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Status of Living Marine Resources off the Pacific Coast of the United States as Assessed in 1991

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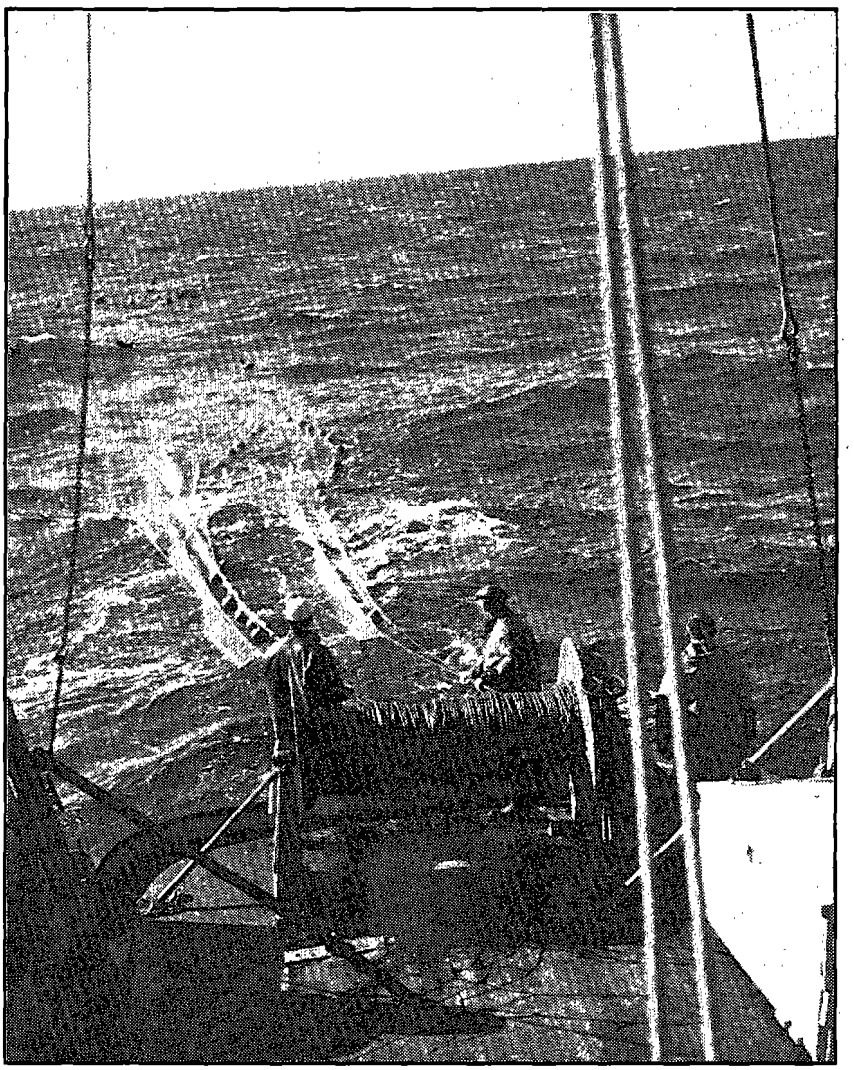
INTRODUCTION

Status of Stocks off the Pacific Coast

This report provides a species-by-species description of the status of living marine resources off the Pacific Coast of the United States as assessed in 1991. The descriptions are for resources that are primarily under the research and management jurisdiction of the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration, U.S. Department of Commerce. This NMFS Technical Memorandum has been compiled from reports written by scientists at the three NMFS Science and Research Centers located on the Pacific Coast. It is one of a series of regional reports on the status of living marine resources throughout the United States.

The resources are grouped under four major headings: groundfish resources, pelagic resources, Pacific salmon, and marine mammals. There are other regional resources of commercial and recreational importance that are not included in this report; these are mostly inshore marine resources under the jurisdiction of the Pacific Coast States of Washington, Oregon, and California.



National Marine Fisheries Service Science Centers

The Alaska Fisheries Science Center and the Northwest Fisheries Science Center located in Seattle, Washington, and the Southwest Fisheries Science Center located in La Jolla, California, have overlapping responsibility for research in the Federal waters and rivers of the west coast of the United States.

The region is bounded in the north by the Canadian border and the south by the Mexican border. The range encompasses cold temperate waters to the north and warm subtropical waters to the south and open waters toward the Hawaiian Islands.

The region supports important commercial fisheries for Pacific salmon, Pacific halibut, Pacific whiting, anchovy, sablefish, flounders, and rockfishes. The region also supports important tuna fisheries and popular sport fisheries for Pacific salmon, Pacific halibut, steelhead trout, and billfishes. It is home to and an important migratory area for a wide array of marine mammal

Pacific Coast Groundfish Resources

Species	Recent Average Yield (t) (1988-90)	Current Potential Yield (t)	Long-term Potential Yield (t)	Status of Utilization
Pacific whiting	177,381	228,000	226,000	full
Dover sole	18,413	22,500	16,300	near full
Other rockfish E-M-C	8,273	unknown	unknown	unknown
Other rockfish V-C	5,671	4,500	unknown	unknown
Widow rockfish	11,947	7,000	8,300	full
Sablefish	11,279	8,900	8,700	full
Other fish	6,300	unknown	unknown	unknown
Thornyheads	5,752	7,900	unknown	unknown
Yellowtail V-C	4,903	4,300	4,200	full
Lingcod	2,887	7,000	7,000	unknown
Pacific cod	2,595	3,200	unknown	unknown
Bocaccio C-M-E	1,750	800	2,400	over
English sole	2,321	1,900	4,500	full
Canary rockfish	2,227	2,900	3,500	full
Petrale sole	2,157	3,200	3,200	unknown
Pacific ocean perch	1,090	0	2,500	over
Shortbelly rockfish	0	13,000	29,000	under
Jack mackerel	0	52,500	12,000	under
Total-whiting	87,520	154,200	131,800	
Total with whiting	264,901	382,200	357,800	

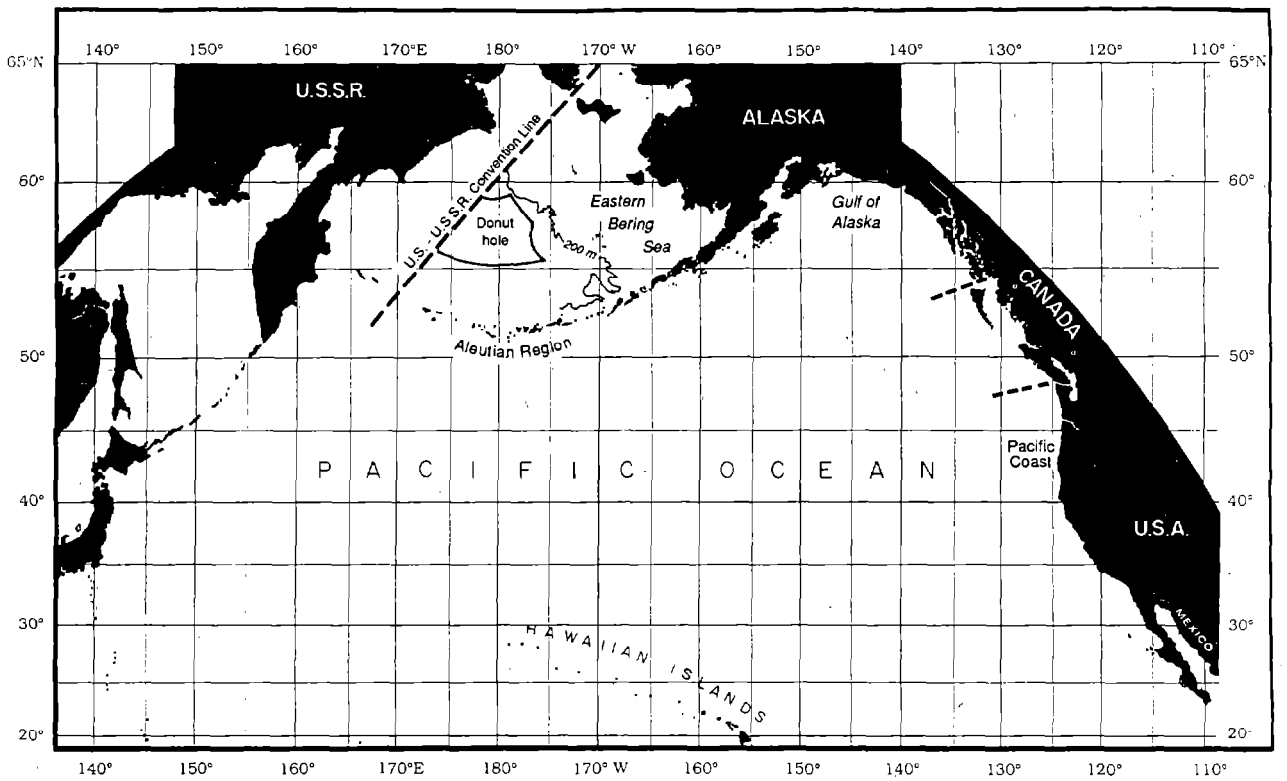
Pacific Coast Pelagic Resources

Species	Recent Average Yield (t) (1981-90)	Current Potential Yield (t)	Long-term Potential Yield (t)	Status of Utilization
Northern anchovy	128,000	166,000	219,000	moderate
Jack mackerel	14,200	52,600	100,000	under

Pacific Coast Salmon Resources Off Washington, Oregon, and California

(in thousands of fish)

Species	Recent Average Yield (1988-90)	Current Potential Yield	Long-term Potential Yield	Status of Utilization
Pink	3,496	3,496	3,496	Over
Coho	2,693	3,231	3,231	Over
Chinook	2,274	2,274	2,274	Over
Sockeye	1,788	1,788	1,788	Over
Chum	1,017	1,017	1,017	Over



Map illustrates the range of distribution of marine resources native to California, Oregon, and Washington.

species (e.g., gray whale, California sea lion, killer whale, and harbor porpoise.).

The mission of the NMFS Science Centers is to plan, develop, and manage scientific research programs designed to generate the best scientific data available for the better understanding and management of the region's resources and the environmental quality essential for their existence.

The Centers provide scientific data and technical advice to their constituents for better utilization and management of the Nation's living marine resources. Their primary constituents are the Pacific, North Pacific, and Western Pacific Fishery Management Councils; NMFS headquarters and regional offices; state and federal agencies; U.S. commissioners of international commissions; the fishing and fish processing industry; and the general public.

Pacific Coast Groundfish -Resources

Pacific Coast groundfish constitute a diverse group of fish species harvested in the U.S. Exclusive Economic Zone (EEZ) off Washington, Oregon, and California. This group of 83 species is managed by a federal fishery management plan (FMP), the Pacific Coast groundfish FMP, through auspices of the Pacific Fishery Management Council.

Most of the groundfish are harvested by trawl gear. The total catch in 1989 was about 300,000 metric tons (t). The recreational catch was about 7,000 t, primarily rockfish. The ex-vessel value of the 1989 commercial catch was $21.6 million for the Pacific whiting joint venture fishery, and $67.5 million for shoreside deliveries of all species, for a total of $89 million. Comparable valuations for the recreational fishery are not available.

Most major species of west coast groundfish are fully utilized. Stock assessments generally indicate that the surplus biomass has been removed from most of the long-lived stocks (e.g., sablefish, Dover sole, several rockfish species). The current potential yield is similar to long-term potential yield (LTPY). Pacific whiting is also fully utilized, and its potential yield experiences the greatest degree of natural variability. Stocks of Pacific ocean perch and bocaccio need to be rebuilt following depletion by foreign fishing and a series

of weak year classes. Two species are underutilized: shortbelly rockfish and jack mackerel. Both are midwater fish and have relatively large biomasses, but a market has not yet developed for either species.

The recent average yield (RAY) of Pacific whiting is 177,000 t, 10 times greater than the RAY of any other species. Dover sole, widow rockfish, and sablefish are a second tier grouping with landings of ll,000-18,000 t per year. In 1990, thornyheads (two species of deepwater rockfish) moved into this second tier with landings of 10,000 t. The third tier grouping, with annual landings of l000-5,000 t, contains several species. The major rockfish species in this third tier are yellowtail rockfish, canary rockfish, and Pacific ocean perch in the Vancouver-Columbia areas (approximately Washington-Oregon), and bocaccio in the areas off California. Other rockfish species contribute 13,900 t per year to the commercial catch and the recreational catch of all rockfish species is 5,000 t per year. The flatfish species in this third tier are English sole and petrale sole. In addition a large fraction of the category "other fish" is now composed of arrowtooth flounder harvested primarily off northern Washington. Finally, lingcod and Pacific cod contribute 2,600 t and 2,900 t, respectively.

A precise stock assessment is only available for Pacific whiting. Assessments for other species will not be much improved until quantitative survey methods can be applied throughout their range. An expanded effort to monitor all fishery takes is also necessary. Chief management problems are excess harvesting capacity and allocation among users. Both management problems are exacerbated by the complex multispecies nature of the fishery.

A difficult management problem which generates a high level of public involvement is allocation of the available catch. The Council faces U.S.-Canada allocation of Pacific whiting, onshore-offshore allocation of whiting, fixed gear-trawl allocation of sablefish, and recreational-commercial competition for some rockfish. Technical analysis of these issues generally rests on an economic analysis that rarely has adequate information on all sectors of the fishing industry. For some of these problems, the concept of individual transferable shares has been identified as a potential long-term solution.

Probably the most severe problem facing managers of the Pacific Coast groundfish fishery is control of the excess harvesting capacity. Today, this problem is manifested as increasingly severe trip limits that cause frustration for fishermen, managers, enforcement agents, and biologists. Tomorrow, the problem could be unexpected stock declines caused by unmonitored discard. A license limitation program, which would be a first step towards alleviating this problem, is under con-. sideration.

Pelagic Resources

The two major pelagic resources that occur in commercial quantities off the Pacific Coast are northern anchovy and mackerels. They both occur primarily off California.

Northern anchovy has been exploited by fisheries in both California and Mexico. In the United States, the fisheries have been managed by the Pacific Fishery Management Council since 1978. Current regulations impose no numeric limit on live bait catch. and provide a 7,000 t quota for other nonreduction uses. The regulations also specify optimum yield for the reduction fishery as 1) zero when the spawning biomass is less than or equal to a cutoff level of 350,000 t, and 2)

the difference between the spawning biomass and the cutoff, up to a limit of 200,000 t, when the spawning biomass is greater than 300,000 t. The biological rationale for the 300,000 t threshold in the optimum yield formula for reduction fishing is to prevent depletion of the resource and to provide an adequate forage reserve for marine fish, mammals, and birds. Although total anchovy harvests and exploitation rates since 1983 have been less than both the theoretical level for maximum sustained yield and historical levels prior to 1983, abundance continues to decline slowly. In the absence of a bilateral agreement with Mexico, fishery managers in the United States assume that U.S. fishermen are entitled to 70% of the total optimal yield and set quotas on this basis.

The jack mackerel is similar to several other species of *Trachurus* (horse mackerel) which occur in temperate eastern boundary currents worldwide. The southern California segment of the stock has been fished since the late 1940s. The fishery is continuing at a low level. Jack mackerel and Pacific mackerel *(Scomber japonicus,* elsewhere known as chub mackerel) are not distinguished on landings receipts and are considered to be commercially equivalent. The southern California fishery is not presently managed under. the Magnuson Fishery Conservation and Management Act (MFCMA), and there is no limit on allowable catch.

The large adults, which occur offshore, are sometimes taken incidentally in trawls. An annual incidental catch of 12,000 t (north of 39°N latitude) has been set. In 1991 there was increased interest by foreign, joint venture, and domestic industries, and the acceptable biological catch (ABC) was raised to allow development of such a fishery. The fishery failed to materialize, but signs of interest continue. Stock size is thought to be 1.5 million t, and potential yield is unknown.

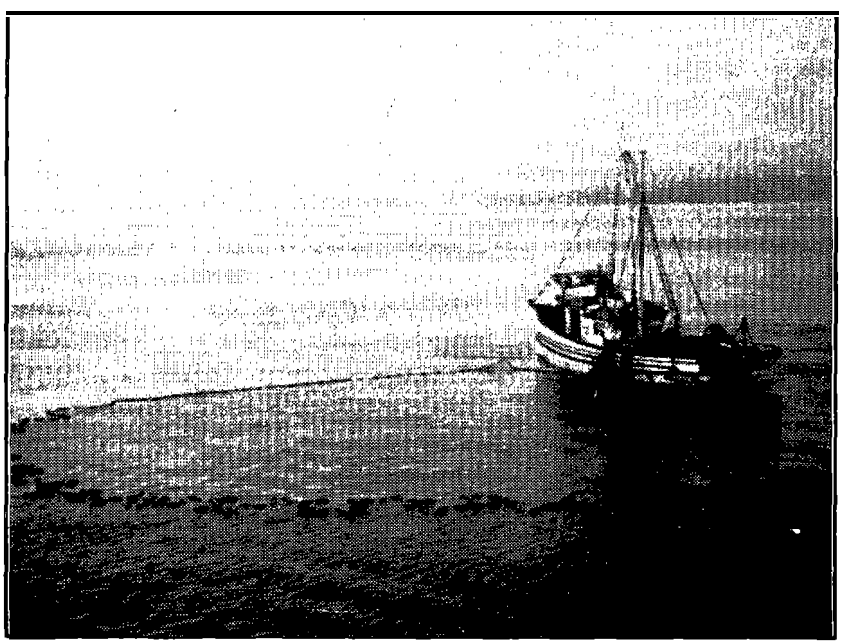
Salmon Resources

There are five species of Pacific salmon native to Washington, Oregon, and California: sockeye, chinook, pink, chum, and coho salmon. Salmon are anadromous species--they spawn in freshwater, migrate and rear in the open ocean, and return to their home stream or lake to repeat the life cycle.

The Pacific salmon fishery contributes significantly to the food supply, economy, and recreational fishing industry all along the Pacific Coast. It has always been an integral part of the culture and heritage of the Pacific Northwest. Although most of the salmon are caught in commercial and native fisheries, a significant portion are caught by recreational fishermen.

The combined commercial-. landings in recent years of all species had an annual ex-vessel value of about $140 million. It is much more difficult to place a value on the recreational fishery since there is not a consensus on how to do this precisely. Some sport-caught salmon have been valued as high as $295 per fish. Nevertheless, it is obvious that the average recreational catch for the past 3 years of 1.2 million salmon would be worth many millions of dollars annually.

The summary table on Pacific salmon includes production data of both hatchery and natural spawners. Although the yield for each species will vary annually;, pink, chum, and sockeye salmon are not expected to deviate much from recent year averages. For all five species, there is excess fishing capacity, and severe limitations on fishing are required to protect the stocks. For this reason, all species are listed as overutilized.



Management of the Pacific Coast salmon resources is rather complex with a number of agencies being involved. Since Pacific salmon migrate long distances in the ocean across geo-political boundaries they are affected by management concerns of the U.S.-Canada Pacific Salmon Commission (PSC), the state fishery agencies, Indian management entities, and the Pacific Fishery Management Council (PFMC)

Sockeye, Pink, and Chum Salmon

These species are not managed under a federal fishery management plan. Overall management of these three species rests primarily with the Pacific Salmon Commission and state and tribal fishery agencies.

The U.S. stocks of pink, sockeye, and chum salmon appear to be fairly stable, fluctuating in abundance in response to variable annual survival rates. Some U.S. catches of sockeye and pinks are dependent on stocks originating in the Fraser River of Canada. The number of these fish that U.S. fishermen can harvest is limited under terms of the U.S.-Canada Salmon Treaty signed in 1985 covering the salmon fisheries from Southeast Alaska to northern Oregon.

One sockeye stock of concern is the sockeye run from the Snake River. In April 1991, this stock was recommended for listing as endangered under the Endangered Species Act (ESA). In 1988, there were 4 adults and 2 redds reported in the spawning escapement; in 1989, l adult, 1 redd, and a second potential redd; and in 1990, no adults or redds were identified. The depressed condition of this stock is almost certainly due to the destruction of the freshwater habitat and the construction of several dams on the Columbia and Snake Rivers. These increased hazards and changes in the freshwater habitat have caused the virtual demise of these fish. It will take a tremendous effort to restore this resource.

Chinook and Coho Salmon

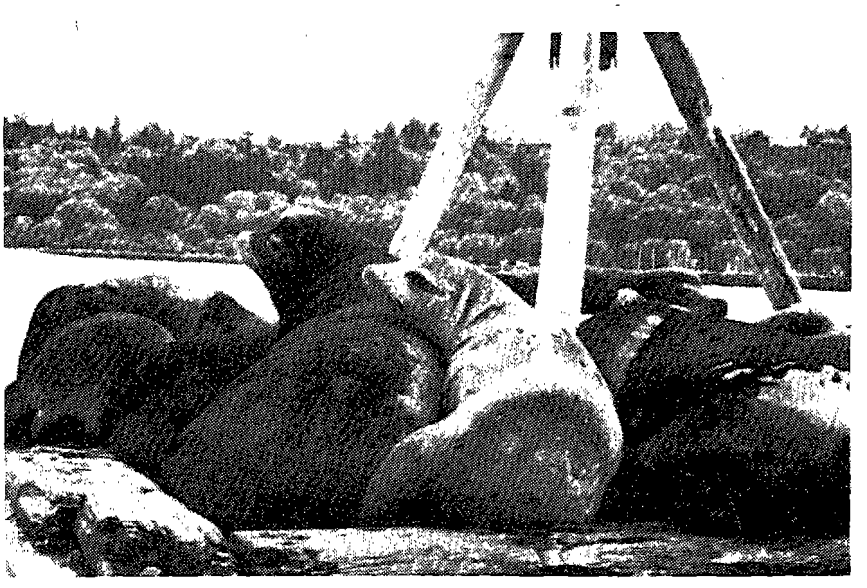
These species are managed by a Federal fishery management plan through auspices of the Pacific Fishery Management Council. The management is complicated with Judge Boldt's ruling in the early 1970s that Treaty Indians are entitled to up to 50% of the catch of salmon runs returning through the Indian's "usual and accustomed" fishing areas. With Indian fisheries occurring in inland rivers and Puget Sound as well as in the ocean, designing fishing seasons that properly achieve treaty rights and still achieve adequate escapements has been very difficult and has resulted in a significant shift of catch from the ocean fisheries off Washington to inland fisheries. Currently, management of catches is achieved primarily via catch quota allocations to various user groups.

One major change to the landings was the change from natural production to hatchery production. Whereas the early landings were entirely from natural spawning stocks, in recent years, a large share of the production has been from hatchery fish. This is particularly true for coho salmon. Although hatchery fish can be used to supplement natural production, they also may compete with or even replace natural spawners. Thus, there is some concern about the relationship between natural and hatchery fish.

A petition was received in June 1990 to list lower Columbia River natural coho as endangered, and this stock has been declared extinct. In view of the large production of who from hatcheries on the Columbia River, the management of Columbia River coho salmon has been directed toward harvesting these hatchery fish to prevent wasting large numbers of coho returning in excess of hatchery needs. Petitions for listing as endangered under the ESA also were received in June 1990 for spring, summer, and fall chinook from the Snake River. In 1990, the Sacramento winter-run chinook was listed as threatened. If a species is listed as endangered, it could have very severe ramifications not only to salmon management, but also to other industries.

Many other chinook stocks are also depressed with declining escapement and/or failure to meet escapement goals. Some examples are Shasta River chinook, Klamath River chinook, spring/summer chinook above Bonneville Dam, spring/summer chinook above Lower Granite Dam, and Snake River fall chinook. For all the upper Columbia River salmon stocks, the changes in the freshwater environment have had a devastating effect on their survival. The large number of dams that have been built is one very visible factor. Dams that are passable to salmon still take their toll on returning adults and, of course, there are dams that are completely impassable that have eliminated large spawning areas. Also, conditions at dams cause significant losses of downstream migrating young

salmon through delayed migrations and mortality from passing through the turbines. The lack of adequate water for fish passage has been a problem. Here again, elimination of some of these devastating factors and improvement of the freshwater habitat are needed if these stocks are to be restored.



Marine Mammal Resources

Information on selected marine mammal populations off Washington, Oregon, and California is presented. Forty-two species of marine mammals in U.S. waters of the North Pacific Ocean are under the jurisdiction of the Department of Commerce. This includes 31 species of whales, dolphins and porpoises, and 11 species of seals and sea lions. Six species are unique to Alaska, one species, the Hawaiian monk seal, is unique to Hawaii.

Fourteen of the most commonly observed species are normally found close to shore, such as the California gray whale and California sea lion. The other species usually remain in offshore waters, on remote islands, or are rare in number and seldom seen. Most marine mammal species make long-distance migrations or move hundreds of miles within smaller areas of the ocean between seasons of the year. These movements, especially by whales and dolphins, are for traveling from one feeding ground to another or to spend the breeding season in lower latitudes and the major feeding and calf-rearing seasons in higher latitudes.

There are several populations of marine mammals that spend the majority of the year in California; offshore waters of Washington and Oregon are generally transition areas for animals moving between the southern breeding grounds and rich feeding grounds of Alaska. A few species are found year-round in Washington and Oregon, such as the harbor porpoise and Pacific harbor seal; but this is also true for these species in California and Alaska. These unique zoogeographic differences have led to unique life history strategies and result in the need to manage several populations or stocks per species. Management of marine mammals is carried out under the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973. Both Acts require that management of marine mammals be based on the identification and enumeration of populations or Stocks.

Two species, the vaquita or Gulf of California harbor porpoise and the Guadalupe fur seal, are not endemic to the United States (although **a** few male Guadalupe fur seals do occasionally show up in California). The vaquita is included because of its rarity and the active conservation efforts carried out by the U.S. and Mexican governments.

A summary of the status of the stocks, impact of incidental take, and description of individual stocks are presented.

Glossary of Terms

Population: An interbreeding group of living marine organisms, such as a species in a geographical area.

Stock: A portion of the population that is reasonably well mixed and is geographically distinct in terms of fishery and management.

Year class: Fish of the same stock born in the same year. Occasionally a stock produces a very small or large year class. The strengths of these year classes are followed closely because they can be pivotal in determining the stock abundance over a period of years.

Recruitment: The amount of fish, in numbers or weight, that reach a certain size or age in a specific year. This term is also used in referring to the number or weight of fish from a year

class reaching a certain age. For example, all fish reaching their second year would be age-2 recruits. This is often used to describe the strength of a year class.

Absolute abundance: A measure of the actual size of a stock. It may be expressed in weight **(biomass)** or numbers of individual animals.

Relative abundance: An index of stock abundance, measured commonly by catch per unit effort (CPUE). The index assumes that the amount of catch per unit of fishing effort is directly proportional to abundance of the stock.

Sustainable yield: The number or weight of fish in a stock that can be removed from the stock without reducing the stock's biomass from one year to the next, assuming that environmental conditions remain the same.

Long-term potential yield (LTPY) : The maximum long-term average yield (catch) from the resource. It is similar to maximum sustainable yield (MSY).

Current potential yield (CPY): The current catch that may be obtained from the resource. It is similar to acceptable biological catch (ABC) which measures the biological production potential of the stock.

F&cent **average yield (RAY):** The current average catch. It includes catch landings and discards.

Mortality rate: The rate at which fish die from natural 'causes or through fishing Mortality rates can be described in several ways. The easiest--total annual mortality rate--defines the fraction of the fish within a group that die during the year. These rates are difficult to use mathematically when describing the relative contribution of different types of natural or fishing mortality to the total mortality of fish during a year.

Instantaneous mortality rate: To overcome the limitation of annual rates, fisheries biologists use instantaneous rates to describe mortality. An instantaneous mortality rate is the fraction of the population of fish that dies in a very short (instantaneous) period of time. There is a relatively simple mathematical conversion between instantaneous rates and annual rates. For example, the total instantaneous mortality rate, often denoted by Z, is equivalent to the annual rate A according to the formula:

$A = 1 - e^{-z}$.

Natural mortality rate (M) is the mortality due to natural causes. It is very difficult to estimate, and values are often assumed based on the general life history of a particular species.

Fishing mortality rate (F) is the mortality due to fishing.

Total mortality rate (Z) is the combined effect of all sources of mortality acting on a fish population.

Thus Z=M+F.

Fishing mortality rate: The part of the total mortality rate applying to a fish population that is casual by man's harvesting. Fishing mortality is usually expressed as an instantaneous rate, ranging from zero for no fishing to very high values such as 2.0.

There are specific rates of F that measure how close a stock is to full exploitation. They are defined in terms of an increase in yield from a year class over its life span as fishing mortality increases.. When no fish are taken, there is no yield from the year class. As fishing incresses, the yield increases, but at a decreasing rate.

$\mathbf{F_{max}}$ is the point at which the increased yield for additional effort is zero; that is, additional fishing mortality will not increase yield, but in fact, may decrease it as fish are caught before they are fully grown.

$\mathbf{F_{max}}$ is a point at which the increase in yield for increased effort is 10% of what it was when fishing mortality was very low.

$\mathbf{F_{msy}}$ is the rate of fishing mortality when maximum sustainable yield for the stock is achieved.

Exploitation rate: The proportion of a population at the beginning of a given-time period that is caught during that time period (usually expressed as a yearly percentage).

Catch quota: A portion of a total allowable catch **(TAC) al**located to an operating unit, such as a size class of vessels or a country.

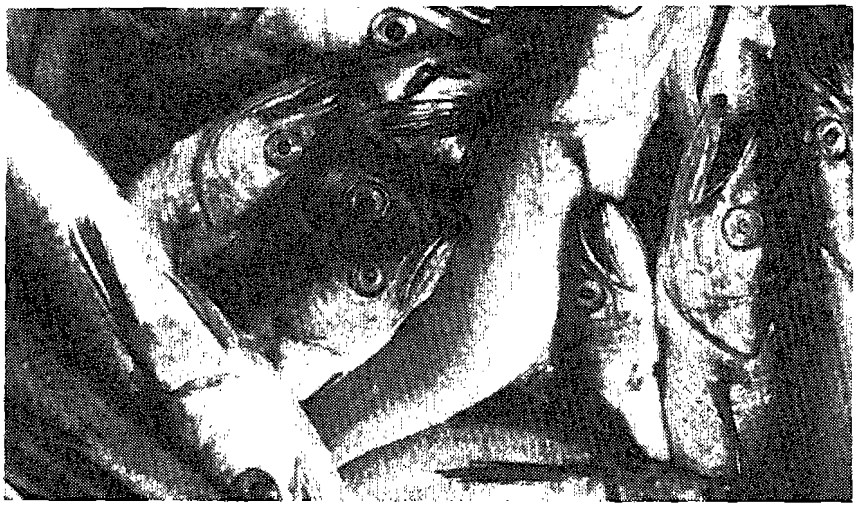
Total allowable catch (TAO The total regulated catch from a stock in a given time period, usually a year.

Virtual population analysis (or cohort analysis): A mathematical analysis of the abundance of a given year class (or cohort of fish).over its life in the fishery.

Yield Per Recruit Analysis: A calculation of the theoretical yield that would be obtained from a recruit if it is harvested according to a certain exploitation pattern over the life span of the fish.

