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BIOLOGY & ECONOMICS OF THE FISHERY FOR JACK MACKEREL IN THE NORTHEASTERN PACIFIC

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1.0. PREFACE

This report was prepared as a Draft Fishery Management Plan for the Pacific Fishery Management Council. The Council is one of seven regional councils established by the Fishery Management and Conservation Act of 1976, and is responsible for developing management plans for marine fisheries off the coasts of California, Oregon and Washington. The draft plan was developed in 1978 and 1979, but was discontinued in 1980, in favor of less costly alternative modes of management.

A large amount of information on the biology, economics, and sociology of the jack mackerel fishery and resource is contained in the draft plan, making it worthy of distribution. Because it is no longer intended as a Fishery Management Plan but rather as a scientific report, sections discussing proposed management have been deleted. The remaining sections are presented with essentially no editing.

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Alec D. MacCall
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.0. Executive Summary

I. Plan objectives

(1) To prevent overfishing of the jack mackerel resource within the U.S. Fishery Conservation Zone (FCZ).
(2) To allow a fishery for jack mackerel within the U.S. FCZ so as to achieve the optimum yield on a continuing basis.
(3) To provide a basis for developing cooperative international management of the jack mackerel resource.
(4) To avoid conflict among user groups.
(5) To avoid interference with the Pacific whiting fishery.
(6) To promote efficiency in the utilization of the jack mackerel resource within the FCZ, recognizing the multiple species context of the fishery, both economically and ecologically.
(7) To methodically explore the productivity of the resource.

II. Management unit

The fishery management unit is the jack mackerel resource in the U.S. Fishery Conservation Zone off the Pacific coast. The resource is considered to be a single stock.

III. Marine environment

(a) Distribution: Jack mackerel are distributed throughout the north-eastern Pacific, ranging from the southern tip of Baja California to the Aleutian Islands. Smaller jack mackerel are concentrated in the Southern California Bight, while larger and older jack mackerel are found farther offshore in deeper water and along the northern coastline.

Jack mackerel exhibit both inshore-offshore and coastal migration. Small jack mackerel favor the habitat of rocky offshore banks, rocky perimeters of islands, and occasionally rocky coastal areas. Large jack mackerel are found further offshore, either solitary or in small loose schools.

(b) Schooling behavior: A common schooling behavior of small jack mackerel is to concentrate beneath floating kelp and debris in the open sea. Oil drilling platforms also concentrate fish. These fish are available for commercial harvesting only if they drift away from the platforms. There appear to be both potential benefits and hindrances as a result of the presence of these platforms. The effect that these platforms will have on fishing conditions can be determined only through future evaluation.

(c) Predator-prey relationships: Jack mackerel feed primarily on macroplankton, consisting primarily of copepods, pteropods and euphausiids (see Section 9.5.1 of FMP). At time, jack mackerel feed almost exclusively on juvenile squid and anchovies.

Jack mackerel may be a major source of forage to billfish, but are a relatively minor source to small predators (see Section 9.5.2 of FMP). At certain times and places, however, jack mackerel may be a major food source to any predators sufficiently large to prey upon them.

Jack mackerel presumably do not contribute significantly to food supplies of marine birds (see Section 9.5.2 of FMP). The fish are too large to be ingested by most bird species and tend to school too deep, making them inaccessible to surface feeders. Brown pelicans (<u>Pelecanus occidentalis californicus</u>), an endangered species, have been observed feeding upon fish presumbed to be jack mackerel, but studies of stomach contents have not encountered jack mackerel remains. It is unlikely that abundance of jack mackerel significantly influences brown pelican populations.

Marine mammals apparently do not feed significantly on jack mackerel. One study encountered jack mackerel infrequently in the stomachs of California sea lions (<u>Zalophus californianus</u>) and northern fur seal (<u>Callorhinus ursinus</u>) (see Section 9.5.2 of FMP).

(d) Spawning biomass: Estimates of spawning biomass are derived from data obtained on California Cooperative Oceanic Fisheries Investigations (CalCOFI) ichthyoplankton surveys. The spawning biomass in the CalCOFI region is estimated to be in the range of 0.7 to 1.4 million short tons. The total spawning biomass is assumed to be 1 to 2 million short tons (see Section 9.3 of FMP).

Mean apparent density of jack mackerel larvae as calculated from CalCOFI samples shows considerable year-to-year fluctuation. However, there has been no visible trend in abundance over the past 25 years.

IV. <u>Utilization</u>

The primary user group of the jack mackerel fishery resource is the commercial purse seine fishermen in the southern California communities of San Pedro and Port Hueneme. This fleet harvests several other species besides jack mackerel, including Pacific mackerel, anchovy, squid, Pacific bonito and bluefin tuna. It is estimated that approximately 400 persons are directly involved in the jack mackerel fishery, with many more involved to a lesser extent. There are probably over 5,000 persons employed by processing plants that can jack mackerel as well as other products. While jack mackerel is a small portion of the total fish processed, it undoubtedly accounts for many jobs during certain parts of the year (see Section 8.0 - 8.5 of FMP for discussion of socio-economic characteristics).

Jack mackerel are also utilized by recreational anglers, both as a target species and as bait for larger predators. Normally, jack mackerel constitute less than 1% of the California charterboat catch, but in some years have contributed as much as 8.6% of the total charterboat catch (see Section 8.4 of FMP).

V. Optimum Yield Considerations

There is insufficient information on the jack mackerel resource and fishery to estimate maximum sustainable yield (MSY) or equilibrium yield (EY). A potential yield estimator is used to provide an interim limit to catches while data sufficient to estimate MSY are being accumulated (see Section 9.6.4 of FMP). For many fisheries, potential yield may differ considerably from MSY, and thus potential yield should not be treated as a goal for fishery development. Ranges of potential yield (see Section 9.6.4 of FMP) are estimated for three segments of the resource as follows:

(1) 24 to 210 thousand short tons for 0 to 8-year-old fish,
(2) 14 to 50 thousand short tons for 9 to 15-year-old fish,
(3) 13 to 30 thousand short tons for 16 to 30-year-old fish.

The total stock is estimated as having a potential yield of 56 to 290 thousand short tons only if the catch is balanced among the age classes.

Primary biological and ecological considerations are summarized below:

(1) Spawning biomass of jack mackerel is estimated to be between one and two million short tons.

(2) Jack mackerel are relatively long-lived fish. Although annual variability in recruitment is large, variability of the total stock biomass is relatively small.

(3) Yield-per-recruit analysis suggests nothing is to be gained by increasing the age at first entry into the fishery.

(4) Jack mackerel appear to feed primarily upon copepods, pteropods, euphausiids, juvenile squid and anchovies. No substantial predation upon other commercially or recreationally important fish schools is suspected.

(5) Adult jack mackerel do not appear to be major food sources for other important fish species like bonito, albacore or bluefin tuna, although striped marlin and, at times, yellowtail have been found with significant quantities of jack mackerel in their stomachs.

(6) Adult jack mackerel have not been found to be a major food item for marine birds or mammals.

(7) Given the inexact nature of the potential yield analysis, the uncertainty about effects of fishing upon recruitment, weakness of abundance monitoring capability, and the possibility of ecological interactions with larger predator fish, controlled growth of the fishery would best serve the biological/ecological interests because of the risk of overfishing.

The primary social and economic factors that should be considered in the determination of optimum yield are summarized as follows (see Section 12.2 of FMP):

(1) Jack mackerel is one of several pelagic fish species that are important to southern California purse seine fishermen.

(2) Although the level of employment specifically generated by jack mackerel is small (see Section 8.1 and 8.5 of FMP), approximately 35 vessels and 400 fishermen earn a significant amount of their incomes from fishing for jack mackerel. Growth in the fishery would undoubtedly result in more employment and attract new firms.

(3) The extent to which the canned mackerel market develops in future years depends largely upon domestic marketing efforts and price competition with imports.

(4) An incidental catch of jack mackerel is taken in the Pacific whiting fishery. Any severe restriction placed on this incidental catch could retard the development of the domestic fishery and could prevent the successful harvest of the optimum yield of Pacific whiting.

BIOLOGY AND ECONOMICS OF THE FISHERY FOR JACK MACKEREL
IN THE NORTHEASTERN PACIFIC

4.0. INTRODUCTION

The Fishery Conservation and Management Act of 1976 (Public Law 94-265) provides for the United States' exclusive fishery management authority over the fishery resources within a Fishery Conservation Zone extending from the seaward boundary of the United States' territorial sea (3 miles from shore) to a point 200 miles from shore. The responsibility for developing management plans for the fisheries in the Zone is vested in eight Regional Fishery Management Councils. The Pacific Fishery Management Council is responsible for the fisheries off the coasts of the states of Washington, Oregon and California. Implementation and enforcement of any regulations pertinent to fisheries management within the Fishery Conservation Zone are the responsibility of the Secretary of Commerce. The Jack Mackerel Fishery Management Plan was developed for and by the Pacific Fishery Management Council and is submitted to the Secretary of Commerce for approval and implementation.

The Jack Mackerel Fishery Management Plan is based on available scientific information on the population dynamics of the species, status of the resource and its fisheries. Values for such important parameters such as abundance, rate of natural mortality, and maximum sustainable yield can only be approximated. Therefore the present Plan is intended to provide a management regime whereby the resource may be explored and developed. Through deliberate expansion of the fishery, the necessary management information will accrue and a more precise management regime can eventually be developed. Approximate values of future resource potential are developed in this Fishery Management Plan which serves as a reference for further development of a fishery, and which are useful in reducing the risk inherent in uncontrolled expansion. A jack mackerel is shown in Figure 4.0-1.

4.1. Goal

This Fishery Management Plan for jack mackerel (*Trachurus symmetricus* Ayres) determines the optimum yield within the U.S. Fishery Conservation Zone and provides suggested management measures to achieve Fishery Conservation and Management Act objectives and National Standards for Fishery Management Plans.

4.2. Objectives

(1) To prevent overfishing of the jack mackerel resource within the United States Fishery Conservation Zone (FCZ).

(2) To allow a fishery for jack mackerel within the U.S. FCZ so as to achieve the optimum yield on a continuing basis.

(3) To provide a basis for developing cooperative international management of the jack mackerel resource.

(4) To avoid conflict among user groups.

(5) To avoid interference with development of a domestic Pacific whiting fishery.

(6) To promote efficiency in the utilization of the jack mackerel resource within the FCZ, recognizing the multiple species context of the fishery, both economically and ecologically.

(7) To methodically explore the productivity of the resource through controlled expansion of the fishery.

These objectives are discussed in Section 14.1.

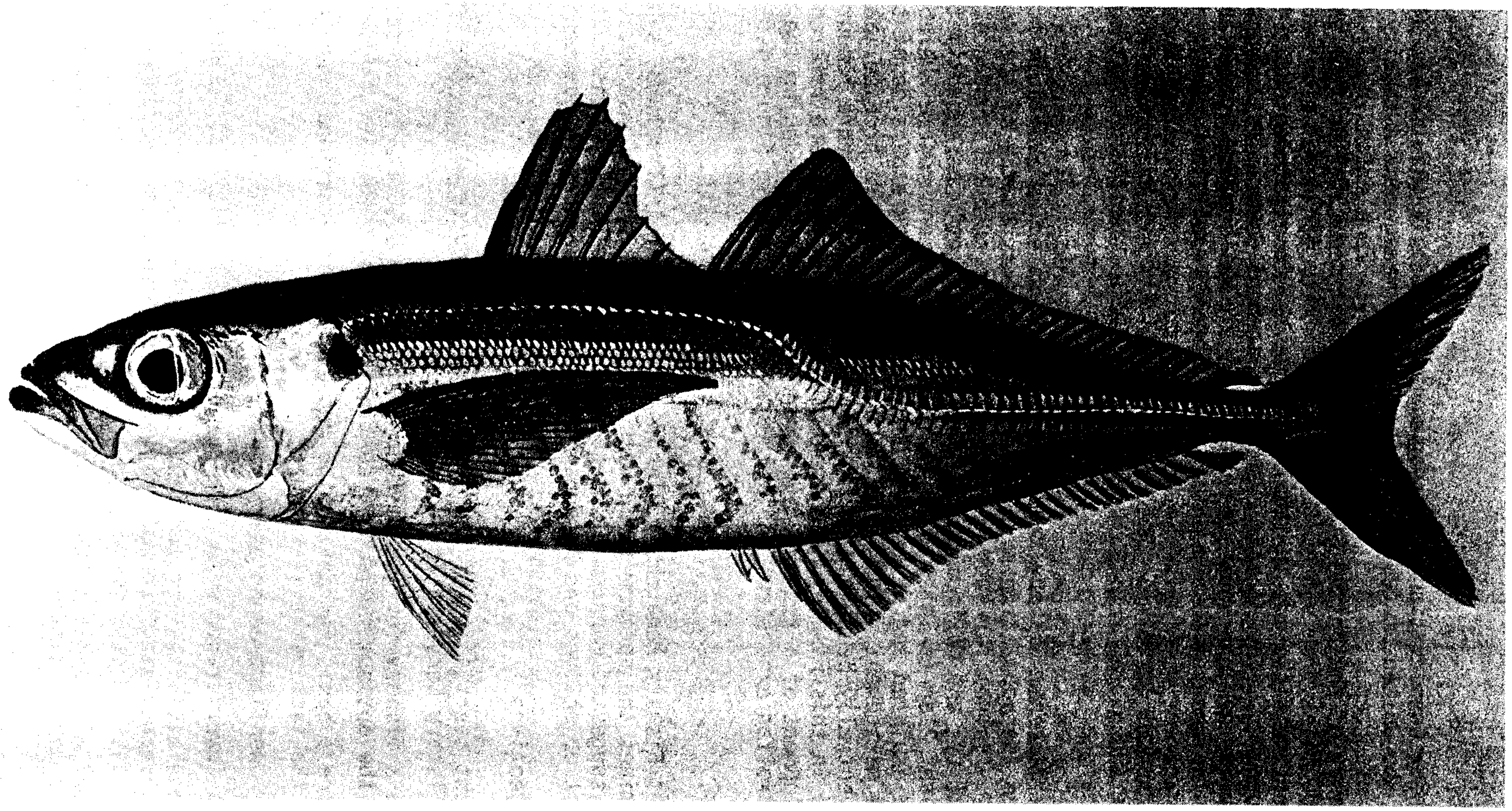

Figure 4.0-1. Jack mackerel, Trachurus symmetricus Ayres (drawing by George Mattson).

4.3. Definitions

The following definitions are given to words used uniquely in this plan.

Small fish - Jack mackerel up to about 18" (457 mm) fork length (FL). These fish are found in greatest abundance in southern California waters.

Large fish - Jack mackerel greater than 18" (457 mm FL). These fish are usually found along the northern California, Oregon and Washington coasts and offshore.

Spawning biomass - The equivalent weight of mature female fish plus an equal weight of male fish necessary to produce an observed quantity of spawned products. Younger female fish with fractional relative fecundities contribute a corresponding fraction of their weight to the spawning biomass.

Pacific whiting - *Merluccius productus*, Pacific hake.

5.0. DESCRIPTION OF THE FISHERY

5.1. Areas and Stocks

There is no evidence to determine if subpopulations of jack mackerel exist. For convenience, the resource will be considered to be a single stock (see 9.2). This stock occupies the area east of a line drawn between the tip of Baja California and the Aleutian Islands (Fig. 5.1-1). Small fish, up to approximately 5 years of age, are found in nearshore waters and around islands, with their center of abundance off southern California. Large fish are found in offshore waters and along the northern coast.

