

6 Pacific Sardine, *Sardinops sagax*



Pacific sardine, *Sardinops sagax*. Photo credit: Department archives.

History of the Fishery

At one time the Pacific sardine was California's most valuable fishery; first developed in the early 1900s in response to a growing demand for food during World War I. However, the true beginning of the famed sardine industry started when Frank Booth moved to Monterey in 1900 where he founded the F.E. Booth Company and built a sardine plant in 1902. The fishery boomed during the 1920s and peaked at over 771,600 short tons (700,000 metric tons) in 1936 (Figure 6-1). In the 1930s and 1940s Pacific sardine supported the largest commercial fishery in the western hemisphere, with sardines accounting for nearly 25 percent of all the fish landed in the United States by weight. In the 1940s, the fishing fleet consisted of 376 vessels and more than 100 canneries and reduction plants which employed thousands from San Francisco to San Diego, California.

The fishery declined and collapsed in the late 1940s due to overfishing and changes in environmental conditions, remaining at low levels for nearly 40 years. As the fishery declined, there was a southward shift in the catch, with landings ceasing in Canadian waters during the 1947-1948 season, in Oregon and Washington in the 1948-1949 season, and in the San Francisco Bay in the 1951-1952 season. Season start dates have varied over time, beginning August 1 in the Monterey area and September 1, October 1 and November 1, depending on the decade in the Los Angeles area. The demise of the fishery became a classic example of a 'boom and bust' cycle, a known characteristic of clupeoid stocks.

In 1967, the California Fish and Game Commission (Commission) authorized a moratorium on directed fishing for sardine. Prior to this, sardine harvest was mostly limited by controlling the amount of whole fish used for reduction, case pack requirements, and fishing season restrictions. However, there was no limit on total catch for the commercial fishery. These controls were intended to limit the amount of sardine used for reduction to fishmeal and oil, as this was considered a less desirable use. In an attempt to let the fishery rebound, landings were restricted to an incidental catch limit of 15 percent by weight when mixed with other fish loads between 1967 and 1973. However, liberal requirements to accommodate the use of these incidentally

caught sardine and allowances for live and dead bait allowed several hundred tons of sardine to be taken per year. In 1974, a moratorium on fishing sardines was established which halted directed commercial fishing efforts, eliminated sardine for use as live bait, but still allowed a 15 percent incidental catch limit. Up until 1981, sardine landings totaled less than 50 short tons (45 metric tons) per year.

