Management of the Pacific Sardine

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In 1967, the California Legislature placed a moratorium on landings of Pacific sardine *(Sardinops caerulea)* for any purpose, including bait. This was the most decisive act of management during the 50-year history of the fishery. It also was tacit admission that a viable fishery for the Pacific sardine had ceased to exist. A modest fishery for this species does continue off Baja California.

The history of the sardine fishery during the past 5 decades is best documented by the landings (Table 1). The fishery first developed in California and British Columbia, hence from its inception it was international. The tardiness of Oregon and Washington in entering the fishery was due to legal restrictions, not removed until 1935, against reduction of sardines to meal and oil. The fishery for the Pacific sardine grew rapidly during the first 2 decades, reached its highest level in the 1936-1937 season, continued at a high level for almost a decade, and then progressively declined. The decline was first evident in the Pacific Northwest; it progressed southward to central California and later to southern California. Even the catch off Ensenada, Baja California, has markedly declined in recent years, and most catches now are made from off central and southern Baja California.

Two principal uses were made of sardines: they were either canned or reduced to fish meal and oil. Most fish landed in British Columbia were reduced to fish meal and oil. The modest fisheries that developed in Oregon and Washington also were exclusively for reduction. California processors began as canners, and canning continued as an essential part of their operation, but they soon realized that reduction of whole fish to meal and oil could be a profitable supplement to the canning operation. The resulting controversy that developed between processors and management agencies is the main topic of discussion in this paper. Most Baja California landings have been canned.

The term "management" of a fishery has two entirely different meanings. Fishery scientists are striving for scientific management, designed to ensure a continuing high yield of the resource. This concept is often simplified to the phrase "maximum sustainable yield." Recently, many fishery scientists have redefined their goal to be an attempt to obtain the maximum economic yield for a fishery. Mostly, these attitudes remain concepts,

Table 1.–Seasonal catch (tons) of sardines along the Pacific coast [Each season includes June through the following May[1]]

Season	Pacific Northwest				California[2]							
					Northern California							
	British Columbia	Washington	Oregon	TOTAL	Reduction ships	San Francisco	Monterey	Total	Southern California	TOTAL California	Baja[3] California	Grand total
1916-17	...	...	...	...	...	...	7,710	7,710	19,820	27,530	...	27,530
1917-18	80	...	...	80	...	70	23,810	23,880	48,700	72,580	...	72,660
1918-19	3,640	...	...	3,640	...	450	35,750	36,200	39,340	75,540	...	79,180
1919-20	3,280	...	...	3,280	...	1,000	43,040	44,040	22,990	67,030	...	70,310
1920-21	4,400	...	...	4,400	...	230	24,960	25,190	13,260	38,450	...	42,850
1921-22	990	...	...	990	...	80	16,290	16,370	20,130	36,500	...	37,490
1922-23	1,020	...	...	1,020	...	110	29,210	29,320	35,790	65,110	...	66,130
1923-24	970	...	...	970	...	190	45,920	46,110	37,820	83,930	...	84,900
1924-25	1,370	...	...	1,370	...	560	67,310	67,870	105,150	173,020	...	174,390
1925-26	15,950	...	...	15,950	...	560	69,010	69,570	67,700	137,270	...	153,220
1926-27	48,500	...	...	48,500	...	3,520	81,860	85,380	66,830	152,210	...	200,710
1927-28	68,430	...	...	68,430	...	16,690	98,020	114,710	72,550	187,260	...	255,690
1928-29	80,510	...	...	80,510	...	13,520	120,290	133,810	120,670	254,480	...	334,990
1929-30	86,340	...	...	86,340	...	21,960	160,050	182,010	143,160	325,170	...	411,510
1930-31	75,070	...	...	75,070	10,960	25,970	109,620	146,550	38,570	185,120	...	260,190
1931-32	73,600	...	...	73,600	31,040	21,607	69,078	121,725	42,920	164,645	...	238,245
1932-33	44,350	...	...	44,350	58,790	18,634	89,599	167,023	83,667	250,690	...	295,040
1933-34	4,050	...	...	4,050	67,820	36,336	152,480	256,636	126,793	383,429	...	387,479
1934-35	43,000	...	...	43,000	112,040	68,477	230,854	411,371	183,683	595,054	...	638-054
1935-36	45,320	10	26,230	71,560	150,830	76,147	184,470	411,447	149,051	560,498	...	632,058
1936-37	44,450	6,560	14,200	65,210	235,610	141,099	206,706	583,415	142,709	726,124	...	791,334
1937-38	48,080	17,100	16,660	81,840	67,580	133,718	104,936	306,234	110,330	416,564	...	498,404
1938-39	51,770	26,480	17,020	95,270	43,890	201,200	180,994	426,084	149,203	575,287	...	670,557
1939-40	5,520	17,760	22,330	45,610	...	212,453	227,874	440,327	96,939	537,266	...	582,876
1940-41	28,770	810	3,160	32,740	...	118,092	165,698	283,790	176,794	460,584	...	493,324
1941-42	60,050	17,100	15,850	93,000	...	186,589	250,287	436,876	150,497	587,373	...	680,373
1942 43	65,880	580	1,950	68,410	...	115,884	184,399	300,283	204,378	504,661	...	573,071
1943-44	88,740	10,440	1,820	101,000	...	126,512	213,616	340,128	138,001	478,129	...	579,129
1944-45	59,120	20	...	59,140	...	136,598	237,246	373,844	181,061	554,905	...	614,045
1945-46	34,300	2,310	90	36,700	...	84,103	145,519	229,622	174,061	403,683	...	440,383

