open sea; within it salt water and fresh water mix.

Etiology - All the causes of a disease or abnormality.

Euphausiid - Shrimplike crustaceans that spend their entire lives in the sea; “krill”.

Extirpation - Situation when something is no longer present.

Exclusive Economic Zone (EEZ) - The region from 3-200 nautical miles searward of the 48 contiguous states, Alaska, Hawaii, and U.S.-affiliated islands. The U.S. National Marine Fisheries Service (NMFS) regulates fisheries within this area.

Ex-vessel - Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain for the catch is an ex-vessel price.

FL - See Fork Length.

Falcate - Shaped like a sickle.

Fathom - A unit of measurement. One fathom equals six feet or 1.83 meters.

Filter feed - See Suspension Feed.

Finfish - A common term to define fish as separate from shellfish.

Fingerling - A term commonly used for any juvenile fish, most commonly used for a life stage in trout and salmon. A fingerling is the stage after fry and before smolt.

Finlet - Small fins located posterior to the anal and dorsal fins. Examples are found in the mackerels (family Scombridae).

Fishery - All the activities involved in catching a species of fish or group of species.

Fishery-dependent - Describes data about fish resources collected by sampling commercial and recreational catches.

Fishery-independent - Describes data about fish resources collected by methods other than sampling commercial and recreational catches. An example of such a method is sampling in marine reserves.

Food chain - A linear sequence of organisms in which each is food for the next member in the sequence.

Food web - A network describing the feeding interactions of the species in an area.

Fork length - The length of a fish as measured from the tip of its snout to the fork in the tail.

Front - A major discontinuity separating ocean currents and water masses in any combination.

Fully utilized - Situation when the amount of fishing effort used is about equal to the amount needed to achieve the LTPY.

Gaff - A pole with a large hook at its end.

Galactans - Plant polysaccharides. Examples are agar-agar and carrageenan.

Gamete - An egg or a sperm.

Gammarid - A member of the suborder Gammaridea and the order Amphipoda. Distinctive gammarid characteristics include that the first segment of the thorax is fused to the head and that they live in salt water, fresh water, and tropical forests. An example is the beach hopper.

Gastropod - A member of the class Gastropoda. Gastropods have a flattened foot, usually a cap-shaped or coiled shell, a mouth apparatus known as a radula, and are characterized by a twisting of the body, known as torsion. Examples include limpets, whelks, and periwinkles.

Gastrula - A stage in the development of a fertilized egg.

Gel chromatography - A method for comparing DNA or genes of different organisms.

Genetic introgression - The transfer of a small amount of genetic material from one (usually plant) species to another as a result of hybridization between them and repeated back-crossing.

Ghost fishing - Situation when abandoned fishing gear continues to catch organisms.

Gillnet - A curtainlike net suspended in the water with mesh openings large enough to permit only the heads of the fish to pass through, ensnaring them around the gills when they attempt to escape.

Gill rakers - Bony, tooth-like structures on the anterior edges of gill arches. Used for protection or for straining out food.

Gonad - Animal organs which produce gametes (eggs or spermatazoa). Female gonads are ovaries; male gonads are testes.

Gonosomatic index - The ratio of the weight of a fish's eggs or sperm to its body weight. The index is used to dermine the spawning time of a species of fish.

Gravid - Heavy with eggs or young.

Green mud - Greenish sand deposits in which glauconite is abundant.

Groundfish - A species or group of fish that lives most of its life on or near the sea bottom.

Gurdy - Spool used in trolling upon which the fishing line is wound. The gurdies are usually powered, but on some of the smaller boats, like salmon dories, they are often hand-operated.

Haplosporidian - A member of the phylum Haplosporidia, which contains spore-forming parasitic protists. One member of this group, Haplosporidium nelsoni, also called MSX disease, has recently caused widespread disease in Crassostrea virginica, the eastern oyster, on the U.S. east coast.

Haplotype - A set of genes that determines different antigens but are closely enough linked to be inherited as a unit.

Haptera - Basal outgrowths that form part of a holdfast.

Harvest - The total number or poundage of fish caught and kept from an area over a period of time. Note that landings, catch and harvest are different.

Heterosis - Segmentation in which the parts are different. Also, the tendency of cross-breeding to produce an animal or plant with a greater hardiness and capacity for growth than either of the parents; hybrid vigor.

Hermaphrodite - An individual with both male and female organs.

Histology - A branch of anatomy that deals with the minute structure of animal and plant tissues as discernible with a microscope.

Holdfast - The rootlike structure at the base of an alga that attaches to rocky substrate.

Hydroacoustics - Sound waves travelling through water.

Hydrography - The arrangement and movement of bodies of water, such as currents and water masses.

Hydroid - Benthic colonial cnidarians (a phylum that includes jellyfish, sea anemones and corals), some of which produce free-swimming jellyfish.

INPFC - International North Pacific Fisheries Commission.

IWC - International Whaling Commission.

Immunodiffusion - Any of several techniques for obtaining a precipitate between an antibody and its specific antigen. One technique is to suspend one in a gel and letting the other migrate through it from a well; another is to let both antibody and antigen migrate through the gel from separate wells to form an area of precipitation.

Intertidal - Between the high and low tide marks and periodically exposed to air.

Isopods - An order of crustaceans characterized by a small flattened bodies, sessile eyes, and both benthic and planktonic species.

Isotherm - An imaginary line passing through points on the earth's surface having the same mean temperature.

Jetty - A rocky structure constructed from land into the sea to protect shore-based property.

Jig - An artificial lure made to simulate live bait. It is usually made with a lead head cast on a single hook and is heavier than most other lures.