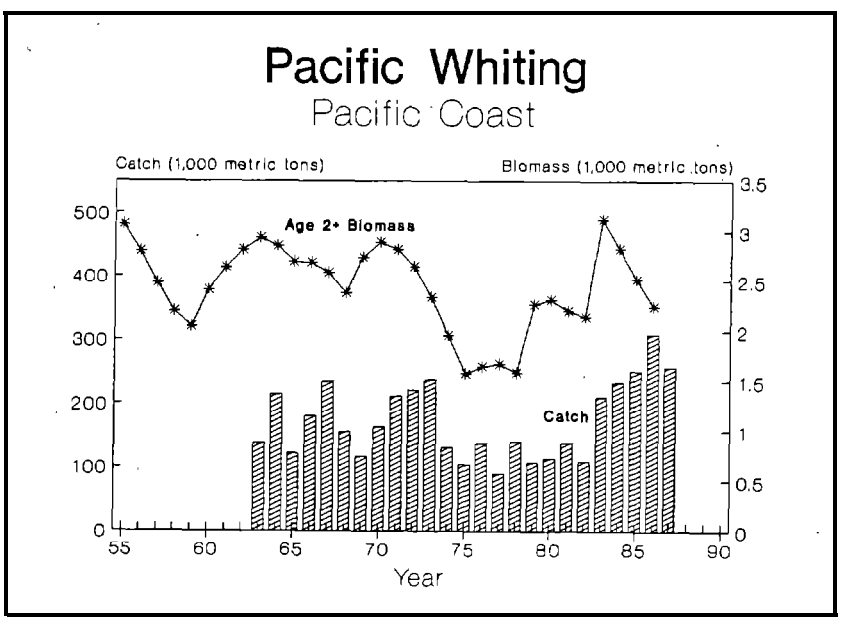
1. PACIFIC WHITING

Pacific whiting ***(Merluccius productus),*** also known as Pacific hake, is a migratory gadoid distributed along the west coast of North America from Baja California to Queen Charlotte Sound. Adult Pacific whiting migrate north in spring and summer to feed along the continental shelf and slope from northern California to Vancouver Island. Larger fish tend to migrate farther north. In autumn, Pacific whiting migrate south to spawning areas from Point' Conception to Baja California. The peak spawning months are January and February. Spawning occurs as much as 400 km offshore. Recruitment is extremely variable for this species: strong year classes are about two orders of magnitude larger than the weak year classes. Years with cold water temperatures in the winter months tend to have low mean recruitment, while warm years have higher though more variable recruitment.



Asymptotic length is 56.3 cm for males and 61.2 cm for females. Annual variations in growth have been detected and appear to be related to changes in water temperature and the size of the adult biomass. Most Pacific whiting are infected with a myxosporean parasite that releases enzymes after the death of the fish, resulting in a rapid breakdown of the muscle tissue. Important items in the diet of Pacific whiting include euphausiids, shrimp, sand lance, eulachon, and herring. Significant predators on Pacific whiting juveniles include rockfishes, sablefish, and sooty shearwaters. The adults are preyed on by California sea lions; northern fur seals, and northern sea lions.

The midwater trawl fishery for Pacific whiting, operating in both U.S. and Canadian waters, targets on dense feeding aggregations of fish that occur along the shelf break from April to November. Trawling typically takes place only during the daylight hours because the aggregations disperse at night as the fish rise to the surface to feed on euphausiids. The total catch of Pacific whiting in 1990 was 257,000 t, a decline of 17% from the record catch of 308,000 t in 1989. In 1990, disagreement over the allocation of the annual yield between the United States and Canada resulted in the total catch exceeding the ABC. Annual mean catches over the period 1980-90 were 178,000 t. The mean catch for 1988-90 was 272,000,153% of the



PACIFIC WHITING
Pacific Coast
COMMERCIAL CATCH (1,000 t)

	United States			Canada	TOTAL
	Foreign	Joint Venture	Domestic		
1980	44.0	27.5	0.8	17.6	89.9
1981	70.4	43.6	0.8	24.4	139.1
1982	7.1	67.5	1.0	32.2	107.7
1983	0.0	72.1	1.1	40.8	113.9
1984	14.7	78.9	2.7	42.1	138.4
1985	49.9	31.7	3.9	25.0	110.4
1986	69.9	81.6	3.5	55.7	210.6
1987	49.7	106.0	4.8	73.7	234.1
1988	18.0	135.8	6.9	90.5	251.2
1989	0.0	203.6	7.4	97.8	308.8
1990	0.0	171.0	12.8	73.3	257.1

1980-90 average. The fishing morality rate on age 2+ fish was 0.15 in 1989 and 0.14 in 1990. The higher catches of recent years reflect the increasing interest in Pacific whiting by Soviet, Polish, and Japanese processors as their access to Alaska groundfish resources is curtailed. During 1980-90, the annual U.S. catch was 72% of the total U.S.-Canada catch of Pacific whiting, while during 1988-90, the average U.S. catch was 68% of the total.

The coastal population of Pacific whiting has been surveyed every 3 years since 1977. The midwater component of the stock is surveyed using hydroacoustic methods, while the demersal component is surveyed by the multispecies west coast triennial trawl surveys. The two components are assumed to be additive. The demersal component varies between 6 and 23% of the total biomass. The total biomass measured by the survey in 1989 was 1,637,000 t, a decline of 24% from the biomass measured in 1986.

Pacific whiting are assessed using the stock-synthesis model, a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliarv information. Projected spawning biomass for the start of 1990 was 873,000 t, a 12% decline from 1989. Spawning biomass and yield are expected to decline gradually as the large 1980 and 1984 year classes move out of the fishery. The 1985 and 1986 year classes are believed to be weak, while the 1987 year class, which will support the U.S. fishery for the next several years, appears to be of moderate size.

This chapter was written by Martin Dorn.

For further information

Dorn, M. W., and R. D. Methot. 1990. Status of the Pacific whiting resource in 1989 and recommendations for management in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-182, 84 P.

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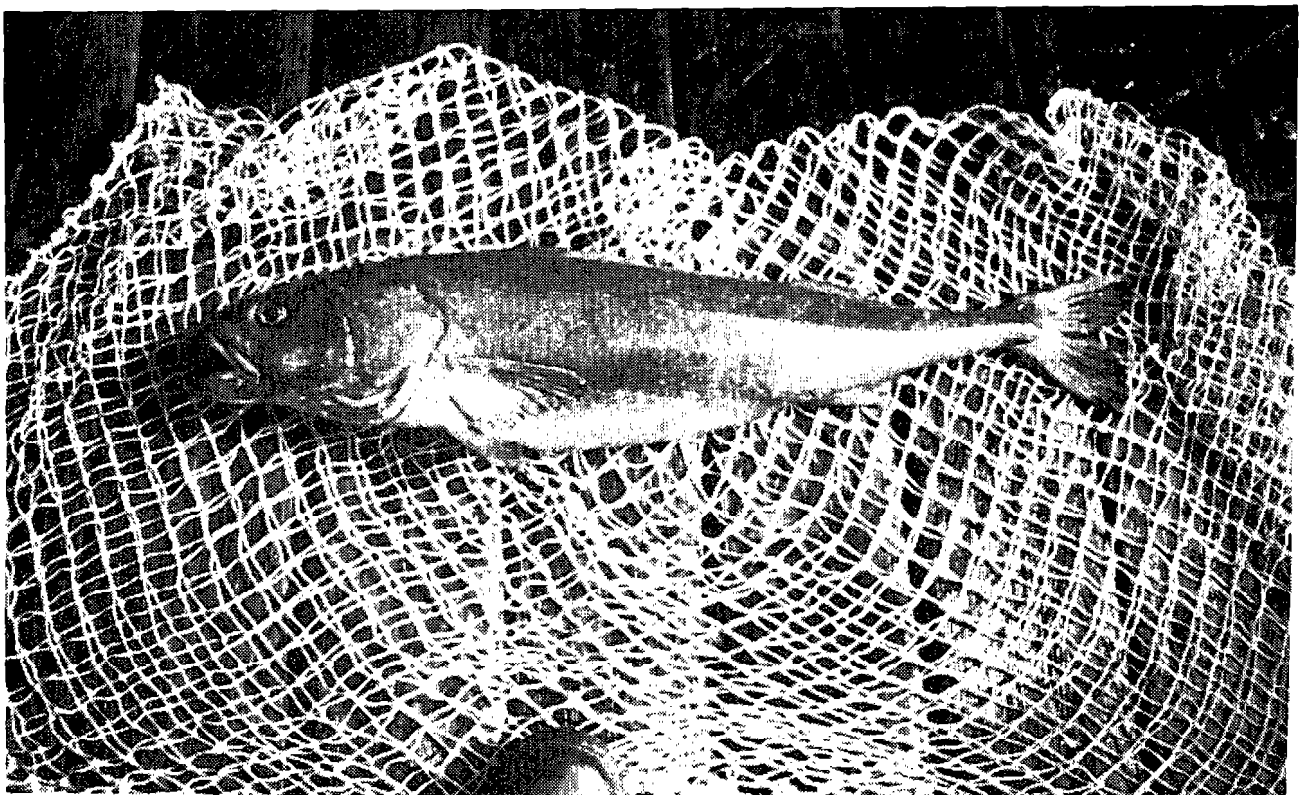
PACIFIC WHITING
Pacific Coast

Average catch (1980-90)	=	178,000 t	
Long-term potential yield (MSY)	=	226,000 t	
Acceptable biological catch (1990)	=	253,000 t	
Importance of recreational fishery	=	Minor	
Management	=	Groundfish FMP	
Status of exploitation	=	Fully exploited	
Age at 50% recruitment	=	4.4 years (males)	4.1 years (females)
Length at 50% maturity	=	Unknown (males)	38 cm (females)
Assessment approach	=	Age-structured, separable analysis	
Fishing strategy	=	Variable F	
F (1990)	=	0.14	

2. SABLEFISH



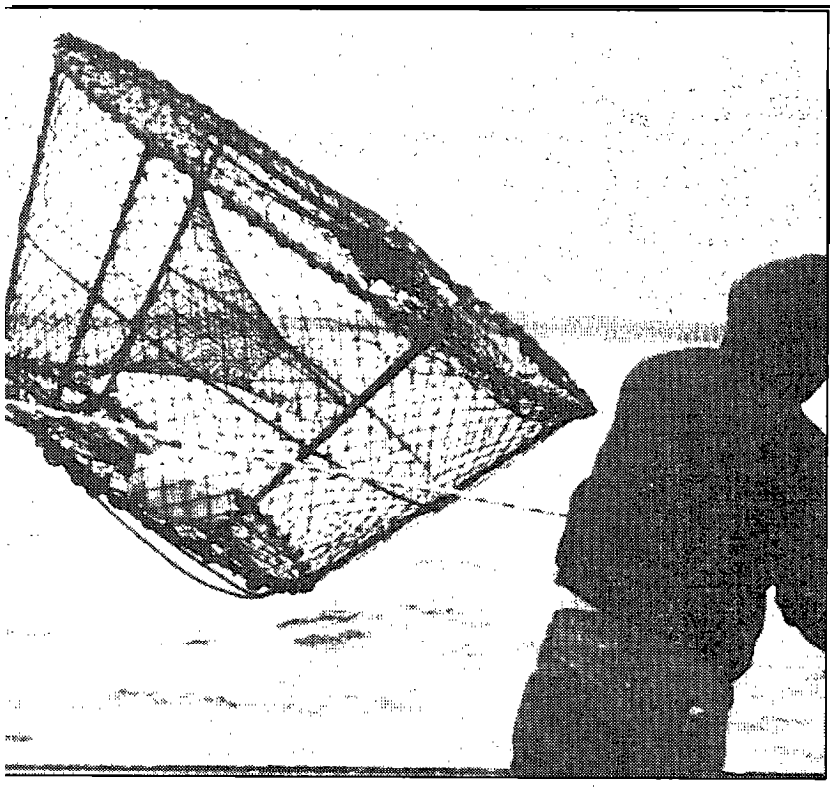
Sablefish *(Anoplopoma fimbria)* occurs from Baja California to the Asiatic coast of the Bering Sea. Along the west coast of the United States, they occur over a wide range of depths. Early juvenile sablefish are neustonic and age-0 fish may school in midwater. By age 1.5, sablefish are primarily demersal and typically found on the continental shelf in water depths less than 200 m. Adults are found on the outer shelf and continental slope, especially within and near submarine canyons and gullies. The oldest and largest individuals may be found at abyssal depths. Tagging studies indicate that many sablefish exhibit little alongshore movement, but some may move thousands of miles. Sablefish spawn from November to April, with peak spawning activity occurring in January and February. Sablefish are fast growing as juveniles, reaching a length of 38 cm by age 1.5 years. Female sablefish mature at a length of approximately 57 cm (age 5). Mature adults grow little and exhibit great variation in size at age. Sablefish may attain ages of 50+

SABLEFISH
Pacific Coast
COMMERCIAL CATCH (t)

YEAR	Line	Pot	Trawl	TOTAL
1980	1,661	3,548	3,940	9,149
1981	2,084	3,789	5,681	11,554
1982	1,805	6,419	10,373	18,593
1983	1,338	5,667	7,515	14,521
1984	1,173	3,925	8,975	14,076
1985	2,866	3,799	7,631	14,297
1986	3,792	2,289	7,099	13,179
1987	4,196	1,990	7,577	12,763
1988	3,206	2,055	5,582	10,843
1989	2,514	1,995	5,746	10,254
1990	2,233	1,657	5,137	9,028

years and reach sizes of over 100 cm. Adult sablefish eat euphausiids, tunicates, and fish.

Sablefish have a long history of harvest by three major gear types: longline, pot, and bottom trawl. The longline fishery began off Washington and Oregon in the early 1900s and landings. in this area quickly rose to about 1,700 t per year. This longline fishery extended into California beginning in the mid- 1920s. The trawl fishery also began in the early 1900s but did not approach the magnitude of the longline landings until the 1940s. The feasibility of sablefish harvest by pot gear was demonstrated during the early 1970s, and a major pot fishery. developed by 1974. During the period 1956-70, the mean annual catch in the Columbia and Vancouver International North Pacific Fisheries Commission (INPFC) areas was 1,190 t by longline and 470 t by trawl; the mean annual catch in the Eureka, Monterey, and Conception INPFC areas was 430 t by longline and 750 t by trawl for the same period. In stock assessments, the sablefish population is assumed to be in equilibrium with this mean harvest level in 1971, prior to the surge in catch during the mid-1970s. In 1990 the total sablefish landed catch was 5,137 t by trawl and 3,891 t by nontrawl (pot and line gear) for a total value of $9.47 million.



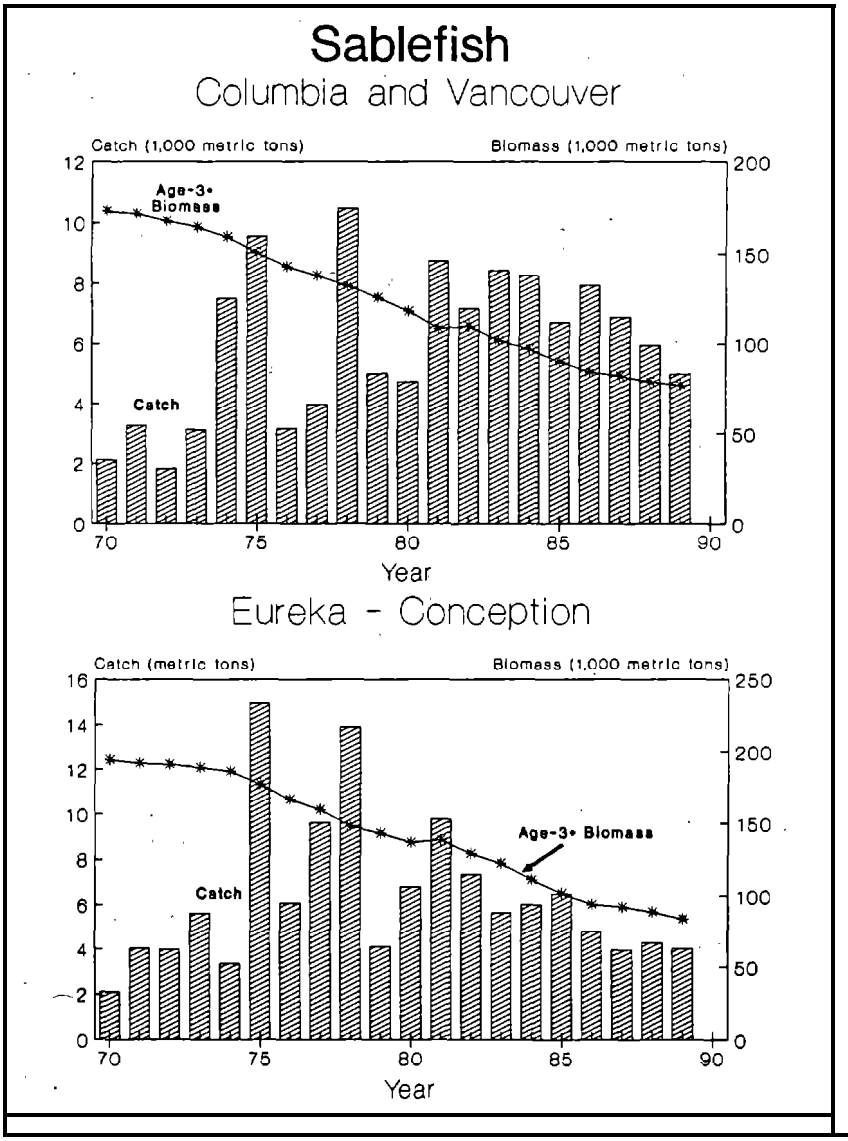
The commercial fishery for sablefish is regulated by the Pacific Fishery Management Council. In recent years, the harvest of sablefish has been constrained by an annual quota and an allocation between trawl and nontrawl gear. In addition, there is a minimum size of 52 cm fork length and an 11.43 cm minimum mesh size in bottom trawls. Pot and longline gear target on sablefish and much of their catch is frozen and exported. In 1991, the major nontrawl season began on 1 April and extended only through 23 May. Trawlers catch sablefish along with other groundfish species, and year-round availability of fresh fish is one objective of the Council's groundfish fishery management plan (FMP). Trip limits have been implemented for sablefish and several other, species in an attempt to distribute the landed catch throughout the year. Unmonitored discard caused by these trip regulations is a growing concern.

SABLEFISH
Pacific Coast

Average catch (1980-90)	=	12,600 t
Long-term potential yield (MSY)	=	6,900 t
Acceptable biological catch (1990)	=	8,900 t
Importance of recreational fishery	=	Minor
Management	=	Groundfish FMP
Status of exploitation	=	Fully exploited
Age at 50% recruitment	=	5 years (males) 5 years (females)
Length at 50% maturity	=	51 cm (males) 55 cm (females)
Assessment approach	=	Size and age structured analysis
Fishing strategy	=	constant, F = 0.14
F (1990)	=	0.13

Three types of surveys contribute to the assessment of west coast sablefish. A standardized pot survey has been conducted biennially since 1979 in the northern areas (Columbia and Vancouver INPFC areas) and since 1984 in the southern areas (Eureka, Monterey, and Conception INPFC areas). This survey indicates declining density of sablefish, especially larger fish in the northern area. Trawl surveys on the continental shelf (30-200 fathoms) have been conducted triennially beginning in 1977 and have extended from at least as far south as Monterey Bay, California, to at least as far north as the U.S.-Canada border. These are indicators of abundance for age l-2 sablefish. Trawl surveys on the continental slope (100-700 fathoms) were conducted in the southern Columbia INPFC area in 1984, 1988, and 1989 and in the Eureka INPFC area in 1990. These indicate a sablefish biomass in the Columbia-Vancouver INPFC area of about 67,000 t.

The assessment of sablefish utilizes the above three surveys and the size and age composition of the commercial landings since 1986. These data are integrated in a size-and age-structured separable assessment model termed stock synthesis. In the 1990 assessment, the northern area (Columbia and Vancouver INPFC areas) was assessed independently of the southern area because of the lower growth rate observed in the south and the low rate of mixing within the stock. Generally the model indicates that the stock has been fished down to near its target level, so that the expected spawn production per recruit is near 35% of that in the unfished stock. Uncertainty in this stock-assessment is related to poor tracking of the decline in large fish, as well as conflicting results from trawl (which suggest that the population is aging but the biomass is high) and pot surveys (which indicate that biomass is declining).



This chapter was written by Richard D. Methot.

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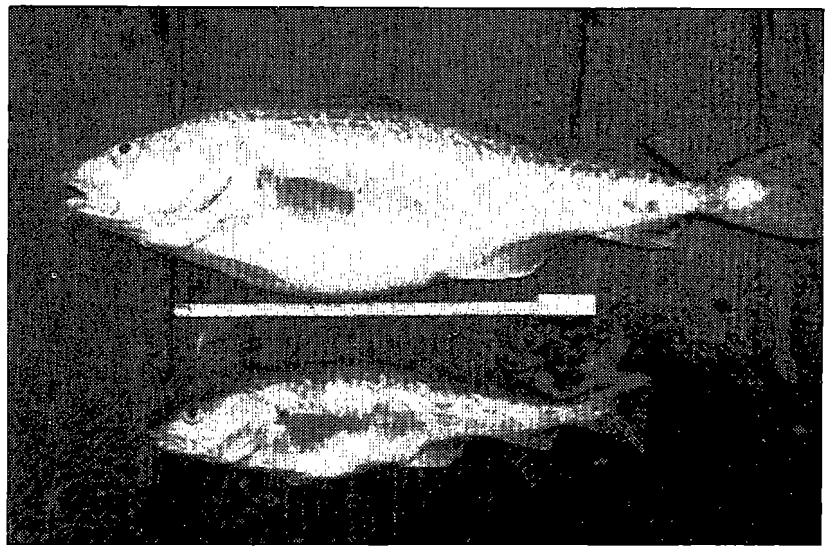
3. PACIFIC COD

Pacific acific cod *(Gadus macrocephalus)* is a demersal gadid similar to Atlantic cod in appearance and life history characteristics. Pacific cod are distributed in the North Pacific Ocean from central California to the Bering Sea and south along the Asiatic coast to Japan. Pacific cod are most abundant on the continental shelf between 50 and 200 m. The abundance of the coastal stock declines rapidly south of the U.S.-Canada boundary. Spawning of Pacific cod off the west coast of the United States has not been documented, though a small inshore stock regularly spawns off Port Townsend, Washington, in northern Puget Sound. Spawning occurs in February-March at Amphirite Bank off west Vancouver Island. The diet of Pacific cod consists of small fish (primarily sand lance and herring) as well as a wide variety of invertebrates (including euphausiids, shrimps, crabs, and squid).



Pacific cod are at the southern limit of their range off the west coast of the United States. Populations in this area have faster growth rates, mature at a younger age, and have higher natural mortality rates than the more abundant northern stocks. Asymptotic size is approximately 74 cm, and the natural mortality rate lies in the range 0.55-0.63. The stock in this area is more prone to, recruitment failure than the northern stocks of Pacific cod, suggesting that the environmental conditions necessary for successful spawning and larval success occur infrequently in this area. Water temperature appears to play a critical role in de-

PACIFIC COD
Pacific Coast
CATCH (1,000 t)

YEAR	CATCH
1980	1.3
1981	1.3
1982	0.9
1983	0.6
1984	0.6
1985	0.4
1986	0.3
1987	2.3
1988	3.3
1989	2.2
1990	1.1

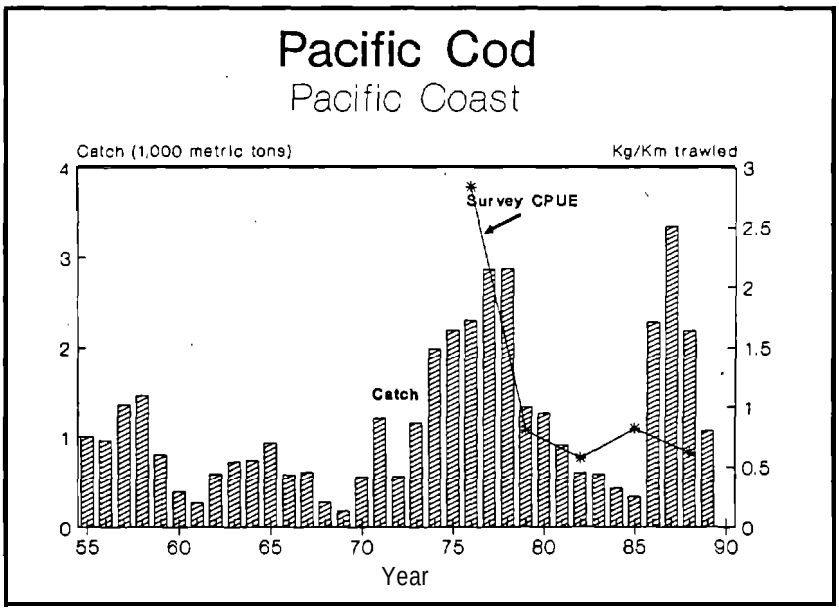
PACIFIC COD
Pacific Coast

Average catch (1980-90)	=	1,302 t
Long-term potential yield (MSY)	=	Unknown
Acceptable biological catch (1990)	=	3,100 t
Importance of Recreational fishery	=	Minor
Management	=	Groundfish FMP
Status of exploitation	=	Fully exploited?
Age at 50% recruitment	=	2.5 years (males) 2.3 years (females)
Length at 50% maturity	=	50 cm (males) 53 cm (females)
Assessment approach	=	Abundance trend
Fishing strategy	=	Not available
F (1990)	=	Unknown

termining recruitment success. Tagging studies indicate the existence of migratory exchange between stocks in U.S. waters and the stock occurring off the west coast of Vancouver Island.

Pacific cod are captured primarily by commercial bottom trawls. Commercial-sized aggregations of Pacific cod are found on the spawning grounds in winter and in feeding areas in summer. The fishery in U.S. waters is primarily conducted in summer, with about 75% of the catch landed from April to September. The fishery for cod is opportunistic, because aggregations of Pacific cod occur sporadically in U.S . waters. Lingcod and Pacific cod often occur together in the catch. The recreational fishery is currently small relative to the commercial fishery. The annual ex-vessel value of Pacific cod landings has averaged $1.28 million from 1988 to 1990.

Results of the triennial west coast trawl survey indicate that Pacific cod biomass in U.S. waters was high in 1977, declined steeply in 1980, and remained relatively stable until 1989. The bulk of the large catches from 1987 to 1989 in U.S. waters was composed of an exceptionally strong 1985 year class that was also present in the west Vancouver Island and Hecate Strait Pacific cod stocks. The current ABC of 3,100 t was set slightly lower than the maximum annual catch in recent years--3,300 t landed in 1988. The management strategy of allowing a high fishing mortality rate when Pacific cod are present in commercial quantities in U.S. waters is justified by the high natural mortality rate, the rapid growth rate, and the extreme variability of recruitment of Pacific cod in this area.



This chapter was written by Martin Dorn.

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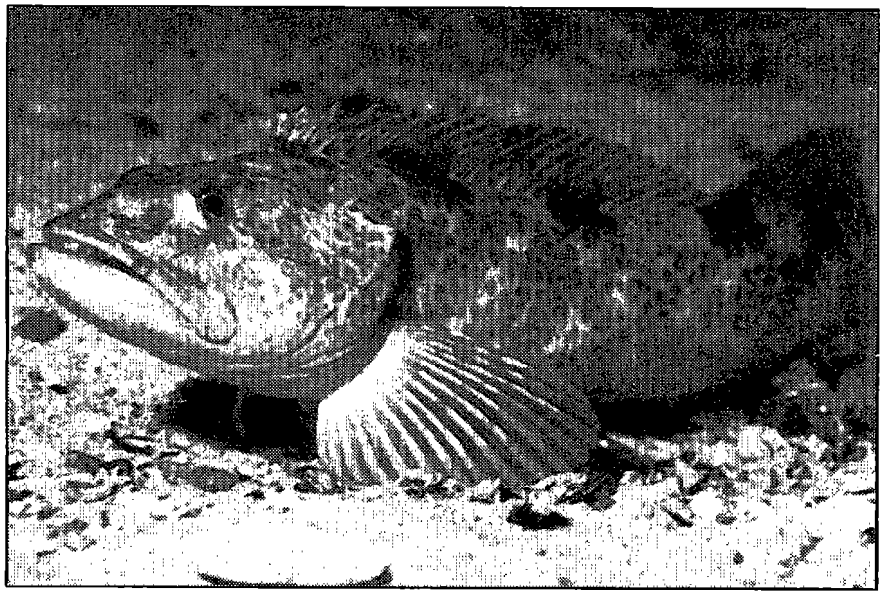
4. LINGCOD



Lingcod ***(Ophiodon elongatus)*** is a demersal greenling species found in nearshore waters off the west coast of North America from Baja California to the Alaska Peninsula. Their center of abundance is off British Columbia and they are uncommon south of southern California. Lingcod are found over a wide range of substrates at depths from 3 to 400 m, but most occur in rocky areas from 10 to 100 m. Canadian tagging studies have shown that adult lingcod exhibit strong home-site fidelity; however, individual fish do make long movements of as much as 690 km. Adult lingcod are piscivorous, feeding on rockfish (genus Sebastes), Pacific whiting, and Pacific herring. Average age for maturity of female lingcod is 4 years or a length of 68 cm and age 2 or a length of 50 cm for males. In U.S. landings, lingcod range in length from 40 to 80 cm and in weight from 0.5 to 6.0 kg. The species has a maximum reported length of 150 cm and maximum reported weight of 154 kg.

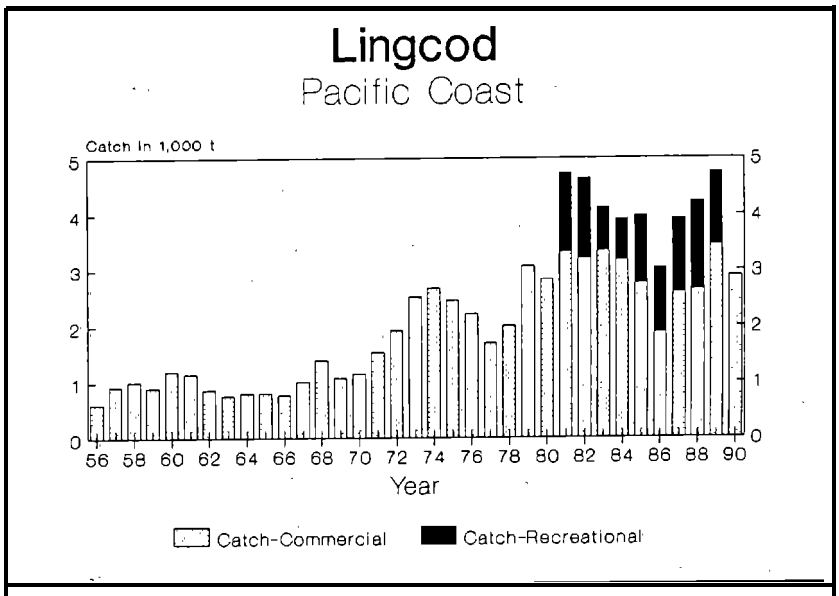
Lingcod have a unique form of reproduction, which involves territoriality, nests, and a guardian male. Males establish territories in rocky areas in shallow water (low tide line to 30 m) where currents are strong enough to oxygenate the egg mass and prevent death of the embryos. Peak spawning occurs in January and February. A female chooses a male and its nesting site for spawning. In the nest, the eggs are cemented to each other within a gelatinous mass. After spawning, the male remains to guard the nest from predation until hatching is complete. The guardian male is very aggressive during this period and is therefore highly susceptible to sport fishing. An unguarded egg mass is invariably eaten by predators. The eggs hatch about 7 weeks after they are spawned. The larvae and juveniles are pelagic until the end of June when the juveniles migrate to benthic habitats.