1946-47	3,990	6,140	3,960	14,090	...	2,869	31,391	34,260	199,542	233,802	...	247,892
1947-48	490	1,360	6,930	8,780	...	94	17,630	17,724	103,617	121,341	...	130,121
1948-49	...	50	5,320	5,370	...	112	47,862	47,974	135,752	183,726	...	189,096
1949-50	...	...	...	...	...	17,442	131,769	149,211	189,714	338,925	...	338,925
1950-51	...	...	...	...	...	12,727	33,699	46,426	306,662	353,088	...	353,088
1951-52	...	...	...	...	...	82	15,897	15,979	113,125	129,104	16,184	145,288
1952-53	...	...	...	...	...	...	49	49	5,662	5,711	9,162	14,873
1953-54	...	...	...	...	...	...	58	58	4,434	4,492	14,306	18,798
1954-55	...	...	...	...	...	...	856	856	67,609	68,465	12,440	80,905
1955-56	...	...	...	...	...	...	518	518	73,943	74,461	4,207	78,668
1956-57	...	...	...	...	...	...	63	63	33,580	33,643	13,655	47,298
1957-58	...	...	...	...	...	...	17	17	22,255	22,272	9,924	32,196
1958-59	...	...	...	...	...	...	24,701	24,701	79,270	103,971	22,334	126,305
1959-60	...	...	...	...	...	...	16,109	16,109	21,147	37,256	21,446	58,702
1960-61	...	...	...	...	...	...	2,340	2,340	26,538	28,878	19,899	48,777
1961-62	...	...	...	...	...	...	2,231	2,231	23,297	25,528	21,270	46,798
1962-63	...	...	...	...	...	...	1,211	1,211	2,961	4,172	14,620	18,792
1963-64	...	...	...	...	...	...	1,015	1,015	1,927	2,942	18,384	21,326
1964-65	...	...	...	...	...	...	308	308	5,795	6,103	27,120	33,223
1965-66	...	...	...	...	...	...	151	151	568	719	22,247	22,966
1966-67	...	...	...	...	...	...	23	23	321	344	19,531	19,875
1967-68[4]	...	...	...	...	...	...	10	10	61	71	27,657	27,728

[1] Data for British Columbia were supplied by the Canadian Bureau of Statistics and the province of British Columbia; those for Washington by the Washington Department of Fisheries, and for Oregon by the Fish Commission of Oregon. Tonnages delivered to the reduction ships and data for Baja California were compiled by the United States Fish and Wildlife Service from the books of the companies receiving fish. California landings were derived from the records of the California Department of Fish and Game.

[2] Before the 1931-32 season, fish landed in Santa Barbara and San Luis Obispo Counties are included in Southern California. Beginning with the 1931-32 season fish landed north of Point Arguello are included in the Monterey landings and those south of Point Arguello are included in the Southern California landings.

[3] The amount of sardines landed in Baja California before the 1951-52 season is not known. Landings for Isla Margarita in Southern Baja California are not included since the landing data are incomplete. The partial record for this port indicated landings of 895 tons during the September 1965–May 1966 period and 203 tons during the June 1966–December 1966 period.