Juvenile - A young fish or animal that has not reached sexual maturity.

Keystone species - A species that maintains community structure through its feeding activities, and without which large changes would occur in the community.

Knot - A unit of speed equal to one nautical mile per hour (approximately 51 centimeters per second).

LTPY - Long-term potential yield.

La Niña - An episode of strong trade winds and unusually low sea surface temperature in the central and eastern tropical Pacific. The antithesis of El Nino.

Lampara net - An encircling net (similar to purse seine yet that does not close completely) used in shallow water.

Landing - The number or poundage of fish unloaded at a dock by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the points at which fish are brought to shore. Note that landings, catch, and harvest define different things.

Lateen - A sailing rig used by early salmon fishing vessels off California.

Leader - A length of monofilament or wire that connects the main fishing line to the hook used for capturing fish.

Limited entry - A program that changes a common property resource like fish into private property for individual fishermen. License limitation and the individual transferable quota (ITQ) are two forms of limited entry.

Limiting factor - A factor primarily responsible for determining the growth and/or reproduction of an organism or a population. The limiting factor may be a physical factor (such as temperature or light), a chemical factor (such as a particular nutrient), or a biological factor (such as a competing species). The limiting factor may differ at different times and places.

Limnology - The study of freshwater ecosystems, especially lakes.

Littoral zone - The intertidal zone.

Longline - See Setline.

Long-term potential yield - The maximum long-term average yield that can be achieved through conscientious stewardship, by controlling the proportion of the population removed by harvesting by regulating fishing effort or total catch levels.

Lunate - Refers to the caudal fin shape that is indented and looks like a crescent.

MLMA - Marine Life Management Act.

MLPA - Marine Life Protection Act.

MMPA - Marine Mammal Protection Act.

MRFSS - Marine Recreational Fisheries Statistics Survey.

MSY - See Maximum Sustainable Yield.

Macrophyte - A plant that is large enough to be seen with the naked eye.

Mariculture - The raising of marine finfish or shellfish under some controls. Feed and ponds, pens, tanks or other containers may be used. A hatchery is also mariculture but the fish are released before harvest size is reached.

Maturity - The age at which reproduction is possible.

Maximum sustainable yield - The largest average catch that can be taken continuously (sustained) from a stock under average environmental conditions. This is often used as a management goal.

Mean - The sum of the data divided by the number of pieces of data; the average.

Median - Within a data set, the median is the the number that divides the bottom 50% of the data from the top 50%.

Megalopa - A larval stage of crabs that follow the zoea stages.

Meristem - The point or region from which active growth takes place.

Mesohaline - A zone of water from 1.8% salinity to .5% salinity.

Mesopelagic - A somewhat arbitrary depth zone in offshore or oceanic waters, usually below 600 feet and above 3,000 (200-1000 meters).

Metric ton - 2200 pounds.

Midden - A refuse heap left by prehistoric Native Americans, usually marking campsites.

Milt - A term for the sperm of fish such as salmon, trout, and herring.

Mollusk - A group of freashwater and saltwater animals with no skeleton and usually one or two hard shells made of calcium carbonate. Includes the oyster, clam, mussel, snail, conch, scallop, squid, and octopus.

Mooching - A method of salmon fishing from a drifting or propelled boat. The bait is sunk deep with a heavy sinker then brought upward at an angle as the boat is maneuvered forward a few yards or the line retrieved. The bait is then allowed to sink once again to the bottom and the procedure repeated.

Morphology - The physical characteristics of an individual.

Myctophid - A member of the Myctophidae family of fishes. Commonly called lanternfishes, they are abundant in all oceans of the world, usually at 200-1000 meters depth.

Mysid - A member of an order of shrimplike crustaceans, mostly epibenthic.

NEPA - National Environmental Policy Act.

NFMP - Nearshore Fishery Management Plan.

NISA - National Invasive Species Act.

NMFS - National Marine Fisheries Service.

NPDES - National Pollutant Discharge Elimination System.

Nacre - A smooth, shining, iridescent substance forming the inner layer in many shells; mother-of-pearl.

Nekton - Organisms with swimming abilities that permit them to move actively throught the water column and to move against currents. Examples include adult squid, fish and marine mammals.

Neuston - Organisms that inhabit the uppermost few millimeters of the surface water.

Non-point source - Sources of pollution such as general runoff of sediments, fertilizer, pesticides, and other materials from farms and urban areas as compared to specific points of discharge such as factories.

Nudibranch - Sea slug. A member of the mollusk class Gastropoda that has no protective covering as an adult. Respiration is carried on by gills or other projections on the dorsal surface.

Nursery - Habitat suitable for protection and growth during an organism's early life stages.

Nutricline - The depth zone where nutrient concentrations increase rapidly with depth.

Oocyte - An egg before the completion of maturation.

Oophagy - The first young to "hatch" in each of the two oviducts proceed to eat the other embryos in the oviduct with them.

Open access - A fishery in which no restrictions on entry or gear occur. Licenses may be required in an open access fishery, but if no quotas on fishermen exist the fishery is still considered to be open access.

Operculum - The covering of the gills of a fish. Found in higher order fishes.

Optimum yield - The harvest level for a species that acheives the greatest overall benefits, including economic, social, and biological considerations. Optimum yield is different from maximum sustainable yield in that MSY considers only the biology of the species. The term includes both commercial and sport yields.

Organic - Deriving from living organisms.

Otolith - Calcareous concretions in the inner ear of a fish, functioning as organs of hearing and balance. There are three pairs of otoliths in the skull of each fish, and these are termed sagittae, lapilli, and asterisci. Otoliths are used by fishery biologists for numerous studies.