There is presently only one fishery targeting on jack mackerel. This fishery uses purse seine gear, and operates out of southern California ports, harvesting small fish from local waters. More northern fisheries take jack mackerel incidentally. The salmon troll fisheries operate in nearshore waters north of Pt. Conception, and take an unknown but probably large number of jack mackerel which are discarded at sea. The foreign trawl fleets, which operate offshore north of Point Arena, take jack mackerel incidentally to fishing for Pacific whiting (*Merluccius productus*) (see 5.2.3.2), but have actually avoided taking jack mackerel in recent years. If an expanded domestic offshore trawl fishery develops out of northern California and Oregon ports, large jack mackerel may become a target species, and will almost certainly be an incidental species of significant magnitude. Recreational fisheries all along the Pacific coast occasionally take jack mackerel but do not consistently target on the species.

In the Vancouver Island area of Canada, large jack mackerel have been caught at the surface by purse seiners and are taken incidentally in the bottom trawl fisheries (Hart, 1973). Although jack mackerel are quite abundant at times, there is no directed fishery for the species. Incidental catches are insignificant and are not included in catch records (S.J. Westrheim[1], personal communication).

The distribution of jack mackerel extends northward into the Gulf of Alaska east of 160°W. A high seas experimental salmon gillnet survey found jack mackerel to be relatively abundant (Larkins, 1964). Incidental catches along the coast of southeast Alaska occur infrequently. Any incidental catches that might occur are not documented (D. Cantillon[2], personal communication).

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[2] D. Cantillon, Alaska Department of Fish and Game, Juneau, Alaska

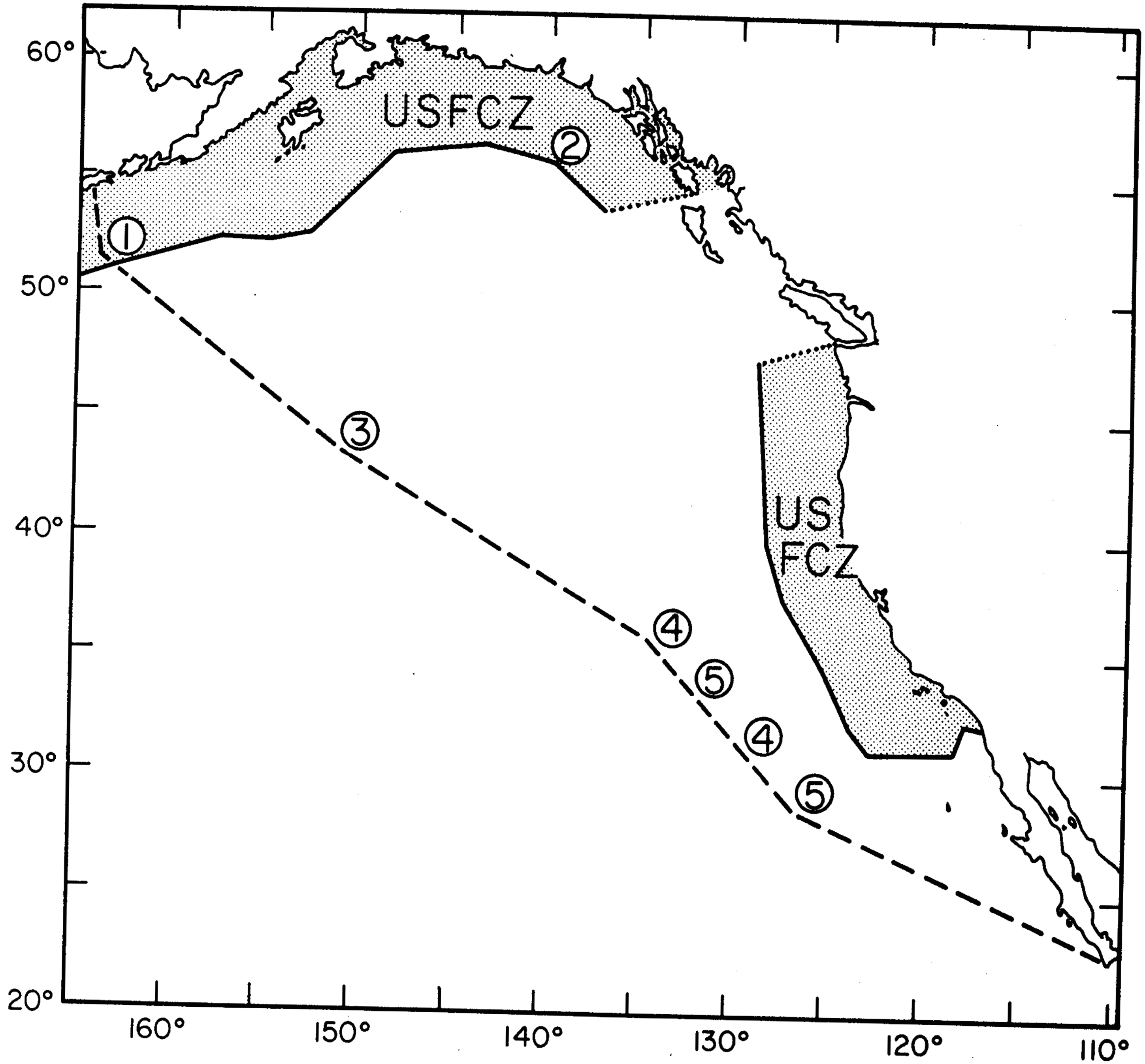

Figure 5.1-1. Distribution of the jack mackerel resource (modified from Blunt, 1969). Circled numbers indicate the periphery as determined by various sampling methods. 1) Gillnet catches, INPFC, 1963. 2) Gillnet catches, INPFC, 1955. 3) Eggs and larvae, NORPAC, 1955. 4) Night-light stations, CDF&G, 1957-1968. 5) Eggs and larvae, CalCOFI, 1950-1978.

5.2. History of the Fishery

5.2.1. Domestic

5.2.1.1. Commercial

The jack mackerel, *T. symmetricus*, was reported in the commercial landings of fish in California as early as 1888, but was of minor commercial importance before 1947. Of much greater commercial importance were the more profitable Pacific sardine, *Sardinops sagax caeruleus*, and the more desirable Pacific mackerel, *Scomber japonicus*. Much of the jack mackerel catch between 1926 and 1946 was absorbed by fresh fish markets and consisted primarily of fish taken from mixed Pacific sardine and Pacific mackerel schools. Landings were low, varying between 200 and 15,000 short tons. During these years, it was referred to as "horse mackerel" and had relatively little market appeal. In 1947 the fishing industry, after being hit hard by poor sardine landings, turned to jack mackerel and landed 64,524 short tons. The following year, the U.S. Food and Drug Administration authorized the common name "jack mackerel" for use on labeling. This name was expected to have greater consumer appeal than the original official name "horse mackerel." Jack mackerel have been a major contributor to California's commercial landings ever since (Table 5.2-1). The current status of the domestic commercial fishery is discussed in Section 8.0.

By far the largest tonnages of jack mackerel (over 90%) have been landed in the Los Angeles (San Pedro) area throughout the history of the fishery (Table 5.2-2). A smaller volume of fish has been consistently landed at Port Hueneme. Landings at Monterey have been sporadic. Insignificant amounts of jack mackerel have been landed north of Monterey Bay. These northern landings primarily serve the fresh market and bait fish demand (Roedel, 1953, p. 45-64). Small quantities have been taken off the Oregon coast, where the fish are said to occur regularly in the summer (Cleaver, 1951, p. 29).

The jack mackerel net used by the San Pedro purse seine fleet usually has a stretched mesh size of 1-3/8 inches. The net can be used to capture jack mackerel, Pacific mackerel, Pacific sardine, Pacific bonito, tunas and squid. Anchovies are not taken by mackerel nets. The anchovy net usually has a stretched mesh of 11/16 inch, and may also be used to capture larger pelagic fishes, but is seldom used for jack mackerel. While anchovy and jack mackerel are alternative target species for the wetfish fleet, they are seldom alternative species during any single fishing trip.

Landings of jack mackerel are recorded during every month of the year (Table 5.2-3). There is no predominant seasonality in the fishery. The major fishing months over the past 17 years have been September through December. There has been a shift in the most dominant months in the past 5 years, with most fishing now taking place in July, August and September. The smallest monthly landings have been made in April and May.

The geographical distribution of southern California jack mackerel catch locations is shown in Table 5.2-4 (refer to Fig. 5.2-1 for exact areas). Catch localities have been strongly influenced by fishing effort directed toward Pacific sardines and, to a much lesser extent, toward Pacific mackerel. When sardines were available, major catches of jack mackerel were taken at the northern end of the Southern California Bight, an area favored by sardine fishermen. When more desirable species were unavailable, fishing effort became directed at jack mackerel. Jack mackerel were usually abundant in inshore waters until the early 1960's. Since then inshore abundance has been unpredictable and fishermen shifted to San Clemente Island, and Tanner and Cortez Banks, where jack

Table 5.2-1. Annual commercial jack mackerel landings (short tons).

	California		Mexico[1]			California		Mexico	
Year	Cannery	Bait	Cannery	Total	Year	Cannery	Bait	Cannery	Total
1945	4,516	n.a.			1965	33,333	0.0	4210	37,543
1946	7,547	n.a.			1966	20,431	12.5	6460	26,904
1947	64,524	n.a.			1967	19,090	0.0	2143	21,233
1948	36,449	0.0			1968	27,834	79.0	1775	29,688
1949	25,625	0.0			1969	25,960	51.5	1668	27,680
1950	66,628	0.2	(3500)	70,128	1970	23,873	0.0	n.a.	23,873[2]
1951	44,919	0.0	(2000)	46,919	1971	29,942	4.5	98	30,040
1952	73,261	16.6	(1500)	74,778	1972	25,559	2.5	159	25,721
1953	27,875	0.7	(1500)	29,376	1973	10,308	60.0	425	10,793
1954	8,667	0.2	220	8,887	1974	12,729	0.0	148	12,877
1955	17,877	0.0	6650	24,527	1975	18,390	0.0	2064	20,454
1956	37,881	0.0	7100	44,981	1976	22,446	n.a.	2501	24,947
1957	41,006	0.0	(4000)	45,006	1977[3]	52,486	n.a.	1443	53,929
1958	11,033	3.1	(1000)	12,036	1978[3]	33,977	n.a.	584	34,561
1959	18,754	20.0	(250)	19,024					
1960	37,473	2.0	(2500)	39,975					
1961	48,803	0.0	1967	50,770					
1962	44,990	0.0	3489	48,479					
1963	47,721	7.5	15077	62,806					
1964	44,846	0.0	3436	48,282					

n.a. = not available

[1] Parentheses indicate approximate landings; source reports did not distinguish between jack mackerel and Pacific mackerel.

[2] Actual total is greater but unknown.

[3] Preliminary.

Table 5.2-2. California landings of jack mackerel by area and total ex-vessel value of landings, 1945-1978 (short tons and $1000).

Year	Eureka area	San Francisco area	Monterey area	Santa Barbara area	Los Angeles area	San Diego area	Total landings	Total value ($1000)	Percent Los Angeles area landings to total landings
1945	-	-	125	-	4,391	-	4,516	145	97%
1946	-	-	3,581	-	3,966	-	7,547	327	53
1947	-	-	1,077	6,774	56,552	121	64,524	3,323	88
1948	-	-	4,444	2,841	29,149	15	36,449	2,136	80
1949	-	-	2,090	1,413	22,109	13	25,625	1,111	86
1950	-	440	15,756	1,335	49,075	13	66,628	2,572	74
1951	-	-	389	2,604	41,906	21	44,919	2,016	93
1952	-	1	138	4,704	68,294	125	73,261	4,755	93
1953	-	2	600	4,310	22,955	9	27,875	1,994	82
1954	-	-	3,123	1,381	4,163	-	8,667	661	48
1955	-	-	65	4,905	12,893	15	17,877	712	72
1956	-	2	1,227	7,029	29,534	90	37,881	1,532	78
1957	-	2	1,160	10,747	29,098	-	41,006	1,603	71
1958	-	18	1,602	3,100	6,315	-	11,033	531	57
1959	-	1	5,453	2,701	10,600	-	18,754	897	57
1960	-	3	1,133	6,599	29,739	-	37,473	1,582	79
1961	-	11	1,826	7,398	39,570	-	48,803	2,029	81
1962	-	2	1,025	4,786	39,177	-	44,990	1,869	87
1963	-	0.5	826	3,511	43,384	-	47,721	1,989	91
1964	0.5	1	1,292	6,090	37,464	-	44,847	2,109	84
1965	-	0.5	1,376	3,567	28,390	0.3	33,333	1,829	85
1966	0.4	0.2	618	3,395	16,411	7	20,431	1,424	80
1967	0.3	0.1	468	2,016	16,607	-	19,091	1,447	87
1968	0.1	-	481	2,126	25,228	-	27,834	2,122	91
1969	-	-	225	1,402	24,334	-	25,961	1,967	94
1970	-	1	258	1,692	21,923	0.5	23,874	1,881	92
1971	-	0.5	82	1,148	28,706	5	29,942	2,416	96
1972	2	0.5	62	386	25,109	0.5	25,559	2,153	98
1973	-	4	242	12	10,004	47	10,308	992	97
1974	2	2	9	333	12,376	8	12,729	1,496	97
1975	-	2	18	1	18,369	0.5	18,390	1,693	100
1976	5	0.5	54	1,987	20,393	7	22,447	2,244[1]	91
1977[1]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	52,486	5,249	n.a.
1978[1]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	33,977	3,740	n.a.

n.a. = not available
 - = no landings, or less than 100 lbs.

[1] preliminary

Source: California Dept. of Fish and Game, California Marine Fish Landings for 1960-1975, Fish Bulletin No.'s 117, 121, 125, 129, 132, 135, 138, 144, 149, 153, 154, 159, 161, 163, 166, 168; Statistical Report of Fresh, Canned, Cured and Manufactured Fishery Products for 1976, Circular No.51.

National Marine Fisheries Service, Current Fishery Statistics No. 7800, Fisheries of the United States, 1978.

Table 5.2-3. Monthly landings of jack mackerel in California, 1945-1978 (short tons).