[4] Preliminary figures, estimated from percentage of sardines contained in loads of mixed fish as reported on California landing receipts. Under the moratorium on sardine landings a tolerance of up to 15% sardines was allowed in loads of mixed fish. In addition, an unknown amount of sardines (probably less than 500 tons) was landed illegally in 1967-68.

inasmuch as opportunities to apply scientific management to a resource have been exceedingly few; Pacific halibut and yellowfin tuna of the eastern Pacific are two notable exceptions.

Most management measures consis. of piecemeal, pragmatic regulations, often influenced by special interest groups. These regulations are proclaimed by a federal agency for a territory, negotiated *quid pro quo* between nations, or passed by state legislatures and delegated to conservation agencies for implementation. The latter has been the usual pattern of managing the sardine resource.

The legal regulation of the sardine industry between 1917 and 1942 was summarized by Schaefer, Sette, and Marr (1951). In British Columbia no limitation was placed on the quantity of fish that could be used for reduction, but minor regulations were placed on fishermen as regards size and mesh of purse seine gear and, from time to time, on the season of fishing. Oregon and Washington, after approving the use of sardines for reduction, imposed no limitations on quantity landed or on season of fishing. Essentially, the fishery in the Pacific Northwest was a seasonal, opportunistic one, without regulation as to the quantity of landings or the use made thereof. The fishery off Baja California has had no legal restrictions on gear, seasons, quantities, or use.

Canning versus Reduction

Most of the legal regulation was in California and concerned the use of whole fish for reduction to fish meal and oil. To understand the controversy, a short historical account of the sardine processing industry in California is needed. Sardine canning began on a small scale as early as 1889 at San Francisco and 1894 at San Pedro. The industry grew slowly during the next 2 decades, although canneries were built at two additional ports, Monterey (1902) and San Diego (1909). The stimulus for greatly increasing the sardine pack came from food shortages during World War I. The case pack of sardines rose from less than 100,000 cases annually in 1915 to nearly 1 million cases in 1919. Monterey developed into the principal sardine canning port. San Pedro was a strong second, and activity was less in the San Francisco Bay area and at San Diego.

The sardine canning industry used mostly adult fish. Preparatory to canning, about 1/2 the weight of each fish was removed as waste material or offal, including the head, viscera, and usually a portion of the tail end. The cleaned fish were then packed, 4 to 8 per can, usually in tomato sauce or mustard, in the familiar 1-pound oval tins. These cans usually were packaged 48 per case which became the standard case pack of sardines. In the early days of the industry, the offal was barged to sea and discarded. During World War I, reduction plants were established at the principal ports to handle offal of canneries and surplus whole fish. These community reduction plants proved profitable, and for this reason short-lived; each cannery soon obtained its own reduction equipment. By 1920, most California sardine canneries had reduction facilities as part of their operation.

Processors soon learned that it was more profitable to convert sardines into meal and oil than to can them. Reduction of some whole fish was, at times, inevitable as part of the canning operation, inasmuch as wide fluctuations in landings of sardines sometimes created an oversupply. In addition, unavoidable machinery breakdowns at the canneries sometimes made it necessary to divert the sardines on hand to the reduction plant to avoid waste. Plant operators not only wished to increase the "overage" resulting from the canning operations, but to be permitted to reduce whole fish without regard to canning. Opposed to this unrestricted reduction was the sentiment of conservation organizations in California, succinctly stated in 1927 by B. D. Max Greene, attorney for the California Fish and Game Commission: "It seems repugnant to every right-thinking citizen to see fresh fish used for any purpose other than human consumption." These opposing interests—plant operators trying to gain permission to use as much of the sardine catch for reduction as they saw fit and conservation organizations seeking to curtail reduction—became the protagonists in a continuing struggle.

The first clash came as early as 1919. In the spring of that year, several canneries diverted much of their fish to reduction plants, because the sardines were claimed to be of inferior quality for canning. The legislature then in session passed a law which prohibited the use of whole fish for reduction without the prior

written permission of the Fish and Game Commission. This law also prohibited any cannery from receiving more fish than it could use for canning without spoilage.