Otter trawl - A cone-shaped net that is dragged along the sea bottom. Its mouth is kept open by floats, weights and by two otter boards which shear outward as the net is towed.

Overfishing - Harvesting at a rate greater than that which will meet the management goal.

Overutilized - When more fishing effort is employed than is necessary to achieve LTPY.

Oviparous - Producing eggs that hatch outside the female's body.

Oviphagous - Refers to an organism that consumes eggs.

Oviposit - To lay or deposit eggs, especially by means of a specialized organ, as found on certain insects and fishes.

Ovoviviparous - Pertaining to an animal that incubates eggs inside the mother until they hatch.

PFMC - Pacific Fishery Management Council.

PSMFC - Pacific States Marine Fisheries Commission.

PacFIN - Pacific Fishery Information Network. A database containing West Coast fishing landings that is maintained by the Pacific States Marine Fisheries Commission.

Palp - Any of various sensory and usually fleshy appendages near the oral aperture of certain invertebrates.

Papilla - A nipplelike protuberance of the skin.

Paranzella net - A bag-shaped net towed by two vessels that run at various distances apart to keep the mouth open and at various speeds according to the depth desired. The paranzella net initiated the West Coast trawl fishery in 1876 but by World War II it had been replaced by the less expensive otter trawl.

Parturition - Birth.

Patchy distribution - A condition in which organisms occur in aggregations.

Pectoral fins - Paired fins on the front lower sides of the chest.

Pedicle - In jointed brachiopods, a short stalk, composed mostly of tough connective tissue, that emerges through a hole or notch in the posterior part of the larger valve. Muscles that are inserted into the pedicle make it possible for an jointed brachiopod to change its orientation.

Pelagic - Refers to fish and animals that live in the open sea, away from the sea bottom.

Pelecypod - A bivalve.

Penaid - Member of a family of shrimp, used in shrimp culture.

Periostracum - A protective layer of chitin covering the outer portion of the shell in many mollusks, especially freshwater forms.

Pharyngeal - Of, pertaining to, or connected with the pharynx.

Pharyngeal teeth - Teeth developed on the pharyngeal bone in many fishes.

Phycocolloid - A colloidal substance obtained from seaweeds.

Phytoplankton - Microscopic planktonic plants. Examples include diatoms and dinoflagellates.

Pinniped - A member of the order of marine mammals that includes the seals, sea lions, and walruses, all having four swimming flippers.

Piscivorous - An organism that feeds on fish.

Planktivorous - An organism that feeds on planktonic organisms.

Plankton - Plants or animals that live in the water column and are incapable of swimming against a current.

Pleopod - One of the swimming limbs attached to the abdomen in crustaceans.

Plug - A nonspecific term for any artificial lure having a distinct "body" made of wood or plastic and having one or more sets of single, double, or triple hooks hattached. Most plugs are designed to wobble or create a commotion in the water when retrieved.

Pneumatocyst - A gas-filled bladder at the base of each kelp blade that helps buoy the frond in the water column.

Point source - Specific points of origin of pollutants, such as factory drains or outlets from sewage-treatment plants.

Polychaete - Marine segmented worms belonging to the phylum Annelida; some are planktonic, but most are benthic.

Population - Fish of the same species inhabiting a specified geographic area.

Potamodromous - Refers to fish that migrate entirely within fresh water.

Potential yield - The yield estimated to be available for exploitation.

Procaryote - A member of a group of unicellular organisms comprising the bacteria and the cyanophyceae, whose cell structures differs from all other organisms.

Productivity - The rate at which a given quantity of organic material is produced by organisms.

Protandry - An organism functions first as a male, then as a female.

Protogynous - Female in the first phase of one's life.

Pteropod - A holoplanktonic (permanent resident of the plankton community) snail having two swimming wings.

Purse seine - A net that is cast in a circle around a school of fish. When the fish are surrounded, the bottom of the net is closed up, preventing escape.

RecFIN - Recreational Fisheries Information Network. A database of the National Marine Fisheries Service (NMFS).

Recruit - An individual fish that has moved into a certain class, such as the spawning class or fishing-size class.

Recruitment - A measure of the number of fish that enter a class during some time period, such as the spawning class or fishing-size class.

Red tide - A red coloration of seawater caused by high concentrations of certain species of micro-organisms, usually dinoflagellates, some of which release toxins.

Reduction fishery - Harvested fish are processed into fish meal, oils, or fertilizer.

Regime shift - A long-term change in marine ecosystems and/or in biological production resulting from a change in the physical environment.

Riffle - A shallow extending across the bed of a stream over which the water flows swiftly so that the surface of the water is broken in waves.

Riprap - Piles of rock used to support river banks.

River-run - Describes upstream migration of anadromous fish.

Roller trawl - A trawl net equipped with rollers that enable the net to go over rocky areas without snagging.

Round haul net - A net, such as a purse seine, that encircles schools of fish.

Running-ripe - A high state of reproductive readiness.

Sac-roe - Fish eggs that are encased in a clear membrane. Sac-roe are found in herring, among other species.

Salinity - The total amount of dissolved material (salts) in seawater.

Salmonid - A member of the Salmonidae family of fishes. Salmonids are the dominant fishes in the cold-water streams and lakes of North America, Europe, and Asia, where they support large recreational and commercial fisheries.

Satellite pop-up tag - A specialized tag usually used to mark pelagic fish to study their migrations. Data from the tag is transmitted to researchers via a satellite.

Scaphopod - A member of the phylum Mollusca and class Scaphopoda which have an elongate conical shell and live buried within the sediment, feeding on foraminiferans and other small animals.