Commercial lingcod landings from U.S. waters have averaged 2,700 t since 1970, at which time there was a rapid increase from a previous level of around 1,000 t. This increase was the result of market demand. Since 1970, landings have had wide fluctuations, probably due to strong and weak year classes moving through the fishery. Commercial landings come predominantly from trawls, averaging 83% of the total landings from 1981 to 1990. However, the nontrawl fishery (70% hook and line in recent years) has increased from 13% of the total landings in 1981 to 21% in 1990. Lingcod landings are largest in Washington and are progressively smaller in Oregon and California. Canadian landings are similar in size to U.S. landings, averaging 2,800 t during the period from 1980 to 1985. The commercial fishery is managed with an ABC of 7,000 t.

There are also restrictions on where gill nets may be used. More extensive restrictions are currently under consideration. The recreational catch is a large component of the total lingcod catch, averaging 1,219 t or 30% of the combined commercial and recreational lingcod catch during the years 1981-89. This is one of the few west coast groundfish species with a significant recreational fishery. The recreational fishery is managed with a three washington and Oregon) to five (California) fish bag limit -and California imposes an additional 56 cm (22 in) minimum size limit.

There is no coastwide lingcod monitoring program to obtain length-frequency or age-structured data, and therefore no mortality estimates exist on which to base an assessment. While there are areas where lingcod are locally depleted (severely in some instances, such as Puget Sound), there is no evidence of overfishing on the overall population.

This chapter was written by Peter B. Adams.



PACIFIC LINGCOD
Pacific Coast
COMMERCIAL AND RECREATIONAL CATCHES (t)

Year	Commercial	Recreational	Total
1981	3,320	1,410	4,730
1982	3,205	1,442	4,647
1983	3,351	768	4,119
1984	3,179	735	3,914
1985	2,752	1,225	3,977
1986	1,884	1,152	3,036
1987	2,585	1,341	3,926
1988	2,636	1,596	4,231
1989	3,447	1,300	4,747
1990	2,896	-	-

Average commercial catch (1980-90)	= 2,917 t
Long-term potential yield (MSY)	= Unknown
Acceptable biological catch (1990)	= 7,000 t
Importance of recreational fishery	= 30% of catch
Management	= Groundfish FMP
Status of exploitation	= Unknown
Length at 50% recruitment	= Unknown
Length at 50% maturity	= 68 cm (females) 50 cm (males)
Assessment approach	= Catch landings
Fishing strategy	= $F_{35\%}$ = unknown
F (1990)	= Not available

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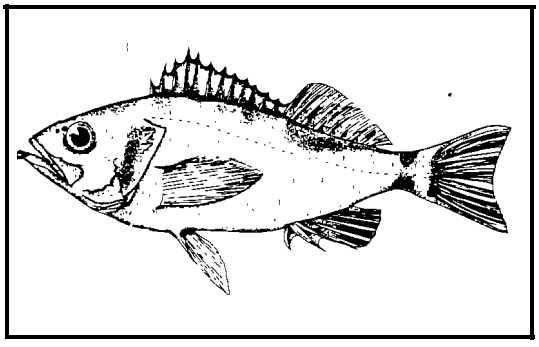
5. PACIFIC OCEAN PERCH

Pacific ocean perch (Sebastes alutus) is a member of the family Scorpaenidae and is one of over 65 species in the genus Sebastes, commonly referred to as rockfish. Distribution along the North American coast ranges from La Jolla, California, to the western boundary of the Aleutian Archipelago and along the continental slope of the eastern Bering Sea. Two major stocks of Pacific ocean perch have been identified along the west coast of the United States. One stock inhabits the Vancouver INPFC area and the other stock occupies the Columbia INPFC area. Both stocks are managed by the PFMC.

A demersal species, Pacific ocean perch are usually associated with cobble, gravel, rocky, or boulder-type substrates found in and along gullies, canyons, and submarine depressions of the outer continental shelf and upper slope regions. Substrate and bottom topography, however, are not the only factors determining Pacific ocean perch distribution; food, water temperature, state of maturity, oxygen content of the water, and other hydrographic factors also influence its occurrence. Although Pacific ocean perch can be found at depths ranging from 50 to 700 m, commercial quantities generally occur between 100 and 400 m.

Pacific ocean perch are slow growing and long lived. Longevity has been estimated at 90 years, which is consistent with an estimated instantaneous natural mortality rate of 0.05. This species begins to recruit to the commercial fishery at about age 5 and are fully recruited by age 10, corresponding with fork lengths of about 26 cm and 32 cm, respectively. The bulk of the commercial catch is comprised of individuals ranging from 25 to 50 cm. Females are viviparous, retaining eggs in the ovary after fertilization until yolk sac absorption. Mating takes place in late fall or early winter, with subsequent larval extrusion occurring in late winter or early spring.



Prior to 1965, the Pacific ocean perch resource in the Vancouver and Columbia INPFC areas were harvested almost entirely by Canadian and U.S. vessels. Generally under 200 gross tons and less than 33 m in length, these vessels had very little at-sea processing capabilities. These characteristics restricted, for the most part, the distance from home ports the vessels could fish and limited the size of their landings. Landings from 1956 to 1964 averaged 2,018 t and 1,980 tin the Vancouver and Columbia INPFC areas, respectively.

Catches increased dramatically after 1964 with the introduction of large distant-water fishing fleets from the Soviet Union and Japan. Both nations employed large factory stern trawlers as their primary method for harvesting Pacific ocean perch. These vessels generally operated independently by processing and freezing their own catch, and the use of support vessels (e.g., refrigerated transports, oil tankers, supply ships) permitted the-large stem trawlers to operate at sea for extended periods of time. Peak removals by all nations combined amounted to 16,358 t from the Vancouver INPFC area in 1966 and 23,976 t from the Columbia INPFC area one year later in 1967.

Immediately following these peak removals, production declined very rapidly. Apparently, these stocks were far too limited to sustain the large removals during the mid-1960s. By 1969, the Pacific ocean perch stocks were severely depleted throughout the Oregon to Vancouver Island region. Harvests within the past 10 years (1980-89) have averaged about 1,060 t and 975 t in the Vancouver and Columbia INPFC areas, respectively. Catches since 1979, however, have been restricted by the PFMC in an attempt to rebuild the resource.

The two major stocks of Pacific ocean perch have been assessed periodically since the intense pulse of exploitation during 1966-68 by the foreign fleets. Biomass estimates have been calculated by dividing landings by estimated exploitation rates. Based on this approach, the mean exploitable biomass in the Vancouver INPFC area during 1966-68 was estimated at about 34,000 t. Following the years of heavy fishing,

catch per unit of effort (CPUE) for the Washington-based fleet in the Vancouver INPFC area dropped to 55% of the 1966-68 levels, indicating a decrease in biomass to 18,700 t during 1969-71. Catch rates declined further during 1972-74, lowering the estimated mean biomass during this period to 16,700 t. The mean weighted CPUE rose slightly in the period from 1975 to 1977, raising the biomass estimate to 17,800t. In the Columbia INPFC area, mean biomass estimates declined from 23,000 t during 1966-68 to 7,300 t during 1969-72 and 4,300 t during 1973-74. An area-swept extrapolation from commercial CPUE data in the Columbia INPFC area resulted in a biomass estimate of between 8,000 and 9,600 t in 1977.

Research surveys have been used to provide 'fishery independent assessments of the abundance, distribution, and biological characteristics of Pacific ocean perch. Coastwide trawl surveys were conducted in 1977, 1980, 1983, 1986, and 1989 with the objective of defining the distribution and measuring the abundance of the major groundfish species taken in bottom trawls.

In addition, trawl surveys directed specifically at assessing the Pacific ocean perch resource were conducted in 1979 and 1985. The resulting estimates of biomass, however, were usually characterized by large variances. Such large variances were probably due to the highly contagious distribution of this resource. And other factors such as inadequate sampling, inappropriate sampling gear, and fish behavior may have also contributed to the wide confidence intervals about the point estimates.

A rebuilding program was established for Pacific ocean perch in 1981 following depletion of the resource during the 1960s and early 1970s. In an 1987 asement of the program, trawl survey information and a variety of analytic models were used to evaluate the current and future condition of the resource. The results of the assessment indicated that the Pacific ocean perch stocks were still at depressed levels of abundance and that stock recovery would likely be a very slow process. A more recent review ofcommercial fishery length data did not indicate any significantly strong year classes entering the fishery. Research surveys, however, which generally capture younger fish, did indicate evidence of incoming strong year classes. Although this signal is encouraging, significant rebuilding has yet to occur.

Baaed on stock-reduction analysis (SRA), an analytical approach, long-term potential yield has been estimated at about 3,000 t for both stocks combined. But because no significant rebuilding has occurred, the ABC has been set to zero in both the Vancouver and Columbia INPFC areas in an effort to promote rebuilding at the maximum rate. The PFMC, however, recognizes that incidental catches of Pacific ocean perch occur in other directed fisher&. Hence, trip limits have been set to allow a purely incidental fishery.

This chapter was written by Daniel H. Ito.

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PACIFIC OCEAN PERCH
Pacific Coast
COMMERCIAL CATCH (t)

	AREA	
	Vancouver	Columbia
1980	835	1,535
1981	790	1,102
1982	830	623
1983	1,147	1,397
1984	886	1,028
1985	1,039	891
1986	1,835	766
1987	1,289	610
1988	927	701
1989	1,008	1,104

PACIFIC OCEAN PERCH
Pacific Coast

Average catch (1980-89)	= 2,034 t
Long-term potential yield (MSY) (Vancouver-Columbia area)	= 3,000 t
Acceptable biological catch (1990)	= Zero
Importance of recreational fishery	= None
Management	= Groundfish FMP
Status of exploitation	= Over-exploited
Length at 50% recruitment	= 32-34 cm
Length at 50% maturity	= 32.2 cm (Females) 29.4 cm (Males)
Assessment approach	= Stock reduction analysis
Fishing strategy	= F = M
F(1990)	= < 0.10

6. SHORTBELLY ROCKFISH

The shortbelly rockfish *(Sebastes jordani)* is a viviparous, semidemersal species reaching a maximum length of 30-32 cm and a maximum weight of 350 g. Shortbelly rockfish get their name from the fact that, unlike other rockfish species, their anal vent is located well forward of their anal fin. Shortbelly rockfish become sexually mature between 2 and 3 years of age. The maximum recorded age for shortbelly rockfish is 24 years, but fish older than 18 years are uncommon. This species has been found from San Benito Island, Baja California to La Perouse Bank, British Columbia. The highest concentration is thought to be between Santa Cruz, California, and Bodega Bay, California, with another secondary concentration in California's Channel Islands area.' Shortbelly rockfish have been found in depths up to 283 m, with the majority between 90 and 165 m. Euphausiids constitute 99% of their diet.

Large schools of shortbelly rockfish are typically found near the edge of the continental shelf over sand substrates. The size of the schools is highly variable but can be several kilometers in diameter and quite dense. There is evidence that shortbelly rockfish schools are segregated by age or size, with larger and older fish often found in somewhat deeper water than younger and smaller ones. Research trawls typically have shown that few other species are mixed in with shortbelly rockfish schools.

Spawning occurs from November through May with peak spawning from January through late March. Females 17-30 cm in length would be expected to release from 6,000 to 50,000 larvae. Juveniles are pelagic for approximately 6 months. Juvenile shortbelly rockfish are a major part of the diet of chinook salmon and many species of seabirds.

At present there is no directed commercial or sport fishery for this species due to their small size. However, shortbelly rockfish have a strong potential for developing into a commercial fishery due to their high abundance in some areas of the California coast. The current estimated biomass between Santa Cruz and Bodega Bay is approximately 200,000 t. The PFMC has adopted an interim coastwide ABC of 13,000 t until further studies are conducted to determine the true MSY for this species. Both the Soviet Union and Japan have recently expressed an interest in harvesting shortbelly rockfish, possibly as **a** joint venture operation.

This chapter was written by Donald E. Pearson.

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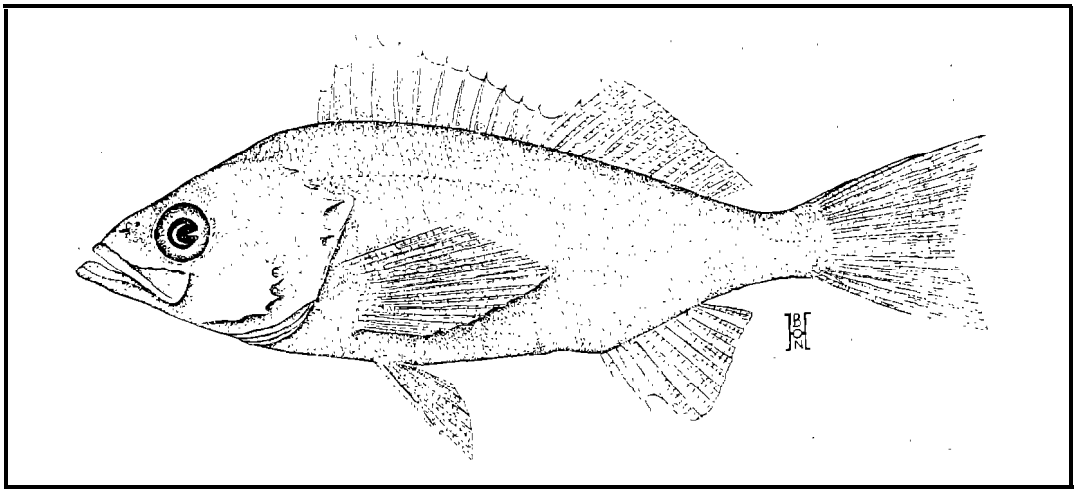
SHORTBELLY ROCKFISH
Pacific Coast

Average catch (1980-90)	= 4 t
Long-term potential yield (MSY)	= 13,431 to 23,504 t
Acceptable biological catch (1991)	= 13,000 t
Importance of recreational fishery	= None
Management	= Groundfish FMP
Status of exploitation	= Unexploited
Length at 50% recruitment	= 20 cm (Females) 20 cm (Males)
Length at 50% maturity	= 16 cm (Females) 16 cm (Males)
Assessment approach	= Yield per recruit
Fishing strategy (F = M)	= 0.20-0.35
F (1990)	= 0

7. WIDOW ROCKFISH

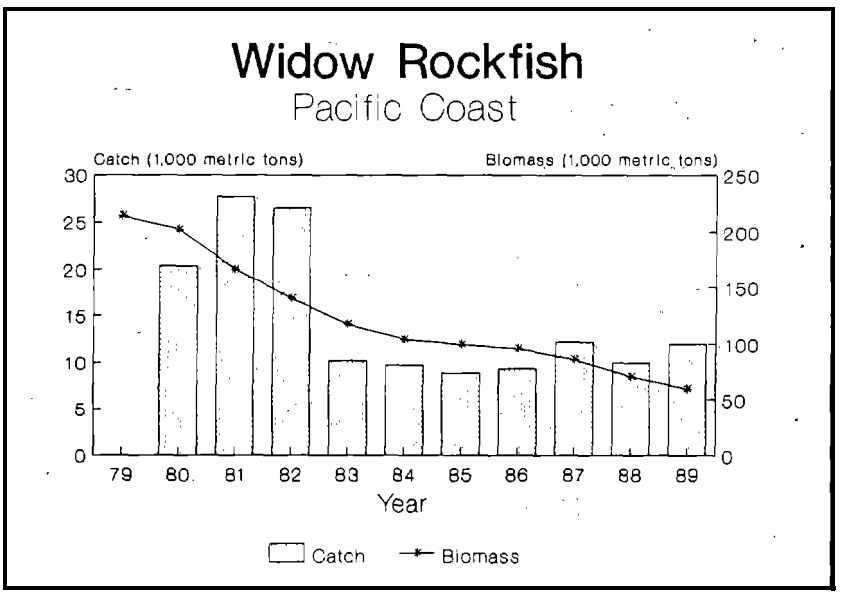


The widow rockfish ***(Sebastes entomelas) is*** a viviparous, semi-pelagic species. Adults reach a maximum length of 56-60 cm and a maximum weight of 2.5 kg. Average length in commercial landings isbetween 45 and 48 cm with average weights of 1.25-1.5 kg. Male and female widow rockfish grow at different- rates, with males typically smaller at age than females. In recent years, the average length has been declining in commercial landings. Widow rockfish mature sexually at age 5. The maximum recorded age for this species is 59 years.

Widow rockfish inhabit depths up to 320 m but are fished commercially at depths of 90-180 m. Adults typically associate with areas having moderate relief near the edge of the continental shelf. At night they form dense, midwater schools which disperse at dawn. This species is distributed from Todos Santos Bay, Baja California, to Kodiak Island, Alaska. The major concentration of widow rockfish is found between northern California and British Columbia. Fish in the north grow faster and reach a greater length than those in the south. Widow rockfish feed primarily on euphausiids, sergestids, salps, myctophids, and a variety of small fish.

Spawning occurs between November and April with peak spawning in February. A 46-cm female will release approximately 130,000 larvae, while a 55-cm female will release approximately 1.1 million larvae. The juveniles are pelagic for several. months and then settle to the bottom.

Recreational landings are insignificant compared. to total commercial landings or recreational landingsof other rockfish species. The majority of widow



WIDOW ROCKFISH
Pacific Coast
RECREATIONAL AND
COMMERCIAL CATCH (t)

YEAR	Rec	Comm
1980	0	20,390
1981	22	27,691
1982	186	26,513
1983	64	10,211
1984	80	9,671
1985	54	8,856
1986	61	9,329
1987	22	12,190
1988	34	9,958
1989	42	12,006

rockfmh are caught by commercial vessels using midwater trawl gear. Landings were small prior to 1978 when fishermen first began to use sonar and midwater trawl gear to make large catches at night. With the development of markets for fresh fillets, landings increased from less than 1,200 t in 1978 to more than 27,000 t in 1981 (the year with the highest landings). During that time, widow rockfish went from a relatively insignificant species in west coast groundfish landings to being the single most important rockfish species in Washington, Oregon, and California. The PFMC implemented regulations to protect the stock in 1982. In 1983, landings were reduced to 10,200 t. Between 1983 and 1989, average landings were 10,300 t due in large part to the regulations imposed by the PFMC.

Stock assessments for widow rockfish have been based on stock-synthesis modeling and cohort analysis using catch-at-age data obtained from port sampling. Analysis of age composition has shown that annual recruitment rates to the population are highly variable. Strong year classes occurred in 1970-71, 1977-78, and 1980-81, while the 1972-74, 1976, and 1982-83 year classes were relatively weak. Annual biomass estimates consistently declined from 1979 to 1990, and older fish have gradually disappeared from the landings. 'However, the lack of a reliable survey estimate of abundance has made it difficult to estimate the absolute abundance of the stock. Based on available data and the current approach to management, abundance should stabilize at about the current level, with the long-term average yield about equal to the ABC for 1991 (7,000 t).

This chapter was written by Donald E. Pearson and Joseph E. Hightower.

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WIDOW ROCKFISH
Pacific Coast

Average commercial catch (1980-89)	= 14,682 t	
Long-term potential yield (MSY)	= 6,000 - 7,600 t	
Acceptable biological catch (1991)	= 7,000 t	
Importance of recreational fishery	= Insignificant	
Management	= Groundfish FMP	
Status of exploitation	= Fully exploited	
Length at 50% recruitment	= Females: 35-40 cm	Males: 35-40 cm
Length at 50% maturity	= Females: 37 cm	Males: 36 cm
Assessment approach	= Stock synthesis, cohort analysis	
Fishing strategy	= $F_{35\%}$ = 0.21-0.26	
F (1990)	= 0.35-0.72	

8. BOCACCIO

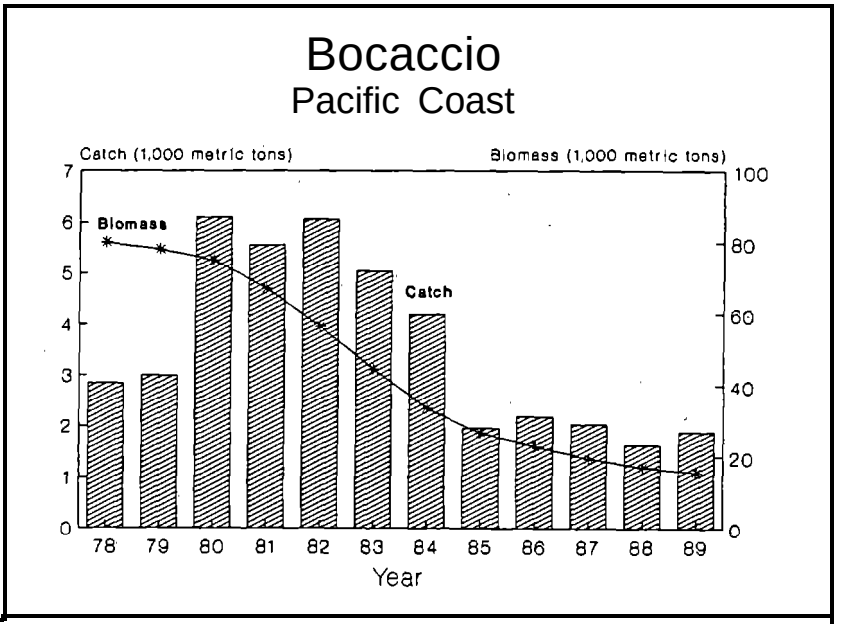
Bocaccio *(Sebastes paucispinis)* is a substrate-associated viviparous rockfish reaching a maximum length of 90. cm. Among rockfish, bocaccio are noted for their relatively rapid growth, large adult size, and high variation in year-class strength. Some individuals from strong year classes are landed by the trawl fishery at age 1, but full recruitment generally does not occur until age 2 when bocaccio are approximately 40 cm in length. During the past decade, landings have been dominated by the 1977 and 1984 year classes. As a consequence of the high variability in year-class strength, the size and age structure of the population fluctuates greatly over time. In 1986 most fish landed by the trawl fishery were less than 40 cm in length, while in 1989 the majority exceeded 50 cm; this change reflects the growth of the 1984 year class.

Although some female bocaccio are sexually mature at 36 cm in length, 50% maturity is reached at 48 cm (age 4). Because fecundity is relatively low for fish smaller than 50 cm, fish below this size contribute relatively little to the total reproductive output of the population. A 70-cm female can produce more than 1 million planktonic larvae. Larvae are released in the December-May period, except in southern California where larvae are released from October to March. 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 two broods in a season, but this appears to be less common to the north. Juveniles remain pelagic for some time and are most common within 30 m of the sea surface, but move deeper later in the spring, settling to substrate in late May or early June at lengths of 35-50 mm. Although bocaccio older than 30 years have occasionally been landed in the United States, the bulk of the population is less than 15 years old.

Bocaccio are found from central Baja California to Kodiak Island. There appears to be **a** break in the distribution near Coos Bay in southern Oregon. Adult bocaccio are found from depths of 27 to 320 m. The bulk of bocaccio landed by the commercial trawl fishery are caught at depths of 110-220 m, and younger and smaller fish are more common in shallower water.

The principal commercial fishing gear used to catch bocaccio is the bottom trawl. In 1989 two-thirds of the total landed catch was caught by trawls, one-sixth by set nets, and one-sixth by recreational anglers. There is also a small commercial hook and line fishery. Bocaccio from the Mexican border to Coos Bay, Oregon, are managed separately from other species while bocaccio to the north are included with "other rockfish ." Fishing is managed under the groundfish FMP of the PMFC.

Landings of bocaccio were about 3,000 t annually during the late 197Os, increased to over 6,000 t by 1980 with the recruit-. ment of the large 1977 year class, and have declined to 2,000 t since 1985. The majority of the recreational catch is split between southern and northern California, with relatively light catches in Oregon and Washington. The trawl fishery is centered near Monterey, California. Kecreational survey data, port sampling data from the commercial fishery, and data from a triennial trawl



BOCACCIO ROCKFISH
Pacific Coast
RECREATIONAL AND
COMMERCIAL CATCH (t)

YEAR	Rec	Comm
1982	1,551	5,107
1983	566	5,362
1984	238	4,357
1985	385	2,177
1986	584	1,963
1987	191	2,188
1988	158	1,716
1989	247	2,081
1990	-	2,050

survey were used to assess the California-southern Oregon stock. Both recreational and trawl survey indices of abundance indicate a decline in stock biomass over the past decade, due at least in part to poor recruitment over this period. The assessment indicates that biomass declined from about 75,000 t in 1978 to between 7,000 and 14,000 t in 1990. Within this region, estimated spawning biomass in 1991 was less than 25% of the average, unfished level. The recommended yield for all fisheries combined within this region ranged from 800 to 1,700 t compared to 1989 landings of 1,900 t. Based on the above information, the ABC for the California-southern Oregon region was reduced from 6,100 t to 800 t for the 1991 season. Landings are controlled by trip limits applied to the rockfish assemblage as a whole, and to bocaccio individually. Trip limits were first specifically applied to bocaccio in 1991.

The recovery of bocaccio south of Coos Bay, Oregon depends on the occurrence of one or more strong year classes. There are some indications in the recreational and trawl survey length composition data that the 1987 or 1988 year classes may be relatively strong, but more data are required to confirm this. However, fish in these year classes will not contribute significantly to the spawning capacity of the stock until at least 1992.

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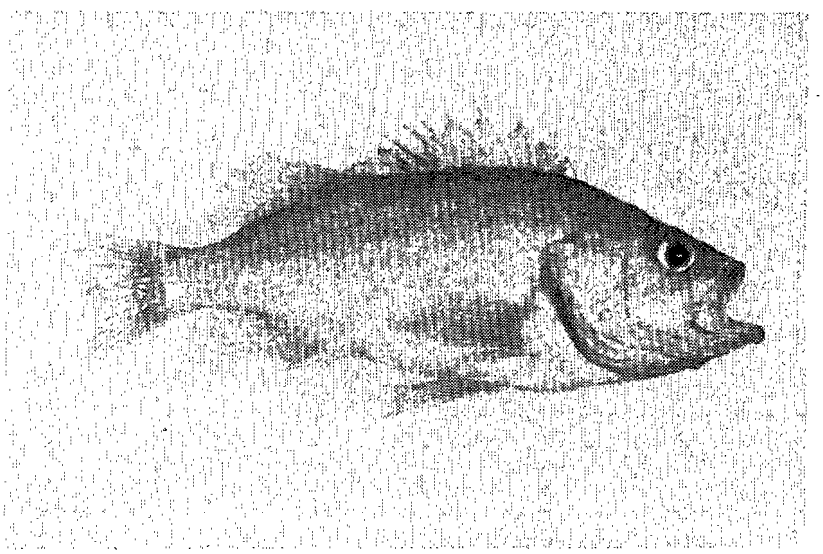
BOCACCIO ROCKFISH
Pacific Coast

Average catch (1980-90): U.S. waters	= 3,900 t
California & S. Oregon	= 3,400 t
Long-term potential yield (MSY)	
California & S. Oregon	= 2,400 t
Acceptable biological catch (1991)	
California & S. Oregon	= 800 t
Importance of recreational fishery	= Important in California
Management	= Groundfish FMP
Status of exploitation	= Over-exploited in California and S. Oregon
Length at 50% recruitment	= 39 cm (trawl)
Length at 50% maturity	= 48 cm (females); 42 cm (males)
Assessment approach	= Stock synthesis model
Fishing strategy	= $F_{35\%}$ = 0.12
F (1989)	= 0.3

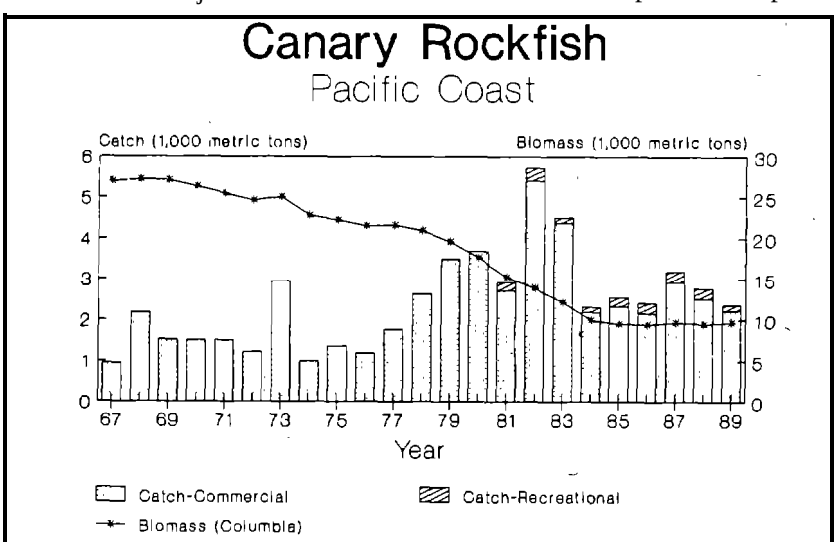
9. CANARY ROCKFISH

Canary rockfish ***(Sebastes pinniger)*** is a viviparous, demersal rockfish. Immature fish are often found in nearshore rocky reefs while older, mature adults inhabit offshore rocky reefs. Canary rockfish reach a maximum length of 75-80 cm and weights up to 7.3 kg. Average length in commercial landings is between 50 and 55 cm with average weights of 1.9-2.5 kg. Male and female canary rockfish grow at different rates, with males typically smaller at age than females. In recent years, the average length and age has been declining in commercial landings. Canary rockfish are mature at ages 7-9 and have a maximum reported age of 78 years. Male canary rockfish tend to have greater longevity than females, possibly due to higher natural mortality of older females. Canary rockfish inhabit depths up to 275 m but are fished commercially in depths of 90-180 m. This species is distributed from Cape Colnett, Baja California, to Cape Bartolome, Alaska. The major concentration of canary rockfsh is found between northern Oregon and British Columbia. There is no apparent difference in length at age between fish in the north and those in the south. Canary rockfish feed primarily on euphausiids; however, decapods, squid, herring, and a variety of other fish and macroplankton are also consumed.



Spawning occurs between November and April with peak spawning from December through January. A 50-cm female will release approximately 800,000 larvae while a 60-cm female will release approximately 1.4 million larvae. The juveniles are pelagic for several months and then settle to the bottom.

Recreational landings are between 3 and 10% of total commercial landings with the majority of sport-caught canary rockfish being taken in California. In California commercial landings, most canary rockfish are caught by longline gear; while in Oregon (the center of the fishery), the majority are caught by bottom trawling. From 1942. through 1947, a large fishery existed in the Columbia INPFC area to supply the military. During this fishery, an average of 4,248 t per year was landed. Columbia INPFC area landings averaged 4,004 t per year from 1947 through 1966 and 2,326 t per year from 1966 through 1989. Canary rockfish are regulated as part of the ***Sebastes*** complex under the



groundfish FMP of the PFMC. Trip limits are placed on landings of this complex; however, there are no specific landing limits for canary rockfish. In 1982 (the year with the highest landings since 1967), canary rockfish constituted 4% of the total west coast groundfish landings; by 1989, they constituted only 2%.