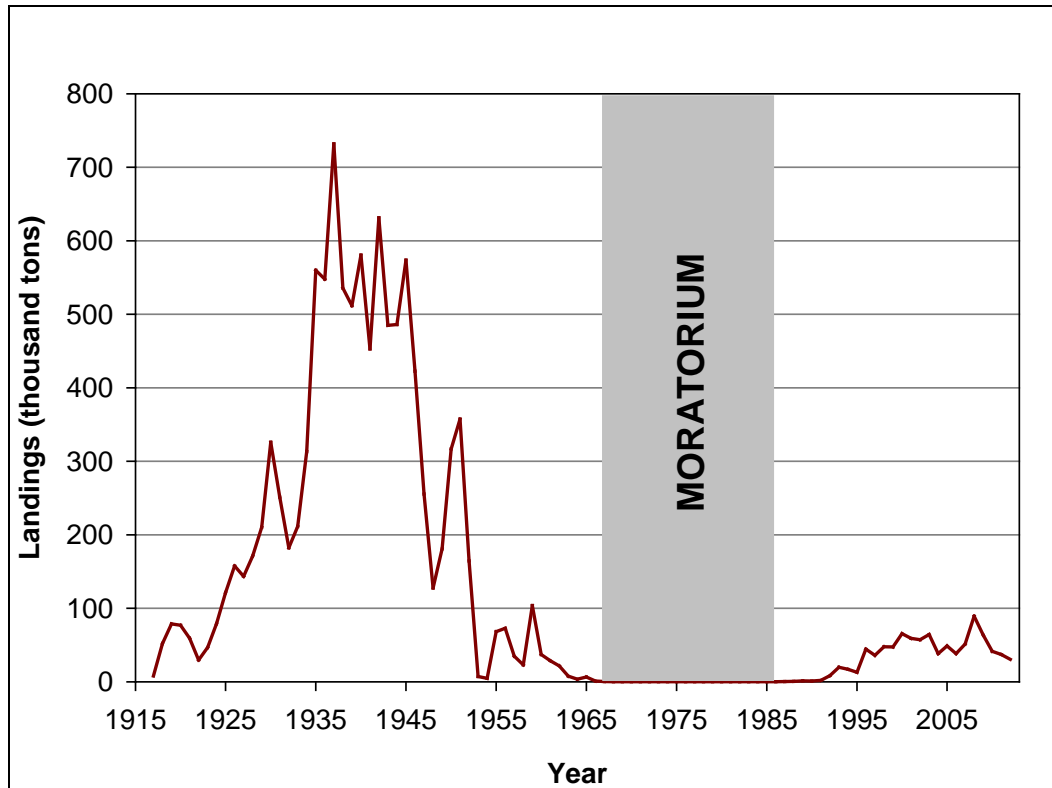


Figure 6-1. Pacific sardine commercial landings, 1916-2011. Data source: California Department of Fish and Wildlife (Department) catch bulletins (1916-1986) and Commercial Fisheries Information System (CFIS) data (1987-2011), all gear types combined.

In the early 1980s sardine were taken as incidental catch in California’s Pacific mackerel (chub) and jack mackerel fisheries. Most of the sardines from those sources were used for pet food and an even smaller amount was canned for human consumption. Currently, nearly one quarter of the U.S. sardine harvest is eaten domestically, either fresh or canned. The other three quarters is frozen and exported, mainly to Asia for consumption and bait, but also to Australia for use as feed in bluefin tuna farming. As sardine abundance continued to increase, a directed fishery was reestablished. In 1986, California lifted its eighteen year moratorium and limited the fishery to 1000 short tons (907 metric tons) per year. The season was set to the calendar year, unlike the pre-bust fishery. The sardine population was declared fully recovered in 1999 when the estimated biomass was over 1.1 million short tons (1.0 million metric tons), the stock was found to occupy its historical range from Mexico to Canada, and all age classes were present in the population.

A federal Coastal Pelagic Species Fisheries Management Plan (CPS FMP) was put into place in 2000, for waters off of the west coast of the U.S. The CPS FMP implemented the use of a harvest guideline (HG) for the fishery based on biomass estimates, and divided it into three allocation periods for each season. The allocation periods were set as: 1) January 1 through June 30, 35 percent of the HG; 2) July 1 through September 14, 40 percent along with any portion not harvested from the first allocation period; and, 3) September 15 through December 31, 25 percent along with any remaining balance not harvested earlier in the year. The initial HG in 2000 was based on the 1999 total biomass estimates for sardine. The 2000 sardine fishery opened on January 1, with a harvest guideline of 205,844 short tons (186,791 metric tons) for the west coast fishery (Figure 6-2). This was a large increase, nearly 65 percent, over the previous year's quota set by the Department. The fishing fleet primarily utilizes round haul gear such as: purse seines, drum seines, and lampara nets.