The law was tested in two legal cases, one brought against a San Pedro canner who reduced more than the allowable 25 percent overage of whole fish, the other against a Monterey citizen who attempted to operate an independent reduction plant. Both cases were finally tried by the California Supreme Court. The Court's decision upheld the constitutionality of the legislative acts and, further, annunciated the principle that the general right and ownership of the fish are in the people of the state and, consequently, the state has the right to regulate and control the taking and disposition thereof.

Despite these favorable decisions, the control of overage proved difficult until the Fish and Game Commission succeeded in tying overage to case pack by requiring at least 15 cases of 48, 1-pound ovals to be packed per ton of sardines received. The expected case pack from a ton of sardines in good condition is at least 20 cases, hence the ruling allowed 25 percent overage. Later, the allowable overage was increased to 32.5 percent (13.5 cases per ton).

The struggle then entered a new phase. Operators who wished to be straight reductionists put to sea in floating reduction plants, to get beyond the jurisdiction of the State of California. They failed on their first attempt. The *Peralta*, an old concrete vessel, was anchored as a floating reduction plant in Monterey Bay, over 3 miles from shore. The court action taken against the *Peralta* in 1926 resulted in a historic decision concerning territorial jurisdiction over a bay. Monterey Bay, 19 miles between promontories, was found to be completely under the jurisdiction of the State of California. However, a 1927 injunction against the *Lake Miraflores*, a self-propelled vessel equipped as a floating reduction plant and operated 5 miles offshore from San Pedro Bay, resulted in a decision that the vessel, when operated in international waters, was outside the state's jurisdiction. As a result of this decision, *Lake Miraflores* in 1930 began operation as a floating reduction plant outside the continental limits off San Francisco. In 1931, this floating plant processed over 31,000 tons of sardines.

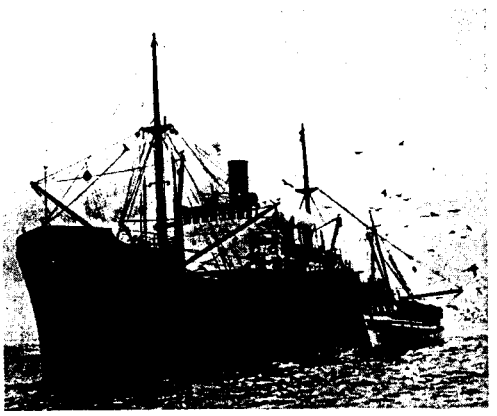

Figure 1. The reduction vessel, *Lake Miraflores*, first to operate outside the continental limit, beyond the jurisdiction of the State of California.

Concurrent with the beginning of the operation of floating reduction plants at sea, the sardine industry ashore was severely affected by the financial depression of the early 1930's. Landings at shore plants had decreased from 325,170 tons in the 1929-1930 season to 133,605 tons in the 1931-1932 season. As canned sardines accumulated in warehouses, canneries had to curtail their operations severely. Sardine fishing boats were put on low catch limits. As noted by Schaefer et al. (1951), it became common practice for the fishermen to bring in more fish than had been ordered, on the off chance that the excess fish could be sold. The immediate reaction of the Fish and Game Commission was an order to fishermen requiring them to avoid taking more fish than they could sell. This action merely intensified pressures to alleviate the economic plight of fishermen and plant operators by relaxing the restrictions on reduction of whole fish. The Fish and Game Commission then, as an emergency measure, decided to grant to each plant making application a permit to reduce up to 7,500 tons of sardines for the manufacture of edible oil and meal during the 1932-1933 sardine season. Soon after the close of the 1932-1933 sardine season, the California Legislature amended the law relative to use made of reduction products, permitting their sale for

any purpose. This change permitted the operation of straight reduction plants.

The granting of reduction permits to shore plants did not immediately curb the activity of the reduction vessels. A second vessel, *Lansing,* joined *Lake Miraflores* in 1932. The peak of the offshore operation was reached in the 1936-1937 season when a fleet of nine floating reduction plants processed 235,610 tons of sardines. The competition of the unregulated reduction ships forced liberalization of reduction quotas granted under permit to shore plants. In 1938, the offshore operation was terminated—partly because it had become uneconomical due to increased labor costs, including the requirements of the Seamen's Union for duplicate crews; partly because the supply of fish had fallen off; and partly because of changes in the California law. Several vessels continued to operate, under permit, as dockside reduction plants, however.