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1945	594	108	-	2	5	9	5	5	53	484	847	1,902	4,516
1946	413	389	15	7	8	33	3	28	704	314	745	4,888	7,547
1947	1,675	5,065	1,397	714	36	319	179	316	3,633	3,446	22,089	25,658	64,524
1948	7,712	5,730	2,020	193	192	6	909	2,901	8,449	1,135	660	6,542	36,449
1949	3,215	1,513	1,710	614	259	81	1,342	2,314	3,257	8,215	2,019	1,086	25,625
1950	587	6,655	4,094	2,585	3,722	920	6,554	3,582	19,082	8,623	6,011	4,216	66,628
1951	4,813	2,261	3,109	5,297	4,337	4,199	3,423	4,578	4,683	4,346	2,922	954	44,919
1952	2,746	278	1,191	3,843	2,922	2,548	4,210	8,612	19,180	9,645	16,487	1,600	73,261
1953	702	122	2,037	7,686	2,449	5,145	5,820	549	1,648	1,002	675	43	27,875
1954	32	137	444	427	280	99	3,455	2,462	805	-	158	369	8,667
1955	53	647	512	579	238	135	4,097	2,050	317	721	3,602	4,931	17,877
1956	4,768	4,998	2,233	1,588	2,751	1,193	772	1,346	3,178	5,269	7,226	2,563	37,881
1957	8,237	8,973	4,365	2,304	1,495	2,324	542	1,636	1,479	4,856	4,625	123	41,006
1958	1,946	2	746	96	38	304	56	893	1,309	4,395	849	402	11,033
1959	59	193	1,576	1,261	1,456	3,267	200	86	1,016	3,347	4,450	1,826	18,754
1960	5,453	2,420	7,859	1,954	627	496	381	2,469	3,142	3,069	7,005	2,600	37,473
1961	1,095	1,867	961	1,578	2,905	4,499	1,981	1,853	4,841	10,419	10,117	6,690	48,803
1962	5,212	1,728	2,304	2,159	3,644	3,510	1,448	304	557	10,021	10,246	3,860	44,990
1963	6,625	3,082	2,008	3,121	3,134	2,910	1,419	5,301	5,082	8,631	5,228	1,184	47,721
1964	72	1,602	4,424	3,055	1,528	7,003	2,285	3,304	5,732	7,308	5,464	3,072	44,847
1965	444	1,529	1,262	630	1,980	6,158	2,636	3,102	4,549	3,845	3,813	3,390	33,333
1966	543	911	1,060	1,848	4,899	3,901	706	2,289	841	1,419	848	1,169	20,431
1967	486	1,949	2,131	2,255	2,557	4,135	1,066	1,713	348	442	544	1,467	19,091
1968	2,003	1,408	408	2,624	2,874	3,436	1,673	1,462	1,355	3,676	3,567	3,351	27,834
1969	1,896	2,010	2,669	2,135	2,401	1,975	3,292	1,689	2,838	3,476	848	735	25,961
1970	683	250	909	794	3,004	1,045	2,189	2,269	3,097	5,433	2,662	1,542	23,874
1971	1,289	1,213	4,303	2,580	713	2,516	1,165	3,291	1,115	874	8,285	2,601	29,942
1972	2,847	1,765	2,403	326	272	862	3,500	4,958	6,715	324	1,092	498	25,559
1973	127	213	237	360	723	3,422	1,721	932	236	1,619	591	130	10,308
1974	640	791	100	275	1,559	315	2,718	2,252	320	1,708	1,670	183	12,729
1975	214	1,426	424	414	598	621	436	716	3,128	4,112	2,451	3,853	18,390
1976	3,130	3,051	2,252	1,468	1,381	1,292	2,412	2,304	1,155	848	1,598	1,559	22,447
1977[1]	4,519	2,666	4,509	7,893	3,603	7,201	6,861	2,361	1,365	2,158	5,909	3,355	52,486
1978[2]	1,443	1,285	3,246	1,963	329	325	5,633	6,354	4,307	4,819	3,392	881	33,971
	Average percent of monthly landings to yearly total landings:												
1945-1976	7.2	6.5	6.4	5.9	5.5	7.0	6.9	7.8	11.2	12.3	14.0	9.4	
1945-1959	7.7	7.6	5.2	5.6	4.1	4.2	6.5	7.1	13.7	11.5	15.1	11.7	
1960-1978	6.7	5.4	7.4	6.1	6.8	9.5	7.2	8.5	8.9	13.1	13.1	7.4	
1974-1978	6.6	7.1	6.3	6.4	5.9	5.3	12.8	11.0	8.0	11.6	11.0	7.7	

n.a. = not available

[1] preliminary

[2] estimates

Source: California Dept. of Fish and Game, California Marine Fish Landings for 1960-1975, Fish Bulletin No.'s 117, 121, 125, 129, 132, 135, 138, 144, 149, 153, 154, 159, 161, 163, 166, 168; Statistical Report of Fresh, Canned, Cured and Manufactured Fishery Products for 1976, Circular No. 51; California Commercial Fish Landings by Region, 1977.

California Dept. of Fish and Game estimates, 1978.

Table 5.2-4. Geographic distribution of southern California jack mackerel catches, expressed as percent of total. Map of geographical regions is in Figure 5.2-1 (following page).

Season	Northern Bight 1	Southern Bight 2	San Pedro local 3	Catalina Island offshore 4	San Clemente Island 5	Tanner and Cortez Banks 6	California landings (1000 tons) Jack mackerel	Pacific sardine	Pacific mackerel
1945-46							5	404	26
1946-47							7	234	29
1947-48	46.5	7.9	18.6	20.7	6.2	-	71	121	20
1948-49	44.0	8.0	21.8	23.3	2.9	-	24	184	19
1949-50	44.6	4.2	33.3	8.3	9.6	-	40	339	25
1950-51	32.2	11.0	44.1	4.8	7.9	-	53	353	17
1951-52	20.0	8.0	47.2	4.5	12.8	7.5	35	129	16
1952-53	6.9	0.7	6.9	7.5	13.9	64.1	79	6	9
1953-54	35.6	0.2	5.2	0.7	43.3	15.0	8	4	4
1954-55	10.4	22.0	30.7	7.7	29.2	-	7	68	13
1955-56	25.9	21.7	34.3	5.9	12.1	0.1	29	74	13
1956-57	35.3	10.3	46.0	3.0	5.4	-	46	34	29
1957-58	68.0	3.3	16.8	2.1	7.8	2.0	15	22	28
1958-59	89.1	0.9	6.9	1.5	1.6	-	13	104	12
1959-60	50.7	0.3	23.7	23.2	2.1	-	25	37	20
1960-61	46.0	1.2	12.7	12.4	27.7	-	32	29	19
1961-62	37.5	2.6	12.2	17.7	16.5	13.5	51	26	22
1962-63	13.9	6.8	22.6	13.6	17.1	26.0	46	4	23
1963-64	16.8	4.4	24.3	28.9	8.4	17.2	45	2	17
1964-65	27.1	3.8	9.9	8.6	13.8	36.8	38	6	12
1965-66	17.0	0.7	8.4	8.1	4.6	61.2	31	-	4
1966-67	14.0	0.1	3.6	10.1	25.6	46.6	21	-	2
1967-68	2.4	3.2	3.1	3.4	5.8	82.1	19	-	1
1968-69	7.6	6.4	16.1	26.8	27.0	16.1	30	-	2
1969-70	7.0	0.5	7.4	11.1	23.7	50.3	18	-	1
1970-71	1.1	0.1	4.1	34.7	23.7	36.3	29	-	-
1971-72	5.7	3.1	13.9	17.1	13.9	46.3	28	-	-

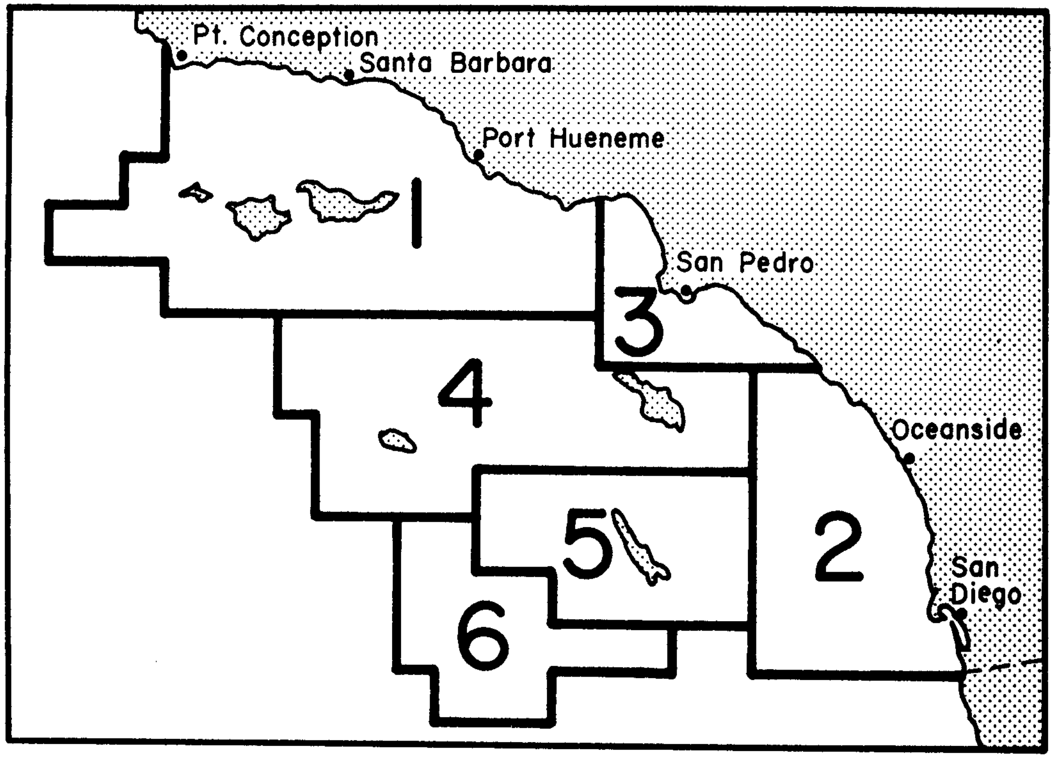

Figure 5.2-1. Catch localities for jack mackerel given in Table 5.2-2.

mackerel availability was most reliable. The major geographical shift occurred in the early 1960's with the loss of the Pacific sardine and Pacific mackerel fisheries (see Table 5.2-2), but a similar short-term shift occurred in the early 1950's when the more desirable species were temporarily unavailable. There has also been an apparent shift in the geographical distribution of jack mackerel in southern California. In the 1930's, Fry (1937, p.22) reports that "Horse mackerel are much more abundant in [Channel Islands] waters than along the mainland shore . . . " Fishermen recall abundant jack mackerel in the Channel Islands area in the 1950's, but recent exploratory trips to that area have encountered very few jack mackerel (A. Pisano[1], personal communication).

The southern California live bait fishery (for a detailed description, see the FMP for the northern anchovy, NMFS 1978, pp. 11, 23, 44) has occasionally caught significant quantities of jack mackerel (Table 5.2-1). However, in most years, jack mackerel have been a negligible component of the live bait catch.

5.2.1.2. Recreational

Jack mackerel are a target species for recreational fishermen when they are available. In southern California, pier and barge fishermen occasionally make large catches of young fish. Occasional runs of large jack mackerel have attracted southern California fishermen, but unpredictable availability has prevented a sustained recreational fishery.

From central California north, anglers may occasionally seek large jack mackerel, but most fish are landed incidentally while fishing for salmon. There are two main forms of ocean recreational fishing for salmon, trolling and "mooching." Trolling consists of towing a bait or lure behind a moving vessel, generally using a heavy weight to achieve the necessary depth. A common gear employs an automatic weight release upon hook-up, and a run of jack mackerel (as well as Pacific whiting, Merluccius productus, or bocaccio, Sebastes paucispinis) can contribute to a frustrating and expensive fishing trip. On the other hand, "mooching" for salmon is the standard technique aboard partyboats carrying large numbers of recreational fishermen. This method is employed at anchor or drifting, with anglers imparting an up and down motion to dead bait (e.g., herring) suspended beneath the vessel. In this case, a run of jack mackerel will provide an enjoyable fishing experience, especially if salmon are not biting well.

The reported recreational catch (Table 5.2-5) is fragmentary and probably does not include many fish taken incidentally to salmon fishing. Fishing from partyboats, anchored barges and piers accounts for most of the reported landings. The private boat fleet often obtains its own bait by fishing for jack mackerel under night-lights.

5.2.2. Mexico

5.2.2.1. Commercial

There appears to be little directed fishing for jack mackerel in Mexico. From 1961 to 1969 annual landings averaged 4,450 tons; however, only 584 tons were reported landed in 1978 (Table 5.2-1).

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[1] A. Pisano, Fishermen's Cooperative Associaton, San Pedro, California.

Table 5.2-5. Recreational catch of jack mackerel.

California Partyboat Catch (numbers)

(sources: Young (1969); CDF&G California Marine Fish Landings)

Year	Catch	Year	Catch	Year	Catch
1948	2531	1958	27867	1968	13588
1949	2932	1959	11820	1969	11272
1950	557	1960	8537	1970	15725
1951	202	1961	28891	1971	10611
1952	4395	1962	9029	1972	5913
1953	196280	1963	9342	1973	15789
1954	19407	1964	6577	1974	12467
1955	39473	1965	25619	1975	5677
1956	23493	1966	19027	1976	5504*
1957	6878	1967	16236	1977	8789*

* preliminary

Other Recreational Fishery Segments

Area and Segment	Time	Annual catch (numbers)	Source
Southern California			
Shoreline	1965-1966	243	Pinkas, Oliphant & Haugen (1968)
Pier and Jetty	1963	4030	
Private boat	1964	649	
Partyboat	1963-1966	10161	
Total	1963-1966	15083	
Private boat (launching ramps)	1976-1978	3905	V. Wine, CDF&G, personal communication
Anchored barges (not included in partyboat)	1970	9945	P. Gregory, CDF&G personal communication
Central California			
Shoreline	1957-1961	0	Miller & Gotshall (1965)
Pier	1958	2522	
Skiff	1959-1960	1854	
Partyboat	1960	9403	
Total	1958-1961	13779	
Washington			
Partyboat	1977	ca.500	A. Millikan, WDF, personal communication

The Baja California purse seine fleet (excluding tuna vessels) consists of approximately 45 vessels ranging from 15 to 300 tons hold capacity. Except for ten large vessels which can potentially harvest anchovy year-round at Ensenada, most of the fleet operates out of Ensenada during the summer, usually May to November. During the winter these vessels harvest sardines and thread herring in the Gulf of California. The Ensenada fleet uses gear and methods similar to the San Pedro wetfish fleet, and can similarly target on a variety of species, including jack mackerel. Much of the fishing effort by the Ensenada fleet is now directed toward harvesting anchovies for reduction. A few vessels have contracts with processors to deliver fish, including jack mackerel, for canning. One processor has expressed interest in increasing output of canned jack mackerel. Most of the cannery equipment in Ensenada was originally installed for the sardine fishery and is now rather old.

5.2.2.2. Recreational

A small partyboat fleet operates out of Ensenada and may occasionally take jack mackerel. Long-range partyboats operating out of southern California regularly catch small quantities of young jack mackerel for use as live bait for the large game fish sought off southern Baja California.

5.2.3. Foreign fishery

The target of the foreign trawl fleet has been Pacific whiting, Merluccius productus, although many other species are also caught (see California, Oregon and Washington Groundfish Fishery FMP). One of these is jack mackerel. In the earlier years, 1966-74, if jack mackerel was caught, it was not identified in the fishery statistics or it was included in the "other species" categories. The first foreign catches were reported by Poland in 1975.

5.2.3.1. Foreign vessels and gear

Foreign distant-water fleets are composed of modern and self-sustaining vessels. These fleets typically include a variety of support vessels such as refrigerated transports, oil tankers, personnel and supply transports, hospital ships, tugs, patrol vessels, and research vessels. Fleet activities may be highly organized with vessels deployed in such a way as to optimize fishing and scouting operations.

Most vessels fishing in the Washington-California region are factory stern trawlers which process their own catches and provide a variety of fishery products. Such vessels have the ability to remain on the grounds for weeks, seldom ceasing fishing due to weather conditions.

The fishing fleet from the Soviet Union includes the stern trawlers "large freezer fishing trawlers" (BMRT's) and "fishing trawlers with freezers" (RTM's). These classes have gradually replaced the smaller side trawlers (SRT's) that made up the fleet in the 1960's. The BMRT has been the most common factory trawler; it is 3,170 gross tons and carries a crew of about 90 compared to the SRT's 265-335 tons and crew of 22-26. The RTM is of the general size as the BMRT but has the advantage of a larger deck area aft for handling fish and gear.