Scute - A type of sharp scale found on fish such as sturgeon and jackmackerel.

Sea wall - Any solid structure onshore used to protect the land from wave damage and erosion.

Seed - Juvenile shellfish, such as clams, oysters, and mussels.

Serological - An adjective referring to the branch of science dealing with the properties and reactions of blood sera.

Sessile - Referring to animals that are permanently attached to a substrate.

Set gillnet - A gillnet that is anchored on both ends.

Setline - Fishing gear made up of a long main line attached to which are a large number of short branch lines. At the end of each branch line is a baited hook. When catching groundfish, setlines are laid on the seafloor. When catching swordfish, shark or tuna they are buoyed near the surface. Setlines can be twenty or more miles long. They are also called longlines.

Sexual dimorphism - A phenomenon in which males and females differ markedly in shape, size, color, or other ways.

Short ton - 2000 pounds.

Single rig gear - Refers to a boat using a single trawl net (instead of two trawl nets) when fishing for shrimp.

Simple random sampling - A sampling procedure for which each possible sample is equally likely to be the one selected. A sample obtained by simple random sampling is called a simple random sample.

Skiff - Any of various small boats, especially a flat-bottomed rowboat.

Slough - A place of deep mud or mire. Also, a small backwater.

Smolt - A term for a specific life stage in salmonids. In anadromous populations parr (small active fish with series of bars on their sides) transform into silvery smolts and migrate to the sea. Once in the ocean (or large lakes), the smolts gradually become mature and return to their home streams for spawning.

Somatic cell - All cells other than those in sexual gametes (egg and sperm).

Spat - A flat young oyster.

Spatfall - Attachment of shellfish larvae to substrate where they develop into their adult forms.

Spawn - The term for reproduction in fishes.

Spermatophore - An aggregation of sperm held together by gelatinous material, or a gelatinous packet of sperm which is inserted into or attached to the female as part of reproductive behavior.

Spinning gear - A type of recreational fishing reel with an open spool on the front end.

Spoon - An artificial lure with a curved or dished out body that wobbles but does not revolve. A spoon attracts fish by its movements as well as color.

Sporophyte - A plant that produces spores.

Stipe - The stem-like part that connects the holdfast and blade of a frondose alga.

Stock - A grouping of fish usually based on genetic relationship, geographic distribution, and movement patterns. Also a managed unit of fish.

Stratified random sampling - A sampling method in which one (1) divides the population into subpopulations (called strata), (2) obtains from each stratum a simple random sample of size proportional to the size of the stratum, and (3) uses all of the members obtained in step 2 as the sample.

Substrate - A solid surface on which an organism lives or to which it is attached (also called substratum); or, a chemical that forms the basis of a biochemical reaction or acts as a nutrient for microorganisms.

Subtidal zone - The benthic zone extending from the low tide mark to the outer edge of the continental shelf.

Suspension feeder - An organism that feeds by capturing particles suspended in the water column.

Sympatry - The common occurrence of two taxa (closely related forms) in the same geographic area.

TAC - See Total Allowable Catch.

TL - Total length.

Telemetry - The process of tracking movements of organisms using transmitting tags.

Territorial sea - A zone extending seaward from the shore or internal waters of a nation for a distance of twelve miles (19.3 km) as defined by the United Nations Conference on the Law of the Sea (UNCLOS). The coastal state has full authority over this zone but must allow rights of innocent passage.

Test - The shell of a sea urchin.

Thermocline - The water layer in which temperature changes most rapidly with increasing depth.

Threatened species - A classification under the Endangered Species Act. A species is considered threatened if it is likely to become an endangered species in the foreseeable future through a significant portion of its range.

Tidal prism - The volume of water between the high tide level and low tide level.

Total allowable catch (TAC) - The annual recommended catch for a species or species group. The regional fishery management council sets the TAC from the range of the allowable biological catch.

Trammel net - An entangling net that hangs down in several curtains.

Trawl - A sturdy bag or net that can be dragged along the ocean bottom, or at various depths above the bottom, to catch fish.

Trematode - Any of a class (Trematoda) of parasitic flatworms including the flukes.

Trocophore - A free-swimming larval stage of polychaete worms and some mollusks, characterized by having bands of cilia (hair-like structures) around the body.

Troll - To trail artificial or natural baits behind a moving boat. The bait can be made to skip along the surface or trailed below at any depth to just above the bottom. A bait or lure trailed behind an angler walking along a pier, bridge, or breakwater is also called trolling.

T**rophic level -** The nutritional position occupied by an organism in a food chain or food web; e.g. primary producers (plants); primary consumers (herbivores); secondary consumers (carnivores), etc.

Tunicate - Sessile benthic animals belonging to the phylum Chordata.

Turbidity - Reduced visibility in water due to the presence of suspended particles.

Underutilized - When more fishing effort is required to achieve the LTPY.

Upwelling - A rising of nutrient-rich water toward the sea surface.

VPA - See Virtual Population Analysis.

Vector - A physical quantity that has magnitude and direction. Examples are force, acceleration, and velocity.

Veliger - A free-swimming larval stage of mollusks.

Velum - A ciliated, sail-like appendage of a veliger larva.

Ventral fins - Paired fins on the lower part of the body; they may be near the anus, below the pectoral fins, or near the throat. They are also called pelvic fins.

Virtual population analysis (VPA) - A type of analysis that uses the number of fish caught at various ages or lengths and an estimate of natural mortality to estimate fishing mortality in a cohort. It also provides an estimate of the number of fish in a cohort at various ages.

Viviparous - Bringing forth living young, rather than being an egg-layer.

Water column - The water from the surface to the bottom at a given point.