The system of reduction under permit meanwhile had become an entrenched part of the California fishery. Reduction was a most profitable operation for more than a decade, including the war years.

Canners had the advantage in tonnage received for reduction. In addition to the tonnage granted under permit, they had the overage of whole fish resulting from the lenient case-pack requirement of 13.5 cases per ton. That this overage was considerable is shown by the canner's performance in later years when reduction was unprofitable. For example, processors obtained 22.2 cases per ton while canning 2.26 million cases during the 1958-1959 sardine season. If this level of performance is a good yard-stick, the overage of whole fish obtained under a case pack requirement of 13.5 cases per ton was over 39 percent. During the height of the reduction period, 1935-1945, sardine case pack averaged about 3 million cases per year, while overage of whole fish from the canning operation averaged approximately 92,000 tons per year (see Table 2).

In the mid-1930's, tonnage allowances under permit for reduction were used only partially. In 1936-1937, the peak season for sardine landings, only 43 percent allowable reduction tonnage was taken; permits were issued to 74 plants, an increase of 54 over the initial 1932-1933 season (Table 3). For several years the number of permits was stabilized at about this level. A small increase in permits took place during World War II, and a marked increase immediately thereafter—to a high of 109 in the 1947-1948 season. In that season the tonnage granted per permit was 2,752 tons, the amount processed was a mere 120 tons. Most of the reduction plants constructed after the war never processed any sardines. A postwar boom in sardine reduction never materialized because the resource had reached too low a level.

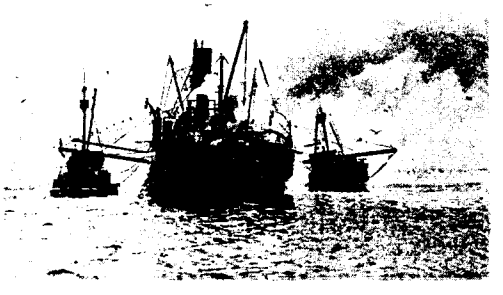

Figure 2. The reduction vessel, *Lansing,* unloading two purse seiners simultaneously.

Seasonal Limits

Other than control of tonnage of whole fish used for reduction by means of the permit system and case-pack requirements, the principal restriction on sardine fishing in California was its limitation to definite seasons since 1928. The open season differed between the central California and southern California fishing areas:

Open Season: Central California (Monterey and San Francisco)

1929-30 through 1947-48: Aug. 1—Feb. 15
1948-49 through 1956-57: Aug. 1—Jan. 15
1957-58 through 1960-61: Aug. 1—Dec. 31
1961-62 through 1966-67: Aug. 1—Mar. 1
1967-68 to present: closed

Open Season: Southern California (San Pedro)

1928-29 through 1942-43: Nov. 1—Mar. 31
1943-44 through 1947-48: Oct. 1—Mar. 1
1948-49 through 1956-57: Oct. 1—Feb. 1
1957-58 through 1960-61: Sep. 1—Dec. 31
1961-62 through 1966-67: Sep. 1—Mar. 1
1967-68 to present: closed

Table 2.–Sardines (tons) processed for canning or for reduction to fish meal and oil by the California sardine industry, 1926-27 through 1965-66 seasons