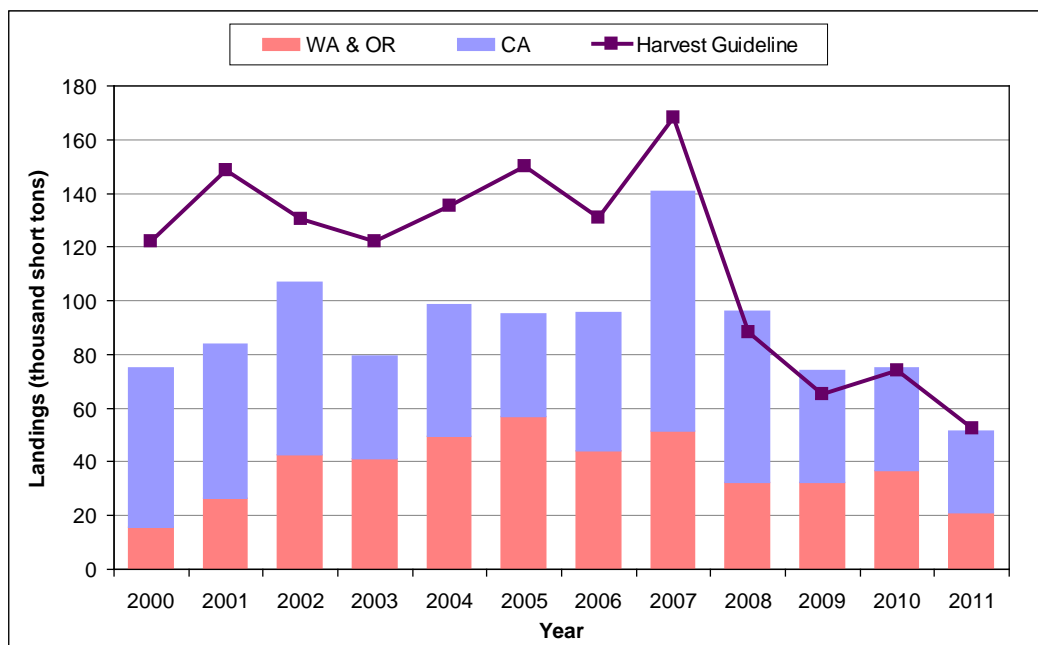


Figure 6-2. Pacific sardine commercial landings and harvest guideline for California, Oregon, and Washington fisheries, 2000-2011. Data source: CFIS data (California) and PacFIN data (Oregon and Washington), all gear types combined.

In 2007, landings in California peaked at nearly 90,000 short tons (81,600 metric tons), which was the highest since the 1950s (Figure 6-3). In 2008, the HG was set at 89,093 short tons (80,825 metric tons) which was a decrease of 42 percent from the previous year. This HG was setting the fishery up for landings to be constrained for the first time since the population had been declared recovered in 1999. This potential for early closures during the allocation periods resulted in a derby style fishery where there was a race to catch sardine. The directed fishery for the first allocation period lasted 150 days and ended over a month prior to the start of the new allocation period. This increased fishing intensity was due to the belief that fishermen were competing for the allocation. Average daily landings increased during the second allocation period and

vessels began fishing on the weekends which was previously not a normal occurrence. By the third allocation period, fishing efforts had intensely increased and fueled a frenzied atmosphere. The final fishery allocation for 2008 lasted only nine days.