Stern trawlers use nets with a variety of configurations, and this gear seems to undergo frequent modifications. They are always quite large with the bottom trawls having headropes at least 35 meters long and midwater trawls with headropes of at least 38 meters (Hitz, 1970). Bottom trawls have been fitted with large rollers (bobbins) along the footropes to allow operation over rough bottom. In recent years, prior to the trawl PMP, the U.S.S.R. agreed to lessen the impact on rockfish stocks by not bottom trawling. This has been a regulation under the trawl PMP. Midwater trawls are aimed with the aid of net-sonde equipment, which relays information to the vessel's bridge regarding the position of the trawl relative to the seabed surface and fish concentrations.

The Soviet whiting fishery is pursued under the expeditionary concept, whereby a variety of support and fishing activities are coordinated. During the peak of the season, as many as 100 or more vessels have participated in the fishery. In addition to fishing vessels, there usually are refrigerated transports, tugs and patrol vessels. An expeditionary commander is responsible for the activities of the fleet. Some vessels are usually deployed throughout the fishing area to scout for whiting concentrations and to fish relatively small schools. The majority of the fishing vessels are usually divided among two to three areas where whiting concentrations are greatest. As many as 30-35 BMRT's have been observed fishing in concert on large concentrations of fish.

Poland is a rather recent participant in the whiting fishery, appearing first in 1973 with an exploratory probe, then with a fleet of eight vessels in 1974, 13 vessels in 1975, and six vessels in 1976. Three fishing companies send vessels to the northeastern Pacific Ocean, and it appears that most vessels operate independently, although organized fishing by six to eight vessels has been observed. Trawlers are serviced by cargo vessels which resupply the fleet and accept frozen processed products for delivery to Mexican and European ports.

Most Polish fishing vessels are the relatively new (post-1970) "B-418" factory stern trawlers, built in Poland. They are 89 meters in length, 2,475 gross tons, and carry a crew of 80-98. They are equipped with mechanized filleting lines, are fully refrigerated, and have meal and oil plants. All fishing in the Washington-California area is midwater trawling. Nets are as long as 176 m, with a vertical mouth opening of 24 m and a horizontal opening of 75 m. Fish are located hydroacoustically, and the trawls are aimed with the aid of the latest electronic equipment.

Other nations that have sent fishing fleets at one time or another to the Washington-California coasts include Japan, German Democratic Republic, Republic of Korea, Federal Republic of Germany, and Bulgaria. With the implementation of the PMP "Trawl Fisheries of Washington, Oregon and California," these nations have not received a catch allocation and have been removed from the fishery.

The number of fishing vessels and support ships by country for 1976, 1977 and 1978 are listed in Table 5.2.6.

Table 5.2-6. Numbers of foreign fishing vessels and support ships for the 1976-78 (1978 incomplete) trawl fishery[1].

Country	1976	1977	1978
U.S.S.R.	72/17	39/13	27/8
Poland	7/2	6/1	6/1
Japan	2/0	0	0
Mexico	0	0	0
Other	10/3	0	0

[1] Fishing vessels/support ships

5.2.3.2. Foreign catch

The catch of jack mackerel by the foreign trawl fishery has been reported by Poland for the years 1975-78 and by U.S.S.R. for the years 1977-78. The reported landings are given in Table 5.2-7.

Table 5.2-7. Reported landings in metric tons by the foreign trawl fishery for years 1975-1978.

Country	1975	1976	1977	1978[1]
Poland	3,736	782	160	260
U.S.S.R.	n/a	n/a	517	7
Mexico	0	0	0	0[2]

[1] Estimated landings through August 11, 1978

[2] Mexico was allocated 100 m tons in 1978.

The allocation for foreign fishing was set at 4,000 mt for 1977 and 1978. U.S.S.R. and Poland were allocated 2,000 mt each in 1977 but their combined landings tallied 677 mt for the year leaving 3,323 mt unharvested. In 1978 an incidental catch of 100 mt was allocated to Mexico leaving U.S.S.R. and Poland with a 1,950 mt allocation each.

General observations by U.S. observers on board Soviet and Polish fishing trawlers since 1976 indicated that jack mackerel are either dumped or made into meal. Also, jack mackerel apparently are not suitable for processing by filleting machines. If concentrations of jack mackerel are caught, then vessels will move to other fishing grounds. It is quite likely that the foreign vessels did not want to fill their jack mackerel allocation prior to filling their hake allocation.

6.0. EXISTING MANAGEMENT LAWS, POLICIES AND JURISDICTIONS

6.1. Domestic, United States

As of 1978 jack mackerel have been fished as a target species only in southern California waters. A jack mackerel harvest is expected to develop in northern California, Oregon and Washington as a result of increased domestic fishing for Pacific whiting (see the California, Oregon and Washington Groundfish Fishery FMP).

6.1.1. California

A variable fraction of the harvest of small jack mackerel is taken from within the 3-mile limit of California jurisdiction. This quantity has been estimated from landings by statistical block area. The fishery seldom operates in depths greater than 100 fathoms (less than 10% of landings). Therefore, only that portion of each statistical area shallower than 100 fathoms is assumed to be a fishing ground, and catches are apportioned to state waters by the fraction of fishing grounds within 3 miles of shore. Table 6.1-1 shows the fraction of the California harvest taken from state waters.

Table 6.1-1. California jack mackerel catch by jurisdiction.

Year	% inside 3 miles	% outside 3 miles
1975	71	29
1974	62	38
1973	15	85

While there are no laws specifically regulating the California jack mackerel fishery, there are a variety of California laws and policies with regard to gear and locality.

6.1.1.1. <u>California Fish and Game Code</u>

Only those regulations pertaining to fisheries targeting on jack mackerel are summarized here. Regulations affecting trawl fishing are given in the California, Oregon and Washington Groundfish Fishery FMP, Table 21.

Roundhaul nets are prohibited in several areas, notably in the vicinity of Orange County, Dana Point, San Mateo Point, Santa Catalina Island, and Santa Monica Bay. Some area closures are seasonal. Jack mackerel may not be taken for live bait in Santa Monica Bay or in the Los Angeles-Long Beach Harbor. Specific regulations are given in Appendix 1.

The California Fish and Game Code also contains laws. governing the take of Pacific mackerel and the allowable incidental catch rate. Jack mackerel is the main species occurring as incidental catch (see Section 8.6.3.).

6.1.1.2. California Fish and Game Commission

The California Fish and Game Commission, through the power given to it by the California legislature, regulates a variety of fishery matters. These regulations are found in "Title 14, State of California Fish and Game Commission Orders, Rules and Regulations," and are given in Appendix 2.

Recreational fishing gear is restricted to hook and line, with a 10-fish bag limit applicable to jack mackerel. Use of midwater trawls in the commercial fishery requires a revocable permit, and fishing logs must be maintained. Whole jack mackerel may not be used for reduction. Incidental catch allowances in the Pacific mackerel fishery are given in Title 14.

On July 22, 1977, the California Fish and Game Commission adopted a State of California Jack Mackerel Management Plan for Extended Jurisdiction. It is the policy of the State of California that the jack mackerel fishery should be limited to 55,000 metric tons (60,500 short tons) until the stock can be established and the impact of the fishery on the stock can be assessed. This policy does not constitute a regulation.

6.1.2. California, Oregon and Washington Groundfish Laws

The relevant laws are those affecting the groundfish fishery and are addressed in the California, Oregon and Washington Groundfish Fishery FMP, Table 21. Those laws which are likely to affect Pacific whiting and jack mackerel fisheries are briefly summarized here.

Logbooks are required in California and Oregon, and are voluntary in Washington. Trawling within 3 n.mi. of the mainland shore is prohibited in California. All three states have extensive regulations regarding construction of trawls. Trawls used for whiting have a minimum mesh of 2.5" in Oregon and Washington. Minimum mesh size is 3.0" for other species in Washington, and 4.5" for other species in Oregon. California requires a minimum mesh size of 4.5".

6.2. Domestic, Other Countries

6.2.1. Mexico

There are no Mexican laws regulating the jack mackerel fishery.

6.2.2. Canada

There are no Canadian laws directly regulating the harvest of jack mackerel. Although the resource extends into Canadian waters, there has been little effort directed at this species by either recreational or commercial fishermen. Jack mackerel are taken in insignificant amounts in the Pacific whiting fishery, usually making up less than 1% of the total catch. There is no market in Canada for these fish and they are usually dumped at sea. The only regulation that would affect Canadian harvest of jack mackerel is a requirement that the incidental catch for the whiting fishery be less than 10% of the total catch.

6.3. Foreign Fishery in the U.S. FCZ

Management of the foreign fishery for jack mackerel was initiated with the implementation of the 1977 Preliminary Management Plan (PMP) for the Trawl Fishery of the Washington, Oregon and California Region. For the years of 1975 and 1976 for which a foreign fishery for jack mackerel is documented, U.S. management of the foreign trawl fishery was designed to protect the Pacific whiting resource, reduce the impact on rockfish and other important species, and to minimize gear conflicts. For example, the Polish catch of jack mackerel declined from approximately 4000 mt in 1975 to 785 mt in 1976. This may have resulted from restriction on fishing days for whiting, the priority target species. Fishing time spent on jack mackerel and other species would only have reduced the whiting catch of individual vessels. Prior to FCMA, management regulations were formulated at bilateral negotiations and as a result the regulations varied somewhat among nations. For further details, see Section 2.15.2 of the 1977 trawl PMP (NMFS, 1977). Since implementation of the PMP, all nations have had to abide by the same regulations.

The Total Allowable Level of Foreign Fishing (TALFF) for jack mackerel in 1977 and 1978 was set at 4000 mt. The 1977 foreign quota allocated to U.S.S.R. and Poland was 2000 mt each. In 1978, 100 mt was allocated to Mexico, leaving U.S.S.R. and Poland with 1950 mt each.

The open season for each foreign country's directed fishing landward of 125°40'W for Pacific whiting or jack mackerel began 1 June and terminated 1 November or when the nation's allotted catch of any species listed in the trawl PMP was reached. West of 125°40'W the open season for jack mackerel began 1 March in 1977 and 1 June in 1978 and terminated on 1 January or when the nation's jack mackerel catch allocation was reached. The areas where fishing by foreign vessels was prohibited were:

(1) 47°30'N latitude to the U.S.-Canada boundary
(2) U.S.-Mexico boundary to 39°00'N latitude
(3) "Columbia River Pot and Recreational Fishery Sanctuary" is that area bounded by the following coordinates:
47°00'N - 125°20'W, 46°20'N - 124°40'W, 46°00'N - 124°55'W
(4) "Klamath River Pot Sanctuary" is that area bounded by the following coordinates:
41°37'N - 124°34'W, 41°37'N - 124°30'W, 41°30'N - 124°28'W
41°20'N - 124°32'W, 41°37'N - 124°34'W
(5) 39°N latitude to 47°30'N latitude landward of 125°40'W longitude prior to 1 June 1977 and after 31 October 1977.

These areas are shown in Figure 6.3-1.

Fishing gear was restricted to pelagic trawls with minimum mesh of 110 mm (4.33 inches), stretched measure in 1977 and 100 mm (3.94 inches) in 1978. Periodic in-season catch reports have been required for purposes of projecting fulfillment of annual catch allocation for each nation.

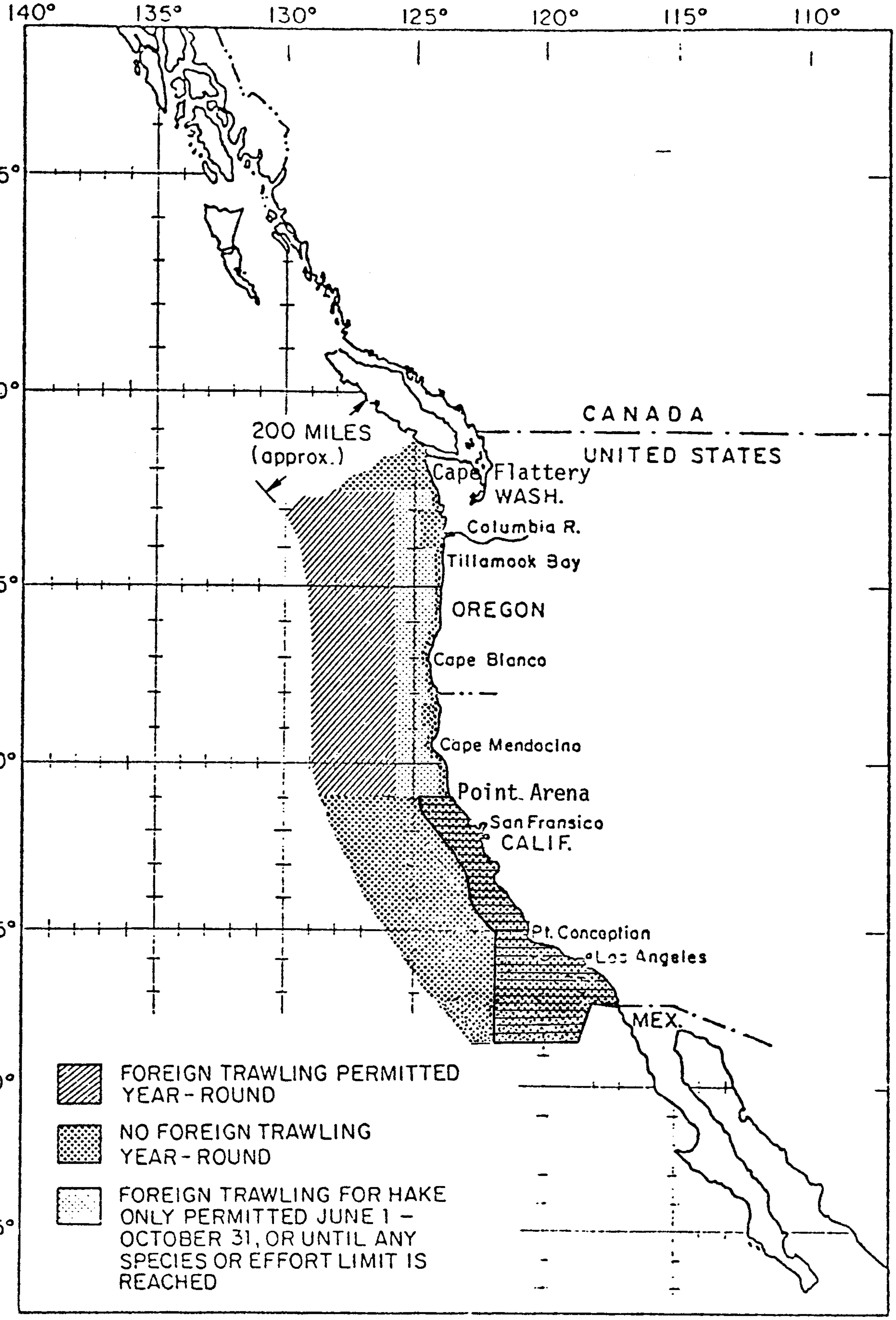

Figure 6.3-1. Time area closures pertaining to foreign trawl fishing in the Washington-California Region in 1978. The horizontally cross-hatched area denotes the southern jack mackerel fishing zone. The northern and offshore jack mackerel fishing zone is all other areas in the FCZ.

6.4. Other Fishery Management Plans

The California, Oregon and Washington Groundfish Fishery FMP regulates the use of trawl gear and the take of groundfish off the Pacific coast. Large jack mackerel are a major source of incidental catch in these groundfish fisheries, especially those for whiting. It is very likely that closure of the groundfish fisheries would effectively close the fishery for large jack mackerel, and conversely, closure of the large jack mackerel fishery would effectively close some of the groundfish fisheries. Until 1980, the groundfish fisheries are governed by the Pacific coast trawl PMP, which also includes jack mackerel regulations. This PMP is replaced by separate FMPs.