Season	A Sardines processed[1]	B Reduction under permit	C Taken at floating reduction plant	D Canning tonnage	E Case pack of sardines	F Tonnage required (22.2 cases/ton)	G Whole Fish overage at canneries (D-F)	H Cases per ton (E/D)
1926-27	143,559	0	0	143,559	2,274,310	102,446	41,113	15.8
27-28	181,176	(6,962)[2]	0	174,214	2,623,840	118,191	56,023	15.1
28-29	252,433	(15,728)[2]	0	236,705	2,972,635	133,902	102,803	12.6
29-30	322,600	(24,508)[2]	0	298,092	4,154,640	187,146	110,946	13.9
30-31	182,961	(16,722)[2]	10,960	155,279	2,155,970	97,116	58,163	13.9
1931-32	162,360	(15,979)[2]	31,040	115,341	1,672,160	75,322	40,019	14.5
32-33	248,956	129,473	58,790	60,693	823,980	37,116	23,577	13.6
33-34	381,662	170,155	67,820	143,687	1,957,760	88,187	55,500	13.6
34-35	592,786	342,637	112,040	138,109	1,876,620	84,532	53,577	13.6
35-36	557,996	169,629	150,830	237,537	3,216,915	144,906	92,631	13.5
1936-37	723,751	274,258	235,610	213,883	2,989,045	134,642	79,241	14.0
37-38	413,414	183,858	67,580	161,976	2,300,430	103,623	58,353	14.2
38-39	572,466	337,849	43,890	190,727	2,573,775	115,936	74,791	13.5
39-40	531,878	303,426	0	228,452	3,134,970	141,215	87,237	13.7
40-41	454,709	223,587	0	231,122	3,116,465	140,381	90,741	13.5
41-42	583,463	211,625	0	371,838	5,155,115	232,212	139,626	13.9
42-43	501,341	229,334	0	272,007	3,704,890	166,887	105,120	13.6
43-44	473,522	241,733	0	231,789	3,150,275	141,904	89,885	13.6
44-45	548,415	277,098	0	271,317	3,656,455	164,705	106,612	13.5
45-46	396,090	137,867	0	258,223	3,750,545	168,943	89,280	14.5
46-47	227,716	43,367	0	184,349	2,719,275	122,490	61,859	14.8
47-48	110,237	13,126	0	87,111	1,487,320	66,996	20,115	17.1
48-49	159,848	8,157	0	151,691	2,643,585	119,080	32,611	17.4
49-50	335,572	44,216	0	291,356	4,284,740	193,006	98,350	14.7
50-51	355,160	36,487	0	318,673	5,270,990	237,432	81,241	16.5
1951-52	126,541	1,022	0	125,519	2,367,860	106,660	18,859	18.9
52-53	3,615	11	0	3,604	70,560	3,178	426	19.6
53-54	2,620	0	0	2,620	62,955	2,836	0	24.0
54-55	67,142	0	0	67,142	1,391,925	62,699	4,443	20.7
55-56	73,190	0	0	73,190	1,531,545	68,989	4,201	20.9
1956-57	31,737	0	0	31,737	732,680	33,004	0	23.1
57-58	20,490	0	0	20,490	479,285	21,589	0	23.4
58-59	101,567	0	0	101,567	2,256,600	101,649	0	22.2
59-60	35,364	0	0	35,364	777,500	35,022	342	22.0
60-61	27,078	0	0	27,078	635,695	28,635	0	23.5
1961-62	22,332	0	0	22,332	504,380	22,720	0	22.6
62-63	1,607	0	0	1,607	48,250	2,173	0	30.0
63-64	1,350	0	0	1,350	36,225	1,632	0	26.8
64-65	4,359	0	0	4,359	111,035	5,002	0	25.5
65-66	–[3]	0	0	–[3]	4,320	195	–	–

[1] Excludes sardines used for purposes other than canning or reduction.

[2] Before the 1932-33 season reduction of sardines permitted only for manufacture of products for human consumption under Fish and Game permit.

[3] Exact tonnage not available, most sardines obtained in loads of mixed fish.

Table 3.--Tonnage granted under permit for sardine reduction in California and tonnage processed by unregulated reduction vessels

Season	Number of permits issued	Total tonnage granted	Tonnage granted per permit	Total tonnage used	Tonnage processed by offshore reduction vessels	Number of reduction vessels	Average tonnage per floating plant
1930-31	0	–	0	0	10,960	1	10,960
1931-32	0	–	0	0	31,040	1	31,040
32-33	20	150,000	7,500	129,473	58,790	2	29,395
33-34	–[1]	–[1]	6,000	170,155	67,820	4	16,955
34-35	–[1]	–[1]	12,000	342,637	112,040	3	37,347
35-36	–[1]	–[1]	4,320	169,629	150,830	4	37,708
1936-37	60	637,500	11,500	274,258	235,610	9	26,179
37-38	74	765,500	var[2]	183,858	67,580	6	11,263
38-39	70	485,764	var[3]	337,849	43,890	6	7,315
39-40	69	402,375	var[4]	303,426	0	0	0
40-41	70	350,000	5,000	223,587	–	–	–
1941-42	74	343,684	4,750	211,625	–	–	–
42-43	76	378,634	4,750	229,334	–	–	–
43-44	75	370,272	4,750	241,733	–	–	–
44-45	78	390,000	5,000	277,098	–	–	–
45-46	85	394,995	4,647	137,867	–	–	–
1946-47	101	394,910	3,910	43,367	–	–	–
47-48	109	299,968	2,752	13,126	–	–	–
48-49	74	99,958	1,350	8,157	–	–	–
49-50	101	75,040	743	44,216	–	–	–
50-51	102	149,997	1,470	36,487	–	–	–
1951-52	84	149,994	1,786	1,022	–	–	–
52-53	60	99,990	1,666	11	–	–	–
53-54	0[5]	0	0	0	–	–	–
				3,378,915	778,560		