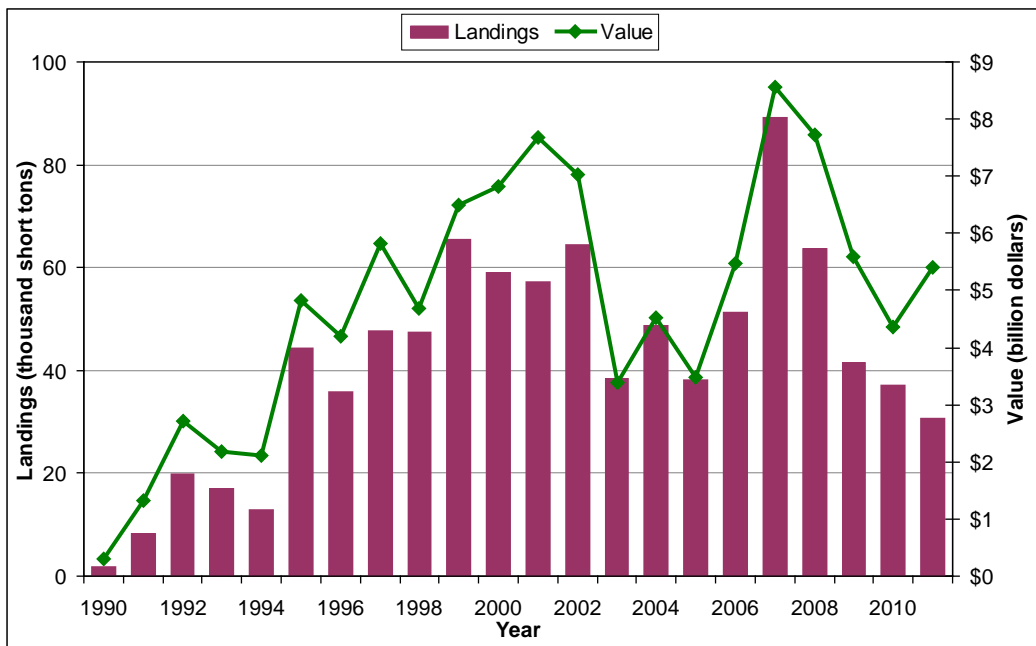


Figure 6-3. Pacific sardine commercial landings and value, 1990-2011. Data source: CFIS data, all gear types combined.

The 2008 sardine fishery was only open 199 days total (55 percent of the year). In 2009, the landings doubled in the number of trips per day compared to 2008. Fishery participants fished with intensity in 2009, believing that the allocation would be reached as quickly as it had the previous year. However, in the last allocation period of 2009, sardine landings dropped significantly as fishermen directed effort to market squid, which commanded a higher market value.

Both 2010 and 2011 showed similar trends compared to the two previous years. In the beginning of 2010, the high abundance of market squid in southern California resulted in little interest in the sardine fishery with squid selling for a much higher price. Inclement weather also played a large role, with vessels not being able to fish due to high surf and winds throughout a large portion of the season. In 2011, Pacific sardine was the second largest fishery in the state of California by volume and the sixth largest in value (Figure 6-3, Table 6-1 and Table 6-2). The fishery continues to be centered in the southern portion of the state with northern fishery (central and northern California) making up only 30 percent of the state's total landed catch (Figure 6-4).

Table 6-1. Largest California commercial fisheries by weight in 2011.			
Rank	Species	Pounds	Value
1	Market squid	267,985,250	\$68,579,285
2	Pacific sardine	61,097,986	\$5,390,048
3	Dungeness crab	20,643,551	\$51,618,869
4	Red sea urchin	11,494,799	\$8,179,865
5	Pink shrimp	7,375,139	\$3,684,168
6	Northern anchovy	5,734,842	\$617,659
7	Dover sole	5,318,533	\$2,258,482
8	Sablefish	5,304,779	\$15,121,468
9	Pacific herring roe	3,453,089	\$859,819
10	Pacific mackerel	2,990,971	\$326,433

Data Source: CFIS data, all gear types combined.

Table 6-2. Largest California commercial fisheries by value in 2011			
Rank	Species	Pounds	Value
1	Market squid	267,975,366	\$68,576,815
2	Dungeness crab	20,494,789	\$51,152,985
3	Sablefish	5,209,444	\$14,771,660
4	California spiny lobster	751,075	\$12,910,205
5	Red sea urchin	11,478,690	\$8,161,570
6	Pacific sardine	61,097,986	\$5,390,048
7	Chinook salmon	990,977	\$5,130,000
8	Spot prawn	342,389	\$3,903,214
9	Pink shrimp	7,375,139	\$3,684,168
10	Swordfish	941,425	\$3,346,077

Data source: CFIS data, all gear types combined.