Stock assessments for canary rockfish have been based on catch-and-age composition data obtained from port sampling, NMFS trawl survey data, and logbook data on commercial trawl effort. The results suggest that equilibrium recruitment within the Columbia INPFC area is 1.25 to 1.75 million age-3 recruits. That level of recruitment results in an estimated virgin biomass of 34,000-43,000 t and a biomass in 1989 of 8,000-16,000 t. The estimated female spawning biomass in 1989 was between 16 and 33% of virgin levels. The 1991 ABC for the Vancouver, Columbia, and Eureka-INPFC areas (2,900 t) is about 20% greater than the average landings from 1966 to 1989; thus, the Sebastes complex trip limits appear to prevent landings of canary rockfish from exceeding desired levels.

This chapter was written by Donald E. Pearson and Joseph E. Hightower.

CANARY ROCKFISH
Pacific Coast
RECREATIONAL AND COMMERCIAL CATCH (t)

YEAR	Rec	Comm
1980	-	3,677
1981	213	2,706
1982	316	5,417
1983	113	4,387
1984	129	2,184
1985	229	2,332
1986	249	2,161
1987	271	2,924
1988	255	2,524
1989	154	2,218

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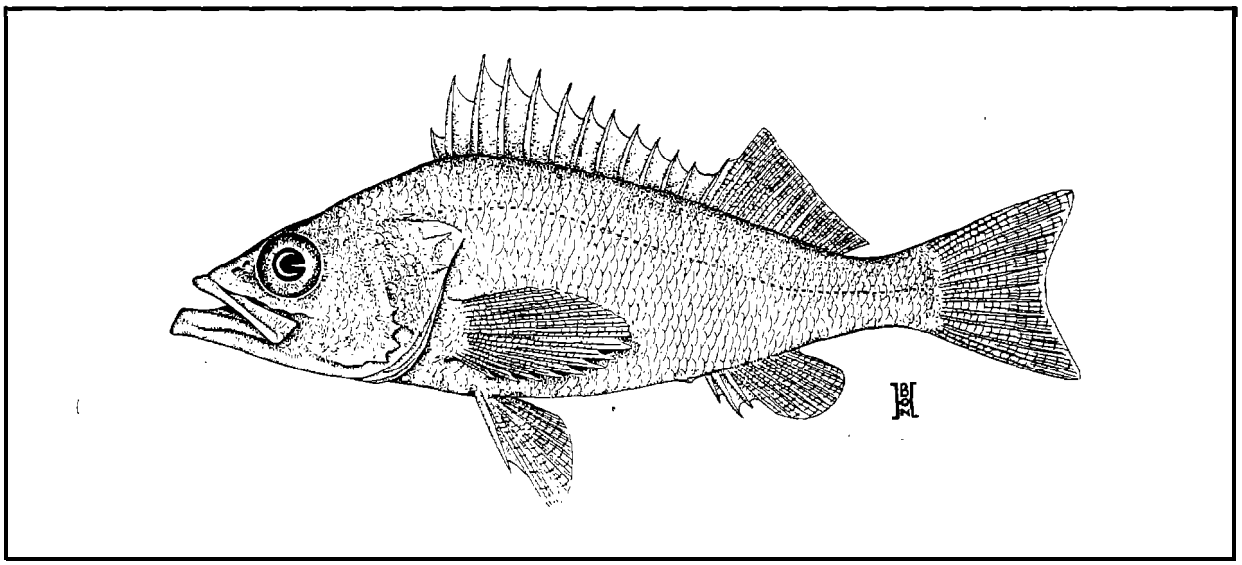
CANARY ROCKFISH
Pacific Coast

Average commercial catch (1980-89)	= 3,053 t
Long-term potential yield (MSY) (Columbia area only)	= 1,195-1,736 t
Acceptable biological catch (1991) (Vancouver-Columbia-Eureka areas only)	= 2,900 t
Importance of recreational fishery	= Important in California
Management	= Groundfish FMP
Status of exploitation	= Fully exploited
Length at 50% recruitment	= Females: 50 cm Males: 41 cm
Length at 50% maturity	= Females: 50 cm Males: 41 cm
Assessment approach	= Stock synthesis, yield per recruit
Fishing strategy	= $F_{35\%}$ = 0.135 to 0.190
F (1989)	= 0.143 - 0.370

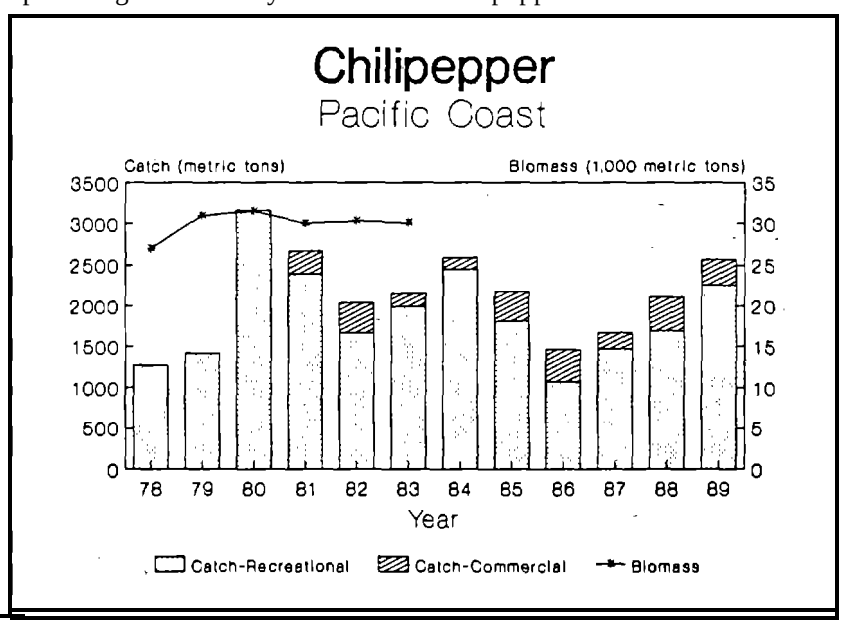
10. CHILIPEPPER



Chilipepper ***(Sebastes goodei)*** is a viviparous, demersal rockfish that reaches a maximum length of 59 cm and weighs up to 2.5 kg. The average length in commercial landings is between 40 and 45 cm with average weights of 0.8-1.1 kg. Male and female chilipepper rockfish grow at substantially different rates, with males typically reaching a maximum length of about 45 cm (17 in). This difference in length reduces the vulnerability of males to commercial trawl gear; thus, females comprise between 65 and 80% of the catch. Chilipepper mature sexually at age 3 (31 and 34 cm for males and females, respectively). The maximum reported age for chilipepper rockfish is 29 years. Chilipepper inhabit depths up to 330 m but are fished commercially at a depth of about 165 m. This species is distributed from Magdalena Bay, Baja California, to Vancouver Island, British Columbia. The major concentration of chilipepper is between Point Conception and Bodega Bay, California. Chilipepper feed on euphausiids, small- squid, lantern fish, anchovy, and juvenile Pacific whiting.

Spawning occurs between November and March with peak spawning in January. A 40-cm female will release approximately 70,000 larvae while a 55-cm female will release approximately 440,000 larvae. The juveniles are pelagic for several months after which they become demersal.

Recreational landings are l0-30% of the commercial landings and virtually all sport-caught chilipepper are taken in Califor-



nia. In' California commercial landings, most chilipepper are caught by bottom trawl, with setnet gear and hook and line contributing a small fraction of the total landings. From 1978 to 1989, chilipepper contributed approximately 30% to the commercial rockfish landings in the Monterey INPFC area. Chilipepper are typically caught in schools mixed with bocaccio. Prior to 1985, bocaccio were more abundant than chilipepper in the commercial landings south of Fort Bragg, California; however, chilipepper have been more abundant than bocaccio since that time. There is some evidence that the average length in commercial landings has declined since 1978. Chilipepper are regulated by the groundfish FMP of the PFMC. The most recent stock assessment for chilipepper (in 1986) was based on catch- and age-composition data obtained from port sampling and NMFS trawl survey data. Results of that assessment suggested that age 3+ biomass was between 25,000 and 50,000 t in 1978-83. The estimated MSY ranged from 2,600 to 4,500 t for the Eureka, Monterey, and Conception INPFC areas. The midpoint of that range (3,600 t) has been used since 1986 as the best available estimate of ABC. Due to the increasing importance of chilipepper in the commercial landings, this species has been given a high priority for further assessment research.

This chapter was written by Donald E. Pearson.

CHILIPEPPER ROCKFISH
Pacific Coast
RECREATIONAL AND
COMMERCIAL CATCH (t)

YEAR	Rec	Comm
1980	-	3,160
1981	272	2,400
1982	369	1,608
1983	160	1,993
1984	146	2,450
1985	362	1,807
1986	386	1,074
1987	203	1,468
1988	415	1,694
1989	308	2,261

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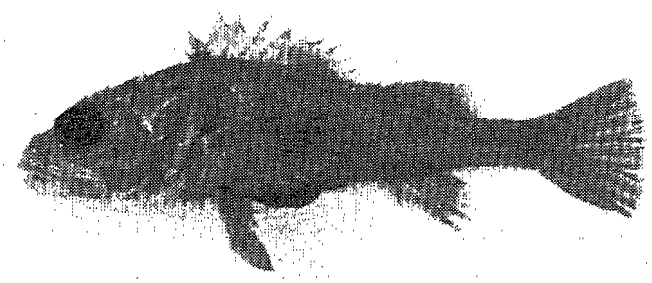
Wyllie Echeverria, T. 1987. Thirty-four species of California rockfishes: Maturity and seasonality of reproduction. Fish. Bull., U.S. 85: 229-250.

CHILIPEPPER ROCKFISH
Pacific Coast

Average commercial catch (1980-89)	= 1,988 t
Long-term potential yield (MSY)	= 3,600 t
Acceptable biological catch (1991)	= 3,600 t
Importance of recreational fishery	= Important in California
Management	= Groundfish FMP
Status of exploitation	= Moderately exploited
Length at 50% recruitment	= Females: 43-45 cm Males: unknown
Length at 50% maturity	= Females: 34 cm Males: 31 cm
Assessment approach	= Catch-at-age analysis
Fishing strategy	= $F_{(MSY)}$ = 0.5 - 0.6
F (1983)	= 0.09 - 0.21

11. THORNYHEADS

Longspine thornyheads ***(Sebastolobus altivelis)*** and shortspine thornyheads (S. alascanus) are similar in appearance, have overlapping. habitats, and are not distinguished in commercial markets although there are differences in important biological characteristics such as growth and mortality.



Longspine thornyheads range from the southern tip of Baja California, Mexico to the Aleutian Islands, while shortspine thornyheads range from northern Baja California to the Bering Sea and the Commander Islands off the Asiatic mainland. Both species are demersal and found in relatively deep water primarily on the continental slope. Longspine thornyheads are found off California, Oregon, and Washington at depths that range from 300 m to more than 1,500 m with the bulk of the population occurring between 500 and 1,100 m. Shortspine thornyheads have a slightly broader depth range and are found off California, Oregon, and Washington from about 90 m to more than 1,500 m with the bulk of the population occurring between 300 and 1,100 m. The upper depth limit for shortspine thornyheads increases toward the northern end of its distribution in Alaska to depths as shallow as 25 m. Large shortspine thornyheads tend to be found in deeper water than small shortspine thornyheads. There is no relationship between depth and length for longspine thornyheads.

Longspine thornyheads mature at smaller sizes and younger ages than shortspine thornyheads. Fifty percent of female longspine thornyheads are sexually mature at about 19 cm total length (TL) and 14 years of age while 50% of shortspine thornyheads are mature at about 21 cm TL and 12-13 years of age.

Both longspine and shortspine thornyheads spawn buoyant masses of eggs during the late winter and early spring that resemble bilobate "balloons" that float to the surface. Juvenile longspine thornyheads have a pelagic period of about 18 to 20 months and settle out at about 40-60 mm TL. In contrast, juvenile shortspine thornyheads settle in shallower water at smaller sizes (22-27 mm TL) and have a shorter pelagic period (about 14-15 months).

In the context of fishery management, differences in growth rate, maximum size, and longevity between longspine and shortspine thornyheads are most important. Longspine thornyheads may live between 40 and 50 years and grow to about 35 cm in length, while shortspine thornyheads may live well in excess of 100 years and grow to about 75 cm.

Thornyhead landings off Washington, Oregon, and California have in creased five fold since 1981 in response to developing Japanese export markets, higher ex-vessels prices, and movement of the bottom trawl fishery into deeper waters. The bulk of thornyheads landed each year are taken off northern California and Oregon. Shortspine thornyheads predominated in landings prior to 1990 but the proportion of longspine thornyheads in landings has increased during recent years, exceeding 50% in 1990. Ex-vessel prices for thornyheads (adjusted for inflation and measured in 1989 dollars) rose from $0.17 per pound in 1981 to $0.40 per pound in 1990, while revenues (the product of ex-vessel prices and landings) from the fishery rose from $663,000 to $8.85 million.

Thornyhead landings increased as a proportion of total landings for the deep-water complex (sablefish, Dover sole, and thornyheads) from about 6% in 1981 to about 17% in 1990. During the same period, thornyhead revenues increased from about 5% of total revenues for the deep-water complex to 31%.

Current (1990) coastwide biomass of longspine and shortspine thornyheads is estimated from research surveys to be between 53,000 and 235,000 t. There is insufficient information available to determine if abundance has changed in recent years. Port samples indicate that mean

lengths of longspine thornyheads taken off northern California have declined since the early 1980s. Catch-rate data for thornyheads from logbooks have proven difficult to interpret primarily because of problems in separating catch rates for the two species and changes in the depth of fishing. Age-composition data are not available for either longspine or shortspine thornyheads.

Acceptable biological catch for groundfish managed by the PFMC is based on maintaining either spawning biomass levels that are 35% as large as in the unfinished population or, for stocks like thornyheads without reliable estimates of unfinished and current biomass, an $F_{0.35}$ target fishing mortality rate. $F_{0.35}$ is the fishing mortality rate that results in a level of spawner biomass per recruit that is 35% of that in the absence of fishing. Current estimates of $F_{0.35}$ for longspine thornyhead range from 0.15 to 0.33 per year and 0.02 to 0.05 per year for shortspine thornyhead.

Processors are currently reluctant to buy thornyheads smaller than 10 inches (25.4 cm) TL. Under current meshsize regulations (4.5-inch minimum meshsize for codends in bottom trawls), substantial numbers of longspine thornyheads less than 10 inches TL are taken when fishing mortality rates are in the range of $F_{0.35}$. Shortspine thornyheads are not subject to this problem. Recognizing the potential waste from discard of small longspine thornyheads under the $F_{0.35}$ harvest policy, target fishing mortality rates that maximize revenue per recruit ($F_{max\$}$) have been calculated. For longspine thornyheads, estimates of $F_{max\$}$ (0.06 to 0.07 per year) are much smaller than estimates of $F_{0.35}$ (0.11 to 0.18 per year) and are similar to estimates of $F_{0.35}$ for shortspine thornyheads (0.02 to 0.05 per year). In contrast, estimates of $F_{0.35}$ (0.021 to 0.050 per year) and $F_{max\$}$ (0.030 to 0.072 per year) for shortspine thornyheads are similar.

Current management advice is that $F_{0.35}$ for shortspine thornyheads be used to set ABC levels for the entire thornyhead market category. The rationale for this advice is that: 1) separate ABCs for longspine and shortspine thornyheads would be impossible since fishermen cannot harvest either longspine or shortspine thornyheads exclusively, 2) the two species are difficult to separate in landings, 3) spawning biomass per recruit for both species will meet or exceed the $F_{0.35}$ target levels, and 4) revenue per recruit for both species will be near maximum values as long as the IO-inch minimum size limit continues.

This chapter was written by Larry D. Jacobson,

For further information

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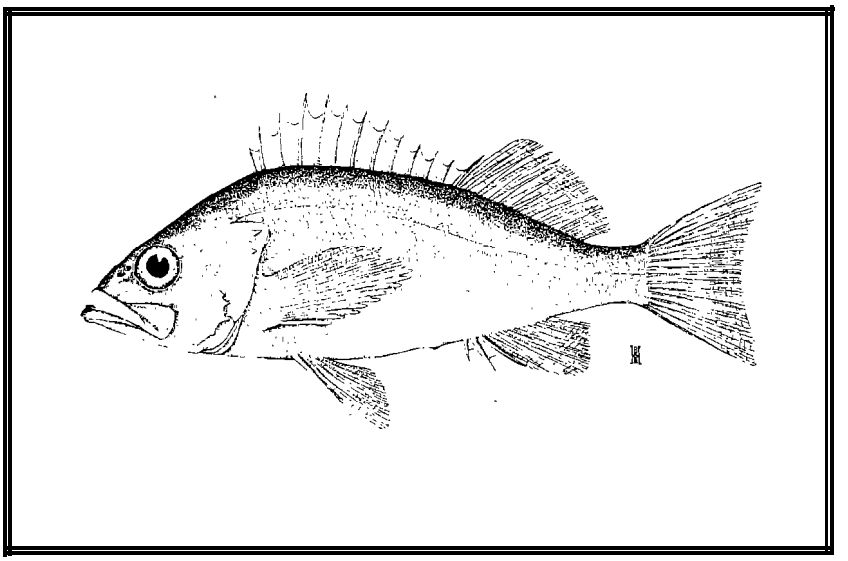
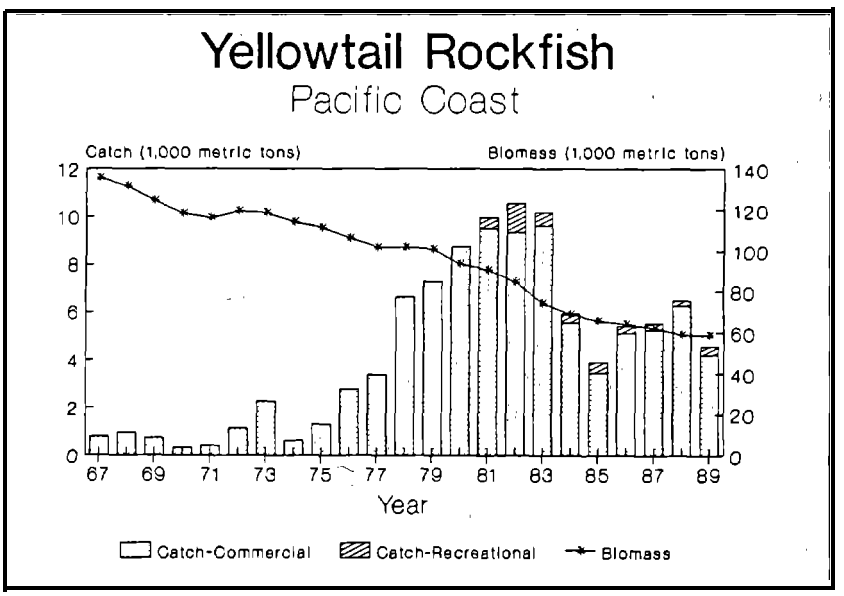
THORNYHEADS
Pacific Coast

Average commercial catch (1981-90):	
Shortspine	= 2,840 t
Longspine	= 1,603 t
Thornyhead market category	= 4,444 t
Commercial catch in 1990	= 10,126 t
Long-term potential yield (MSY)	= 5,100 - 12,000 t
Acceptable biological catch (1990	= 5,100 t
Importance of recreational fishery	= none
Management	= Groundfish FMP
Status of exploitation	= Fully exploited
Age at 50% recruitment (bottom trawls):	
Shortspine	= 19 yrs
Longspine	= 16 yrs
Age at 50% maturity (both species)	= 13-14 yrs
Assessment approach	= Spawning biomass per recruit and survey biomass estimates
Management strategy	= $F_{0.35}$
F (1990)	= ≥ 0.04

12. YELLOWAIL ROCKFISH



Yellowtail rockfish (Sebastes *flauidus)* is a viviparous, semi-pelagic rockfish typically inhabiting offshore rocky reefs. Yellowtail rockfish reach a maximum length of 60-65 cm and weights up to 3.9 kg. Average lengths in commercial landings range between 46 and 52 cm with average weights of 2.4-3.2 kg. Male and female yellowtail rockfish grow at different rates, with males typically smaller at age than females. In recent years, the average length has been declining in commercial landings. Yellowtail rockfish mature sexually at ages 6-7 years and have a maximum reported age of 64 years. Yellowtail rockfish inhabit depths up to 550 m but are not common at depths exceeding 190 m. This species is distributed from San Diego, California, to Admiralty Island, Alaska. The major concentration ofyellowtail rockfish is found between northern Oregon and British Columbia. In the northern part of their commercial range, yellowtail rockfish grow faster, reach a greater maximum length, and spawn later than those to the south. Tagging studies have shown that most yellowtail rockfish do not migrate after reaching -adult size. Yellowtail rockfish feed on a wide variety of prey including euphausiids, decapods, squid, herring, smelt, and myctophids.



Spawning occurs between November and June with peak spawning from February through April. A 35-cm female will release approximately 90,000 larvae while a 55-cm female will release approximately 1 million larvae. Juveniles are pelagic for several months, settle to the bottom, and eventually make their way to offshore rocky reefs.

Recreational landings are 3-15% of total commercial landings with the majority of sport-caught yellowtail rockfish taken off California. In commercial landings, most yellowtail rockfish are caught by bottom and midwater trawl nets; however, hook and line, gill nets, and longline gear also contribute to the landings. Commercial landings increased from about l,000-2,000 t in the late 1960s to nearly 10,000 t in the early 1980s. Since 1982, the

commercial fishery has been regulated by the groundfish FMP of the PFMC. The first regulations specifically limiting the catch of yellowtail rockfish were enacted in 1985. Since that time, additional; more restrictive regulations have been instituted to protect the stock, and annual landings have been about 5,000 t per year. In 1983, yellowtail rockfish constituted 9% of the total west coast groundfish landings; in 1989, they constituted only 4%.

Stock assessments for yellowtail rockfish have been based on catch- and age-composition data obtained from port sampling and from NMFS trawl surveys. Analyses for three Pacific Coast stocks suggest that there has been significant exploitation over the past 15 years with resultant declines in abundance. Total biomass from northern California to southwest Vancouver Island is estimated to have declined from about 136,000 t in 1967 to about 58,000 t in 1990. Total abundance of two of the three stocks is estimated to be below the optimal level. Fishing mortality rates implemented by the PFMC for those two areas are less than recent levels and some rebuilding is expected over the next few years.

This chapter was written by Donald E. Pearson.

YELLOWTAIL ROCKFISH
Pacific Coast
RECREATIONAL AND
COMMERCIAL CATCH (t)

YEAR	Rec	Comm
1980	-	8,759
1981	466	9,512
1982	1,217	9,352
1983	572	9,625
1984	392	5,554
1985	440	3,482
1986	297	5,129
1987	271	5,246
1988	226	6,261
1989	351	4,217

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YELLOWTAIL ROCKFISH
Pacific Coast

Average commercial catch (1980-89)	= 5,700 t
Long-term potential yield (MSY)	= 6,006-6,823 t*
Acceptable biological catch (1991)	= 4,600 t
Importance of recreational fishery	= Important in California
Management	= Pacific groundfish FMP
Status of exploitation	= Fully exploited
Length at 50% recruitment	= Females: 37-43 cm Males: 37-41 cm
Length at 50% maturity	= Females: 39 cm Males: 38 cm
Assessment approach	= Stock synthesis, cohort analysis, yield per recruit
Fishing strategy	= $F_{35\%}$ = 0.18 - 0.25
F (1990)	= 0.19 - 0.29

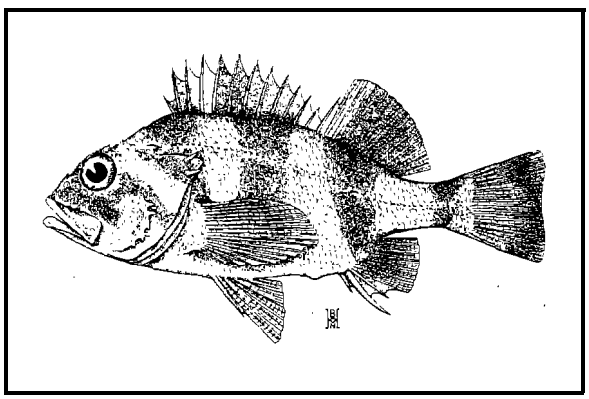
Does not include California south of Cape Mendecino.

13. OTHER ROCKFISH

There are, in addition to those already mentioned, at least 50 other species of rockfish ***(Sebastes*** spp.) taken commercially along the west coast of the United States (California, Oregon, and Washington). Most of the commercial harvest is taken by bottom trawls over the continental shelf. While some of the larger rockfish species reach sizes in excess of 90 cm (e.g., cowcod (S. levis), shortraker *(S.* ***borealis),*** yelloweye *(S.* ***ruberrimus),*** and rougheye (S. ***aleutianus)*** rockfishes), maximum lengths of most range between 30 and 60 cm. The genus includes members that occupy a multitude of habitats and species that exhibit a great diversity of life history strategies. Some are solitary demersal forms, while others shoal in the open ocean.

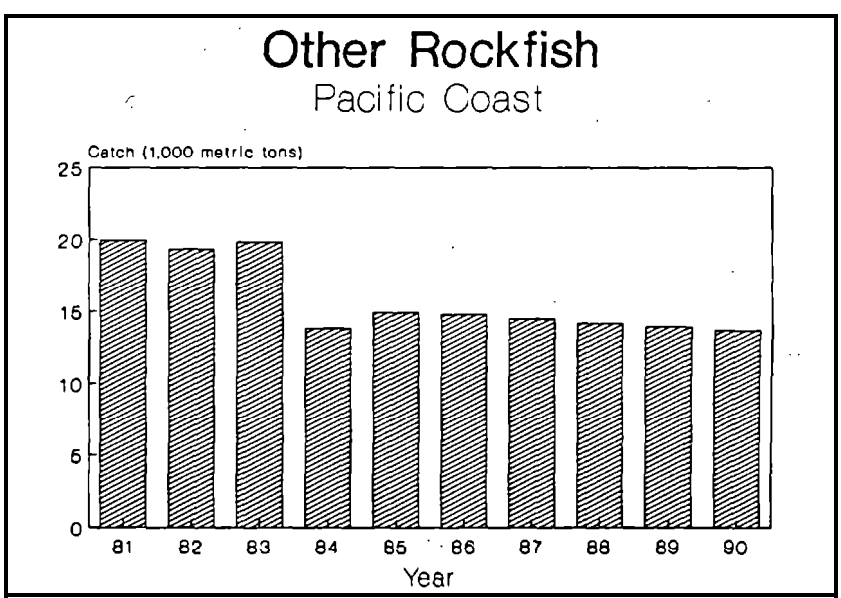
One feature held in common by all rockfish, however, is viviparous reproduction. In general, spawning occur months before fertilization of the eggs. The larvae develop internally and usually are extruded by the female sometime between December and June. The pelagic larval-juvenile period is quite variable, although some species are at least 5-6 months old when settlement finally occur. Reproductive success often varies substantially from year to year, creating large differences in year-class strength. It is also commonplace within the genus for growth to proceed quite slowly. Many species are known to reach ages substantially in excess of 50 years

The majority of rockfish reside on the continental shelf in water depths shallower than 100 fathoms. Many of these species prefer rocky substrates, although some of the more abundant species are found in regions of low relief. Feeding habits within the genus are highly variable, ranging from omnivorous (blue rockfish (S. ***mystinus))*** to the largely piscivorous diets of the large species. Small rockfish tend to feed predominantly on benthic crustaceans, while others feed largely on planktonic organisms, principally krill.



Due to the large number of rockfish species caught in the west coast groundfish fishery, it is not feasible to perform stock assessments for individual species. However, catch data obtained over the last decade through the Pacific Fishery Information Network (PacFIN) show that total landings of other rockfish declined from 20,000 t in 1981 to 13,800 t in 1984. This represents a 31% decline in 4 years. It is uncertain what may have caused the drop. It may simply have been due to improved market recognition of widow, bocaccio, chilipepper, canary, and yellowtail rockfishes during the 1981-84 time period. Since 1985, landings have steadily declined at approximately 2% per year.

Although no detailed stock assessments have been conducted



on these species to date, there is evidence that they are under significant fishing pressure. One recent study examined length-frequency data from commercial trawl landings of 11 rockfish species at central and northern California ports. Results showed distinct declining trends in the mean size of fish caught, as well as drops in the 10th and 90th length percentiles. Similar trends were observed in both males and females of the species Moreover, simple population models showed that to bring about length reductions equivalent to those that were observed, substantial fishing pressure must have taken place.

These species are currently managed under the Groundfish FMP of the PFMC. Based upon historical levels of catch, the 1991 ABC was set at 14,000 t. In addition, there is a coastwide ***Sebastes*** complex trip limit of 25,000 lbs (11.3 t1.

This chapter was written by Steven V. Ralston.