[1] Information not available on number of permits issued or on total tonnage granted under permit for the 1933-34 through 1935-36 season. Minutes of meetings of California Fish and Game Commission were checked for these years, but only partial information on the number of permits granted was contained in the minutes.

[2] Permit tonnage based on plant capacity–12,500 or 16,500 tons.

[3] Permit tonnage based on plant capacity–7,000, 9,500, or 13,000 tons.

[4] Permit tonnage based on plant capacity–5,000, 7,500, or 10,000 tons.

[5] No permits issued subsequent to the 1952-53 season.

This legislation on seasons initially was requested by the sardine industry to restrict operations to the portion of the year when fish were most available and in prime condition for canning or reduction.

Scientific Investigations

Up to this point we have dealt mostly with regulations applied to the sardine fishery in California but not with the scientific basis for these regulations. A number of research agencies have contributed to the scientific investigation of the Pacific sardine resource.

The California Department of Fish and Game began research on the sardine fishery over 50 years ago (1918), the Fishery Research Board of Canada in the late 1920's, the Bureau of Commercial Fisheries in 1937, and Oregon and Washington at about the same time. In 1949, a greatly expanded research program, known as the California Cooperative Oceanic Fisheries Investigations (CalCOFI), was undertaken under the sponsorship of the California

Marine Research Committee. Participating scientific groups included the California Department of Fish and Game, the Bureau of Commercial Fisheries, Scripps Institution of Oceanography, California Academy of Science, and later the Hopkins Marine Station of Stanford University.

Hundreds of research papers have been published about the sardine. Perhaps as much is known about the population structure, distribution, recruitment, and ecology of this fish as of any pelagic marine resource. Little of this information has been used in the management of the fishery. In fairness to management, let it be pointed out that much of the information was available only after the abundance of the resource had decreased markedly.

Scientists working on sardine research problems realized the need for communication and cooperation. From the early days of the fishery, scientists from British Columbia and California exchanged information. In 1938, scientists from the states of California, Oregon, and Washington, the province of British Columbia, and the Bureau of Commercial Fisheries met in the first of a continuing series of annual sardine conferences to discuss research results and plan for future research, often cooperatively. After the initiation of the CalCOFI in 1949, the annual sardine conference was merged with the annual CalCOFI Conference.

Scientists of the California Department of Fish and Game warned about the overutilization of this resource and sought to impose a limit of 200,000 to 300,000 tons on the catch. For a time their warnings were heeded; according to Scofield (1934, p. 50) the Fish and Game Commission in 1929 made a policy decision to limit the total catch of sardines to 200,000 tons. Unfortunately, the Commission never really implemented this decision due to a series of emergency actions resulting from the success of the offshore floating reduction plants and the desperate plight of the sardine industry during the early depression years. Emergencies never really ended; no sooner had the offshore reduction vessels been brought under control than World War II began and the United States became involved in 1941. By the time the war ended, the resource already had begun its decline.

It should be pointed out that, when the California Fish and Game Commission made its policy decision in 1929 to limit landings of sardines to 200,000 tons, it had no legal basis for enforcing such a limit. The Fish and Game Commission could then control only tonnage used for reduction (including overage from canning). At no time did it have control over tonnage actually put into cans. Van Cleve (1944, p. 49) pointed up this lack in the biennial report of the California Bureau of Marine Fisheries covering the 1940-1941 and 1941-1942 seasons: "When regulation is finally undertaken, it must be in the form of control of the total catch. The total catch is not controlled by present restrictions, which curtail only the number of tons of sardines taken for straight reduction and are insufficient for proper management."

Several times over the period of the sardine fishery, the California Fish and Game Commission sought a delegation of authority from the legislature to regulate all phases of the fishery. An urgent request was made for such authority in November 1953, for example, after the second dramatic collapse of the sardine fishery in 1952-1953. Such authority still has not been delegated to the Commission.