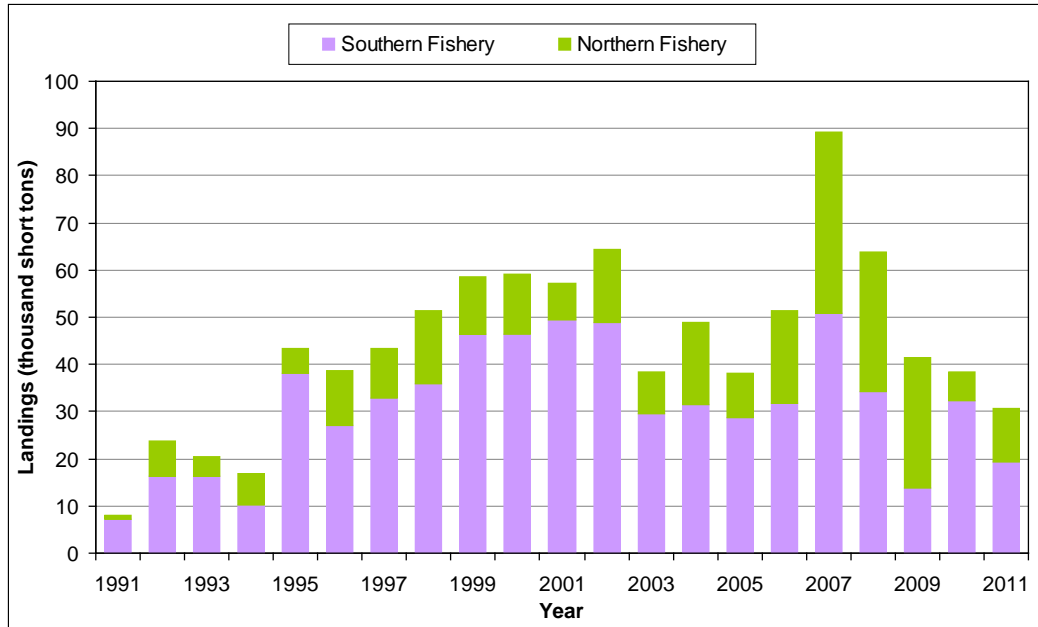


Figure 6-4. Pacific sardine commercial landings in California by region, 1991-2011. Data source: CFIS data, all gear types combined.

Status of the Biological Knowledge

Sardines are small, schooling, pelagic fish that are found in coastal temperate waters and are members of the herring family, Clupeidae. It is one of 18 species from three genera found worldwide. At times, Pacific sardine has been the most abundant fish species in the California Current and are an important forage fish, or prey item, for many species of marine life such as marine mammals, birds, and larger pelagic fish.

Sardine, along with anchovies, vary in abundance due to many different environmental factors. Anchovies tend to favor cold-water oceanic cycles whereas sardine favor the warm-water cycles. The average time for a sardine population to recover is 30 years and it has been found that sardine populations have diminished in the past in the absence of fishing pressure. When the population is abundant, Pacific sardines can be found from the tip of Baja California to southeastern Alaska, but they only occur seasonally in the northern portion of the range. In most areas Pacific sardine can be found with northern anchovy, Pacific whiting, and Pacific mackerel.

It is generally accepted that Pacific sardine form three, possibly even four, subpopulations: a Gulf of California subpopulation, a southern subpopulation off of Baja California, Mexico, a principal northern subpopulation that ranges from northern Baja California, Mexico, to Alaska. The fourth postulated subpopulation is a far northern subset. These subpopulations were assigned on the basis of blood typing. This blood typing shows different surface markers found on the red blood cells between different subpopulations, and helps delineate between 'races' of sardines.

Pacific sardine live as long as 14 years and reach lengths of up to 16 inches (41 centimeters), but 90 percent of the population consists of fish younger than six years old and smaller than 12 inches (30 centimeters). There is a substantial variation in size at age with the size given at a particular age increasing from south to north. It has been found that size and age at maturity decline as biomass decreases. At lower biomass levels, sardine appear to be fully mature at age one, whereas during years with higher biomass levels only some of the age two sardine are mature.

Spawning is thought to be restricted to 55° to 63° F (13° to 20° C), whereas sardine schools have been found in temperatures ranging from 44° to 82° F (7° to 28° C). The most northern and primary spawning ground is located between Point Conception, California and Ensenada, Baja California, Mexico. Spawning occurs in the upper 165 feet (50.3 meters) of the water column, most likely year round, peaking from April through August in the north between Point Conception, California and Bahía Magdalena, Baja California, Mexico, and from January to April in the Gulf of California. The spatial and temporal distribution of spawning is greatly influenced by water temperature. Sardine spawning shifts northward and continues for a longer period of time during warm water conditions. Pacific sardine are serial spawners and spawn several times each season. However, the number of spawning events is unknown. Eggs are found near the water surface and require approximately three days to hatch at 59° F (15° C).

Sardines age three and older were nearly fully vulnerable to the fishery up until 1953, but two and three year old fish became less available as the population declined and fewer fish moved northward. Current catch data suggests that sardine become available to the fishery at age zero, and are fully vulnerable by age three. Sardines younger than age three most likely become vulnerable to the live bait fishery which fishes in the nearshore waters where young sardines are known to occur.