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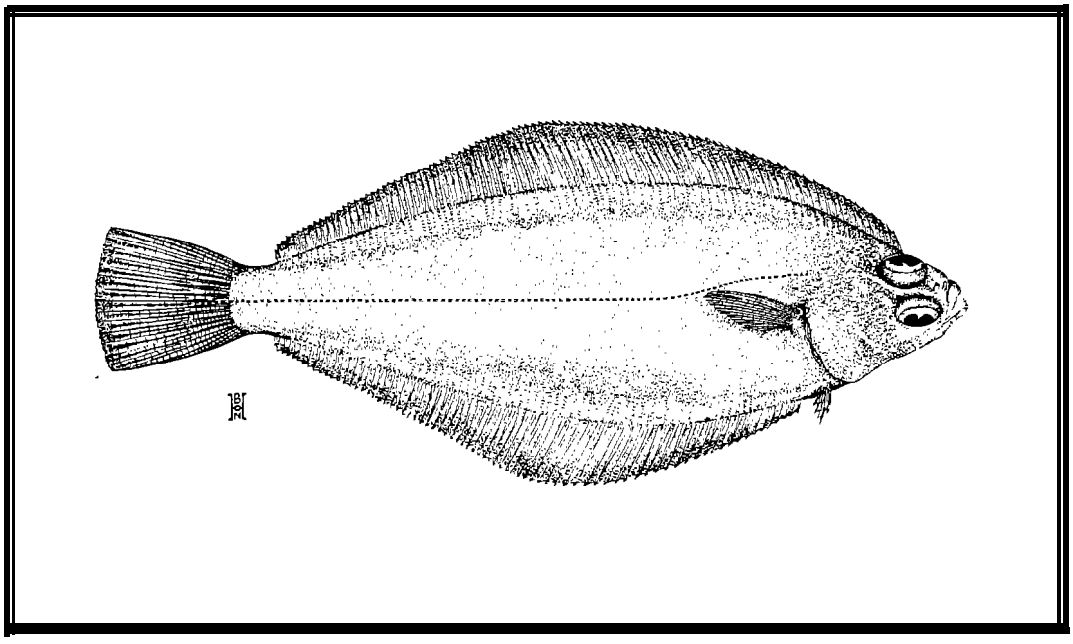
OTHER ROCKFISH
Pacific Coast

Average commercial catch (1984-90)	= 14,247 t
Long-term potential yield (MSY)	= Unknown
Acceptable biological catch (1991)	= 14,000 t
Importance of recreational fishery	= Major
Management	= Groundfish FMP
Status of exploitation	= Unknown
Length at 50% recruitment	= Unknown
Length at 50% maturity	= Females: 15-41 cm Males: 16-40 cm
Assessment approach	= Length trends
Fishing strategy	= None
F (1990)	= Unknown

OTHER ROCKFISH
Pacific Coast
COMMERCIAL LANDINGS (t)

Species	1982	1983	1984	1985	1986	1987	1988	1989	1990
Black	106	374	215	100	172	82	181	137	23
Darkblotched	11	407	984	1,351	881	2,212	1,390	866	950
Redstripe	17	411	134	309	206	247	321	329	330
Sharpchin	2	213	77	272	182	186	346	342	142
Silvergrey	2	263	138	299	276	181	216	173	172
Splitnose	2	96	536	703	263	229	206	190	128
Yelloweye	20	177	83	97	76	115	120	160	82
Yellowmouth	2	498	453	712	288	237	418	334	261
Other	4,135	1,710	1,956	1,742	1,978	1,979	1,341	1,763	958
Unspecified	15,034	15,696	9,228	9,347	10,446	8,999	9,640	9,644	10,598
Total	19,331	19,845	13,803	14,932	14,767	14,468	14,177	13,939	13,643

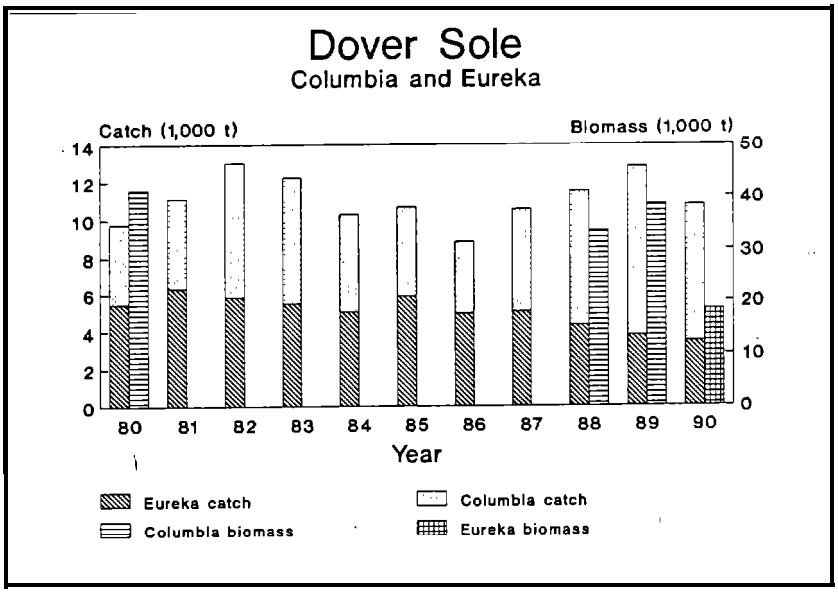
14. DOVER SOLE



Dover sole *(Microstomus pacificus)* occur from northern Baja California to the Bering Sea in waters as deep as 600 fathoms. Abundance is highest in the 200 to 300 fathom range. Tagging studies indicate that fish migrate to deeper water to spawn in winter and return to shallower water in summer. Superimposed on this seasonal migration is the tendency for Dover sole to gradually move to deeper water with age. Prey consists mainly of burrowing invertebrates.

Females grow faster and attain larger sizes (maximum size 60-70 cm) than males (maximum size about 50 cm). Maximum age is about 50 years. Natural mortality is estimated at 0.10.

Dover sole are caught commercially chiefly by bottom trawls. Dover sole, sablefish, and thornyheads occur in similar habitat and are often caught together. Coastwide catches increased from 14,000 tin 1980 to about 20,OOOt from 1982 to 1985, then declined to 15,700 t in 1990. The fishery has gradually moved into deeper water in recent years. Catches in the Eureka INPFC area have declined from 5,000-6,000 t to 3,400 t in 1990. Catches in the Columbia INPFC



area increased in the early 198Os, declined in the mid- 1980s and increased to a high of 9,000, t in 1989. Dover sole landings in 1990 totaled 7,200 t.

DOVER SOLE
Pacific Coast
COMMERCIAL CATCH
(1,000 t)

Year	Catch
1980	14.0
1981	16.1
1982	20.0
1983	19.6
1984	19.0
1985	20.3
1986	16.1
1987	18.0
1988	17.7
1989	18.7
1990	15.7

Stock assessments have been conducted for the Columbia and Eureka INPFC areas only. Estimates of biomass from surveys in the Columbia INPFC area have declined from 41,500 tin 1975 to 33,500 t in 1988 and 38,400 t in 1989. A 1990 survey in the Eureka INPFC area estimated biomass at 18,300 t. The ABC in the Columbia INPFC area was lowered in 1990 from 11,500 t to 6,100 t as a result of the 1990 stock assessment. This latest assessment was based on size and otolith-age data instead of biased scale-age data used in the previous assessment. Fisheries in both the Columbia and Eureka INPFC areas appear to be fully exploited.

This chapter was written by Jack Tumock.

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DOVER SOLE
Pacific Coast

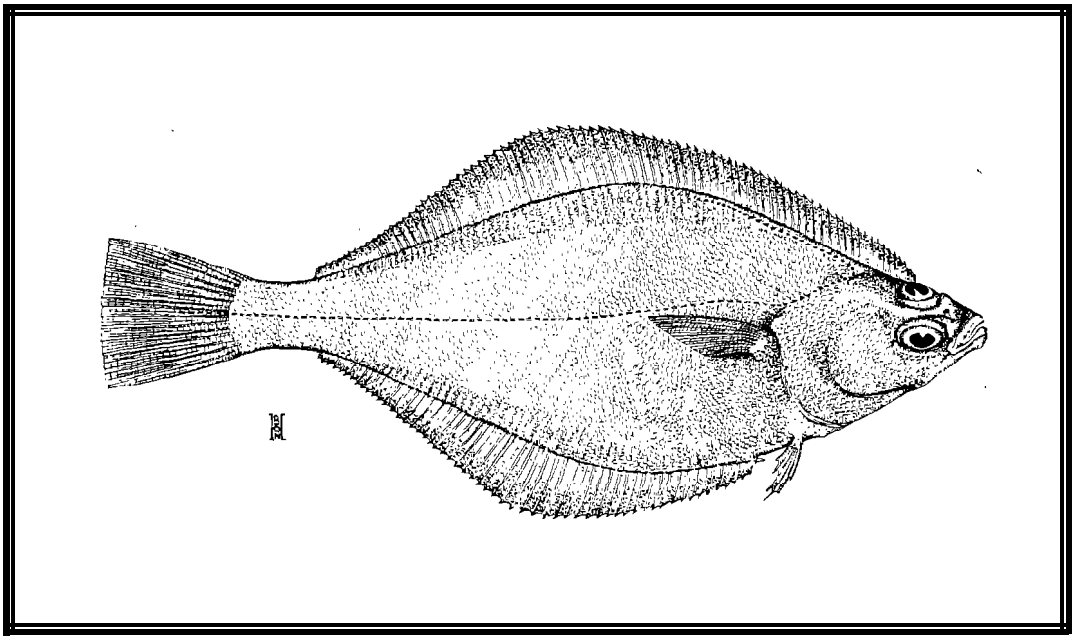
Columbia INPFC Area

Average commercial catch (1980-90)	=	5,991 t
Long-term potential yield (MSY)	=	6,100 t
Acceptable biological catch	=	6,100 t
Importance of recreational fishery	=	Minor
Management	=	Groundfish FMP
Status of exploitation	=	Fully exploited
Length at 50% recruitment	=	32 cm (females) 32 cm (males)
Length at 50% maturity	=	34 cm (females) Unknown (males)
Assessment approach	=	Size-structured, separable assessment
Fishing strategy	=	$F_{35\%}$ = 0.20
F (1990)	=	0.26

Eureka INPFC Area

Average commercial catch (1980-90)	=	5,055 t
Long-term potential catch (MSY)	=	5,400 t
Acceptable biological catch	=	8,000 t
Importance of recreational fishery	=	Minor
Management	=	Groundfish FMP
Status of exploitation	=	Fully exploited?
Length at 50% recruitment	=	32 cm (females) 32 cm (males)
Length at 50% maturity	=	34 cm (females) Unknown (males)
Assessment approach	=	Size-structured, separable assessment
Fishing strategy	=	$F_{35\%}$ = 0.23
F (1990)	=	0.11

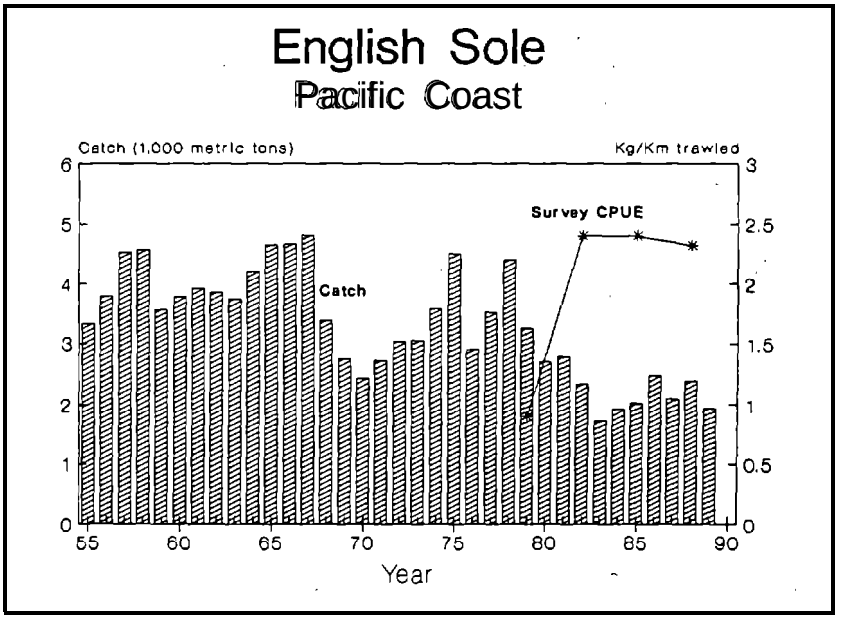
15. ENGLISH SOLE



The English sole *(Parophyrys vetulus)* is a small shallow-water flatfish commonly found in sand substrate habitats from Baja Califomia to Unimak Island in the Aleutian Islands area. Juvenile English sole are found in estuaries and in very shallow coastal waters, while adults move into deeper water on the continental shelf. Most of the population occurs at depths less than 50 fathoms. English sole begin spawning in winter, and peak in January or February. Their diet consists of benthic organisms, such as clams, clam siphons, segmented worms, small crabs, shrimp, and brittle stars.

Female English sole grow more rapidly than males.. The asymptotic length of females is 42.6 cm, while that of males is 36.3 cm. Length at 50% maturity is 31 cm for females and 22 cm for males. A tagging study by the Oregon Department of Fish and Wildlife in 1975 found that most English sole do not migrate long distances along the coast. English sole undergo a seasonal movement from deep water to shallow water in the spring and a return migration to deeper water in the winter that may be related to spawning.

English sole are primarily caught by the near-shore trawl fishery that captures a mix of flat-.



fish including rex sole *(Errex zuchirus),* petrale sole, and starry flounder ***(Platichthys stellatus).*** English sole have a long history of full exploitation on the west coast. The landed catch of English sole is widely distributed, with significant landings ranging from Monterey, California, to ports in northern Puget Sound. The landed catch consists mostly of females (about 94% by weight) because of the smaller average size of males. The average annual catch during 1980-90 was 2,334 t. Catches declined steeply from 1980 to 1984, and have been fairly stable since 1984 at approximately 2,000 t annually. This annual yield is considerably less than the 3,738 t average annual catch over the 24-year period from 1956 to 1979. The annual ex-vessel value of English sole landings averaged $1.71 million from 1988 to 1990.

ENGLISH SOLE
Pacific Coast
COMMERCIAL CATCH
(1,000 t)

Year	Catch
1980	3.3
1981	2.7
1982	2.8
1983	2.3
1984	1.7
1985	1.9
1986	2.0
1987	2.5
1988	2.1
1989	2.4
1990	1.9

Analyses of the English sole population dynamics (virtual population analysis) conducted in 1984 and 1985 for the northern and southern components of the stock indicated that a series of years with weak recruitments was responsible for the recent downward trend in catches. Periods of strong and weak recruitment have occurred in the past and appear to be related to shifts in oceanographic conditions. Results of the triennial west coast trawl surveys suggest that English sole biomass increased from 1980 to 1983 and then remained stable from 1983 to 1989. Abundance indices from these surveys should follow trends in stock abundance because the surveys cover a significant portion of the depth range of English sole and virtually all of its latitudinal range.

This chapter was written by Martin Dorn.

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ENGLISH SOLE
Pacific Coast

Average commercial catch (1980-90)	=	2,334 t
Long-term potential yield (MSY)	=	Unknown
Acceptable biological catch (1990)	=	1,900 t
Importance of recreational fishery	=	Minor
Management	=	Groundfish FMP, Mesh size regulation
Status of exploitation	=	Fully exploited
Age at 50% recruitment	=	Unknown (males) 4.1 years (females)
Length at 50% maturity	=	22 cm (males) 31 cm (females)
Assessment approach	=	Virtual population analysis
Fishing strategy	=	Not available
F (1990)	=	Unknown

16. PETRALE SOLE

Petrale sole ***(Eopsetta jordani)*** is distributed from northern Baja California to the Gulf of Alaska and the Bering Sea. Petrale sole are found in commercial abundance in water depths less than 100 fathoms, but the species can be found in depths up to 300 fathoms. Spawning takes place in late winter and early spring. Spawning has been documented in Esteban Deep off central Vancouver Island and Willapa Deep off southern Washington. Recruitment is highly variable and dependent on oceanographic conditions. Prey include euphausiids, sand lance, herring, and shrimp, as well as other bottom fish.

Maximum age exceeds 20 years for both males and females. Natural mortality is estimated to be in the range of 0.16-0.20. Maximum size is about 70 cm.

Petrale sole are caught commercially by bottom trawls. Coastwide catch increased from 2,050 t to 2,630 t in 1982, decreased to about 1,750 t from 1984 to 1987, and increased to 2,140 t in 1990. The mean catch from 1980 to 1990 was 2,044 t. About 50% of the catch comes from the Columbia INPFC area (from Cape Blanco, Oregon) north to 47°30'N latitude (near Cape Elizabeth) off central Washington. In this area, the mean catch from 1980 to 1990 was 1,000 t. Catch has remained fairly stable since 1956 and is currently near the historical mean catch of 900 t (from 1956 to 1979).

The most recent stock assessment of petrale sole was in 1987 for the Columbia INPFC area only. The 1990 ABCs for the total U.S. west coast and the Columbia INPFC area are 3,200 t and 1,100 t, respectively. Exploitable biomass in 1986 was estimated to be 2,611 t and F = 0.46.

Based on the results of triennial west coast trawl surveys, coastwide biomass of petrale sole declined from 1980 to 1983 and increased from 1986 to 1989.

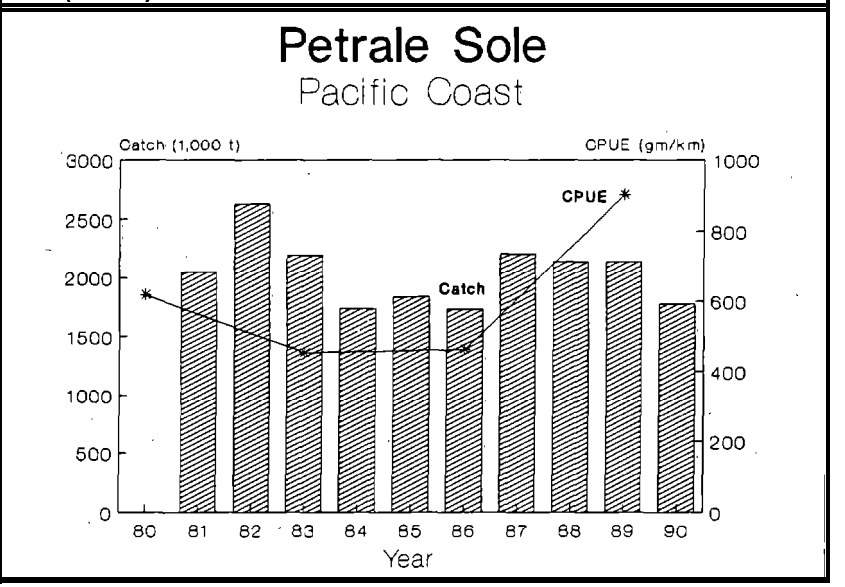
This chapter was written by Jack Tumock.

PETRALE SOLE

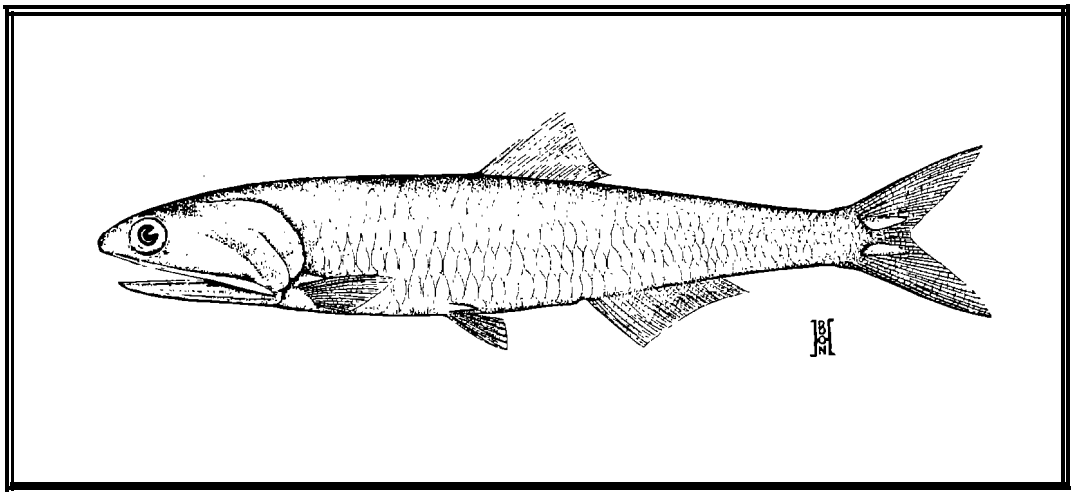
Average commercial catch (1980-90)	=	1,000 t
Long-term potential yield (MSY)	=	Unknown
Acceptable biological catch (1990)	=	1,100 t
Importance of recreational fishery	=	Minor
Management	=	Groundfish FMP
Status of exploitation	=	Fully exploited
Age at 50% recruitment	=	4.5 years (females) 4.5 years (males)
Length at 50% maturity	=	40 cm (females) 36 cm (males)
Assessment approach	=	Abundance trend
Fishing strategy	=	$F_{35\%}$ = unknown
F (1990)	=	unknown

PETRALE SOLE
Pacific Coast
COMMERCIAL LANDINGS
(1,000 t)

YEAR	Landings
1980	2.05
1981	2.63
1982	2.19
1983	1.74
1984	1.84
1985	1.73
1986	2.20
1987	2.14
1988	2.14
1989	1.76
1990	1.78



17. NORTHERN ANCHOVY



Northem anchovy *(Engrauliss mordax)* 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 stock, which supports U.S. fisheries, ranges from approximately San Francisco, California (38% latitude),. to Punta Baja, Baja California (30% latitude).

Northern anchovies are small, short-lived planktivorous fish typically found in schools near the surface in waters that range from 12° to 21.5°C. They rarely exceed 4 years of age and 18 cm total length.

Northern anchovy spawn throughout the year but spawning increases during late winter and early spring and peaks during February to April. Both eggs and larvae are found near the surface. Northern anchovy are all sexually mature at age 2. The percentage of 1-year-olds that are sexually mature in a given year depends on water temperature. Substantial numbers of zero and l-year-old northern anchovies are taken by both the reduction and nonreduction fisheries.

The central stock of northern anchovy has been exploited by fisheries in both California and Mexico. Anchovy landed by the reduction fishery are converted to meal, oil, and soluble protein products. Anchovy harvested by the live-bait fishery are not landed but kept alive for sale to anglers as bait and chum. Anchovy landed by the nonreduction (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.

Anchovy landed for reduction increased from 155 t in 1965 to 25,000 t in 1966. Landings ranged from 13,000 to 84,000 t per year during 1966-72. Landings increased to 118,000 t in 1973 and ranged from 73,000 to 142,000 t per year during 1973-77. In response to decreases in fish meal prices, landings declined to an annual average of 39,000 t during 1978-82. Reduction landings have been extremely low since 1983, largely as a result of low prices paid to fishermen.

The average price for anchovy landed by the reduction fishery during the period from 1974 to 1988 was about $63 per t (1989 dollars are used in this report), while the price paid during 1989 was only $36 per t. Revenues (landings in t times dollars per t paid to fishermen) during 1989 were only $3,900. During the last year in which reduction landings exceeded 50,000 t, reduction processors paid $82 per t.

The live-bait fishery takes a variety of species but anchovies comprise about 85% of the catch. From 1981 to 1990, the anchovy live bait catch ranged from 3,600 to 7,000 t per year and averaged 4,500 t annually. The price paid to fishermen for anchovy landed as live bait has been about $709

per t. On this basis, revenues in the live-bait fishery during 1989 were about $3.4 million.

Nonreduction (other than for live bait) landings averaged about 1,400 t per year from 1981 to 1990. From 1980 to 1988, the ex-vessel price of anchovy landed for nonreduction purposes other than live bait averaged about $300 per t. Revenues during 1989 (assuming $304 per t, 1988 value) were about $0.70 million.

Anchovy landed in Mexico are used primarily for reduction, although a small amount are used as bait. Mexican landings reached a high of 259,000 t in 1981, fell to 178,000 t in 1982, and have ranged between 79,000 and 124,000 t per year since 1983. Mexican landings surpassed California landings in every year from 1977 to 1989 and comprised more than 90% of total landings from 1983 to 1989. In 1990, however, Mexican landings comprised only 1% of total landings.

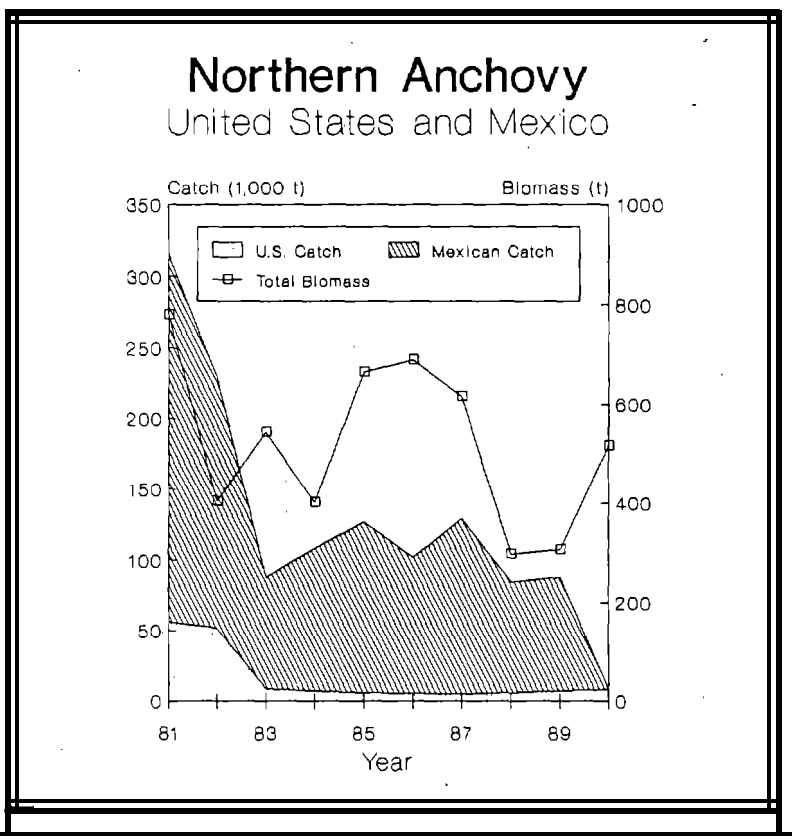
Northern anchovy fisheries have been managed by the PFMC since 1978. Current regulations impose no numeric limit on live-bait catch and provide a 7,000 t quota for other nonreduction uses. The regulations also specify optimum yield for the reduction fishery as 1) zero when the spawning biomass is less than or equal to a cutoff level of 350,000 t and 2) the difference between the spawning biomass and the cutoff, up to a limit of 200,000 t, when the spawning biomass is greater than 300,000 t. In the absence of a bilateral agreement, 70% of optimum yield is allocated to U.S. fisheries so that, for example, 0.7 x 7,000 = 4,900 t is allocated each year for the U.S. nonreduction (other than live bait) fishery.

The biological rationale for the 300,000 t threshold in the optimum yield formula for reduction fishing is to prevent depletion of the resource and to provide an adequate forage reserve for marine fish, mammals, and birds. The well-being of ecologically dependent species, especially the endangered brown pelican, which feeds on northern anchovy, is an important issue in the management of anchovy fisheries.

As a final safeguard against stock depletion, the management plan for northern anchovy defines overfishing as harvests of any kind when the spawning biomass during the current and preceding season falls below 50,000 t. All fisheries (reduction, live bait, and other nonreduction) are closed in the second season if the spawning biomass falls below 50,000 t for two consecutive seasons and the closure continues in subsequent seasons until the spawning biomass equals or exceeds 50,000 t.

Although the central subpopulation of northern anchovy is a transboundary stock harvested by fisheries in Mexican as well as U.S. waters, there is no bilateral management agreement with Mexico. In the absence of such an agreement, fishery managers in the United States assume that U.S. fishermen are entitled to 70% of the total optimal yield and set quotas on this basis.

Biomass of northern anchovy in the central subpopulation averaged 400,000 t from 1984 to 1970, increased rapidly to 1.8 million t in 1974, and then declined to 490,000 t in 1978. Since 1978, biomass levels have tended to decline slowly. Northern anchovy biomass during 1989 was 307,000 t. Although there is little evidence to support this hypothesis, the recent decline in anchovy



abundance may be due to warm water conditions that have prevailed since the mid-1970s. Maximum sustained yield of northern anchovy in the central stock (without making allowances for feeding by some ecologically dependent species and ignoring variation in environmental factors that cause changes in abundance) is estimated to be about 219,000 t per year at a total biomass level of about 586,000 t implying an optimal exploitation rate of about 37%. Exploitation rates exceeded 37% three times (1980-82) during the history of the fishery.

Although total anchovy harvests and exploitation rates since 1983 have been less than both the theoretical level for MSY and historical levels prior to 1983, abundance continues to decline slowly. Annual harvests and exploitation rates in the near future are expected to be lower because the Mexican reduction fishery has reportedly become unprofitable and is expected to cease operations.

NORTHERN ANCHOVY
Pacific Coast
CATCH (t)

YEAR	U.S.	MEXICO	TOTAL
1981	56,234	258,700	314,934
1982	51,837	177,587	229,424
1983	8,487	79,389	87,876
1984	7,302	101,118	108,420
1985	5,784	121,081	126,865
1986	5,504	96,417	101,921
1987	4,875	124,475	129,350
1988	5,656	79,230	84,886
1989	7,044	80,823	87,867
1990	8,050	99	8,149

This chapter was written by Larry D. Jacobson.

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NORTHERN ANCHOVY
Pacific Coast

Average catch (1981-90):	U.S.	= 16,000 t
	Mexico	= 112,000 t
	Total	= 128,000 t
Long-term potential catch (MSY)		= 219,000 t
Optimum yield in 1990:	U.S. reduction	= 116,000 t
	U.S. nonreduction	= 5,900 t
	U.S. live bait	= unrestricted
	U.S. total	= 121,000 t
	Mexico reduction	= 50,000 t
	Total	= 166,000 t
Importance of recreational fishery		= Significant (bait)
Management		= Pacific northern anchovy FMP
Status of exploitation		= Low 1990, Moderate 1989
Age at recruitment		= 0-1 years
Age at maturity		= 1-2 years
Assessment approach		= Stock synthesis model
Management strategy		= Optimum yield formula based on annual spawning biomass estimate
F (1990)		= < 0.05

18. JACK MACKEREL

The jack mackerel (Trachurus ***symmetricus)*** is a member of the family Carangidae (the jacks) and is similar to several other species of ***Trachurus*** (horse mackerel) that occur in temperate eastern boundary currents worldwide. Spawning occurs from central Baja California to British Columbia, moving northward from spring through late summer. Juveniles appear in the Southern California Bight, which serves as a nursery ground for several years. Older fish move offshore and northward and may be found hundreds of miles from shore (well beyond the U.S. EEZ), especially in the Pacific Northwest. Individual jack mackerel -found in offshore waters may exceed 30 years of age. Most female jack mackerel in the Southern California Bight attain reproductive maturity as 1-year-olds.

The southern California segment of the stock has been fished since the late 1940s when jack mackerel served as a substitute target for the failing sardine fishery. The southern California purse seine fishery has continued at a low level since then. Jack mackerel and Pacific mackerel ***(Scomber japonicus,*** elsewhere known as chub mackerel) are not distinguished on landings receipts and are considered to be commercially equivalent. However, jack mackerel is slightly less favored by purse seine fishermen due to its tendency to occur farther from port and over rocky bottoms where there is increased risk of damage to nets. The southern California fishery is not presently managed under the MFCMA, and there is no limit on allowable catch.

The large adults, which occur offshore, are sometimes taken incidentally in trawls, particularly when Pacific whiting are targeted. During the 1970s, foreign trawl fisheries may have caught 1000-2,000 t annually, but catches by foreign and joint venture fishermen in the 1980s have ranged from zero to about 100 t. Because of the foreign trawl fisheries of the 197Os, management of jack mackerel was placed in the groundfish FMP of the PFMC. An annual incidental catch of 12,000 t (north of 39% latitude) has been used to account for the incidental harvest while avoiding constraints on fishing for other groundfish species, particularly Pacific whiting. In 1991 there was increased interest by foreign, joint venture, and domestic industries, and the ABC was raised to 52,600 t to allow development of a fishery. That fishery failed to materialize, but signs of interest continue.

The PFMC is in the process of transferring management of jack mackerel from the groundfish FMP to a new Pelagics FMP. This will have the advantage of treating both the southern California and the offshore segments of the resource under the same management plan.