The Northern Anchovy FMP can be expected to have an indirect influence on the jack mackerel fishery. Low anchovy quotas are to be expected in some years (see Northern Anchovy Fishery FMP), causing increased fishing pressure to be directed at alternative species, particularly jack mackerel.

7.0. HISTORY OF RESEARCH

Research in California on the jack mackerel resource began with the initial collapse of the sardine fishery in the late 1940's. The early work was directed at species identification and differentiation between nearshore smaller jack mackerel in the purse seine fishery and the larger offshore fish. This work by Roedel and Fitch (1952) and Fitch[1] (personal communication) concluded that jack mackerel was a single species of the genus Trachurus. Carlisle (1971) examined the food habits of jack mackerel. The CalCOFI surveys have sampled eggs and larvae of jack mackerel within the CalCOFI region since 1950. These data provide information on distribution and relative size of the spawning biomass (Ahlstrom, 1968). A few of these surveys were designed to map offshore and northern distribution of spawning jack mackerel. Fecundity was examined by MacGregor (1976).

A synopsis of jack mackerel biology was prepared by MacGregor (1966) and the status of the resource was reviewed by Blunt (1969) and Knaggs (1973). Migration and stock discrimination studies were undertaken in the early 1970's. A tagging experiment (CDF&G, unpublished) demonstrated considerable local movement, but the recapture area was restricted to the area of the southern California fishery. The subpopulation study (Gregory and Tasto, 1976) identified a possible polymorphic enzyme that could be used to separate subpopulations. The enzyme pattern for samples from Baja and southern California indicated that the population of small fish in that area was homogeneous.

California commercial jack mackerel landings have been sampled by California Department of Fish and Game since 1947. Length and age compositions of landings have been routinely monitored and are available (Fleming and Knaggs, 1977; Knaggs and Barnett, 1975; Knaggs, 1974a, b). Wine and Knaggs (1975), using this data source, developed maturation and growth information for jack mackerel. In 1977 a contract study evaluated the potential for an expansion of the jack mackerel fishery to offshore areas, and concluded that for many reasons an expansion would not occur (Combs, 1977).

Soviet research vessels have annually surveyed the offshore segment of the jack mackerel resource since 1977. They have indicated a desire to engage in cooperative research, and such a program may begin in the near future.

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[1]John Fitch, California Department of Fish and Game, Long Beach, Ca.

8.0. SOCIO-ECONOMIC CHARACTERISTICS

8.1. Domestic Commercial Fleet

The majority of the vessels fishing for jack mackerel are located in San Pedro, with a few vessels fishing out of Port Hueneme and Monterey. The number of vessels participating in the jack mackerel fishery varies from year to year (Table 8.1-1). While there were from 65 to 131 vessels reporting landings of more than 0.05 short tons of jack mackerel for the years 1973 to 1976, the core of the fleet, or those vessels landing at least 50 tons, numbered from 24 to 39 vessels. Over the same time span, the number of vessels landing over 500 tons increased from 6 to 18. The characteristics of the vessels that landed jack mackerel are summarized in Table 8.1-2.

Table 8.1-1. Number of vessels landing jack mackerel in California, 1973-1976.

Number of vessels with landings over:	1973	1974	1975	1976
0.05 tons	131	69	65	87
0.5 tons	61	38	48	60
50 tons	39	24	31	35
500 tons	6	12	13	18
1000 tons	4	4	7	9
Total tons landed:	10,308	12,729	18,390	22,447

Source: California Dept. Fish and Game, Annual Statewide Landings Reports, 1973-1976 (unpublished).

Table 8.1-2. Average characteristics of jack mackerel fleet.

Jack mackerel landings in 1976 of:	Average length (ft)	Average net tonnage	Average horsepower	Average year built	Average year last purchased
less than 0.5 tons	49	18	199	1942	1970
at least 0.5 tons	49	29	295	1954	1970
at least 50 tons	65	47	265	1944	1967
at least 500 tons	69	57	267	1948	1971
at least 1000 tons	65	46	261	1941	1968

Source: California Dept. Fish and Game, Vessel Registrations, (unpublished data).

The majority of jack mackerel landings are made by what is known as the "San Pedro wetfish fleet." This fleet consists of approximately 30 to 50 purse seiners, with crews consisting of 9 to 12 men. The San Pedro wetfish fleet concentrates on the following species: northern anchovy (Engraulis mordax), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), Pacific bonito (Sarda chiliensis) and squid (Loligo opalescens). The fleet used to be substantially involved in the Pacific sardine (Sardinops sagax caeruleus) fishery. However, no commercial fishery has been allowed for sardines since 1973. Some of the San Pedro vessels also fish for bluefin tuna (Thunnus thynnus) and occasionally other tunas. Also, directed fishing for Pacific mackerel was prohibited from 1970 to 1976, except for an 18% incidental catch allowance in landings of other species. This moratorium accounts for the low Pacific mackerel catches reported in Table 8.1-3. Due to increased abundance in 1977, the fishery was reopened, and the Pacific mackerel catch is likely to continue to increase in the future, as the stock recovers. The vessels that fish for jack mackerel are likely to be involved in the northern anchovy fishery from October to May, the bluefin tuna fishery from July to August, the Pacific bonito fishery from July to September or later, and perhaps the squid fishery from November to February. They may also make landings of a variety of other species throughout the year.

The multispecies nature of these fisheries is evident from Table 8.1-3, which lists the landings and values of various species by vessels landing jack mackerel. In 1976 the vessels that landed 22,436 tons of jack mackerel also landed 174 tons of Pacific mackerel (as incidental catch), 110,545 tons of anchovy, 2,483 tons of squid, 1,866 tons of Pacific bonito, and 1,300 tons of bluefin tuna. The ex-vessel value of jack mackerel has been over $1 million in every year except 1973, with a top value of $5.25 million estimated for 1977. The majority of the gross income received by the vessels that fish for jack mackerel is from the anchovy fishery, accounting for 40 to 60% of the income from the years 1973 to 1976. The second source of income for these vessels is from jack mackerel, accounting for 12 to 26% of the value; Pacific bonito accounts for 6 to 18%, and both squid and Pacific mackerel have accounted for less than 5% of the total value to these vessels. The resurgence of the Pacific mackerel fishery in the 1977/78 season indicates that this species is becoming more important and may now be representing a higher percentage in both landings and value than in past years.

Vessels fishing for jack mackerel make the majority of the Pacific mackerel landings and approximately 70% of the anchovy landings, ranging from 58% in 1975 to 88% in 1976. The remainder of the anchovy landings are primarily made by Monterey lampara vessels. Over 40% of the Pacific bonito landings have been made by vessels that land jack mackerel, except in 1975, when high seas tuna vessels made the majority of the bonito landings. From 20 to 32% of the total squid landings in the state were made by jack mackerel vessels. The majority of the squid landings were made by scoop boats operating out of San Pedro and lampara boats in Monterey. A small proportion (7 to 28%) of the bluefin tuna landings are made by the vessels that land jack mackerel. Many of the vessels that fish for jack mackerel also fish for other wetfish species; the numbers are listed in Table 8.1-4. More jack mackerel vessels fish for anchovy (42 out of 60 in 1976) and for bonito (35 out of 60) than for squid and bluefin (27 and 19 out of 60, respectively). The number of vessels participating in the Pacific mackerel fishery is likely to increase as that fishery appears to be recovering. Annual quotas for Pacific mackerel are now being set according to State of California law which allows increasing harvests as the biomass increases (see Section 8.6.3).

Table 8.1-3. Landings of wetfish species by vessels landing jack mackerel[1].

	Jack mackerel	Pacific mackerel[3]	Anchovy	Squid	Pacific bonito	Bluefin
Landings (short tons):						
1973	10,289	26	96,879	1,389	7,442	955
1974	12,482	64	59,631	2,985	4,292	889
1975	17,382	134	92,495	3.718	1,275	2,282
1976	22,436	174	110,545	2,483	1,866	1,300
Values[2] ($1000):						
1973	988	4	4,844	100	1,584	447
1974	1,473	10	2,505	298	1,412	505
1975	1,599	14	2,960	260	314	1,118
1976	2,244	17	4,864	124	515	754
Percentage of total California landings taken by jack mackerel fishing vessels[1]:						
1973	~100	93	73	23	48	7
1974	98[1]	97	72	21	46	15
1975	95[1]	94	58	32	8	28
1976	~100	98	88	24	42	14

[1] Only includes vessels landing over 0.5 tons of jack mackerel. Does not include live bait catch.

[2] Values are based on average annual ex-vessel prices, not corrected for inflation.

[3] Pacific mackerel landed as incidental catch under moratorium.

Source: California Dept. Fish and Game, Annual Statewide Landings Reports; Calif. Marine Fish Landings, Fish Bulletins

National Marine Fisheries Service, Preliminary data sheets on commercial landings and values of fish in California (unpublished).

Table 8.1-4. Number of jack mackerel vessels fishing for wetfish species, 1973-1976[1].

Year	Jack mackerel vessels	Number of jack mackerel vessels landing:				
		Pacific mackerel[2]	Anchovy	Squid	Pacific bonito	Bluefin tuna
1973	61	8	43	28	38	16
1974	38	14	31	22	26	20
1975	48	23	35	24	23	26
1976	60	29	42	27	35	19

[1] Includes vessels landing 0.5 tons or more of jack mackerel that also landed 0.5 tons or more of wetfish species.

[2] Pacific mackerel landed as incidental catch under moratorium.

Source: California Dept. Fish and Game, Annual Statewide Landings Reports, 1973-1976 (unpublished).

8.2. Domestic Processors

Jack mackerel are utilized in several different products. Whole fish delivered directly to canneries, which accounts for most of the landings, are processed into canned jack mackerel for human consumption and canned pet food, with the offal reduced for fish meal, oil and solubles. Some landings are delivered directly to fish markets. These fish may be sold to wholesalers or retailers, or frozen whole and packaged into 80-pound boxes and sold to animal food producers to be further processed into canned animal food. Small amounts are smoked for human consumption.

Case pack of jack mackerel (standard cases of canned products for human consumption) has been highly variable in the last 25 years (Table 8.2-1). Production was highest in the early 1950's and early 1960's with a peak production of 1,525,000 standard cases in 1952. There was a drop in the pack of canned mackerel after 1965, declining to 63,000 standard cases packed in 1973. Production declined substantially in 1973 due to the destruction by fire of one of the major canneries in San Pedro. This cannery has now been rebuilt and production in 1977 of 724,891 standard cases was the highest since 1964. The increasing trend in production is expected to continue.

The pack of canned animal food in California has increased markedly in recent years (Table 8.2-2). Over 7.6 million standard cases were packed in both 1974 and 1975. Canned animal food includes jack mackerel, as well as tuna and other species of fish. The exact amount of jack mackerel going into animal food production is not known.

Current practice in canning mackerel is to use the entire fish, less the head, tail and viscera. The remaining body length is cut into sized pieces to be placed vertically in a 1-pound tall can. The number of fish needed to

Table 8.2-1. Pack of canned mackerel, 1950-1978.

Year	Standard cases[1] (1000's)	Weight (1000 lbs)	Wholesale value[2] ($1000)
1950	1,457	65,565	7,492
1951	1,049	47,205	6,259
1952	1,525	68,625	11,363
1953	596	26,820	5,038
1954	366	16,470	2,509
1955	564	25,380	3,339
1956	1,116	50,220	6,435
1957	1,327	59,715	7,404
1958	404	18,180	2,647
1959	587	26,415	4,235
1960	935	42,075	5,804
1961	1,378	62,010	8,529
1962	1,220	54,917	7,560
1963	1,275	57,395	7,603
1964	1,079	48,592	6,760
1965	703	31,655	4,997
1966	413	18,575	3,346
1967	283	12,733	2,363
1968	495	22,294	4,098
1969	386	17,354	3,317
1970	189	8,487	1,534
1971	367	16,517	3,076
1972	306	13,763	2,618
1973	63	2,851	540
1974	84	3,779	921
1975	216	9,738	2,614
1976	148	6,643	2,085
1977	686	30,890	11,869
1978	579	26,072	7,242

[1] Standard cases represent various size cases converted to the equivalent of 48 cans to the case, each containing 15 oz. net weight.

[2] Value constitutes the gross amount received by the producer at the production point, not corrected for inflation.

Source: U.S. Dept. of Commerce, NOAA, National Marine Fisheries Service, Current Fisheries Statistics, Canned Fishery Products Annual Summaries; Current Fisheries Statistics, Fisheries Statistics of the United States, 1978.

Table 8.2-2. Pack of canned pet food[1] in California, 1952-1976.

Year	Standard cases[2] (1000's)	Weight (1000 lbs.)	Estimated wholesale value[3] ($1000)
1952	1,332	63,936	6,793
1953	1,328	63,744	7,025
1954	1,644	78,912	8,582
1955	1,990	95,520	10,268
1956	2,549	122,352	12,082
1957	2,669	128,112	11,957
1958	2,648	127,104	17,238
1959	2,767	132,816	14,222
1960	2,968	142,464	16,502
1961	3,188	153,024	20,945
1962	3,145	150,960	18,430
1963	2,870	137,760	23,046
1964	3,037	145,776	24,539
1965	2,830	135,840	29,008
1966	2,719	130,512	31,486
1967	3,307	158,736	23,711
1968	3,224	154,752	23,503
1969	3,564	170,976	21,277
1970	4,997	239,856	44,923
1971	4,202	201,696	46,642
1972	5,008	240,384	71,564
1973	6,216	298,368	77,389
1974	7,608	365,184	84,373
1975	7,655	367,440	93,161
1976	5,543	266,064	78,932

[1] Pack of canned pet food containing any amount of fish or fish products.

[2] Miscellaneous size cans converted to 48 1-lb. cans to the case.

[3] Values (not corrected for inflation) estimated from average price per case of animal food containing at least 10 lbs. of raw fish in California. Case pack listed here may not include 10 lbs. raw fish per case, therefore value may be misrepresented.

Source: California Dept. of Fish and Game, Statistical Report of Fresh, Canned, Cured and Manufactured Fishery Products, Circulars No. 27-51, 1952-1976.

National Marine Fisheries Service, Fishery Statistics of the United States, Canned Fishery Products Annual Summary, 1976.

make 15 ounces net weight varies but is usually three to five. Brine is added and the fish are cooked in the can. This differs from the canning process for tuna where the fish are cooked before they are placed in the can. Fish that are to be processed directly for pet food are mixed with other ingredients and canned. The leftover heads and tails from the human consumption canning operation are also used for pet food, with the offal directed to the reduction plant and processed into fish meal and oil. According to California Department of Fish and Game Code Section 7704, reduction of whole mackerel is not allowed. However, reduction could be authorized by the California Fish and Game Commission under Code Section 8075. Mackerel are usually mixed with tuna to yield a tuna-mackerel mix meal (Table 8.2-3). The addition of mackerel to the tuna meal raises the protein content to approximately 55%. The proportion of mackerel in the tuna-mackerel mix is unknown, but probably not large. It is estimated to be from 10 to 25%.

It is not possible to ascertain how much of the jack mackerel landed in California goes into each of the various products. One cannery representative estimated that of the fish delivered to the cannery, 70% is directed to the cannery line for human consumption, with the remainder canned for animal food. The product yield in the human consumption canning operation is approximately 50 to 60% for average sized fish in the small fish fishery. A high percentage of the remainder is utilized for pet food, with a smaller proportion delivered to the reduction plant.

The majority of jack mackerel processing takes place at two canneries in the San Pedro area (Terminal Island). Fish are canned both for human consumption and for animal food. In addition to the cannery operations in the San Pedro area, some landings are delivered directly to the markets. Non-cannery deliveries in the Los Angeles area amounted to only 4.7 to 16.2% of the total landings for the years 1968 to 1975. These most likely represent market landings of whole mackerel which are frozen, boxed and then sold to animal food processors. The remainder is sold fresh or frozen, further processed for human consumption, or exported.