Recruitment of juvenile Pacific sardine, such that they reach the size and age where they are vulnerable to the fishery, is greatly variable. Analyses of the stock-recruitment relationship have been controversial, with some studies showing a density-dependent relationship and others finding no relationship at all. Between 1932 and 1965, mean recruitment only slightly exceeded possible replacement of spawners at all levels of abundance, signifying little resilience to fishing. Recruitments occur in strings, with several years of successful recruitment followed by comparable periods of poor recruitment. The timing and length of these strings has a great effect on population growth.

Historically, the northern subpopulation made wide-ranging migrations, moving as far north as British Columbia, Canada, in the summer months and as far south as northern Baja California, Mexico, in the fall. Northern movement increased with age. The migration was complex, with timing and movement affected to some degree by oceanographic conditions. The population is currently expanding, found primarily off central and southern California as well as Baja California, Mexico.

Estimates of sardine abundance from AD 280 to 1970 have been derived from the deposition of fish scales in sediment cores from the Santa Barbara basin. Significant sardine populations existed throughout this time period and varied greatly in size. The deposition record shows nine major recoveries and correlating collapses of the population during the 1700 year period. The average recovery time for those sardine populations was approximately 30 years. The current recovery is similar to past recoveries in terms of both rate and magnitude.

Status of the Population

The estimated spawning biomass of the Pacific sardine averaged 3.8 million short tons (3.5 million metric tons) from 1932 to 1934, and fluctuated from 3.1 to 1.3 million short tons (2.8 to 1.2 million metric tons) from 1935 to 1944. The population then steeply declined over the next two decades, with a few short reversals after periods of successful recruitment, to less than 100,000 short tons (90,719 metric tons) in the early 1960s. During the 1970s, spawning biomass was estimated to be as low as 5,000 short tons (4,536 metric tons). Since the 1980s, the sardine population has increased, and the total was thought to be greater than 1.2 million short tons (1.1 million metric tons) in 1998.

Stock biomass is estimated each year to calculate harvest specifications and is defined as the sum of the biomass for sardine age one and older. In July of 2011, the stock biomass was estimated to be 1,089,497 short tons (988,385 metric tons). From 2007 to 2010 there has been a decrease in the biomass estimates for sardine (Figure 6-5). This has been the cause of the lower HGs which has constrained the fishing efforts of sardine for the past four years.

Historically, the maximum sustainable yield of the fishery in the northern subpopulation was estimated to be 250,000 short tons (226,800 metric tons) or about 22 percent per year, which was far less than the catch of sardine during the height of the fishery. Although combined landings in Mexican and U.S. waters are still well below this level, landings had increased substantially up until 2007. In the absence of a bilateral management agreement between the United States and Mexico, their combined catches of Pacific sardine have the potential for contributing towards and accelerating the next population decline. Disagreement over whether the cause of the decrease in the sardine population was due to overfishing or due to natural events has continued for decades. It is now known that both are important factors. Following the total fishery closure, management of the fishery and the development of more favorable environmental conditions has allowed the sardine resource to recover.