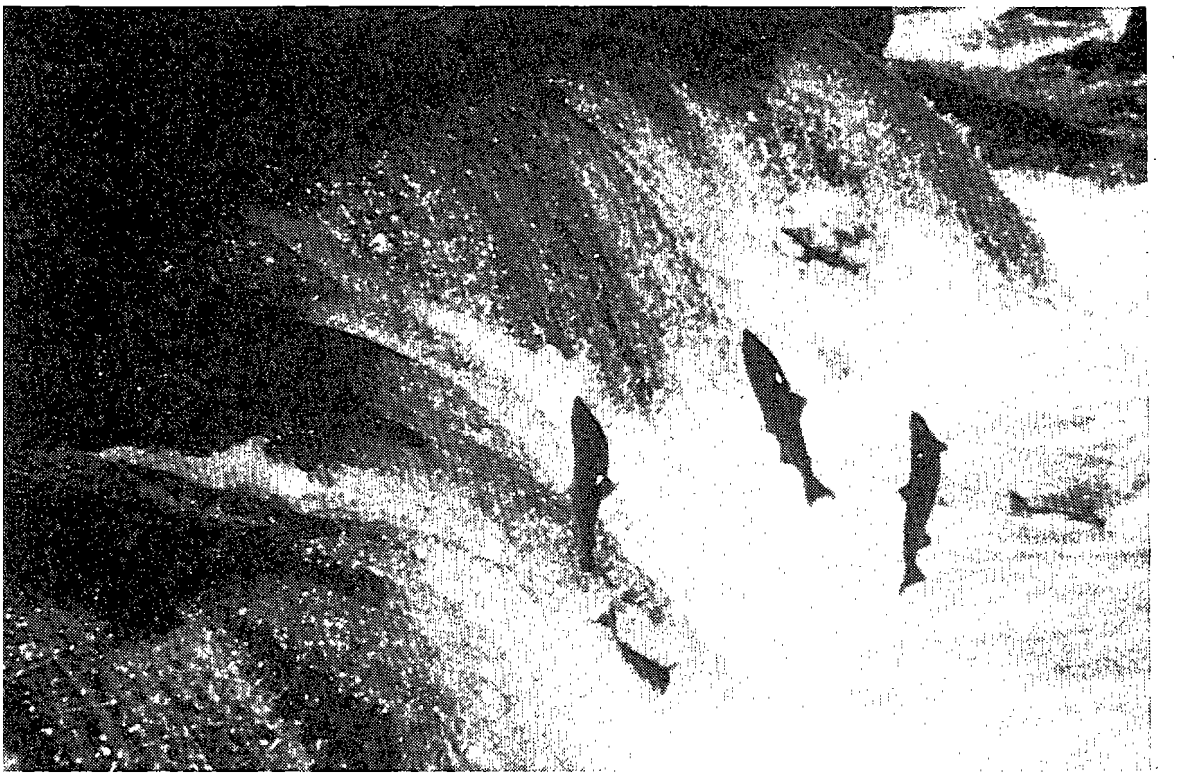
Stock size is thought to be 1.5 million t, and potential yield is unknown. Development of more reliable estimates of stock size and potential yield awaits collection of additional information on age structure and reproductive biology, which could be used to help interpret existing CalCOFI egg and larval survey data. The extensive geographic distribution and heterogeneous structure of the source may make management and assessment of the resource difficult. Trawl, ichthyoplankton, or hydroacoustic surveys for a jack mackerel population assessment would be too large in geographic scope and too expensive to conduct regularly. Much of the necessary information will have to be obtained from the fishery, including catch rates and samples of fish for demographic and physiological analysis.

This chapter was written by Alec D. MacCall.

JACK MACKEREL
Pacific Coast

Average catch (1981-89)	= 14,200 t
Long-term potential yield (MSY)	= 100,000 t
Acceptable biological catch (1991)	= 52,600 t
Importance of recreational fishery	= Minor
Management	= Groundfish FMP
Status of exploitation	= Light
Age at 50% recruitment (off shore)	= 15 years
S. California	= 1 year
Age at 50% maturity	= 1 year
Assessment approach	= Ichthyoplankton
Fishing strategy	= Incidental catch not managed
F (1990)	= 0.01

PACIFIC COAST SALMON



T his section describes the Pacific salmon stocks and fisheries of Washington, Oregon, and California. The species are pink *(Oncorynchus gorbuscha),* sockeye *(0. nerka),* chum *(0. keta),* coho *(0. kisutch),* and chinook (0. tshawytscha) salmon. The major fishery components are the commercial and recreational fisheries located in Puget Sound, in certain Washington coastal rivers, in the Columbia River, in the Klamath River of California, and in the ocean fisheries off all three states. These fisheries have been in existence since the late 1800s and are a continuation of fisheries conducted by Indian fishermen. The pink, sockeye, and chum salmon catches occur primarily in Washington.

Pacific salmon are anadromous. They spawn in streams or lakes and migrate to the ocean where they may travel into international waters. Upon reaching maturity, they return to their home stream to spawn and complete their life cycle.

Management of this resource is complex. Some stocks are affected by management actions of the Pacific Salmon Commission (PSC), state fishery agencies, Indian management entities, and the PFMC. North-migrating stocks are also impacted signiticantly by fisheries off Canada and Southeast Alaska. Two species (chinook and coho salmon) are managed by the PMPC's Pacific salmon FMP. The other three species (sockeye, pink, and chum salmon) are not.

Salmon catches and prices fluctuate considerably from year to year, due principally to variations in survival rates and production. Recently, the combined commercial landings of all five salmon species have had annual ex-vessel values of about $140 million with an average weight of about 36,197 t (80 million lbs). It is much more difficult to place a value on the recreational fishery. Some sport-caught salmon have been valued as high as $295 per fish. Nevertheless, it is clear that the average recreational catch for the past 3 years, 1.2 million salmon, is worth many millions of dollars.

In 1990, there were 4,550 commercial ocean troll boats licensed to fish off California, Oregon, and Washington. In the ocean recreational fishery, about 600 charter boat licenses were sold and there were about 657,000 angler trips or days.

There is more fishing gear than is required to adequately harvest the Pacific salmon resources and

Pacific Coast Salmon Resources

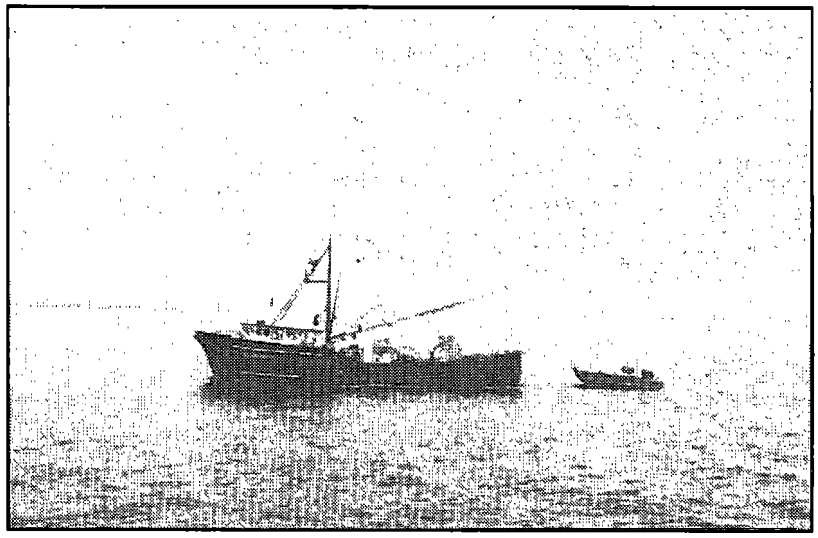
Sockeye Salmon		
Average catch (1960-90)	=	1,654,000 fish
Average catch (1988-90)	=	2,839,000 fish
Long term potential yield	=	2,839,000 fish
Importance of recreational fishery	=	minor
Status of Exploitation	=	fully exploited; over-utilized
Fishing strategy	=	meet spawning escapment goals and treaty obligations
Pink Salmon		
Average catch (1961-89)	=	2,917,000 fish
Average catch (1985-89)	=	3,496,000 fish
Long term potential yield	=	3,496,000 fish
Importance of recreational fishery	=	minor
Status of Exploitation	=	fully exploited; over-utilized
Fishing strategy	=	meet spawning escapment goals and treaty obligations
Chum Salmon		
Average catch (1960-90)	=	617,000 fish
Average catch (1988-90)	=	1,017,000 fish
Long term potential yield	=	1,017,000 fish
Importance of recreational fishery	=	minor
Status of Exploitation	=	fully exploited; over-utilized
Fishing strategy	=	meet spawning escapment goals and treaty obligations
Chinook Salmon		
Average catch (1960-90)	=	1,979,000 fish
Average catch (1988-90)	=	2,274,000 fish
Long term potential yield	=	2,274,000 fish*
Importance of recreational fishery	=	About 20% of the total catch
Status of Exploitation	=	fully exploited; over-utilized
Fishing strategy	=	meet spawning escapment goals and treaty obligations
Coho Salmon		
Average catch (1960-90)	=	3,231,000 fish
Average catch (1988-90)	=	2,693,000 fish
Long term potential yield	=	3,231,000 fish
Importance of recreational fishery	=	About 25-30% of total catch
Status of Exploitation	=	fully exploited; over-utilized
Fishing strategy	=	meet spawning escapment goals and treaty obligations

* Long-term goals for some stocks have been stated as doubling of production primarily through significant improvements of freshwater habitat. If this is achieved, it would increase the long term potential dramatically.

severe limitations on fishing are required to protect the stocks, Thus, all five Pacific salmon species are listed as over-utilized.

Changes in the freshwater environment have had devastating effects on the survival of salmon stocks. The large number of dams, particularly on the Columbia River, is one very visible factor. Dame that are completely impassable have eliminated large spawning areas. Dams that are passable to salmon still take their toll on returning adults. Also, conditions at dams cause significant losses of downstream migrating young salmon through delayed migrations and mortality from passing through the turbines. The lack of adequate water for fish passage has also been a problem. Improvement of the freshwater habitat and reduced mortality are needed to restore stocks.

This section and the following chapters on Pacific salmon were written by Kenneth A. Henry.



ALL FIVE **SALMON** SPECIES
Pacific Coast
COMMERCIAL AND RECREATIONAL
(Catch in 1,000's of fish)

Year	Comm	Rec	Total
1980	5,304	1,304	6,608
1981	9,237	1,104	10,341
1982	7,486	1,144	8,630
1983	5,069	1,124	6,193
1984	4,676	854	5,530
1985	11,199	1,131	12,330
1986	9,055	1,299	10,354
1987	10,462	1,319	11,781
1988	7,123	1,287	8,410
1989	10,771	1,247	12,018
1990	5,903	1,081	6,984
Average			
1960-90	7,537	1,362	8,900
1988-90	7,932	1,205	9,137

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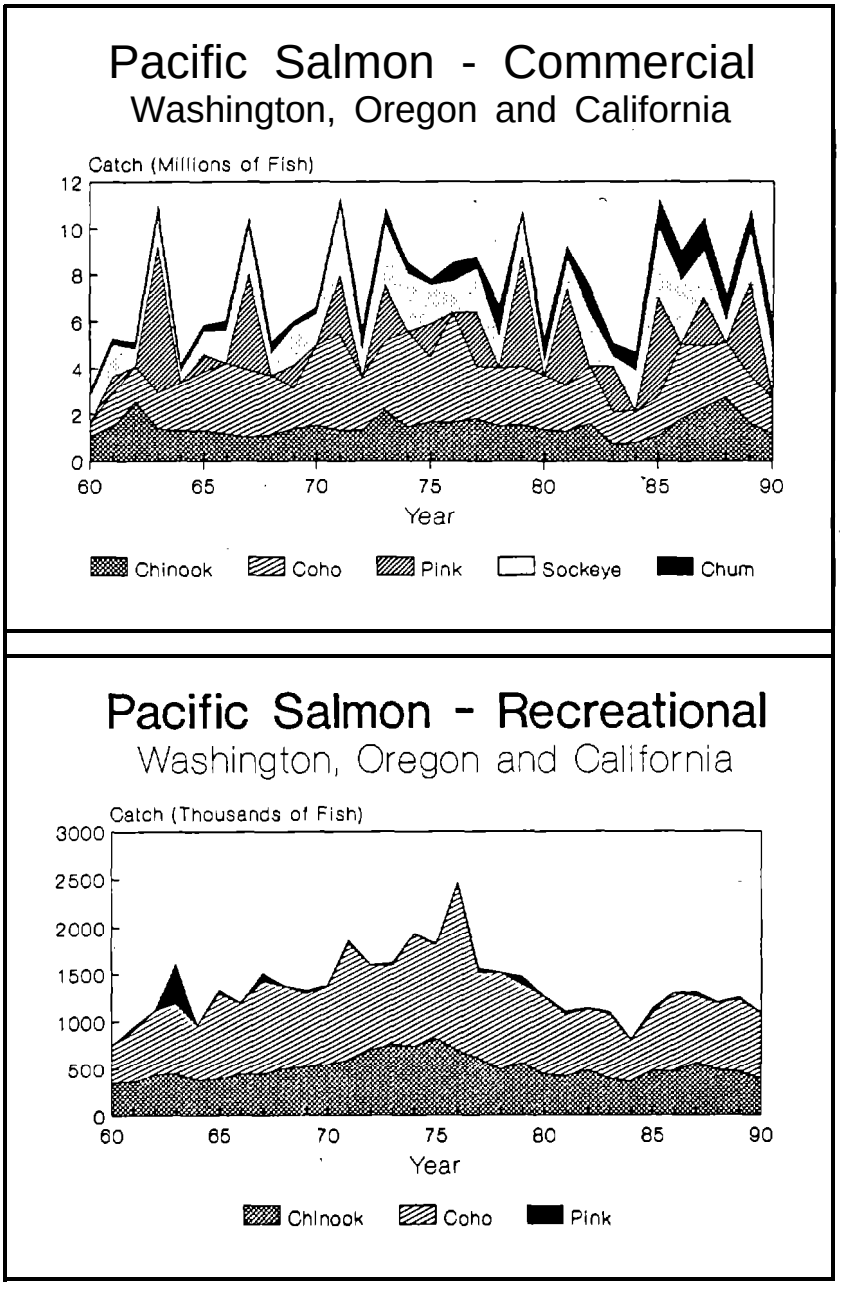
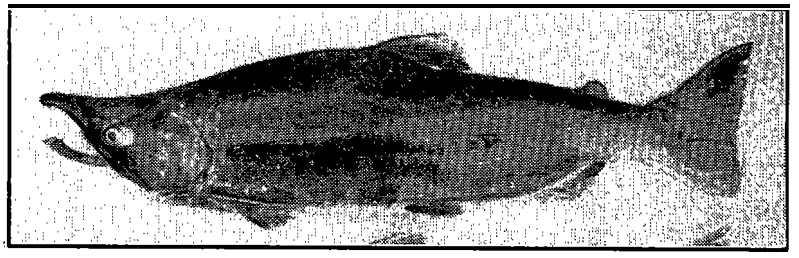


19. SOCKEYE SALMON

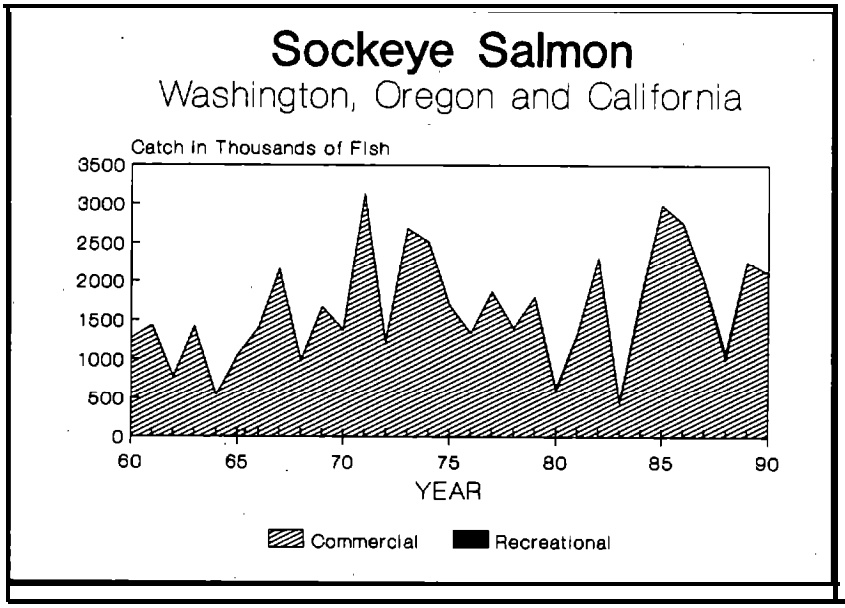
Sockeye salmon from Washington, Oregon, and California originate primarily from a few streams entering Puget Sound and the upper Columbia and Snake Rivers. Female sockeye salmon generally spawn from 3,000 to 4,000 eggs. The young fish typically migrate to the ocean after 1 or 2 years rearing in freshwater lakes. They normally mature after 2 or 3 years in the Ocean and weigh from 1.8 to 3.6 kg (4 to 8 lb), although Columbia River sockeye salmon are generally under 1.8 kg (4 lb). Most return to their spawning grounds as 4- or 5-year-old fish and are slightly less than 1 m long.



Most of the sockeye salmon are caught by net gear (gill net, purse seine, and reef net), although the troll fishery also catches a sizeable number. In Seattle, there is a popular recreational fishery for sockeye on Lake Washington whenever the escapement exceeds spawning requirements. However, this has occurred only six times since 1978. Most of the sockeye salmon caught by Washington fishermen are of Canadian origin returning primarily to the Fraser River.

The total Washington-Oregon sockeye salmon catch has averaged 1.7 million fish from 1960 to 1990 and annually averaged 1.8 million fish from 1988 to 1990. The recreational catch is a very small proportion of this total, averaging considerably less than 50,000 sockeye salmon annually. Most of the sockeye salmon are produced naturally. -Although Fraser River sockeye salmon runs have been at high levels of abundance in recent years, the number of fish that U.S. fishermen can harvest is limited under terms of the new U.S.-Canada Salmon Treaty. Signed in 1985, this treaty covers the salmon fisheries from Southeast Alaska to northem Oregon.

There is considerable concern about the status of the Snake River sockeye salmon. In April 1991, this stock was recommended for listing as endangered under the Endangered Species Act. In 1988, there were only four adults and two redds (nests) reported in the spawning escapement; in 1989, one adult, one redd, and a second potential redd were observed; in 1990, no adults or redds were identified.

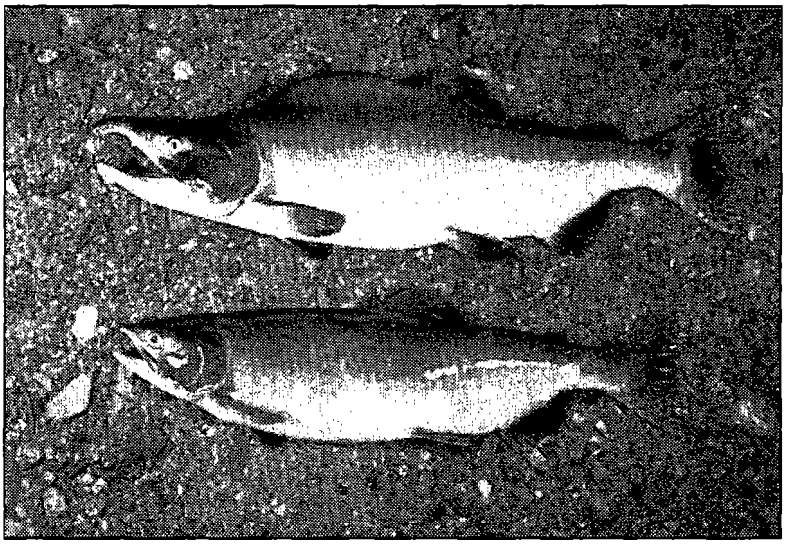


SOCKEYE SALMON
Pacific Coast
COMMERCIAL AND
RECREATIONAL CATCH
(in 1,000's of fish)

Year	Comm	Rec	Total
1980	556	43	599
1981	1,327	0	1,327
1982	2,284	12	2,296
1983	402	28	430
1984	1,713	45	1,758
1985	2,993	1	2,994
1986	2,756	1	2,757
1987	2,005	5	2,010
1988	900	95	995
1989	2,261	0	2,261
1990	2,109	0	2,109
Average			
60-90	1,646	7	1,654
88-90	1,757	31	1,788

20. PINK SALMON

Pink salmon stocks for these three states originate primarily from tributaries of Puget Sound. Females usually bear 1,500 to 1,900 eggs. The fry migrate to salt water shortly after emerging from the gravel. They mature at age 2 weighing from 1.4 to 2.7 kg (3 to 6 lb); although fish up to 4.5 kg (10 lb) have been recorded. In some areas, pink salmon return every year (both odd-year and even-year cycles); the majority of Puget Sound pink salmon return on odd-years.



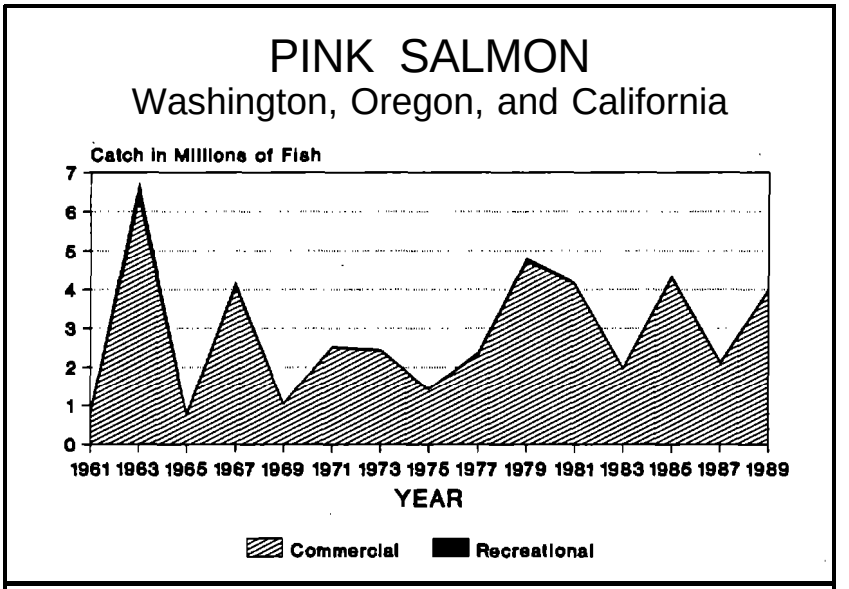
Most of the pink salmon are caught by net gear in Puget Sound; however, trollers have become considerably more proficient in catching pink salmon in recent years. Most of- the pink salmon caught by Washington fisheries are of Canadian origin returning to the Fraser River, although Washington origin pink salmon do contribute significantly to the catch in some years.

The 1961-89 commercial catch (odd years only) averaged 2.9 million pink salmon annually whereas the annual average for 1985-89 was 3.5 million pink salmon. The sport catch over the same two time periods averaged 76,000 and 46,000 pink salmon, respectively. Most of the pink salmon caught are from natural production. Hers again, although Fraser River pink salmon stocks are at a high level of abundance, the U.S. catch has been restrained in recent years under terms of the' U.S.-Canada Salmon Treaty.

The abundance of U.S. pink salmon stocks fluctuates considerably due to varying survival rates, but the stocks appear to be in good condition,

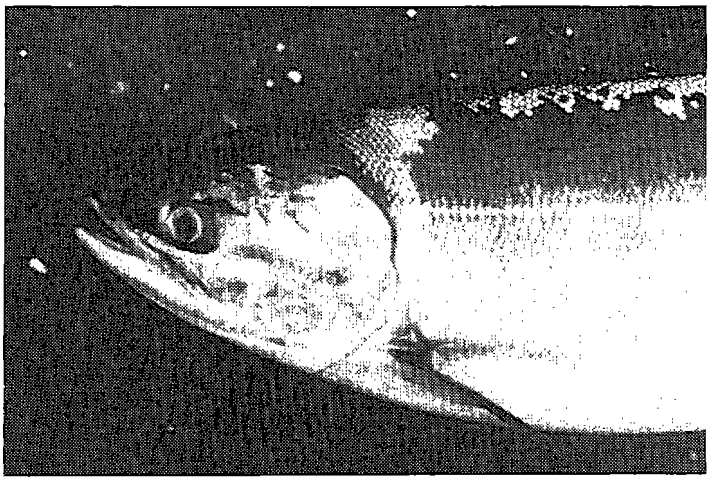
PINK SALMON
Pacific Coast
COMMERCIAL AND
RECREATIONAL CATCH
(in 1,000's of fish)

Year	Comm	Rec	Total
1971	2,499	40	2,539
1973	2,419	29	2,448
1975	1,408	23	1,431
1977	2,322	60	2,382
1979	4,708	103	4,811
1981	4,136	41	4,177
1983	1,953	21	1,974
1985	4,284	63	4,347
1987	2,088	52	2,140
1989	3,977	23	4,000
Average			
61-89	2,844	73	2,917
85-89	3,450	46	3,496



21 . CHUM SALMON

The distribution of significant stocks of chum salmon extends from northern Oregon, northward around the Pacific Rim to the U.S.S.R. and Japan. Japan currently produces large numbers of chum salmon in hatcheries. In the Pacific Northwest, the major chum salmon returns are primarily to Puget Sound tributaries Some important chum salmon stocks exist in streams part way down to the Oregon coast, but they are generally at the southernmost end of their range.



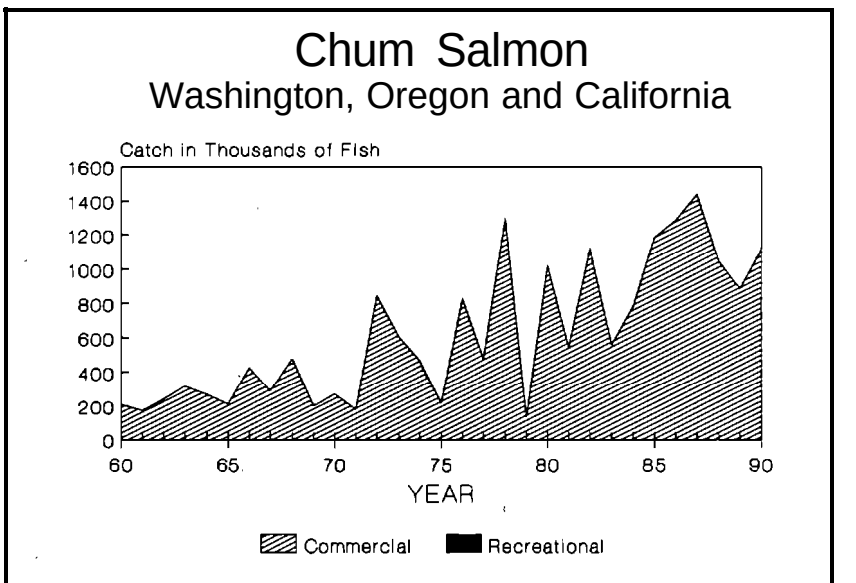
Although chum salmon generally spawn in the lower few miles of the various tributaries, they do migrate hundreds of miles upstream to spawn in large river systems, such as the Yukon River in Alaska. Females spawn up to 2,700 eggs,' and, as with pink salmon, the fry go to salt water shortly after hatching. They remain in the ocean from 2 to 4 years and then return to fresh water to spawn, weighing from 3.2 to 8.2 kg (7 to 18 lb), although some as large as 9 kg (20 lb) have been reported. Most chum salmon returning to Washington and Oregon are 3 and 4 years old. Significant numbers of 5-year-old chum salmon do return to streams in northern British Columbia and Alaska.

Most chum salmon are caught in net gear. A portion of the catch is from Canadian stocks. From 1960 to 1990, catches averaged 617,000 chum salmon annually and from 1988 to 1990, averaged above 1 million chum salmon. Artificial propagation has been increasing, but the bulk of the production is' from natural spawners. The recreational catch is very small.

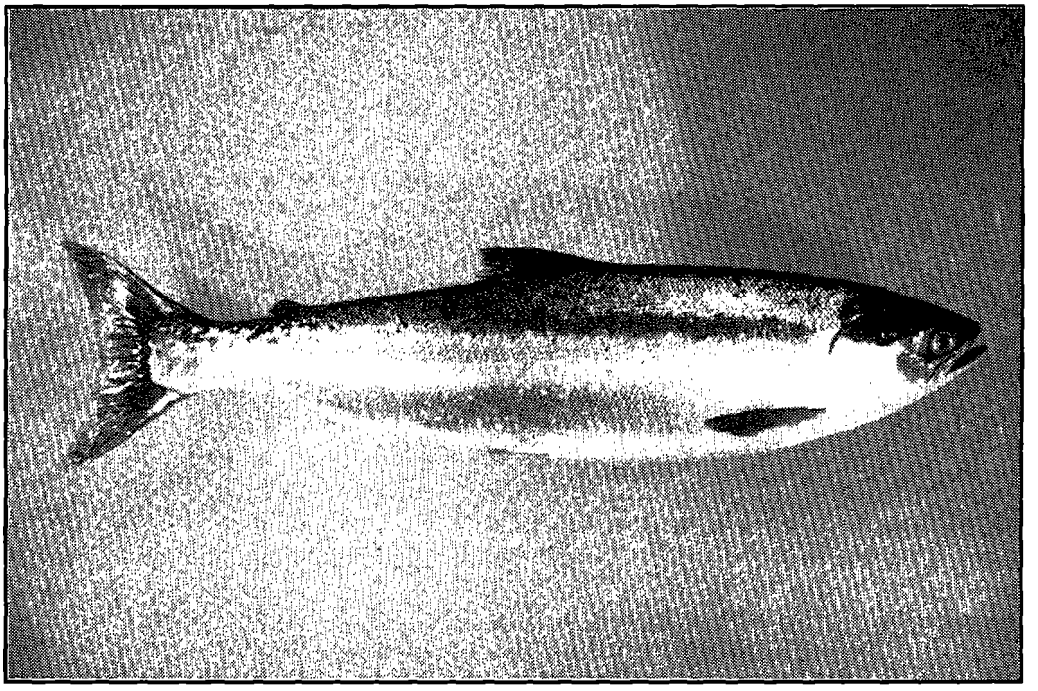
U.S. chum salmon stocks fluctuate due to varying ocean survival, but they appear to be in fairly good condition.

CHUM SALMON
Pacific Coast
COMMERCIAL AND
RECREATIONAL CATCH
(in 1,000's of fish)

Year	Comm	Rec	Total
1980	1,018	2	1,020
1981	542	2	544
1982	1,121	1	1,122
1983	557	1	558
1984	779	1	780
1985	1,185	1	1,186
1986	1,283	2	1,285
1987	1,432	4	1,436
1988	1,048	0	1,048
1989	888	0	888
1990	1,115	0	1,115
Average			
60-90			617
89-90			1,017



22. CHINOOK SALMON



Chinook salmon spawn in streams from Puget Sound, Washington, to San Francisco, California, usually in larger tributaries, with the Columbia River system being a major producer. Other important producers of chinook salmon are Puget Sound, the Umpqua and Rogue Rivers in Oregon, and the Klamath and Sacramento Rivers in California. Chinook salmon stocks are labelled as spring, summer, fall, or winter depending on their time of migration out of the ocean.

Females deposit from 3,000 to 14,000 eggs. Some young fish migrate to the ocean shortly after emergence from the gravel while others over-winter in fresh water before going to salt water. They spend from 2 to 5 years in the ocean before returning to fresh water to spawn and start the cycle again. Chinooks are the largest salmon with some adults weighing over 22.7 kg (50 lb) and reaching about 1.5 m (5 ft) in length. Most weigh from 7.7 to 22.7 kg (17 to 50 lb) at maturity. Some chinook salmon undertake long freshwater migrations to reach their home stream, particularly to the' upper areas of the Columbia and Snake Rivers.