Weir - A low dam or barrier made across a water channel to raise the level of water for different purposes. Also, a barricade.

Wrack zone - A bank of accumulated litter at the strandline.

YOY - Young-of-the-year.

Year-class - The fish spawned and hatched in a given year, a “generation” of fish.

Zoea - A planktonic larval stage of crabs with characteristic spines on the exoskeleton.

Zooplankton - Animal members of the plankton.

Zoospore - A motile spore with one or more flagella or cilia by the vibration of which it swims.

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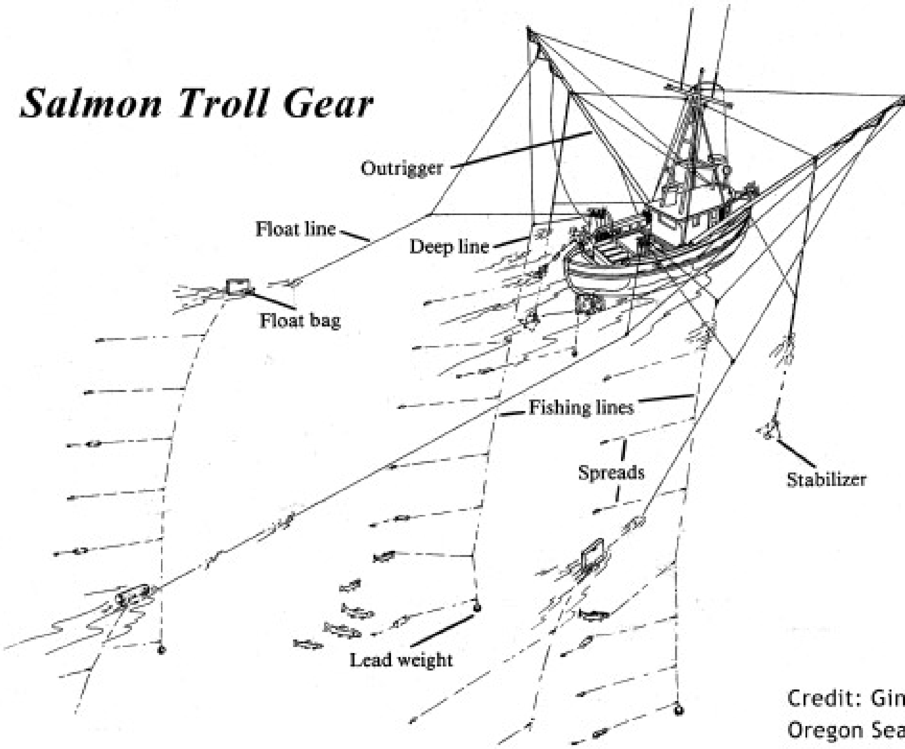
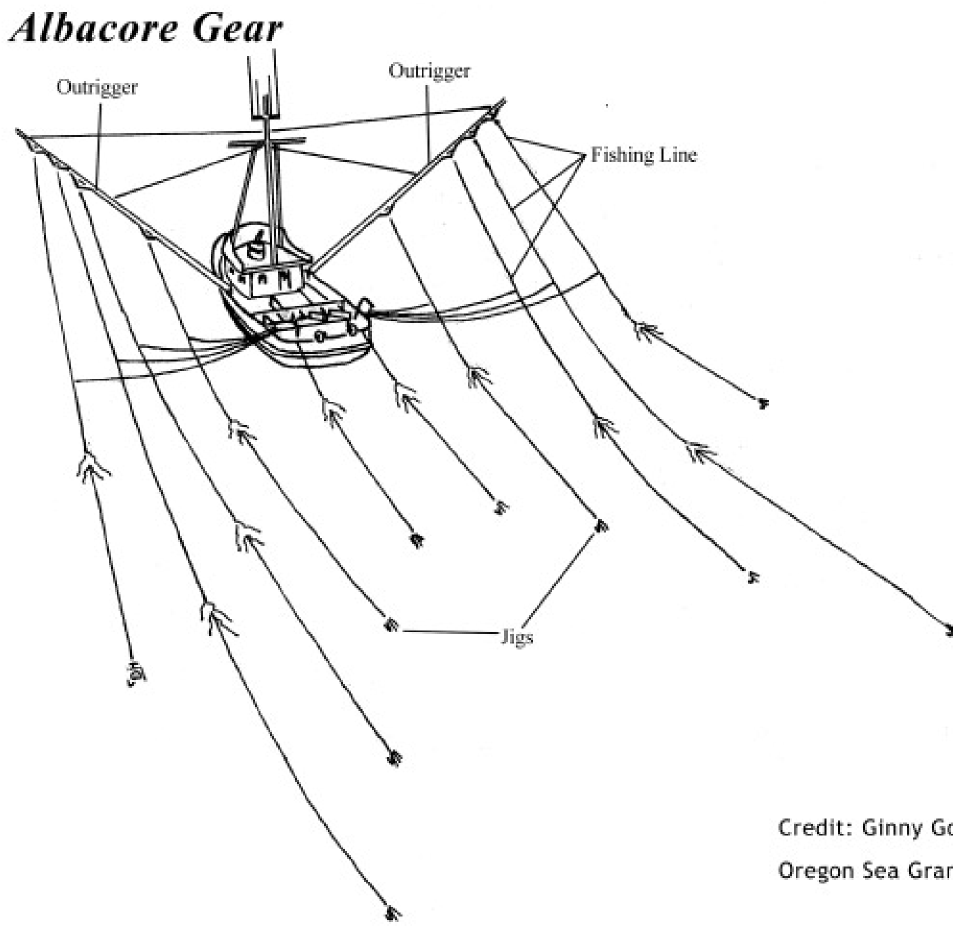
Appendix C:
California's Commercial Fishing Gear