Processing of jack mackerel in the Port Hueneme area is primarily for human consumption. There are two processors, one that cans and another that freezes mackerel. The cannery packs jack mackerel for human consumption in the same manner that mackerel is processed in San Pedro. However, none of the mackerel is processed for animal food. All of the offal is reduced and sold as straight mackerel meal, with a protein content of approximately 64 to 68%. The Port Hueneme cannery is expanding its mackerel line and is adding two additional steamers. Three purse seiners fish regularly for this processor. The other Port Hueneme fish dealer specializes in producing a high quality individually quick frozen product. This processor occasionally experiences difficulty in obtaining a regular supply of high quality fish suitable for freezing. Most of their supplies are provided by the processor's own boat, with some quantities purchased from the top of the load from the purse seiners. Some mackerel is cut, frozen and packaged for bait; other is dried and salted.

One canner packs jack mackerel in the Monterey area. Fish to be canned are often landed in the Port Hueneme area and trucked to Monterey. Small amounts are frozen for human consumption and for bait. The offal is ground, sacked and then frozen, to be used mainly for animal food.

Table 8.2-3. Production and value[1] of tuna and mackerel meal and oil, 1962-1978.

Year	Tuna and Mackerel Meal (tons)	Tuna and Mackerel Meal ($1000)	Tuna and Mackerel Oil (1000 lbs.)	Tuna and Mackerel Oil ($1000)
1962	26,559	2,579	5,008	236
1963	26,957	2,943	5,903	274
1964	21,113	2,229	4,816	272
1965	25,399	3,032	4,794	334
1966	25,290	3,199	4,111	303
1967	25,487	2,758	5,218	268
1968	28,781	2,955	4,549	163
1969	26,870	3,239	4,256	132
1970	26,674	3,753	3,534	168
1971	29,287	3,706	4,933	255
1972	43,226	5,484	5,030	272
1973	43,635	13,243	7,396	494
1974	48,224	11,603	6,819	810
1975	37,209	6,384	6,444	691
1976	40,059	8,820	6,340	554
1977	39,228	10,544	3,807	395
1978	50,244	15,024	4,358	463

[1]Values are not corrected for inflation.

Source: U.S. Dept. of Commerce, Current Fisheries Statistics. No. 7202, Industrial Fishery Products, Annual Summary. 1976. Current Fisheries Statistics No. 7800, Fisheries of the United States, 1978.

Some minor amounts of mackerel are processed outside of the main areas of San Pedro, Port Hueneme and Monterey. Jack mackerel is found throughout California waters, and is taken incidentally to several fisheries. It is likely that some landings are delivered as market fish throughout the state. There are some small smoking operations in northern California. Most all of the smoked mackerel are for local consumption.

8.3. Markets

The major market in the United States is for canned jack mackerel. There is a long history of canning and marketing jack mackerel. During the period 1918 to 1920, jack mackerel was canned as a substitute when the albacore supply was low. In the early 1920's, a cannery put up a specialty pack of mackerel fillets. In the late 1920's, a salmon style pack was successfully marketed in the Philippines, although the package suggested that another type of salmon was being offered at a low price, rather than jack mackerel. In the late 1940's and 1950's, jack mackerel was used extensively as a substitute for Pacific sardines. Currently, the primary product offered in American markets is the 15-ounce tall can packed in brine. Jack mackerel is marketed as a low cost, high protein product. Trends in the wholesale value per 1,000 pounds, deflated according to the Wholesale Price Index, of canned tuna, Maine sardines, bonito and jack mackerel in the period 1960-1975 are shown in Figure 8.3-1. In recent years the price spread between mackerel and the other canned fish products has been large. The value of canned jack mackerel has been remarkably stable except in 1977 when prices increased sharply.

Although the low retail price of jack mackerel makes it one of the best protein bargains of any food on the market, its low price also contributes to its negative image as a "pet food." Mackerel packed for human consumption has occasionally been marketed in the pet food sections of supermarkets.

Domestic canned mackerel (jack mackerel and Pacific mackerel) products must compete with foreign products. Besides the regular pack of mackerel in the tall cans, foreign exporters offer several "gourmet" products packed in various sauces. Pacific mackerel also competes with jack mackerel. Figures are not available on the quantity of canned mackerel products imported into the United States. According to Bureau of Customs records, however, 1,130 tons of canned mackerel were imported into California and Arizona alone in 1976. This includes imports from Japan, South Korea, Portugal and the Netherlands. This quantity includes products to be consumed in California as well as products to be shipped to other states. A small portion of canned mackerel produced domestically is exported. There is also a quantity of fresh and frozen jack mackerel imported into the U.S.

According to industry representatives, the current market for domestically produced canned jack mackerel is strong in certain regions of the United States. The largest markets are the major cities in the east and in the south. The demand is described as stable, with some fluctuations due to lower-priced imports which compete with domestic canned mackerel. Each of the processors contacted in August 1978 indicated a high degree of confidence in the market situation, and anticipated increasing their sales and expanding the markets. Efforts are being made through intensified advertising campaigns to increase consumption of canned mackerel and to open new markets. Most indicated that there was sufficient demand presently to sell all that is currently produced, and that larger markets could be developed. The marketing emphasis was on promoting mackerel as a high protein, low cost product. Several of the plants canning jack mackerel have already expanded or are planning on future expansion.

Another important market is jack mackerel as animal food. The animal food industry has been doing increasingly well over the past decade. There is also substantial demand for tuna-mackerel meal as a feed ingredient by southern California poultry and egg producers. The major substitutes are other fish meals, such as anchovy meal, meat and bone meal, and soybean meal. Another small market exists for jack mackerel utilized as bait. Large game fish such as yellowtail, striped marlin, and large kelp bass are taken by recreational anglers using live jack mackerel as bait.

The final market to be considered is that for small fresh and frozen mackerel. One Santa Barbara area processor has found a small market for a high quality, quick-frozen product. The major demand for this product is from the ethnic communities of the major cities on the west coast. Fresh and frozen mackerel are marketed along the California coast, but little interest was

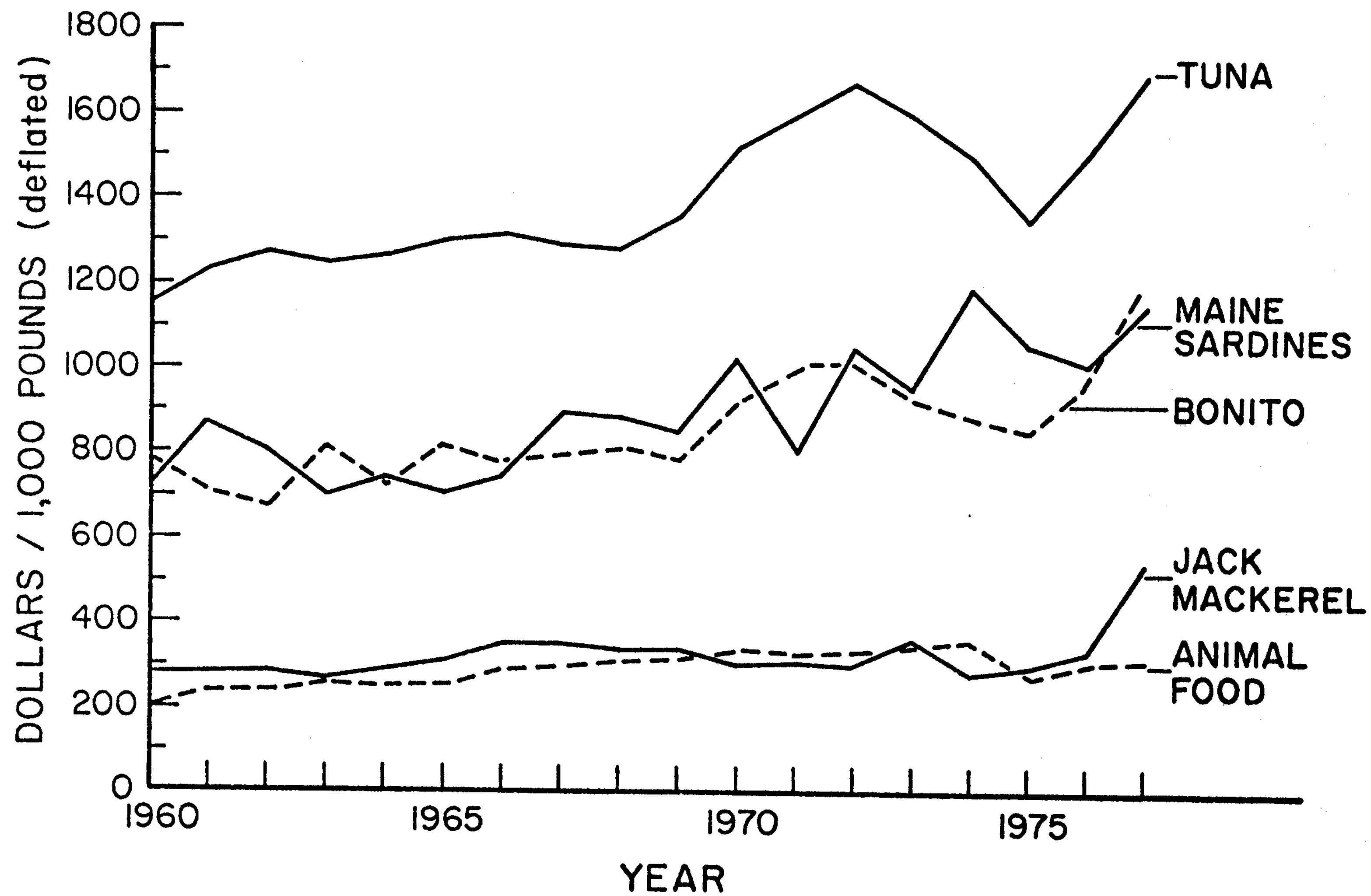

Figure 8.3-1. Wholesale value (deflated)[1] per 1,000 lbs. of canned fish product.

[1] deflated by Wholesale Price Index, 1977=100.

Source: National Marine Fisheries Service, Current Fisheries Statistics, Canned Fishery Products, Annual Summaries.

shown in this market. Mackerel, when it is marketed as fresh or frozen fish, is one of the least expensive species of fish offered. This market will likely continue to be a small portion of the total marketing picture for mackerel.

There appears to be a potential market for large jack mackerel. However, due to lack of year-round supply, processors are reluctant to invest in developing such a market.

8.4. Recreational Fishery

Jack mackerel make a small contribution to the catches of a wide variety of fishery segments (also see Section 5.2.1.2). Normally jack mackerel are less than 1% of the California partyboat catch. But in an unusual year such as 1953, when anglers are actively targeting on the species, jack mackerel have contributed as much as 8.6% of the total partyboat catch. Other comprehensive surveys of recreational catches have generally found jack mackerel catches to be insignificant. Pinkas, Oliphant and Haugen (1968, p. 41) found that jack mackerel contributed 0.2% of the southern California recreational fish catch in 1963 to 1966. Miller and Gotshall (1965, p. 77) report that jack mackerel contributed 0.19% by weight to the recreational catch in central and northern California in 1958 to 1961.

In southern California jack mackerel occasionally provide an important source of live bait for anglers targeting on larger gamefishes such as billfish. Long-range partyboats often procure jack mackerel for bait before embarking on trips to southern Baja California. Much of this bait is obtained directly by the anglers by fishing under night-lights. Commercial live bait suppliers also provide live jack mackerel on occasion, and jack mackerel may provide social and economic benefits to the recreational fishery especially when live anchovies are in short supply as bait.

8.5. Area Community Characteristics

The majority of the small fish jack mackerel fishery takes place from San Pedro in southern California. Over 90% of total jack mackerel landings have taken place in this area in the past few years. Many of the boat owners and operators live in San Pedro. It is uncertain how many of the crew members also live in San Pedro, although most live in the Long Beach-Los Angeles area near San Pedro. Jack mackerel fishing also takes place out of the communities of Port Hueneme and Monterey. If a large fish jack mackerel fishery were to develop along the north coast of California, Oregon and Washington, then fishermen from communities in those areas would participate. Since the jack mackerel fishery is presently centered at San Pedro, this section will be focused on this community.

San Pedro is incorporated by the City of Los Angeles, as are the nearby communities of Wilmington and Harbor City. It is bounded by Terminal Island and Long Beach on the east, Palos Verdes Peninsula on the west, Harbor City, Los Angeles and Wilmington on the north, and the San Pedro Channel on the south.

Many of the vessels that participate in the local fisheries are located at the main channel fishermen's dock of San Pedro Bay. This area is of aesthetic importance and has added greatly to the tourist appeal of San Pedro. Many tourists shop at the neighboring "Ports of Call" Village, and there are several seafood restaurants in the surrounding area. Picturesque fishing boats are important to photographers, artists and visitors who are attracted to the atmosphere of a southern California fishing community.

The canneries and unloading docks are located just a short distance away from the dock where the fishing fleet ties up. The fishing industry and related activities in the harbor form the economic base of the area. There has been a tradition of fishing among Italian and Yugoslavian families in the area. No official figures are available on employment in fisheries in the San Pedro area. There are approximately ten persons employed on an average wetfish boat, and there are approximately 35 boats that actively participate in the jack mackerel fishery. The same crew tends to stay with the boat throughout the year as it fishes for various species. At least 350 persons are directly involved in the San Pedro jack mackerel fishery, with many more involved to a lesser extent. Less than 50 persons are employed directly in harvesting jack mackerel in other communities, for a total of approximately 400 persons throughout the state. There are probably over 5,000 persons employed by the fish processors in the San Pedro area, and less than 200 in other areas. While jack mackerel is a small portion of the total fish processed, it undoubtedly accounts for many jobs during certain parts of the year.

The economic impact of the fishing industry on San Pedro cannot be gauged, but it is of considerable importance. Indicators of economic growth and trends since 1950 are noted in Table 8.5-1. The population in San Pedro has increased over 25% since 1960, a larger percentage increase than that in the county. Little of this increase has been associated with fishing activity. Various social and economic characteristics of the population in 1970 are summarized in Table 8.5-2. San Pedro does not differ substantially from Los Angeles County nor from the State of California, except in that a significantly higher percentage of the population in San Pedro is foreign born. This may be due to the immigrants coming to San Pedro to participate in the fishing industries.

In summary, it should be noted that the fishing industry is of substantial economic and social importance to the community of San Pedro. The fishery for jack mackerel is only one of the many fisheries that takes place there, but many boats and crew participate in this fishery throughout the year.

Table 8.5-1. Economic growth and trends in San Pedro.

	1950	1960	1976
County population (Los Angeles)	4,152,000	6,042,000	6,992,000
San Pedro population	46,400	59,300	75,000
Number of occupied dwellings	n.a.	18,400	24,900
School enrollment, grades 1-6	4,187	6,704	n.a.
Total taxable retail sales in county ($1000)	$5,248,000	$9,841,000	$26,750,000

Source: San Pedro Chamber of Community Development and Commerce, Community Economic Profile for San Pedro, 1977.

Table 8.5-2. Social and economic characteristics of San Pedro, Los Angeles County and California, 1970.