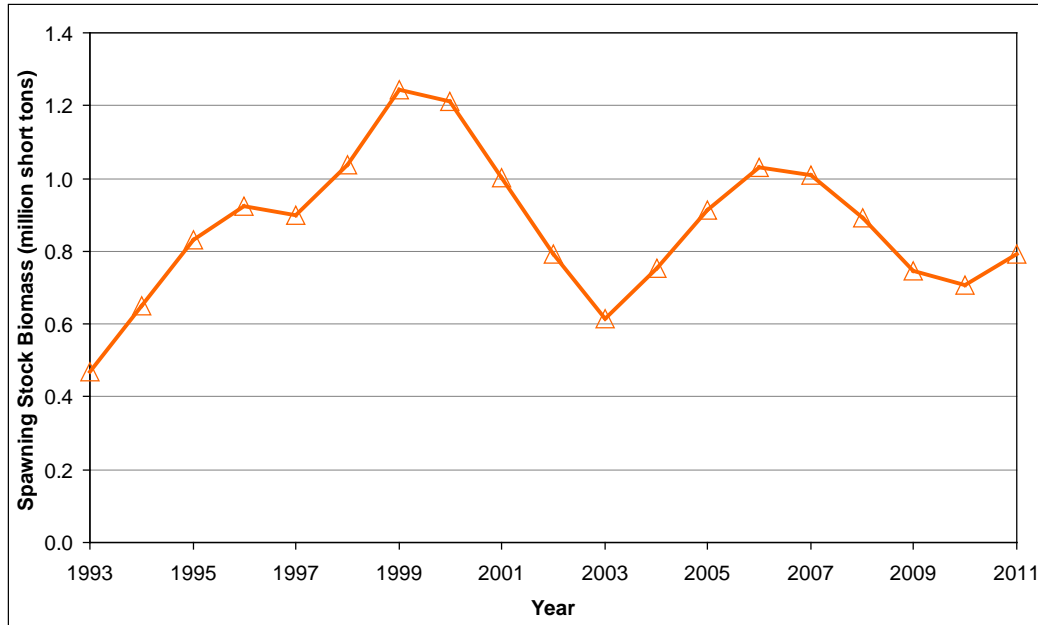


Figure 6-5. Pacific sardine spawning stock biomass, ages one and older, 1993-2011. Data source: Pacific Fishery Management Council (PFMC 2011) SAFE document.

Management Considerations

In 1999, a federal CPS FMP was established to help manage the Pacific sardine fishery as well as other coastal pelagic species along the west coast of the United States. The CPS FMP was implemented by the Pacific Fishery Management Council (PFMC), and was an expansion of the Northern Anchovy FMP which had been in place since 1978. The newly implemented plan transferred management responsibilities from the Department to the NOAA Fisheries Service. The elements of the CPS FMP consist of: 1) fishery management areas consisting of a limited entry (LE) zone and subareas; 2) specifications including a HG, quotas, and allocations; 3) requirements for closing directed fisheries when the HG is reached; 4) a dedicated fishing season for sardine from January 1 through December 31; 5) catch restrictions for incidental catch of sardine when the directed fishery is closed; 6) a federal LE program for the southern subarea; and, 7) authorization for NOAA Fisheries Service to issue exempted fishing permits for the harvest of CPS that otherwise would be prohibited.

The CPS FMP divides management into two categories: actively managed species and monitored species. Pacific sardine fall under the actively managed category and therefore have a HG. The CPS FMP and its operating regulations require NOAA Fisheries Service to set an annual HG for the Pacific sardine fishery based on the annual specifications framework in the CPS FMP. This framework includes a harvest control rule that determines what the maximum HG for the current fishing season will be based mainly on the stock biomass estimation for the year. The HG is allocated into three separate periods to extend fishing efforts throughout the year.

Initially, the U.S. sardine resource was allocated both spatially and temporally with two subareas divided at Point Piedras Blancas, California (north of Morro Bay), with the northern subarea and the southern subarea allocated 33 and 66 percent of the total allocation, respectively. After October 1, the remaining portion of the unused HG was split evenly between the two subareas. As the sardine resource expanded into Oregon and Washington, the line between the northern and southern subareas was changed to Point Arena, California (Mendocino County), with the allocation remaining the same. Beginning in 2006, the U.S. sardine resource allocation changed, moving to a coastwide allocation that was released at three separate times (January 1-35 percent, July 1-40 percent, and September 15-25 percent), to allow for a more equitable harvest opportunity between the three states.

In 2000, federal CPS LE permits were first issued when the CPS FMP went into effect for waters off the west coast of the U.S., with a total of 65 permits issued coastwide. In 2002, a capacity goal of 65 vessels with a calculated gross tonnage of 6229 tons (5650.9 metric tons) was adopted. Any CPS LE permit may be transferred to another vessel with restrictions on the harvesting capacity of the new vessel to which the permit is to be transferred to. These restrictions are as follows: 1) full transferability of permits to vessels of comparable capacity (vessel gross tonnage plus 10 percent allowance), and 2) allow permits to be combined (stacked) up to a greater capacity than the one from which the permit was transferred. At present, 56-57 permits are active in the fishery, with some of the reduction due to permit stacking.