Credit: Ginny Goblirsch
Oregon Sea Grant



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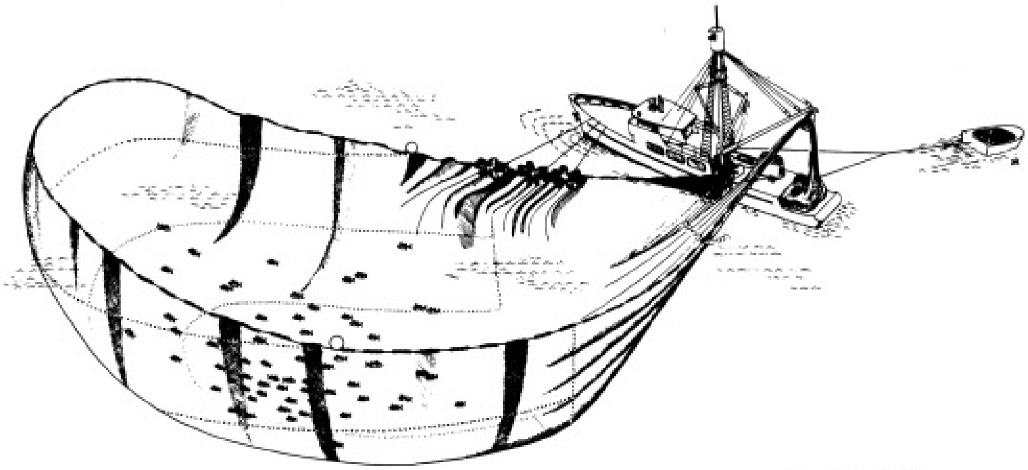
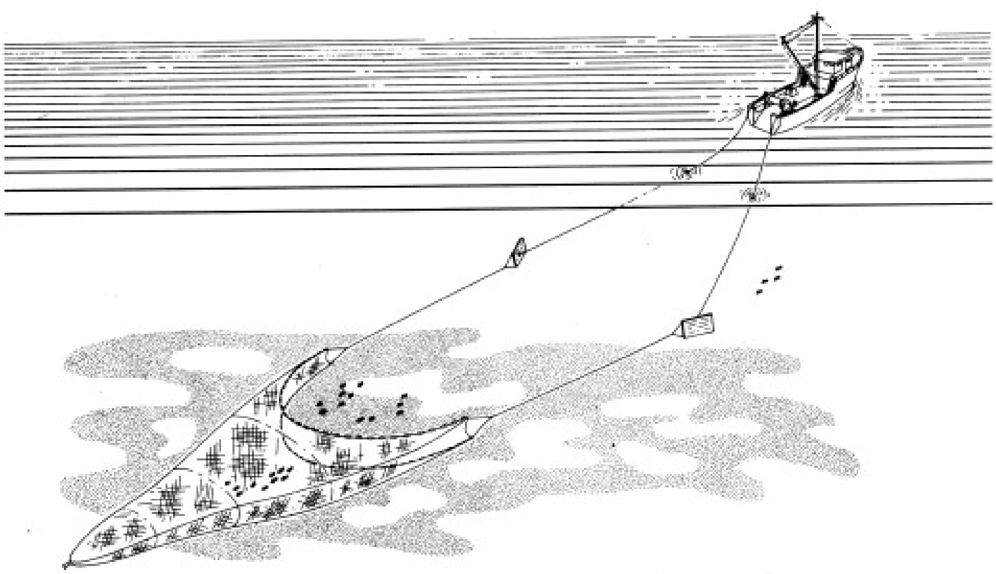
Purse Seine



Credit: NMFS

Otter Trawl



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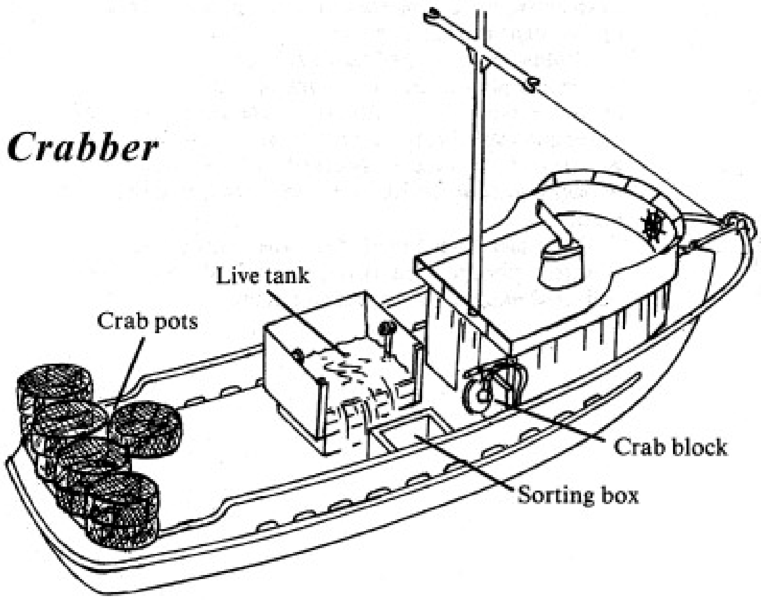
Crabber