	San Pedro	Los Angeles County	State of California
Age composition:			
Percent of population below 19 years of age	37.1	32.1	33.3
Percent of population over 64 years of age	7.6	9.3	9.0
Families:			
Number of families	20,342	1,769,331	5,001,255
Families with single parents	12.4%	-	-
Husband/wife households	82.8%	-	-
Families below poverty level	10.7%	8.2%	8.4%
Families on public assistance	9.2%	-	-
Median income of families	$10,228	$10,972	$11,099
Schooling:			
High school graduates	51.2%	-	-
Adult population with 8th grade education or below	19.6%	-	-
Average years of school completed	11.4	12.4	12.4
Nativity and Parentage:			
Native born, of native parentage	58%	-	-
Native born, of foreign or mixed parentage	24%	-	-
Foreign born	18%	11.3%	8.8%
Employment:			
Males, 16 years or older, in the labor force	81%	78.8%	77.6%
Females, 16 years or older, in the labor force	38%	44.6%	42.2%
Percent of unemployment in civilian labor force	8.4%	6.2%	6.3%
Civilian labor force	23,237	-	-

Source: U.S. Bureau of the Census 1970 Census of Population, PC(1)-C6, California; General Social and Economic Characteristics; and PC(1)-B6, General Population Characteristics.

8.6. Fishery Interactions

8.6.1. Commercial-recreational interactions

With 1978 levels and patterns of commercial and recreational fishing there are no conflicts in evidence with respect to jack mackerel fishing. To some extent, increased commercial fishing effort directed toward jack mackerel could reduce commercial effort directed toward northern anchovy, reducing conflicts perceived by recreational fishermen with respect to anchovies.

8.6.2. Jack mackerel as incidental catch

Large jack mackerel occur as incidental catch in both salmon and albacore troll fisheries. The magnitude of these catches is unknown, and is probably variable. Although these incidental troll catches are almost always returned to the water, mortality is very high due to rough treatment. The domestic and foreign trawl fisheries for whiting also catch jack mackerel (see Section 5.2.3). Some jack mackerel are retained, but dumping may be widespread. Mortality of dumped jack mackerel is undoubtedly very high. Although these incidental catches are returned to the sea, they nonetheless constitute removals from the stock.

8.6.3. Other species as incidental catch in jack mackerel fishery

In southern California waters, Pacific mackerel (Scomber japonicus) often mix with schools of jack mackerel, and are taken in the jack mackerel fishery. Pacific mackerel are managed by a variable quota system which depends on the biomass of the resource. Under 1978 California legislation, season allowable catch is equal to 20% of the amount of Pacific mackerel in excess of 20,000 tons total population (age one and older). This formula will continue until 1981, when it will revert to previous regulations where season allowable catch is 20% of the amount of Pacific mackerel in excess of 10,000 tons spawning population, and 30% of the amount in excess of 20,000 tons spawning population (Appendix 1).

When the Pacific mackerel quota is filled (or is zero), Pacific mackerel may not exceed 18% of the total load when taken incidentally. This restriction has caused considerable difficulty to jack mackerel fishermen, and in the summer of 1977 reduced the harvesting capacity of the domestic fleet. The incidental catch rate has tended to increase as the Pacific mackerel population has recovered in recent years from a formerly depleted condition. Pacific mackerel are equally desirable as a target species to jack mackerel fishermen.

Under current law, expiring in 1981, the Director of California Department of Fish and Game has the authority to vary the incidental catch allowance between 18% and 50% by number, but the low figure applies when the quota is filled. In order to reduce conflicts with the jack mackerel fishery, current regulations allow 20% Pacific mackerel in loads of jack mackerel, and only allow pure loads of 8 tons or less. The effect is to keep the Pacific mackerel quota open as long as possible, minimizing conflict with jack mackerel fishing. In 1981 the incidental catch allowance will return to a constant 18% by weight.

Because the conflict has only existed since 1977, patterns of interaction are not well known. Mixed schooling appears to be most extensive in the spring and summer when a strong year-class of Pacific mackerel is one year old. Mixed schools are much less common on offshore banks than inshore and around islands.

8.7. Revenues Derived from Fishery

8.7.1. Revenue from domestic fishery

8.7.1.1. Tax revenue

Washington, Oregon and California require payment of a privilege fee or tax on landings of jack mackerel. The State of Washington collects 1% of the primary market value. The State of Oregon collects 0.1¢/lb. as did California until the beginning of 1979, when the fee was raised to 0.13¢/lb.

Actual revenues to Oregon and Washington have been negligible because few jack mackerel have been landed. California revenues reached a high in 1977, when approximately $110,000 in fees were collected on landings of 55,123 tons of jack mackerel.

8.7.1.2. Gross revenue

Revenue to the economy is difficult to measure. Gross revenue is approximated by the landed values given in Section 8.1. Landed value fluctuates widely as landings themselves have varied. The year 1973 shows the lowest value ($988,000) while 1977 shows the highest value ($5,250,000) in recent years. Net revenue cannot be calculated because the costs of harvesting are not known. The value of jack mackerel products is also difficult to estimate because of admixture of Pacific mackerel in canning, tuna in meal, and various ingredients in pet food. The wholesale value of canned mackerel was $540,000 in 1973 and $11,869,000 in 1977. Value of products is discussed in Section 8.2.

8.7.2. Revenues from foreign fishery

Provisions of the Fishery Conservation and Management Act of 1976 (FCMA) provide for the charging of foreign fishing vessels reasonable fees for fishing privileges within the U.S. FCZ. The FCMA states "In determining the level of such fees, the Secretary may take into account the cost of carrying out the provisions of this Act with respect to foreign fishing, including but not limited to, the cost of fishery conservation and management, fisheries research, administration and enforcement" (Section 204(b)(10)). The fee schedule established by NOAA in February 1977 consisted of a vessel permit fee and a poundage fee. The permit fee is $1.00 per gross registered ton (GRT) for vessels engaged in catching fish; $0.50 per GRT for vessels engaged in processing fish but not catching fish with a $2,500 upper limit on this charge; and $200 per vessel for any support vessel which itself is not catching or processing fish. The poundage fee is 3.5% of the U.S. exvessel value times the allocation to the foreign nation (Noetzel, 1978, p. 4). Exvessel values are reevaluated each year by NMFS. All fees are paid in advance of the fishing season. Countries that do not completely fill their allocation by the end of the season are eligible for poundage fee refunds. At the present level of harvest, jack mackerel is a secondary species to Pacific whiting. Consequently, only foreign revenues generated by poundage fees for the Washington-California foreign trawl fishery can be attributed to jack mackerel resource. Assuming both U.S.S.R. and Poland requested refunds for the unharvested portion of their allocation, generated revenues for 1977 amounted to $2,204. This is based on an exvessel value of $93 per mt (Federal Register, 2/9/77, 42FR8176). The exvessel values of $110 per mt was set for 1978 and is proposed for 1979.

9.0. BIOLOGICAL AND ENVIRONMENTAL CHARACTERISTICS

9.1. Life History Features

9.1.1. Distribution

The jack mackerel ranges widely throughout the northeastern Pacific. Small jack mackerel are typically found near the coast and islands and over shallow rocky banks. Small fish appear to be most concentrated in the Southern California Bight. Older, larger fish are generally found offshore in deep water and along the northern coastline, only rarely appearing in inshore waters in the south. These large fish range from Cape San Lucas, Baja California to the Gulf of Alaska. The offshore limit of the population is poorly defined, but various sources have been compiled by Blunt (1969) to produce a distributional map (Figure 5.1-1). The offshore limit is approximated by a line running from Cape San Lucas, Baja California, to the eastern Aleutian Islands, Alaska. A large portion of the range lies outside the 200-mile U.S. FCZ.

9.1.2. Age, growth and mortality

Wine and Knaggs (1975) describe growth of jack mackerel taken by the southern California fishery. A general weight-length relationship is

$$W = 0.0000033101\ L^{3.223229}$$

where W is weight in grams, and L is fork length (FL) in mm. This relationship was based on fish ranging from 100 mm to 300 mm FL (cf. Figure 9.2-1), and is not reliable for larger fish. MacGregor (1976) gives lengths and weight for 15 large (over 400 mm FL) jack mackerel, and the Wine and Knaggs formula overestimates weights by about 20%. A weight-length relationship was calculated for MacGregor's fish (n = 30, range = 217 mm to 554 mm FL) by linear regression of log-transformed variates, and Beauchamp and Olson's (1973) correction for log transformation bias was applied, giving

$$W = 0.000012338\ L^{2.97785}$$

This relationship overestimates weights of Wine and Knaggs' smallest fish, and underestimates weights of their largest fish. However, it agrees well with the mid-range of their fish. The second weight-length relationship is appropriate for modeling the entire life span of the jack mackerel (Table 9.1-1), while the Wine and Knaggs (1975) relationship is appropriate for modeling fish in the southern California fishery.

Age of jack mackerel is determined by examination of annuli on otoliths (Knaggs and Sunada, 1974), and appears to be reliable for southern California fish. It has been assumed that the method is also valid for the large offshore fish, some of which have been aged at over 30 years (Fitch, 1956). Length at age has been described by Wine and Knaggs (1975), who obtained the following fit to a Von Bertalanffy growth curve:

$$L_t = 602.86\ \text{mm}\ (1 - e^{-0.093504(t+3.2520)})$$

where L_t is length in millimeters at age t.

Table 9.1-1. Ages, lengths and weights of jack mackerel.

Age (years)	Fork length mm	Fork length inches	Weight g	Weight lbs.
1	198	7.8	85	0.19
2	234	9.2	140	0.31
3	267	10.5	208	0.46
4	297	11.7	285	0.63
5	324	12.8	369	0.81
7	372	14.6	557	1.23
10	428	16.9	846	1.87
15	493	19.4	1289	2.84
20	534	21.0	1635	3.60
25	560	22.0	1883	4.15

The natural mortality rate of the jack mackerel has not been estimated previously. The necessary data for a direct estimate are very difficult to obtain, given the stock structure and migratory habits of the fish (see Sections 9.2 and 9.1.5, respectively). Due to the size selectivity and geographic character of existing fisheries (see Section 9.2), age frequency analysis is not feasible because mortality rates are confounded with rates of emigration. However, other information which correlates with mortality rates is available, allowing reasonable values to be hypothesized.

The growth rate parameter k in the Von Bertalanffy growth equation ($k = 0.09$, see above), tends to be correlated with the natural mortality rate (M) for a wide variety of marine fishes (Beverton and Holt, 1959). This would suggest that M, over the average lifespan, is probably less than 0.25 for the jack mackerel. Another indication of a relatively low rate of mortality is the existence of fish exceeding 30 years of age (Fitch, 1956). Again, average M must be less than 0.25 for such fish to occur (see Holt, 1965).

Both of the above bounds on the mortality rate are for the lifetime average mortality rate. It is highly unlikely that jack mackerel exhibit a constant M throughout their life. Richard Parrish[1] (personal communication) has shown that natural mortality rates of marine species tend to be closely related to their mean size, smaller fish showing characteristically higher mortality rates. Thus it does not seem appropriate to assign the same mortality rate to the small southern California fish as to the large offshore segment. Moreover, there are certainly many more predators in the nearshore area as compared to the offshore waters inhabited by the large fish. Also the change from densely schooled small fish to loosely schooled large fish suggests a decrease in predation (J. Radovich[2], personal communication). Based on the above information, the following alternative schedules of natural mortality rates at age are postulated for the jack mackerel:

Alternative Natural Mortality Rate Schedules

Age	High	Low	Comments
0	0.5	0.5	Small inshore fish are heavily
1	0.5	0.25	preyed upon.
2	0.45	0.225	Fish progressively migrate to
3	0.4	0.20	join offshore segment, mortality
4	0.35	0.175	rate decreases with growth and
5	0.3	0.15	change in habitat.
6	0.25	0.125	
7 and older	0.2	0.1	Offshore migration is complete.

9.1.3. Reproduction

In their study of maturation of jack mackerel from the southern California fishery, Wine and Knaggs (1975) determined that most females become sexually mature at about their first birthday. Although immature fish were found at all times of the year, 50% or more of all females appear to be close to or in spawning conditions during the period March through September. Very young spawners appear to reach a reproductive condition later in the season than do older spawners. Nothing is known of the maturity cycle of the larger offshore fish.

Jack mackerel eggs and larvae first become abundant in the waters far offshore from northern Baja California and southern California in March through June (Kramer and Smith, 1970; Ahlstrom, 1969). There is very little production

[1] Richard H. Parrish, National Marine Fisheries Service, Monterey, Ca.

[2] John Radovich, California Dept. of Fish and Game, Sacramento, Ca.

of eggs and larvae in the Southern California Bight until July and August, presumably when the younger fish begin to spawn (see above). Also, the center of offshore spawning loosely moves north as the summer progresses. The northern and offshore areas of spawning have received very little sampling effort, so the seasonality and geographic limits to spawning by the offshore population are poorly known. A survey of the northeastern Pacific in August of 1955 took jack mackerel eggs and larvae off Oregon and Washington from 100 to 1000 miles offshore (Ahlstrom, 1956). CalCOFI cruise 7210 (October 1972) similarly found a large isolated area of jack mackerel spawning extending from 200 to 600 miles off the coast of Washington, verifying the existence of late northern offshore spawning. The northern limit of jack mackerel spawning was not determined.

MacGregor (1976) calculated the fecundity, in advanced eggs per gram of fish, of thirty jack mackerel. These fish could be conveniently divided into two distinct groups, representing small and large fish. The small fish ($n=15$, $\bar{l}=235$ mm) had a mean fecundity of 65.8 advanced eggs per gram of fish. The large fish ($n=15$, $\bar{l}=519$ mm) had a mean fecundity of 152.3 advanced eggs per gram of fish. The small fish, which would correspond to age 2 years, had a relative fecundity of $65.8/152.3=0.43$ of the large fish on a per unit body weight basis.

9.1.4. Recruitment

Absolute magnitude of recruitment cannot presently be determined. However, examination of contributions of various year classes to the southern California fishery provides a rough picture of recruitment variability. The fishery landings have been determined by processor orders rather than by availability, so actual volume of catch is not necessarily a good indicator of relative abundance. Virtual year class strength, obtained by summing the percentage contributions of a year class to the various seasons in which it was fished, provides a rough indication of year class variability. Age composition data were taken from Knaggs (1974a,b), Knaggs and Barnett (1975), Fleming and Knaggs (1977) and Fleming[1] (personal communication). Because we have used percentage contribution, an average year class will therefore have a virtual strength of 100%. Long-term trends cannot be detected by this treatment, since year classes are effectively compared only with their near neighbors.

The resulting series of virtual year class strengths (Fig. 9.1-1) shows a pattern of runs of weak year classes interrupted by occasional strong year classes. Until the 1966 year class, recruitment seems to have been either very good or very poor, with average recruitment being a rarity. In more recent years, since 1966, year classes seem to have fluctuated less severely; however, the current fishery, from which data are not yet fully available, suggests that the 1976 year class was very strong.

9.1.5. Migration and behavior

Jack mackerel demonstrate an inshore-offshore as well as an up-and-down coast movement within southern California waters. Seasonal movement of jack mackerel stocks and commercial concentrations show these fish to be more available on offshore banks in late spring, summer and early fall than during the remainder of the year.

Exploratory fishing by the INPFC in the Gulf of Alaska indicates a migration of some large jack mackerel from the south during the summer. This

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[1] Eugene Fleming, California Department of Fish and Game, Long Beach, Ca.