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Further Reading

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Pacific sardine commercial landings, 1916-2011.							
Year	Short tons	Year	Short tons	Year	Short tons	Year	Short tons
1916	7,824	1940	452,987	1964	6,569	1988	1,310
1917	52,052	1941	631,240	1965	962	1989	922
1918	78,826	1942	484,874	1966	439	1990	1,834
1919	76,939	1943	486,135	1967	74	1991	8,364
1920	59,260	1944	573,604	1968	62	1992	19,786
1921	29,666	1945	422,531	1969	53	1993	16,915
1922	46,700	1946	255,380	1970	221	1994	12,835
1923	79,080	1947	127,757	1971	148	1995	44,453
1924	121,343	1948	181,019	1972	186	1996	35,889
1925	157,647	1949	316,690	1973	76	1997	47,670
1926	143,371	1950	357,261	1974	7	1998	47,350
1927	171,138	1951	164,450	1975	3	1999	65,579
1928	210,135	1952	7,165	1976	8	2000	59,096
1929	325,886	1953	4,734	1977	2	2001	57,202
1930	251,031	1954	68,252	1978	1	2002	64,323
1931	182,176	1955	72,804	1979	57	2003	38,285
1932	211,305	1956	34,777	1980	23	2004	48,837
1933	313,199	1957	22,931	1981	38	2005	38,176
1934	559,966	1958	103,723	1982	2	2006	51,342
1935	547,879	1959	37,183	1983	1	2007	89,265
1936	731,772	1960	28,766	1984	1	2008	63,719
1937	535,745	1961	21,585	1985	6	2009	41,421
1938	511,695	1962	7,681	1986	428	2010	37,102
1939	580,397	1963	3,566	1987	484	2011	30,550

Data source: Department catch bulletins (1916-1986) and CFIS data (1987-2011), all gear types combined.

Pacific sardine commercial landings and harvest guideline for California, Washington, and Oregon, 2000-2011.			
Year	WA & OR (short tons)	CA (short tons)	HG (short tons)
2000	15,840	59,123	122,221
2001	26,353	57,280	148,840
2002	42,487	64,333	130,523
2003	40,981	38,288	122,221
2004	49,654	48,863	135,305
2005	57,134	38,251	150,069
2006	44,128	51,349	131,069
2007	51,597	89,320	168,269
2008	32,390	63,769	88,386
2009	32,526	41,510	65,291
2010	36,633	38,297	73,897
2011	20,979	30,550	52,718

Data source: CFIS data (California) and PacFIN data (Oregon and Washington).

Pacific sardine commercial landings by area (short tons) and value, 1990-2011.				
Year	North	South	Total	Value
1990	274	1,561	1,834	\$292,105
1991	685	7,277	7,962	\$1,321,779
1992	7,461	16,338	23,799	\$2,711,654
1993	4,381	16,170	20,551	\$2,186,223
1994	6,544	10,305	16,849	\$2,099,411
1995	5,219	38,190	43,409	\$4,827,484
1996	11,578	27,084	38,662	\$4,197,653
1997	10,530	32,943	43,473	\$5,811,814
1998	15,631	35,778	51,409	\$4,685,478
1999	12,299	46,316	58,615	\$6,505,387
2000	12,592	46,531	59,123	\$6,825,665
2001	7,950	49,330	57,280	\$7,676,322
2002	15,311	49,021	64,333	\$7,027,996
2003	8,735	29,553	38,288	\$3,382,044

Pacific sardine commercial landings by area (short tons) and value, 1990-2011.				
Year	North	South	Total	Value
2004	17,484	31,378	48,863	\$4,528,278
2005	9,455	28,796	38,251	\$3,485,958
2006	19,674	31,675	51,349	\$5,465,840
2007	38,396	50,924	89,320	\$8,557,934
2008	29,494	34,275	63,769	\$7,718,091
2009	27,666	13,843	41,510	\$5,596,508
2010	5,942	32,355	38,297	\$4,369,846
2011	11,103	19,447	30,550	\$5,390,048

Data source: CFIS data, all gear types combined.