For the period 1960-90, commercial landings of chinook salmon, both natural and hatchery produced, have averaged 1.5 million fish, while recreational landings averaged 505,000 fish. The ocean chinook salmon catch north of Cape Falcon, Oregon, has been limited by annual catch quotas. Chinook salmon produced in hatcheries are contributing a significant share to these catches.

The NMFS has proposed to list spring-summer and fall chinook salmon runs in the Snake River as threatened under the Endangered Species Act. Escapements for these stocks in recent years have been considerably reduced.

For upriver spring chinook salmon, the goals of 115,000 escaping above Bonneville Dam and 35,000 spring chinook salmon escaping above Lower Granite Dam have not been met since 1978.

For upriver summer chinook salmon, the goal of 80,000-90,000 escaping above Bonneville Dam has not been met since before 1971. Also, the decreasing escapement of these fish above Lower Granite Dam is quite dramatic.

Snake River dam counts (Lower Granite and Ice Harbor Dams) indicate that Snake River fall chinook salmon are also at a very low level of abundance. Coded-wire tags of Lyon's Ferry Hatchery chinook salmon indicate that interdam mortality is **about** 28-42% and that overall harvest is about 74%.

In reviewing the status of Columbia River chinook salmon stocks, it is enlightening to examine the history of commercial salmon landings, where data since 1866 are available. Whereas the early landings were entirely from natural spawning stocks, in recent years, a large share of the landings has been from hatchery-produced fish. The number of chinook salmon landed peaked in 1883 at over 2.3 million. Landings decreased to a low of only 58,000 chinook salmon in 1983 (an El Niño year). Although some of this decline in in-river catch can be attributed to increased landings from the ocean fisheries, the depressed condition of these stocks is apparent from drastic reductions in spawning escapements.

Under the Columbia River Basin Fish and Wildlife-Program, plans have been proposed to double production of certain chinook salmon stocks. If these plans are successful, catches of chinook salmon could increase significantly.

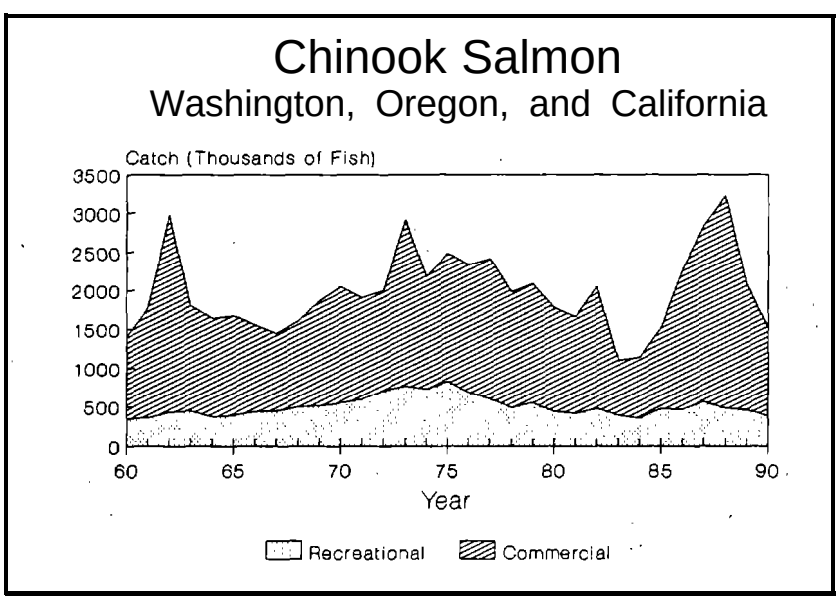
In 1990, the Sacramento River winter-run chinook salmon was listed as threatened under the Endangered Species Act. This stock is in trouble, decreasing from an annual escapement of 35,800 fish in 1971 to only 550 in 1990. When a species is listed as endangered, it could- have very severe ramifications not only to salmon management, but to a variety of other agencies associated- with the production of salmon.

Other chinook salmon stocks also are seriously depressed. In California, Shasta River chinook salmon (Klamath River system) spawning escapements declined from a peak of 61,800 adults in 1931 to only 415 in 1990. Also, total Klamath River chinook salmon abundance declined following record production in 1988, resulting from a high brood year survival rate, to very low production in 1990 and 1991. In Washington, a number of chinook salmon stocks in Puget Sound have not met escapement goals on a continuing basis in recent years. These stocks include Skagit River spring chinook salmon, Stillaguamish River summer-fall chinook salmon, and Snohomish River summer-fall chinook salmon.

For all other chinook salmon stocks from California to Washington, while experiencing annual changes in abundance from varying survival rates, none of the major stocks appear to be in a continuing depressed condition.

CHINOOK SALMON
Pacific Coast
COMMERCIAL AND
RECREATIONAL CATCH
(in 1,000's of fish)

Year	Comm	Rec	Total
1980	1,343	440	1,783
1981	1,247	415	1,662
1982	1,576	479	2,055
1983	712	391	1,103
1984	783	359	1,142
1985	1,044	471	1,515
1986	1,808	464	2,272
1987	2,280	563	2,843
1988	2,736	483	3,219
1989	1,625	466	2,091
1990	1,131	381	1,512
Average			
60-90	1,473	466	2,091
88-90	1,131	381	1,512



23. COHO SALMON

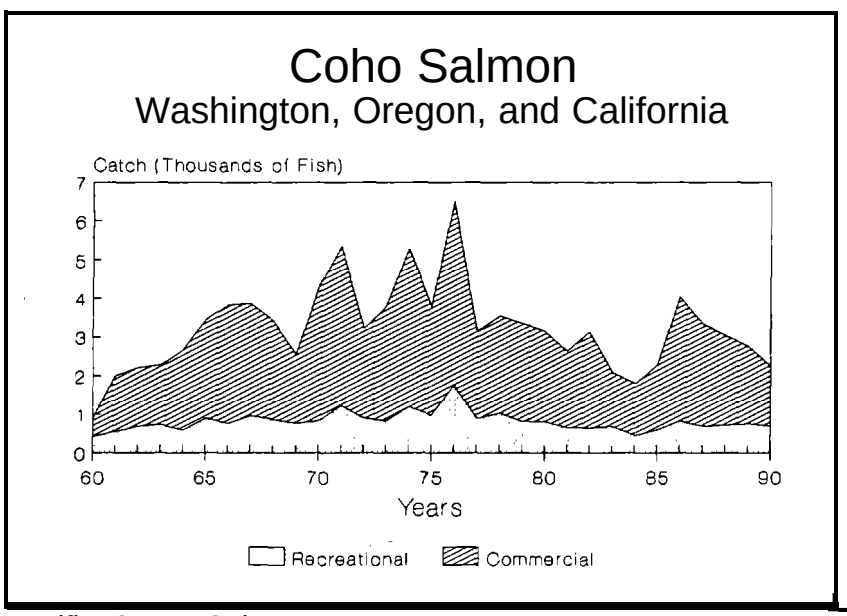
Coho salmon produce from 2,400 to 4,500 eggs. After hatching, the fry usually spend their first year in fresh water before migrating to the ocean. Coho salmon typically spend 1 year in the ocean before returning as adults to their home stream to spawn. They weigh from 2.7 to 5.4 kg (6 to 12 lb) and reach a length of slightly under 1 m (3 ft) at maturity although weights over 11.8 kg (26 lb) have been recorded.

For the period 1960-90, commercial landings of natural and hatchery-produced coho salmon averaged 2.4 million fish, while recreational landings averaged 813,000 fish. For the period 1988-90, commercial catches of coho salmon averaged 2 million fish, while recreational catches averaged 722,000 coho salmon. The ocean catch of coho salmon is limited by annual catch quotas. With some improvement in ocean survival, coho salmon should be able to approach the long-term average combined production. To an even greater extent than with chinook salmon, hatchery-produced coho salmon have become an increasingly important part of the catch, and in some areas, comprise over 80% of the catch.

Coho salmon landings from the ocean fisheries peaked at over 5 million fish in 1976 and then declined rather drastically to around 1 million in recent years. This is in large part due to a shifting of most of the allowable catch from the ocean fisheries to inside fisheries, particularly north of Cape Falcon, Oregon This has mainly resulted from a Federal Court decision in 1974 relating to Indian fishermen salmon entitlement under treaties signed in the 1850s.

The NMFS was petitioned to list lower Columbia River natural coho salmon as endangered under the Endangered Species Act. In view of the large production of coho salmon from hatcheries on the Columbia River, the management of Columbia River coho salmon has been directed toward harvesting these hatchery fish to prevent wasting large numbers of coho salmon returning in excess of hatchery needs. Consequently, the NMFS declined to list lower Columbia River coho salmon and stated, "Native runs, if they persist, would exist only as small remnant populations."

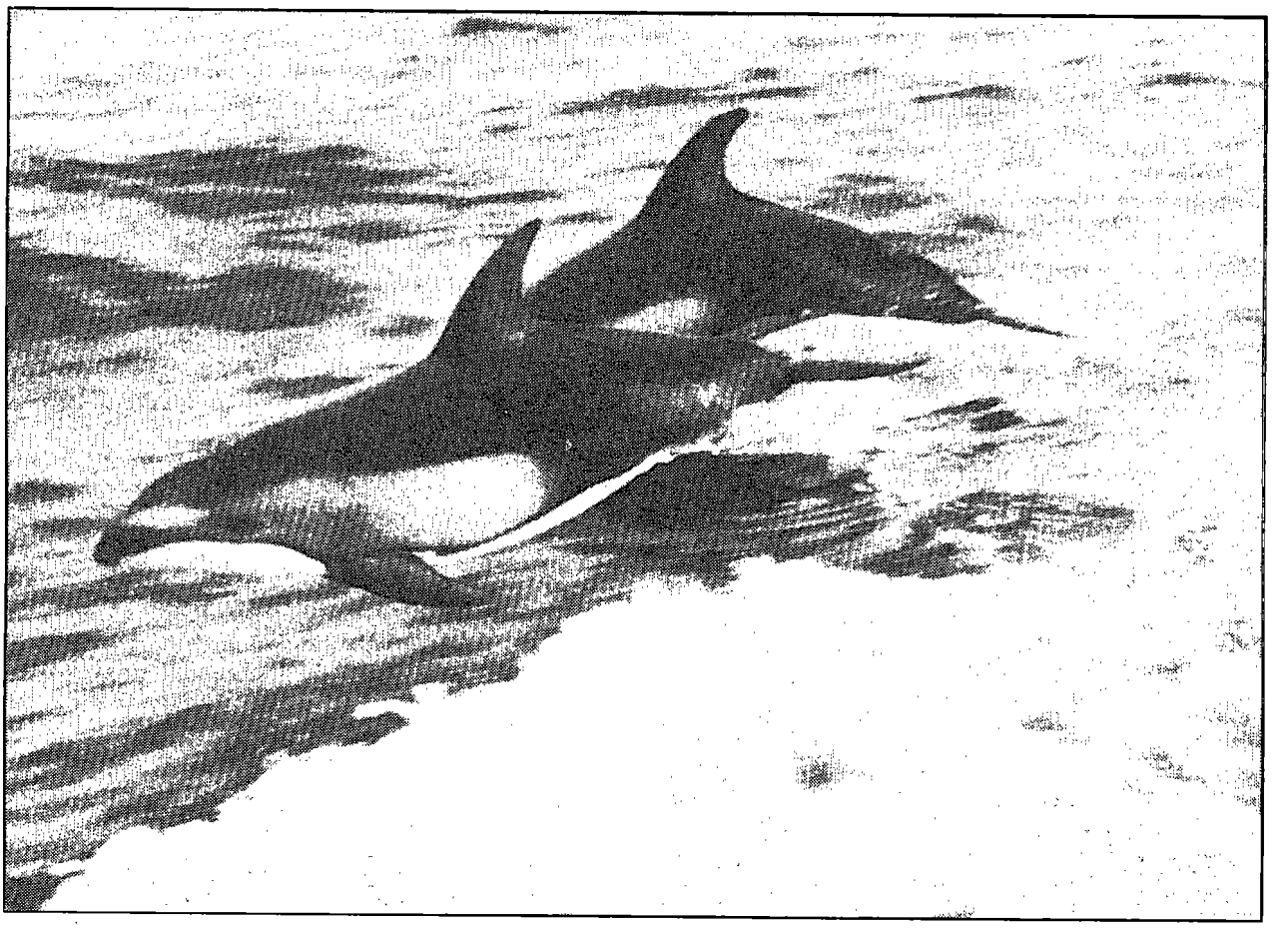
Some other coho salmon stocks have been at low 1evels of production in recent years and have generally-been the constraining stocks under weak stock management. In particular, these are the Washington coastal Queets River stock and Hood Canal and Skagit River stocks in Puget Sound. In addition, the Oregon Coastal Natural coho salmon stock has failed to meet its escapement goal for the past 4 years. A poor stock abundance predictor has certainly been a factor in this instance.



COHO SALMON
Pacific Coast
COMMERCIAL AND
RECREATIONAL CATCH
(in 1,000's of fish)

Year	Comm	Rec	Total
1980	2,344	819	3,163
1981	1,985	646	2,631
1982	2,494	652	3,146
1983	1,417	683	2,100
1984	1,356	449	1,805
1985	1,692	595	2,287
1986	3,207	832	4,039
1987	2,652	695	3,347
1988	2,344	709	3,053
1989	2,020	758	2,778
1990	1,548	700	2,248
Average			
60-90	2,418	813	3,231
88-90	1,971	722	2,693

MARINE MAMMALS



This section presents information on selected marine mammal populations off Washington, Oregon, and California. Forty-two species of marine mammals in U.S. waters of the North Pacific Ocean are under the jurisdiction of the Department of Commerce. This includes 31 species of whales, dolphins, and porpoises and 11 species of seals and sea lions. Six species are unique to Alaska; one species, the Hawaiian monk seal, is unique to Hawaii.

Fourteen of the most commonly observed species are normally found close to shore, such as the California gray whale and California sea hon. The other species usually remain in offshore waters, on remote islands, or are rare in number and seldom seen. Most marine mammal species make long-distance migrations or move hundreds of miles within smaller areas of the ocean between seasons of the year. These movements, especially by whales and dolphins, are for traveling from one feeding ground to another or to spend the breeding season in lower latitudes and the major feeding and calf-rearing seasons in higher latitudes.

There are several populations of marine mammals that spend the majority of the year in California; offshore waters of Washington and Oregon are generally transition areas for animals moving between the southern breeding grounds and rich feeding grounds of Alaska. A few species are found year-round in Washington and Oregon, such as the harbor porpoise and Pacific harbor seal, but this is also true for these species in California and Alaska. The zoogeographic differences have led to varying life history strategies, and resulted in the need to manage several populations or stocks per species. Management is carried out under the

STATUS OF RESIDENT AND SELECTED SPECIES OF MARINE MAMMALS OFF WASHINGTON, OREGON, AND CALIFORNIA

(e) = endangered; (i) = threatened; (d) = depleted

Species	Abundance (95% C.I.)	Trends (+/-%)	Method of Assessment	Assessment Coverage	Status and Authority
Gray whale	21,113 (19,737-22,489)	+3.2%/yr (1968-88)	Land-based counts	Complete	Recovered, ESA (e)
Humpback whales	1,398-2,040	Unknown	Photographic mark-recap.	Complete?	Below OSP, ESA (e)
Killer whale	260 (Puget Sound)	Stable?	Individual Counts	Partial	Unknown, MMPA
Delphinid complex[1]	>150,000 ?	Unknown	--	Partial	Unknown, MMPA
Vaquita	< 100 ?	Declining	--	--	Below OSP,ESA (e)
Harbor porpoise	50,000	Unknown	Line transect	Partial	Uncertain, MMPA
California sea lion	87,000	Increasing	Land-counts	Complete	Near OSP, MMPA
Northern sea lion	5,000	Declining	Land-counts	Complete	Below OSP, ESA (t)
Northern fur seal	6,000	Increasing	Land-counts	Complete	Below OSP, MMPA (d)
Harbor seal	>42,000	Increasing	Land-counts	Complete	Within OSP,MMPA
Elephant seal	67,000	+8.8%/yr (1980-88)	Land-counts	Complete	Within OSP,MMPA

[1] Short-finned pilot whale, northern right whale dolphin, bottlenose dolphin, white-sided dolphin, common dolphin, common dolphin and Grampus, mostly off California.

Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973. Both Acts require that management of marine mammals be based on the identification and enumeration of populations or stocks.

Two species, the vaquita or Gulf of California harbor porpoise and the Guadalupe fur seal, are not endemic to the United States (although a few male Guadalupe fur seals do occasionally show up in California). The vaquita is included in this report because of its rarity and the active conservation efforts being carried out by the U.S. and Mexican governments.

A summary of the status of the stocks, impact of incidental take, and description of individual stocks are described as follows.

This section and the following chapters were compiled by Howard W. Braham and Jay Barlow.

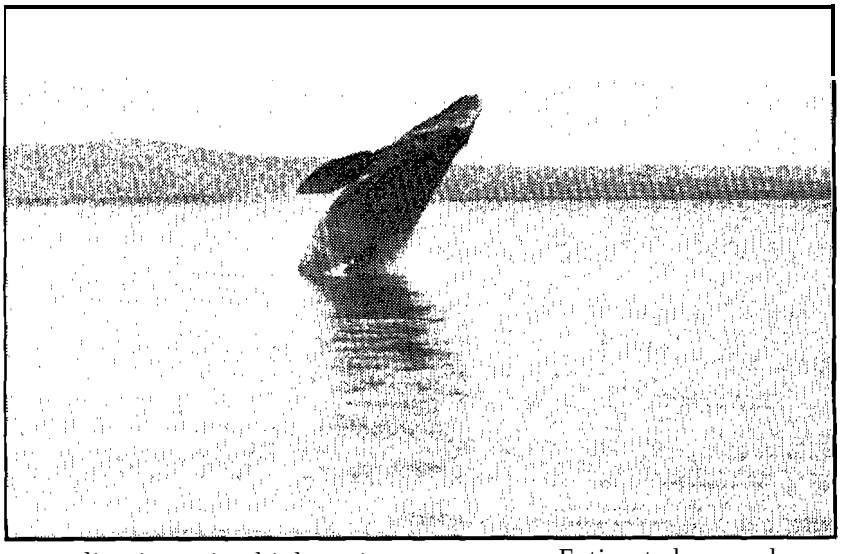
INCIDENTAL TAKE OF SELECTED MARINE MAMMALS IN DOMESTIC FISHERIES IN WATERS OFF WASHINGTON, OREGON, AND CALIFORNIA.

Species	Incidental Take (95%CI) (CV)	Fishery (others)	10-year Trend	Impact of Exploitation
Gray whale	Several tens?	Coastal gillnets	Unknown	Not significant
Delphinid complex[1] and seins	Several tens?	Coastal set nets	Unknowwn	Uncertain
Vaquita	>30/year	Gillnet for shark, totoaba and shrimp	Increasing	Severe depletion
Harbor porpoise	>200/year	coastal set nets for halibut and salmon	Increasing?	Possibly vital
California sea lion	3,200/year (2,000-4,000)	Gillnets for shark, salmon, swordfish, hake and halibut	Increasing	Uncertain
Northern sea lion	Unknown	--	--	--
Northern fur seal	Unknown	--	--	--
Harbor seal	1,400/year (California)	Gillnet for shark, swordfish and halibut	Unknown	Uncertain
Elephant seal	<200/year	"	Unknown	Not significant

[1] Shortfined pilot whale, northern right whale dolphin, bottlenose dolphin, whitesided dolphin, common dolphin and Grampus, mostly off California.

24. GRAY WHALE

There is one stock of gray whales ***(Eschrichtius robustus)*** endemic to the eastern North Pacific Ocean located from the western North American Arctic (United States, Canada, and the Soviet Union) to Baja California and mainland Mexico. The eastern North Pacific, or "California" stock, was heavily exploited by Yankee whalers during the second half of the 19th century and may have been reduced to only a small fraction of its population size prior to commercial exploitation.



In the eastern North Pacific, gray whales are distributed across much of the southern Chukchi Sea and northern Bering Sea where they can be found feeding from May to November. They migrate out of the Bering Sea in late autumn and are distributed along much of the lower U.S. coast between December and March. The peak of the southbound migration passes central California in early January. There is some temporal overlap with the first of the northbound migrants leaving Baja California as the tail end of the southbound migrants arrive. A small number of whales do not undertake a full migration 'to Alaska in spring; instead they stay along the Pacific coast. The northward migration past central California and Oregon usually occum from March to June, but it is not uncommon to see several gray whales in large bays and estuaries, such as Puget Sound, throughout much of the summer. It is also during summer and early autumn when gray whale calves begin to wean, and the incidence of strandings increases. Calf mortality is at its highest just after birth and after weaning.

Gray whales are generally light to dark gray with mottled lighter colored patches from the sloughing of the host-specific ectoparasitic barnacles, ***Cryptolepus rhachianecti.*** As with other baleen whales, adult female gray whales reach sexual maturity at slightly greater lengths (12.95 m, SE = 0.11) than do males (12.43 m, SE = 0.12), with maximum physical maturity reached at approximately 14 m in females and 13 m in males. Mean birth length is 4.6 m (both sexes), 7-8 m at weaning (usually 6-8 months postpartum), and at 1 year 8 m in length or greater. Age at sexual maturity is 9 years (range 6-12 years) for females and 6 years (range 5-9 years) for males. Mean conception date is 5 December and mean birth date is 27 January. Gestation lasts 418 days on average. With an ovulation rate of 0.50/year, and a pregnancy rate of 0.46/year, an adult female gray whale can give birth every 2 years, but a 3-year calving cycle is also common. Estimated annual survival rates are 95% for adults and 89% for juveniles.

The size of the eastern North Pacific stock of gray whales is 21,113 (SE = 688), which is larger than the estimated 15,000-20,000 gray whales in 1850. The population increased at a rate of 3.2% per year (SE = 0.5%) between 1968 and 1988, at the same time a subsistence catch of 167 whales per year (SE = 3.5) was made by the Soviet Union.

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[14]. Rugh D R. Ferrero and M. Dahlheim. 1990. Inter-observer count discrepancies in a shore-based census of gray whales. Mar. Mam. Sci. 6:109-120

25. HUMPBACK WHALE

Humpback whales ***(Megaptera nouaeangliae)*** occur in all oceans of the world. Like most baleen whales, they annually migrate to high-latitude, summer feeding grounds from temperate or subtropical wintering (breeding) grounds. The North Pacific humpback whale population tentatively has been divided into three stocks, based on the relative discreteness of wintering areas: 1) the Mexican stock, 2) the Hawaiian stock, and 3) the Asian stock (near the Ogasawara and Okinawa Islands of Japan). Some exchange takes place between the Mexican and Hawaiian stocks, but to date there is no evidence of any exchange between the eastern and western North Pacific stocks.

Humpback whales that give birth and mate in Mexico are believed to spend the summer feeding off of California, principally north of Point Conception. They are also seen migrating north and south over the continental shelf of Oregon and Washington mainly between March and November. Short-term seasonal distribution patterns have been documented especially along the central California coast and the Gulf of the Farallones. The paucity of sightings along Oregon and Washington is in large part a result of little survey effort. Seasonal distribution of humpback whales on the feeding grounds issubject to variability in oceanographic conditions and the distribution and availability of prey.

The preexploitation population size of humpback whales in the North Pacific Ocean (western and eastern stocks) is not known,

but estimates suggest that it may have been on the order of 15,000 whales. There have been no surveys over a significant period of time to detect trends in abundance.

The current estimate for the eastern North Pacific stock(s) is 1,398-2,040, which is 9-13% of the estimated abundance of humpback whales in the North Pacific prior to commercial exploitation. More than l,000 individual whales were identified off Hawaii between 1977 and 1985. Mark-recapture analysis, based on the photo-identification of individuals, has led to an estimate of 1,600-2,100 whales that annually visit Hawaiian waters. The minimum number of humpback whales that frequent the Gulf of the Farallones, off central California, is on the order of 400 (subject to sampling biases), although the same animals do not always return each year.

For further information

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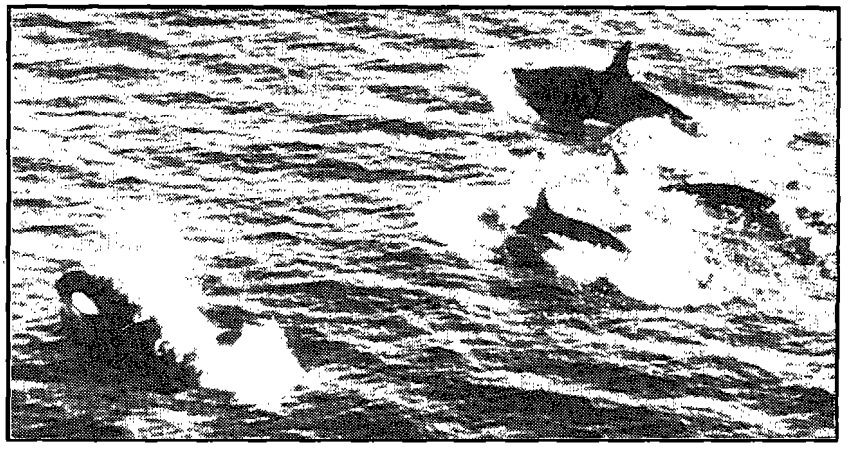
Calambokidis J J.C. Cubbage, G. H. Steiger, K. C. Balcomb, and P. Bloedal. 1990. Population estimates of humpback whales in the Gulf of the Farallones, California, p. 325-334. In P. Hammond, S. A. Mizroch, and G. P. Donovan (editors), Individual recognition of cetaceans: Use of photo-identification and other techniques to estimate population parameters. Cambridge, U.K., Int. Whaling Comm. (Special Issue 12).

Humpback 'Whale Recovery Team. 1990. National recovery plan for the humpback whale ***(Megaptera novaeangliae)*** in waters of the United States of America. U.S. Dep. Commer., NOAA NMFS, Washington, D.C., 82 p.

Perry, A., C. S. Baker, and L. M. Herman. 1990. Population characteristics of individually identified humpback whales in the central and eastern North Pacific: A summary and critique, p. 307- 317. In P. Hammond, S. A. Mizroch and G. P. Donovan (editors), Individual recognition of cetaceans: Use of photo-identification and other techniques to estimate population parameters. Cambridge, U.K., Int. Whaling Comm. (Special Issue 12).

26. KILLER WHALE

The killer whale ***(Orcinus orca)*** is the largest member of the family Delphinidae. Adults range in length from 5 to 9 m. Dorsal fin height can be 1.8 m in adult males and up to 0.9 m in adult females and subadult males. The genus is monotypic with geographical variations in size and color. Differences in call repertoires and overlapping color patterns may suggest some isolation among pods. Recent studies indicate that certain pods may be genetically distinct.



Killer whales have been observed in all oceans and seas of the world and, although reported from tropical and offshore waters, they are more commonly found in colder waters typically within 800 km of major continents. Along the U.S. continental west coast they concentrate near land masses and continental shelf waters, with concentrations noted in Puget Sound, in the adjacent waters of British Columbia, and in Southeast Alaska.

Killer whales typically occur in small pods of fewer than 40 animals. Multipod gatherings have been noted; however, the biological significance of 'these groupings is not known. Pod composition appears to remain constant for many years with little intermixing of individuals among pods. At least two major types of pods have been noted. Transient pods move in and out of areas typically occupied by resident pods. Resident pods of killer whales are usually found in one area year-round (encompassing several thousand square miles) and are dominated by strong matriarchal lineages. The natural mortality rate of killer whales is less than 5% per year and frequently as low as 1%.

Movements of killer whales are believed to be related to the availability of prey, such as spawning salmon, and the movements of seals and whales. Killer whales also prey on cod, herring, flatfish, sablefish, and other fish. Resident pods typically prey on fish, while transient pods may favor marine mammals. Killer whales have never been subjected to significant rates of exploitation and are not taken for subsistence. Incidental takes during fishing operations are rare. No significant fishery interactions have been documented in California, Oregon, or Washington, although fishermen sometimes shoot at them and use seal bombs and other explosives to keep the whales away from their catch.

In Puget Sound there are 3 identified resident pods totaling 84 animals (1987 counts). The largest pod (L) totals 49 animals, and the two other pods (J and K) total 17 and 18 animals, respectively. The number of killer whales in Oregon and California is unknown but probably not large, based on anecdotal accounts during surveys for other species.

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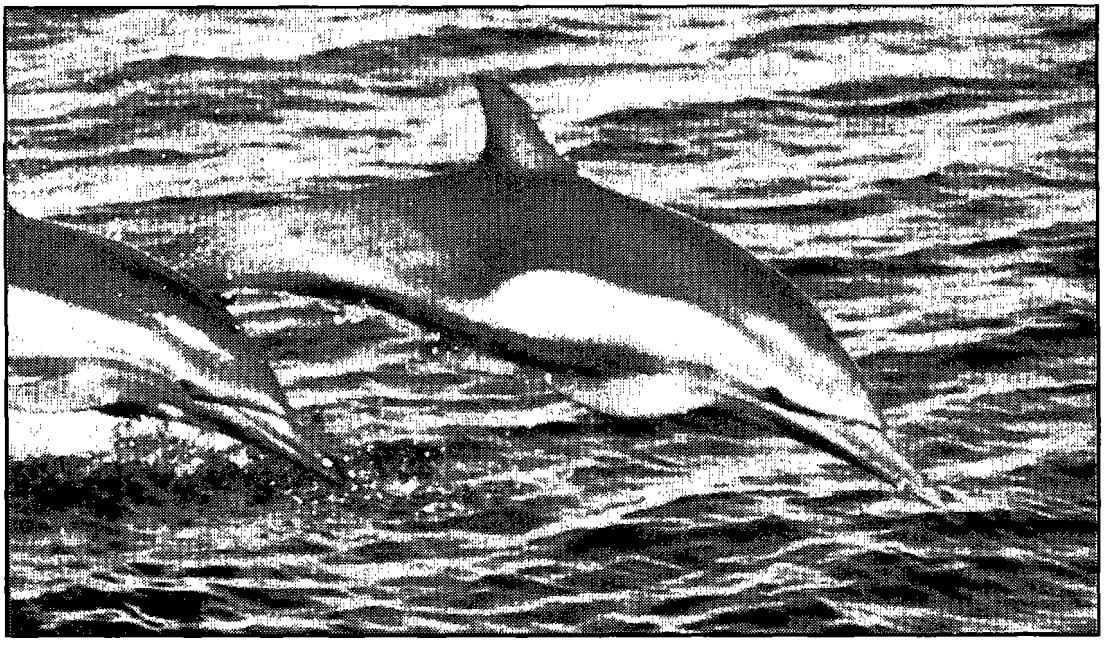
Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales ***(Orcinus orca)*** in the coastal waters of British Columbia and Washington state, p. 209-243. In P. Hammond, S. A. Mizroch, and G. P. Donovan (editors), Individual recognition of cetaceans: Use of photo-identification and other techniques to estimate population parameters. Int. Whaling Comm. (Special Issue 12).