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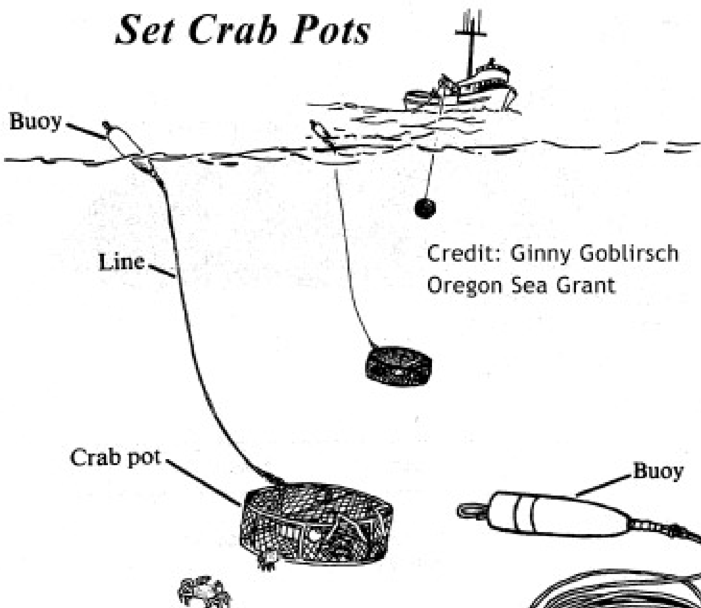
Set Crab Pots



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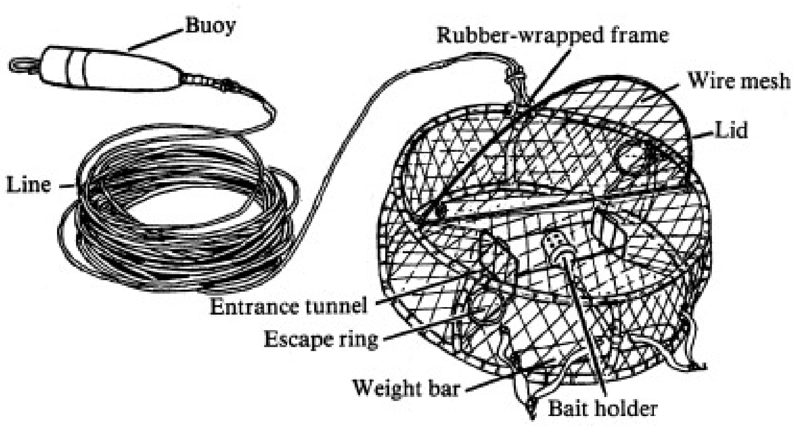
Crab Pot



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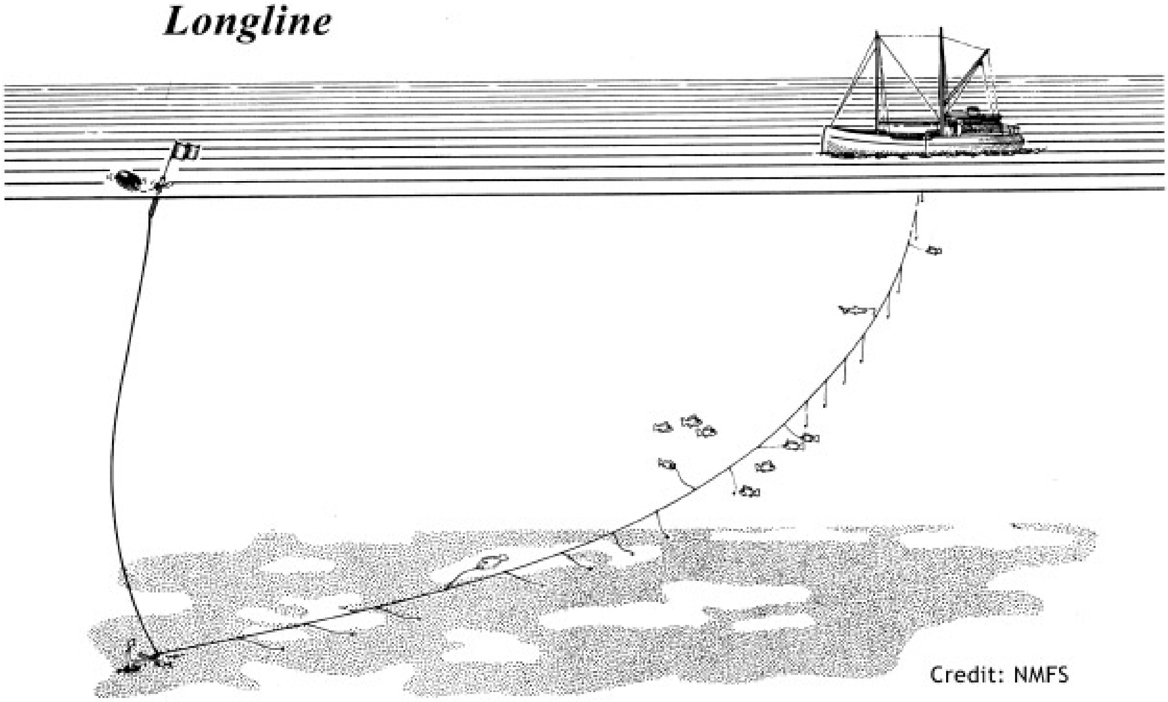
Longline