Population Dynamics

Excellent contributions have been published on the population dynamics of the sardine, including Clark (1939), Widrig (1954), Schaefer (1954), Clark and Marr (1955), Marr (1960), Radovich (1966), Murphy (1966), and Hayasi (1968). We single out Murphy (1966) for comment, as his paper is a synthesis of much of the information learned about the sardine over the years. Observations made by Murphy point up the causes of the decline of the sardine population. Baldly stated, they were overfishing in conjunction with poor survival of some year classes and competition from a flourishing population of northern anchovies, *Engraulis mordax*.

Age composition data of commercial sardine landings had been taken routinely at all ports since 1941, and were available in a less complete form for seasons back to 1932-1933 (Walford and Mosher, 1943; Felin and Philipps, 1948; Mosher and Eckles, 1955; Wolf, 1961. . . .). Using these data, Murphy estimated the maximum sustainable yield of the pre-1949 population (especially between 1937 and 1945)

as 471,000 tons at a spawning population size of about 1 million tons. During this period the catch averaged 570,000 tons. Murphy's work indicated that the spawning stock varied considerably above and below the optimum level during these years. The biologically optimal yield (yield so controlled as to restore and keep the population at its optimum level) also would vary considerably.

A highly significant contribution to our understanding of the population structure of the sardine resource was made by Sprague and Vrooman (1962). Using serological techniques, they demonstrated that the frequency of a blood group system, called by them the "C" system, could be used to distinguish between a northern and southern subpopulation of sardines off the coast of California and Baja California. Vrooman (1964) showed that sardines in the Gulf of California made up a third, genetically distinct subpopulation. Murphy made use of information on subpopulations in explaining the rapid decline of the post-1949 sardine population. The northern race appears to have been much larger than the southern, but also more heavily fished. One consequence of heavy fishing was the reduction in numbers of older individuals in the population to a level where they no longer provided an effective cushion against "reproductive failures." Such a reproductive failure of the northern stock occurred in 1949 and possibly 1950. This stock, lacking the resilience supplied by older fish, collapsed, thus accelerating the decline of the sardine resource. Population parameters changed appreciably with the reversed dominance of the two races. For example, the instantaneous rate of natural mortality rose from approximately 0.40 to about 0.80.

At about the same time that the northern race began its catastrophic decline, the anchovy population began to increase spectacularly, moving into the environmental void created by the decline of the sardine. The documentation of the marked increase in abundance of the anchovy population as the sardine population decreased was one of the highly significant accomplishments of the CalCOFI Program (Ahlstrom, 1966, 1967).

The evidence grows stronger that the Pacific sardine was a rather recent acquisition to the pelagic fish fauna of southern California and that it has been subject to marked fluctuations in abundance. Fitch (1969) failed to find any trace of sardine remains in Pliocene and Pleistocene deposits of marine origin in southern California, whereas otoliths of northern anchovy were in every sample examined (three Pliocene, seven Pleistocene), sometimes in considerable numbers. A few fragments of otoliths of young sardines were obtained from Indian middens, but, even there, otoliths of northern anchovy were much more abundant. Soutar (1967) and Soutar and Isaacs (1969) who investigated fish remains, particularly scales, in sediment cores from anoxic basins, gave particular attention to the Santa Barbara Basin off southern California. Sardine scales were much less abundant in the anaerobic sediment cores than those of northern anchovy or Pacific hake and much more variable in abundance during a sedimentation period estimated to cover the past 1850 years.

Murphy's estimate of the parameters of the sardine population, during the period 1952-1960, gave a maximum yield of 57,000 tons at a population of 178,000 tons. He warned, however, that the increase in the anchovy population would surely alter the parameters of the sardine in such a way as to reduce the maximum sustainable yield: "As a converse, the present situation is not likely to alter rapidly, even if sardine fishing is stopped, unless man or nature acts to reduce the anchovy population somewhat. It appears that judicious utilization of all ecologically similar species within a trophic level offers the only hope for sustained yields."

We concur in this appraisal. If the objective is to maximize the catch or the economic value of the catch of abundant fishery resources and minimize the adverse effects of selective fishing (of which the sardine is a nearly perfect example), it will be imperative to encourage "the judicious utilization of all ecologically similar species within a trophic level."

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