27. DELPHINID COMPLEX

Common dolphin



The status, trends, and impact of domestic fisheries on the coastal and pelagic species of dolphins and porpoises in the family Delphinidae are not well known.

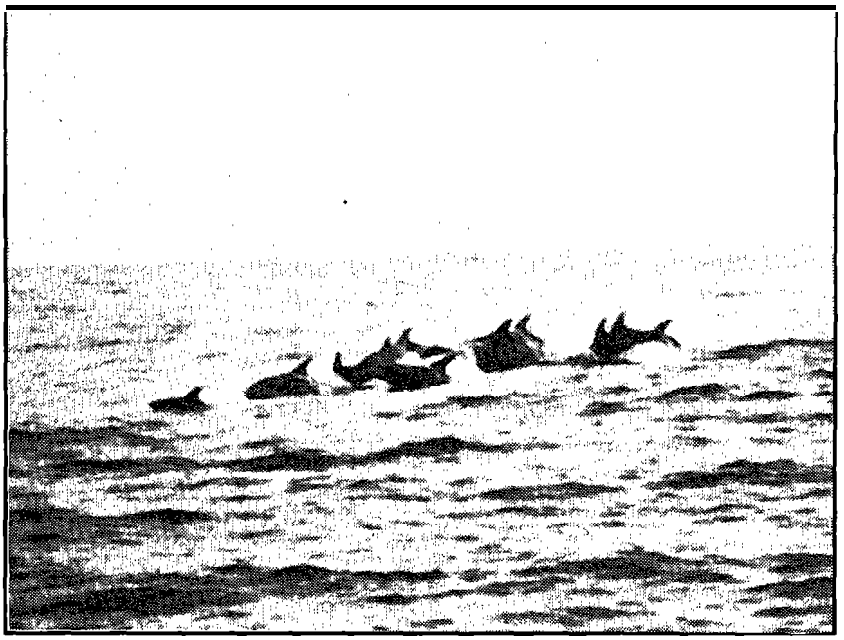
Dall's porpoise ***(Phocoenoides dalli)*** are found from southern California throughout the North Pacific Ocean and Bering Sea to Japan. They are incidentally taken in a variety of gill-net fisheries and occasionally in trawl fisheries. They constitute one of the more frequent delphinid species caught in coastal set nets and driftnets, gill-net fisheries in Puget Sound, and the midwater Pacific whiting trawl fishery (mostly between lat. 41%-46%) off Oregon and Washington.

Pacific white-sided dolphins ***(Lagenorhynchus obliquidens)*** are found throughout the temperate North Pacific Ocean from the waters off Baja California to Japan. They occur year-round off California, Oregon, and Washington, frequenting the continental shelf and slope. On occasion, they form large schools in offshore waters, sometimes in association with other dolphins (e.g., with northern right whale dolphins). Pacific white-sided dolphins are incidentally taken in the midwater Pacific whiting trawl fishery and California drift gill-net fisheries, and were commonly taken in the experimental shark fishery off the Oregon and Washington coast in 1986-87.

The northern right whale dol-, phin ***(Lissodelphis borealis) is*** the only small odontocete in the North Pacific Ocean without a dorsal fin. Two subspecies have been identified, based on color pattern and dental formulas; however, the evidence is equivocal. There may be two or more stocks along the California coast, based on a hiatus in distribution. A satisfactory evaluation of distinct stocks cannot be made because of the lack of information on distribution. Northern right whale dolphins are the most frequently taken delphinid in offshore high seas driftnet fisheries.

Grampus or Risso's dolphin ***(Grampus griseus)*** are distributed worldwide in both tropical and temperate seas. They are common in the waters from California to Washington over the continental shelf, but their movements and abundance are unknown. There is no information on stock differentiation.

Northern right whale dolphins and Risso's dolphins were also frequently taken in the experimental shark fishery. Pilot whales ***(Globicephala macrorhynchus),,*** common dolphins ***(Delphinus delphis),*** and bottlenose dolphins ***(Tursiops truncatus)*** are also taken occasionally in commercial fisheries. ***Delphinue*** is common along coastal and continental waters, especially in the waters south of Oregon. ***Tursiops*** are common in in-shore waters of Baja California



Risso's dolphin

and in California. Pilot whales are no longer common in southern California.

Seasonal fluctuations or shifts in the distribution of populations of delphinids have been noted, but why and how their distribution changes is unclear. It may be, for example, that these highly mobile animals were significantly affected by the El Niño warm water event of 1982-83, causing large shifts in their prey. Sightings of these animals in the past 20 years were in waters north of lat. 50% in spring and summer and lat. 35% in the fall, possibly north of their historic distribution.

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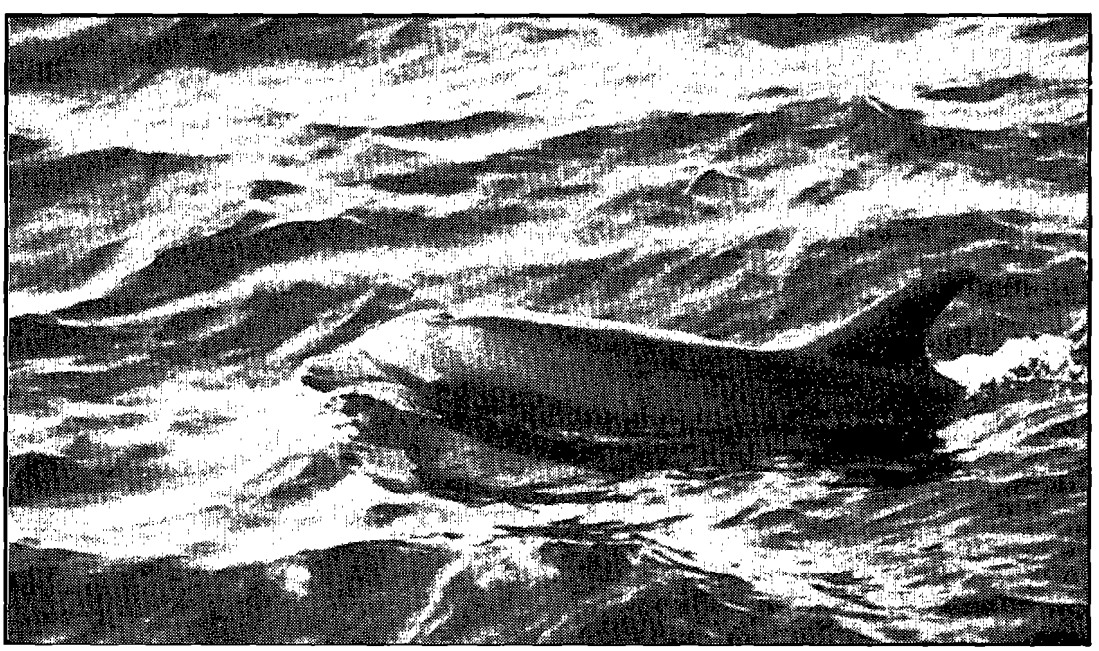

Bottlenose dolphin

28. VAQUITA OR GULF OF CALIFORNIA HARBOR PORPOISE

The vaquita *(Phocoena sinus)* has one of the most limited distributions of any marine mammal. This small porpoise is believed to inhabit only the northern regions of the Gulf of California. Sparse information about these elusive animals has come from a small number of incidental take& and strandings. From these limited specimens, females, which reach a maximum length of 150 cm, appear to be larger than males, which reach 140 cm. No other sexual dimorphism has been noted.

Reliable estimates of population abundance do not exist for the vaquita even though several independent expeditions have surveyed the northern Gulf of California in recent years. Rough minimum population estimates are in the range of 50 to 100 individuals. It is assumed that life history parameters of the vaquita are similar to the harbor porpoise. That is, female maturation probably occurs at 3-5 years of age, mating takes place in late summer, calving occurs in spring to early summer, lactation lasts for approximately 8 months, and the average Calvin-g interval is greater than 1 year. The vaquita. is probably a short-lived animal, possibly 13- 15 years. Population growth rates have been estimated based on ranges of values for reproduction and mortality rates. With a maximum growth rate less than 10% per year, only a few new individuals may be added to the. population each year.

The vaquita is vulnerable to incidental mortality in commercial fishery operations in the Gulf of California. Historically, this species has been taken in the gill-net fisheries for totoaba (Totoaba *macdonaldi)* and for shark, and in shrimp trawls. It has been estimated that the incidental kill was in the range of tens to hundreds of vaquita per year in the early 1970s.

The Mexican government closed the totoaba fishery in 1975 as a result of marked declines in the totoaba stock(s). Totoaba may still be in danger of extinction; however, fishermen in the northern Gulf of California claim that stock levels have recovered and that this fishery should be reopened. Two consecutive years of experimental totoaba fishing operations during the 1980s resulted in the incidental take of 14 vaquita in gill nets near El Golfo de Santa Clara, Sonora, Mexico. From interviews with fishermen, it is estimated that about 32 vaquita are killed each year.

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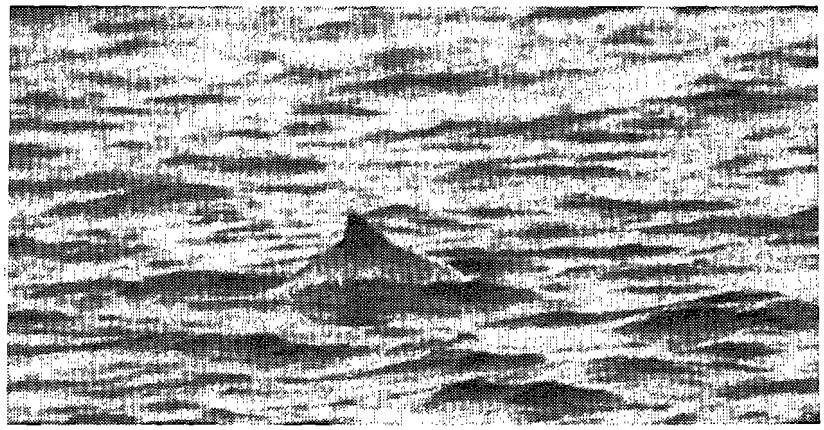
29. HARBOR PORPOISE

The harbor porpoise ***(Phocoena phocoena)*** is a common inhabitant of nearshore areas along the Pacific west coast. In California, they are found only north of Point Conception and appear to be most abundant near the mouths of large rivers, harbors, and bays. The harbor porpoise is one of the smallest 'cetaceans, reaching maximum lengths of about 1.8 m and maximum weights of about 90 kg. Adult females are slightly larger than adult males. Harbor porpoise may travel in groups of up to 10 animals, although they appear solitary when seen in the wild. They' prey on cephalopods and favor schooling nonspiny fish like herring, smelt, mackerel, sardines, pollock, and Pacific whiting. Harbor porpoise are in turn preyed upon by sharks and killer whales. Calves are born during summer (May-July) after an ll-month gestation. Calving intervals are approximately 2 years.



Annual surveys to monitor the abundance of harbor porpoise have been conducted by the California Department of Fish and Game and NMFS since 1984. These surveys have shown that the primary concentration is along the west coast near and around the mouth of the Columbia River with secondary concentrations along the coast of Oregon and Washington. The most recent analysis indicates that there are approximately 11,100 harbor porpoise in California, including the 3,274 animals that make up the putative central California stock. Using the data through 1989, the central California stock is estimated to be 30-97% of its carrying capacity. Total abundance estimates for the Oregon and-southern Washington coasts are 5,215 (range 3,164 to 7,092) and 7,961 (range 3,164 to 12,758), respectively. An estimated 700-1,000 animals occur along the northern Washington coast. Harbor porpoise were once common in Puget Sound but now they are rare. There is no evidence of population increase or decrease along the west coast, and analyses of existing data suggest that a minimum of five additional survey years would be needed to detect a 5-10% annual change in abundance.

The rate of incidental mortality of harbor Porpoise in gill nets in California from 1983 to 1988 was estimated at 200-300 per year, all from central California. Because of recent restrictions on gill-net fisheries along the California coast, the current rate of mortality is estimated to be less than 100 per year. The total incidental take of harbor porpoise in Oregon and Washington is unknown. In 1988, over 100 harbor porpoises were killed incidental to the Makah Tribal salmon setnet fishery along the outer north shores of Washington. Because of reduced fishing effort, the take was only 23 in 1989, 13 in 1990, and 16 in 1991.

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30. CALIFORNIA SEA LION

The California sea lion *(Zalophus californianus)* is found from the Tres Marias Islands, Mexico, to British Columbia. Pupping and mating take place mainly on the Channel Islands, California, and on islands off the Pacific coast of Baja California from late May to late July. The pups are weaned from the age of 8 months to a year or more. Researchers are uncertain about the age at sexual maturity, but it is thought that females are sexually mature at 3 years, while males reach sexual maturity at 4-5years of age. Adult males can weigh over 400 kg and reach 2.6 m in length. Females weigh about 91 kg and reach 1.8 m in length.

California sea lions on rookeries in U.S. waters are assumed to comprise a single stock. In 1986, there were approximately 17,800 California sea lion pups counted on U.S. rookeries, which represent about 21,000 live births. This suggests that the total population in the United States is approximately 87,000 animals. The current growth rate of the population of 6.4% is assumed to have been equal to its rate of growth just prior to the 1982-83 El Nino warm water event (which caused a temporary reduction in the population). Although the pre-exploitation population size is unknown, recent studies indicate that its abundance may he higher than any historical level.

Food habit studies indicate that California sea lions take a variety of prey. They also have learned that fish caught in a net or hooked on a line are easy prey. Their main diet consists of Pacific whiting, rockfish, anchovies, mackerel, walleye pollock, dogfish sharks, market squid, and octopus. During the 1982-83 El Nino warm water event, pelagic red crabs were found to be **a** major source of food for sea lions in California.

The California sea lion is the best known and most often seen of the west coast pinnipeds. In recent years, they have gained notoriety for taking over portions of marinas in Monterey Bay and San Francisco Bay, and are threatening the viability of a native run of steelhead trout *(Oncorhynchus mykiss)* near the Hiram M. Chittenden Locks in Seattle, Washington. California sea lions are reported to consume tons of valuable fish, to destroy fishing gear, and to interfere with fishing operations. Fishermen and some resource managers, faced with increasing fishery interactions, believe that sea lion populations have grown to a point where nuisance animals should be eliminated. It has been estimated that approximately 2,000-4,000 California sea lions are killed annually incidental to gill-net fishing operations in California.

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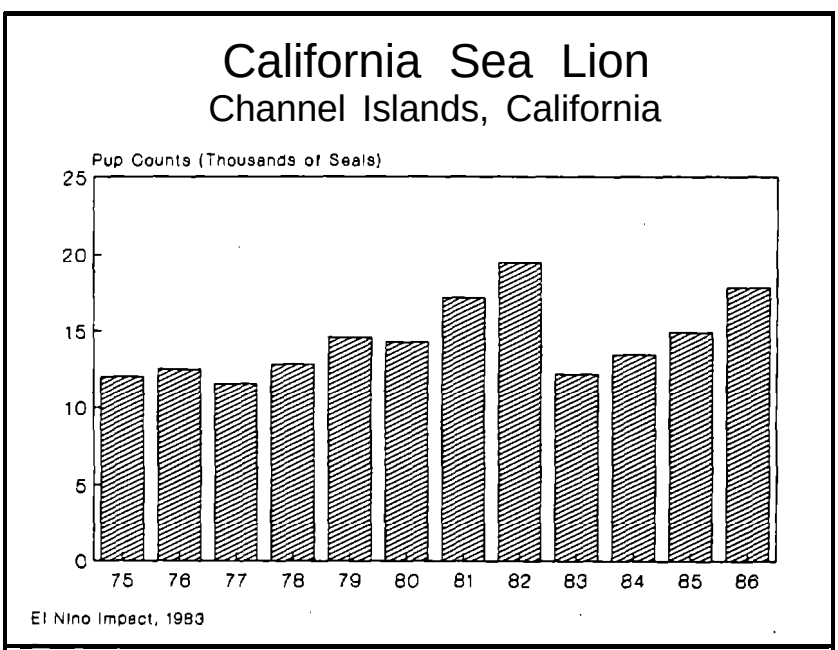

31. NORTHERN SEA LION

The northern sea lion ***(Eumetopias jubatus),*** also known as Steller's sea lion, is endemic to the North Pacific Ocean. Its range is from California to the Kuril Islands, U.S.S.R., and north to lat. 63°N in the Bering Sea. About 50 breeding rookeries occur throughout the species range except in Washington. Sea lions exhibit strong site fidelity, and many disperse widely after reproduction; but they do not migrate. Pupping peaks in mid-June, and lactation lasts 3 months to over 1 year. Sexual maturity occurs at age 4-6 years in females; gestation lasts 9 months after 3 months of delayed implantation. Adult males are territorial and the mating system is polygynous.

In Alaska, northern sea lions feed on Pacific salmon, squid, herring, groundfish (such as walleye pollock), and other tin-fish species. Summer feeding trips by lactating females extend out to at least 20 nautical miles (nmi); in winter they may forage out to several hundred miles. Their feeding behavior off the Pacific Coast is not well understood.

The northern sea lion population was first noticed to be declining in 1976. Since the late 1960s the species has declined by about 70%, principally in Alaska. From the Gulf of Alaska to the Aleutian Islands, the northern sea lion population declined from 67,617 counted in 1985 to 29,804 in 1990 -- a decrease of 56% in just 4 years. The greatest decline since the 1960s has been in the eastern Aleutian Islands (94% decline), the former center of abundance for the species. During the 1980s, all areas of the species' range declined except Southeast Alaska and Oregon; in California, they have been gradually declining since the 1950s. Present abundance in Washington, Oregon, and California is about 5,000.

Northern sea lions are the most frequent marine mammal taken in trawl fisheries in Alaska. The reported take in 1990 was less than 50. Incidental take in foreign trawl fisheries and joint venture walleye pollock roe fisheries in the early 1980s may have contributed to the sea lion's decline. The impact of incidental take on northern sea lions in Washington, Oregon and California is minor.

It is unclear why the decline in northern sea lions has occurred and whether it is directly or indirectly related to commercial fishing activities, disease, or from some unknown natural environmental factors. Other factors such as redistribution, predation, native subsistence, and entanglement in nets and debris apparently are not significant in the decline. Intentional shooting may have been an important source of mortality at various times or in some areas in Alaska.

In 1990 the northern sea lion was listed as a threatened species under the ESA. Since then, federal action has been taken to restrict certain commercial fishing activities near sea lion breeding sites and habitat potentially important for feeding across much of the southern Bering Sea and Gulf of Alaska. No specific areas along the west coast are currently proposed for additional protection; however, Oregon has imposed limits on some commercial fishing around Oregon sea lion rookeries.

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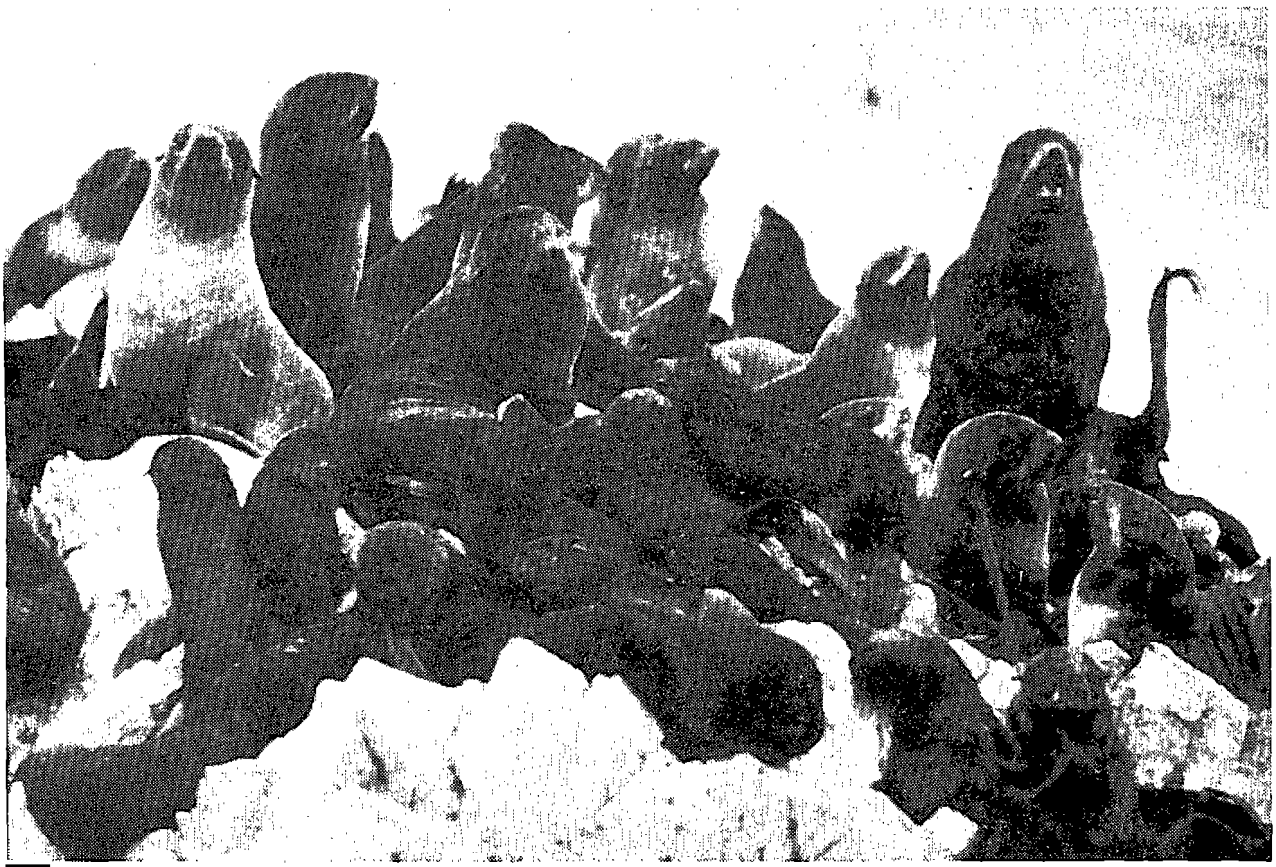
32. NORTHERN FUR SEAL



The northern fur seal *(Callorhinus usinus) is* a monotypic genus ranging across the subarctic waters of the North Pacific Ocean from the Sea of Japan, Okhotsk Sea, Bering Sea, and temperate continental United States. Breeding populations are found on Robben Island (Okhotsk Sea); several Kuril Islands (south of Kamchatka); on the Commander, Pribilof (St. Paul and St. George Islands), and Bogoslof Islands (all in the Bering Sea); and on San Miguel Island, California.

Northern fur seals are found throughout their range in the eastern North Pacific Ocean in nearly all months of the year with periods of peak abundance varying by time and area. Many immature seals of both sexes remain at sea during the first year or two of life and do not return to their island of birth until ages 2 or 3 years. Most fur seals spend about half the year at sea (November through May-June) and the remainder (July-October) on and around their home islands during the breeding season. Fur seals are most frequently seen from about 70 to 130 km from land and usually in greatest numbers along the continental shelf and slope throughout their range primarily because of abundant food resources in this area. The southern extent of the migratory range in the eastern North Pacific Ocean is to about lat. 32% (Califomia-Mexico boundary) and in the western North Pacific Ocean to about lat. 36% (off Honshu Island, Japan).

Older males (l0-15years) from the Pribilof Islands winter farther north in the North Pacific Ocean than younger males and females. Females and young males appear along the continental shelf during their southbound migration from about lat. 57° to 46°N in late November and off California (lat. 40° to 38°N) in late December. In January-April, major concentrations occur between California and British Columbia. The northward migration begins by March; some seals follow the continental

shelf north, then travel west through the Gulf of Alaska and into the Bering Sea through passes in the eastern Aleutian Islands. Fur seals from San Miguel Island, California move north after the mating season and apparently intermingle with their northern counterparts to feed in the eastern North Pacific.

The estimated total number of northern fur seals in the North Pacific Ocean in 1983 was 1.2 milhon. The population on the Pribilof and Bogoslof Islands in 1988 was 871,000; this level is significantly less than observed in the 1950s when the population had reached its highest population size this century. The current population size on San Miguel Island is approximately 6,000. It increased steadily beginning in the late 1960s, when the island was recolonized, until 1981. Between 1982 and 1984 the population on San Miguel Island declined approximately 60% (as measured by pup production), most likely a result of increased mortality of adults and juveniles at sea after the breeding season, and starvation of prematurely weaned pups. The 1982-83 El Nino warm water event was responsible for the decline on San Miguel Island primarily by affecting the distribution of prey. Pup production has since returned to its pre-El Nino levels.

Northern fur seals are taken incidentally in the foreign high-seas gill-net fisheries for squid and salmon. In 1989,208 primarily juvenile northern fur seals were taken (52 dead, 128 alive, 28 lost) in 1,402 observed net retrievals (about 4-10% of the fishing operations). Northern fur seals are also occasionally taken in domestic trawl and other net fisheries. In 1990, only two northern fur seals were reported taken alive in trawl nets in the domestic groundfish fisheries in Alaska, and none were observed taken in 1989. The take in Washington, Oregon, and California is unknown but was probably negligible.

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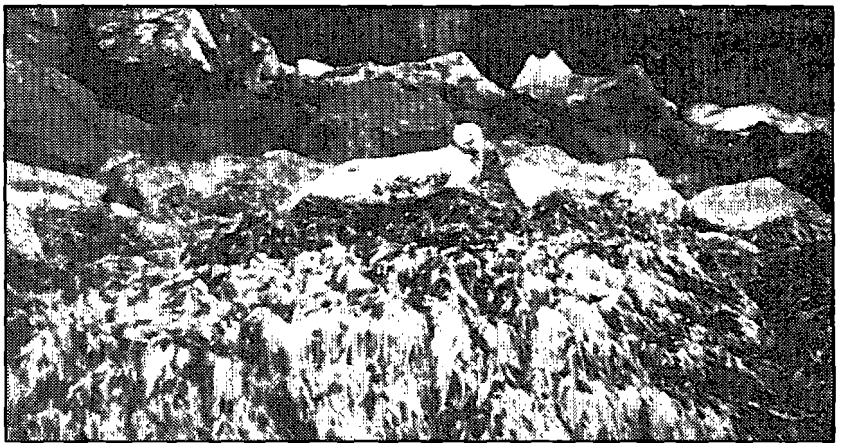
33. HARBOR SEAL

The Pacific harbor seal ***(Phoca vitulina richardsi)*** occurs throughout the eastern North Pacific Ocean from the outer coast of Baja California (about as far south as Cedros Island) north to the eastern Bering Sea, Alaska. In the continental United States, three stocks are recognized for management purposes: 1) inland waters of Washington state, 2) outer coast of Washington and Oregon, and 3) California. Adult males reach lengths of 1.62 m and weigh about 113 kg. Adult females are slightly smaller. The coloration pattern of adults is quite variable, but all have dark spots on light pelage or light spots on dark.

The breeding season (mating and pupping) varies with latitude along the coast, occurring in March-April on the Channel Islands of Southern California, and later with an increase in latitude. In Puget Sound, pups are born from August to October in the south end of the Sound, whereas in the north end of the Sound, pups are born in July and August. In Hood Canal, pupping extends from August to December.

Pups are born at approximately 82 cm in length and weigh about 10 kg. They are weaned at 4 to 6 weeks and weigh about 24 kg. Adult females ovulate and mate at the end of weaning with a 2-month delayed implantation. Sexual maturity occurs at 3-4 years of age for females and 5 years for males. Their diet consists of fish and cephalopods, and in particular, flounder, herring, tomcod, Pacific whiting, squid, and lamprey.



The harbor seal population along the west coast appears to be increasing. Concurrently, the number of haul-out sites occupied has also increased. The 1990 mainland California count was 15,865 seals, and a count at the eight Channel Islands was 2,808 seals. Combining these counts produces a minimum population estimate for the California stock of 18,673. This is thought to be a minimum population size estimate because an unknown fraction of the population is not hauled out during a census. The estimated abundance of harbor seals in Oregon is 7,500-10,000 and in Washington 16,000- 17,000 based on pup counts in 1989. Harbor seals in Washington have been increasing at 7% per year since 1983.

From recent analysis, there is no firm evidence to suggest that the stock in California is above its maximum net productivity level (MNPL). The counts since 1982 show no significant trend, but the occurrence of the 1982-83 El Nino warm water event and the possibility that incidental fishery mortality has increased may have affected the population dynamics of the California stock. It is likely that the survival and reproduction of harbor seals were altered during the El Nino event and that some of the effects persisted for several years after 1983. In addition, the gill-net fishery effort has increased substantially in California since the late 1970s.

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34. NORTHERN ELEPHANT SEAL

The northern elephant seal ***(Mirounga angustirostris) is*** the largest pinniped in the Northern Hemisphere. Adult males reach lengths of greater than 4.5 m and weigh on average about 1,800-2,000 kg. Females reach lengths of 3.4 m and weigh about 907 kg. The male develops a large, bulbous, trunklike snout, from which it gets its common name. Breeding colonies are found on San Miguel Island, Santa Barbara Island, San Nicolas Island, Ano Nuevo Island, the South Farallon Islands, several areas along the coast of California, and on islands off the Pacific side of Baja California. The pupping and mating season is from December through March. The harems consist of one male to 8-40 females. Gestation lasts about 9 months in addition to delayed implantation of about 2 months. Pups are weaned by 4 weeks, but remain on the rookery for another 8-10 weeks, sleeping during the day and gradually beginning to enter the water at night. Departure from the rookery by the pup occurs at approximately 3 months of age. Females can begin to mate by 2 years of age, whereas males reach sexual maturity at age 5. Most young males (5+ years) are prevented from mating by larger, older bulls until the younger seals are at least 8-9 years old; maximum age is probably about age 14 for males and 18-20 for females.

Experiments using time-depth recorders show that during two feeding trips each year adult male elephant seals can dive up to an hour at a time to a maximum depth of 1,500 m. During the 2-5 months at sea, adults dive continuously and remain on the surface to rest for only 4 minutes between dives. Male elephant seals range from California to the Gulf of Alaska and the eastern Aleutian Islands, a distance of at least 4,700 km, twice each year. Adult females forage over deep waters westward along the North Pacific transition zone located between 40° and 45°N twice each year for about 2.5 and 7 months. The adult males and females are, therefore, segregated at sea. Stomach content analyses indicate that just before returning to the California Channel Island, elephant seals feed on squid, small sharks, rays, ratfish, rockfish, and Pacific whiting. They probably feed on squid and mesopelagic fish while at sea.

The exploitation and subsequent recovery of the northern elephant seal population is one of the great success stories of a species near extinction. Biologists estimate that only 100-500 elephant seals were left on Guadalupe Island, Baja California at the low end of their abundance this century before protective legislation was passed. The entire current population may have originated from this small group of animals. Based on pup counts,' the current U.S. population now exceeds 60,000 animals. The apparent grow rate since 1980 has been about 9% annually. Annual surveys indicate that this species has reoccupied most or all of its historical rookeries and hauling grounds. Using data through 1986, the population appears to be near its MNPL.

Elephant seals have been incidentally taken in both driftnet and setnet fisheries. In the early 1980s, it was estimated that 25 animals per year were taken in southern California. Preliminary data suggest a higher level of lethal entanglement is occurring than previously estimated, but the total is still likely to be less than 200 animals per year.

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