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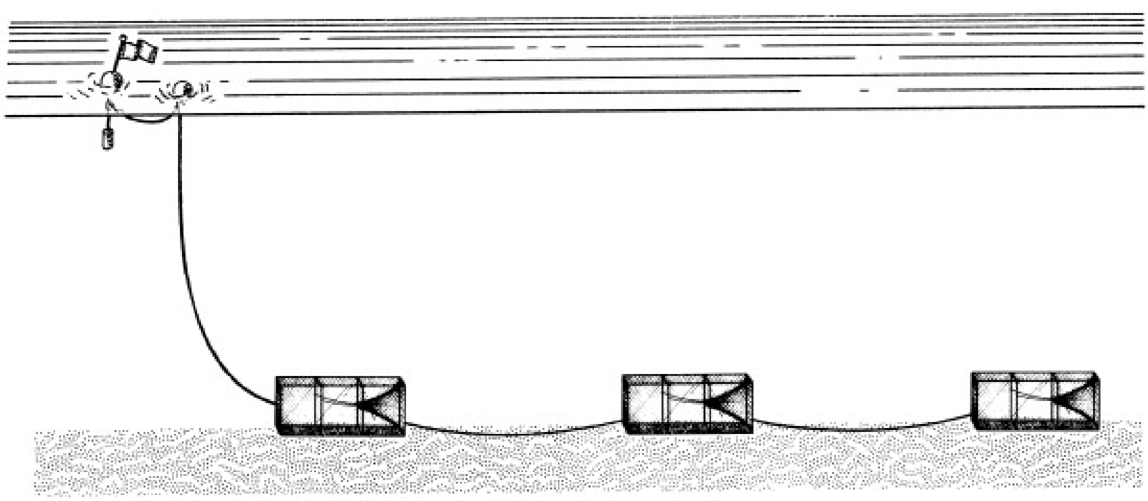
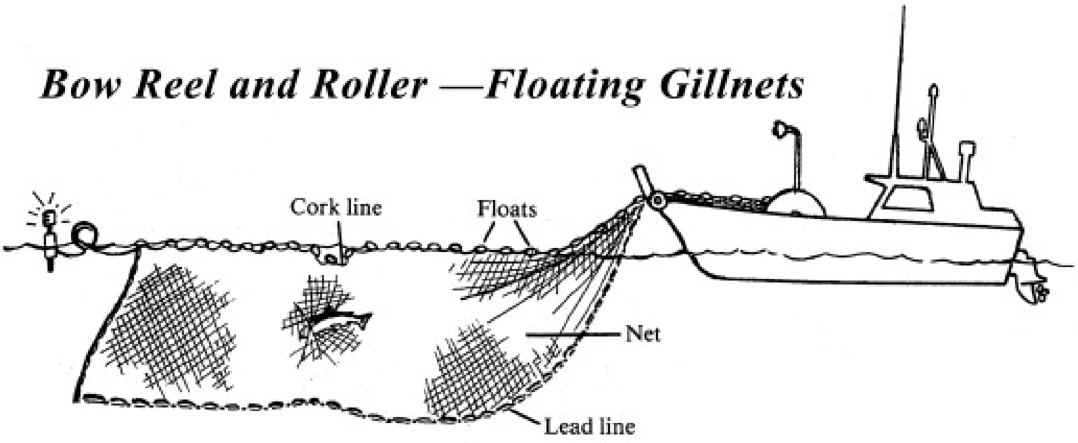
Trap



Credit: NMFS

Bow Reel and Roller —Floating Gillnets



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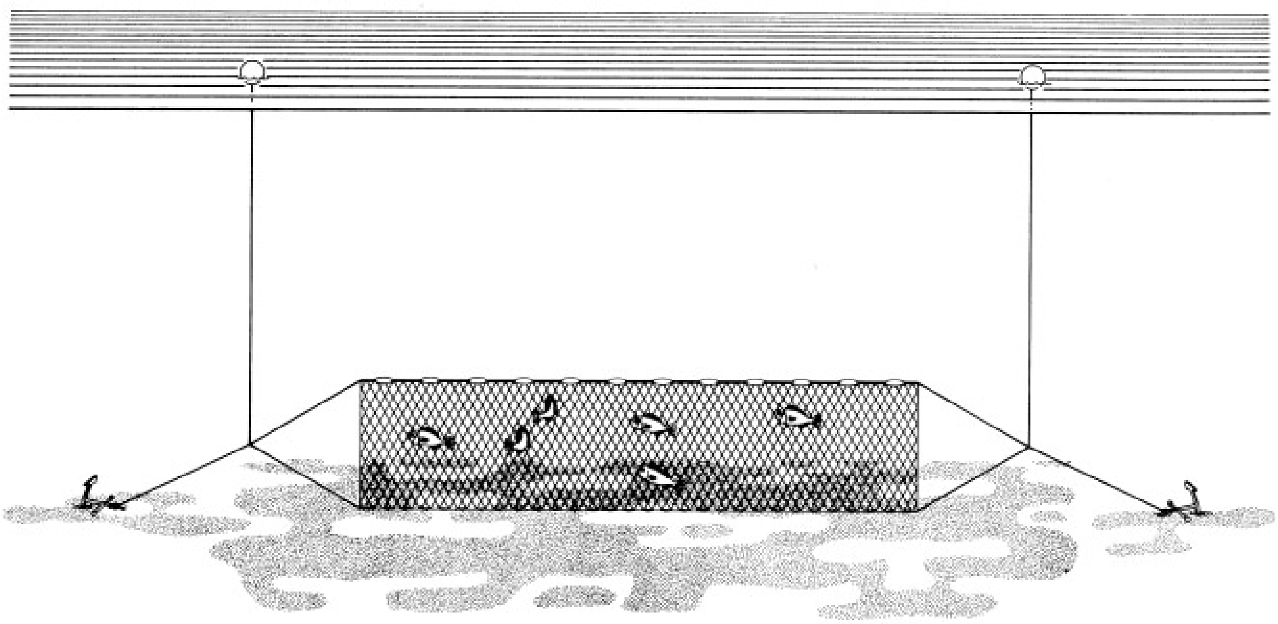
Gillnet



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Index