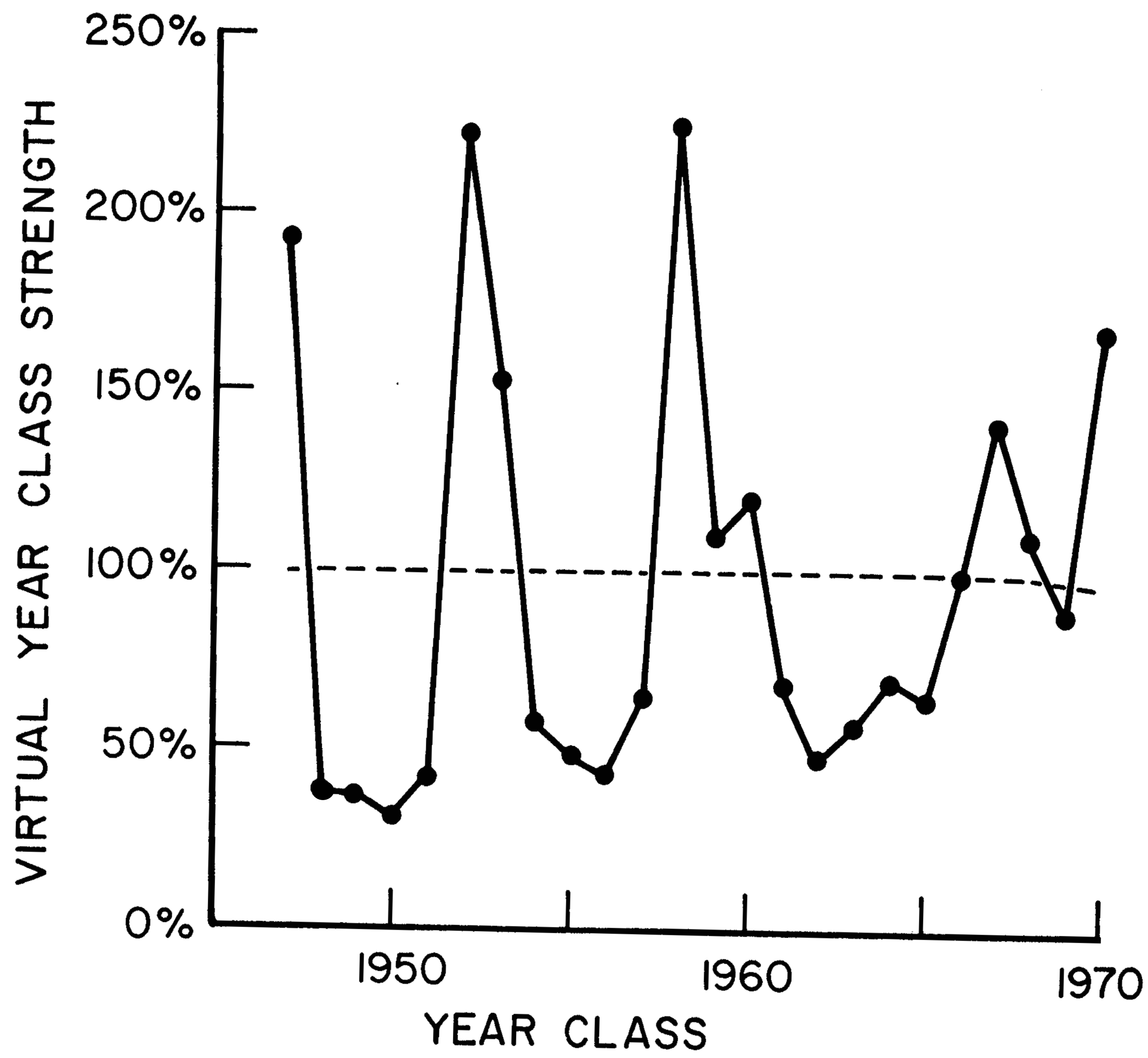

Figure 9.1-1. Relative recruitment strengths of jack mackerel year classes in southern California. Virtual year class strength is measured by the sum of percent contributions to seasonal landings over the lifetime of the year class. The dashed line indicates average strength.

migration is probably related to the warming of surface waters during this season. Not all large jack mackerel make this movement, however, since some are caught in California and Baja California waters throughout the year.

Habitats favored by small jack mackerel consist of shallow rocky banks and the rocky perimeters of islands. Rocky coastal areas associated with kelp beds sometimes contain mackerel schools, especially in waters off Mexico. Schools on banks have often been concentrated around the shallowest rocky areas in waters 9 to 55 m (5 to 30 fathoms) deep. Island-associated schools have been found from 45 m (50 yards) to 0.9 km (0.5 miles) off shore and often in or near kelp beds. Schools in these areas frequently move into deeper surrounding areas at night.

Mais (1974, p.60) has made the following behavioral observations. Jack mackerel schools are found at greater depths from the surface than most other pelagic schooling species of commercial importance. Schools on or near the surface are a rarity. Echo-sounding has located schools 9 to 73 m (5 to 40 fathoms) from the surface. It has not been possible to determine maximum schooling depth.

Echo-sounder recordings of jack mackerel schools indicate rather losse aggregations of much greater horizontal than vertical dimensions, and school density or compaction appears less dense than for anchovies or sardines. Observations of bioluminescent schools at night indicate low density with ragged or ill-defined perimeters.

Jack mackerel schools are much less active and vigorous in swimming than are many other pelagic species. Observations by scuba diving and from the vessel's underwater viewing ports and bridge indicate a relatively low school activity level reflected by slow sluggish swimming action.

The occurrence of fish beneath floating kelp and debris in the open sea is a common schooling behavior which is most prevalent in the late summer and fall months. Small jack mackerel tend to occur closer to the shoreline (both island and mainland) than do larger fish. Large jack mackerel over 400 mm FL are found offshore either solitary or in very loose small schools. However, trawlers fishing on the continental shelves off the states of Washington, Oregon and California have caught commercial concentrations of large jack mackerel.

9.2. Stock Structure

Very little is known of the structure of the jack mackerel population. Extensive meristic and morphometric observations have not uncovered any heterogeneity which could indicate presence of subpopulations (John Fitch[1], personnal communication; Gregory and Tasto, 1976). Some Soviet fishery scientists believe that there is more than one genetic population of jack mackerel (Pashchenko, MS), based on interpretation of existing data, particularly patterns of age-at-maturity. Resolution of the stock structure of the resource requires research (see Sections 14.7). Jack mackerel blood possesses a polymorphic protein, phosphoglucose isomerase (PGI) which could be used to investigate population heterogeneity (Gregory and Tasto, 1976), but a population study of PGI allele frequencies has not been undertaken.

With so little information available, a hypothetical model of stock structure will be employed. This model must be consistent with known facts or reasonable inferences, and should be fail-safe; the stock should not be jeopardized by management decisions arising from the model if it is actually erroneous.

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[1] John Fitch, California Department of Fish and Game, Long Beach, Ca.

There are two distinct and non-overlapping segments shown by available length frequencies (Figure 9.2-1). The southern California purse seine fishery presently catches fish ranging from 10 cm to 30 cm FL, while offshore and northern coastal captures tend to range from 50 cm to 60 cm FL. The intermediate lengths are distinctly lacking in either data set. The southern California fleet captured moderate quantities of fish ranging from 30 cm to 40 cm FL during the early years of the fishery (Figure 9.2-1), but whether this reflected biological availability, fishermen's tactics, or fishing pressure is not known. Length frequencies of jack mackerel taken off Monterey from 1958 to 1967 (not shown) resemble those of the early southern California fishery. The Monterey fish were slightly larger, with one-half of the catch ranging from 30 cm to 40 cm FL, but with few fish larger than 40 cm FL. Length frequency of jack mackerel captured by the California Department of Fish and Game's preseason offshore albacore cruises shows a few fish ranging from 40 cm to 50 cm FL, but no data show the 30 cm to 50 cm fish in the abundance they must presumably have, assuming that the small fish eventually grow and join the large fish segment. Soviet research trawls taken from 1966 to 1977 (Stepanenko, MS) show a clear geographic pattern of jack mackerel mean lengths, with small fish (20-30 cm FL) to the south and inshore, and large fish (ca 53 cm FL) to the north and offshore.

Jack mackerel larvae are abundant in offshore regions from March through July (Kramer and Smith, 1970). Larvae are generally less abundant in the Southern California Bight, and tend to appear there late in the spawning season, in July and August (Ahlstrom, 1969). Wine and Knaggs (1975) found that jack mackerel taken by the southern California fishery tend to reach peak maturity in June, July and August, which is consistent with later spawning of the inshore southern California segment.

Jack mackerel eggs and larvae are distributed widely in the northeastern Pacific. The quantity of spawning products released in the Southern California Bight is a small portion of the total. Nonetheless, the largest known concentrations of young of the year jack mackerel are found in the Southern California Bight. Many of the southern California fish are undoubtedly spawned locally. However, it is likely that the extensive offshore spawning by large fish produces significant numbers of offspring and due to the scarcity of juvenile jack mackerel elsewhere, these fish must find their way to the Southern California Bight. Thus it is reasonable to assume that the southern California segment of the jack mackerel population is not self-sustaining, but depends to an unknown extent on spawning by the offshore large fish segment. A further argument to this effect is suggested by the long periods of poor recruitment evident in southern California landings (Section 9.1.4, Figure 9.1-1). The long life span of offshore jack mackerel may be a mechanism for tiding over such protracted periods of poor recruitment.

9.3. Abundance

CalCOFI ichthyoplankton surveys are the principal source of information on jack mackerel spawner abundance. The CalCOFI region does not encompass the range of the fish (see Figure 5.1-1), necessitating some assumptions. Principally, we shall assume that the density of fish in the CalCOFI region bears a reasonably constant relationship to the size of the total spawning population. CalCOFI surveys have shown that the center of spawning moves northward as the season progresses, from northern Baja California waters in March and April, to as far north as Oregon waters in the fall (Ahlstrom, 1956, 1969; Kramer and Smith, 1970). We do not know whether this shift is due to actual migration of spawners or to progressively later maturation of more northerly fish.

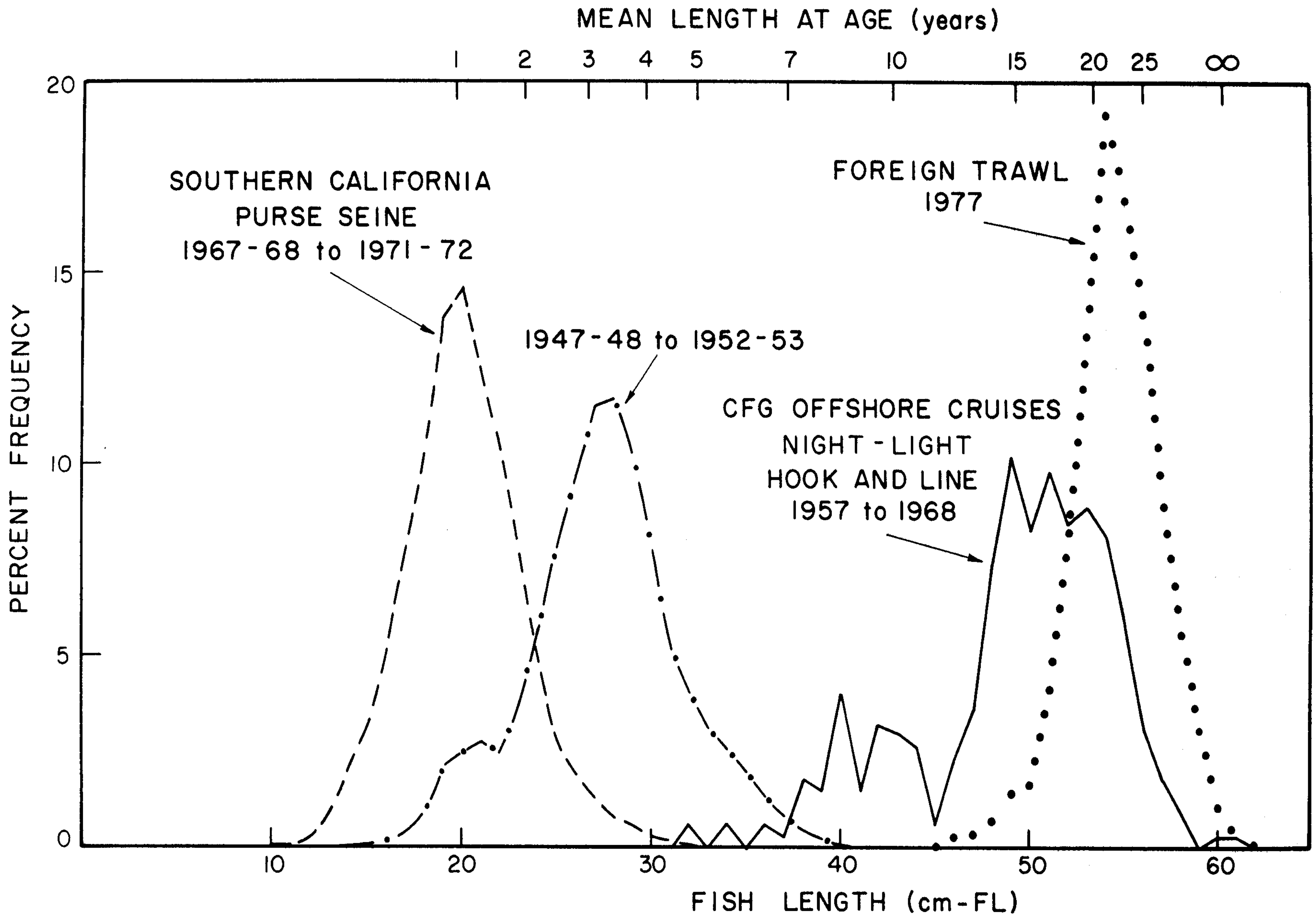

Figure 9.2-1. Length frequency of jack mackerel taken by various fishery segments and surveys. Age scale is not an accurate measure of age at length and is provided only for comparison

Mean apparent density of jack mackerel larvae was calculated from CalCOFI samples in regions most consistently occupied by spawning products. This density is the average quarterly density off northern Baja California in the first and second quarters, and off southern California and central California in the second and third quarters of the year. The near inshore regions of Baja California and southern California were excluded. These densities are plotted in Figure 9.3-1. The unusually low densities during 1958 to 1961 may be due to the influence of abnormally warm oceanic temperatures during 1957 to 1960. The population may have shifted northward, gonadal maturation may have been affected, and abnormally rapid growth of larvae would decrease apparent abundance. Also, it is highly unlikely that abundance changes of the magnitude suggested by the larva density can actually occur, given the low rate of mortality exhibited by offshore jack mackerel. Data for 1958 to 1961 will not be considered as representative of jack mackerel abundance during that period.

Larva densities show considerable year-to-year fluctuation (Figure 9.3-1), but there is no trend showing a long-term change. It would be difficult to show small changes in future jack mackerel abundance using the CalCOFI larva density due to natural variability and to anomalies such as occurred in 1958-1961. There would be little justification for assuming a decrease in abundance has occurred unless quarterly larva densities fall below 1.0 larvae/m^2 for more than 1 survey year, and no abnormal oceanic conditions are evident. Thus a minimum management response time to a decrease in abundance is probably greater than 6 years, given the present triannual schedule of CalCOFI surveys.

Ahlstrom (1968, p.72) estimated the jack mackerel resource to be 2.1 to 4.8 million tons of spawning biomass. Ahlstrom based his estimate on CalCOFI survey estimates of jack mackerel egg production (Farris, 1961). He used two assumptions of fecundity: the low fecundity estimate was two spawning batches per year, based on the two modes of egg diameters observed in ovaries by MacGregor (1966), and the high fecundity estimate was 3-1/3 batches per year, based on a peak egg abundance (when all fish are assumed to spawn) to average egg abundance, and assuming that it takes at least 30 days to mature a batch of eggs. Ahlstrom also assumed that the total stock was 1-1/2 to 2 times that measured in the CalCOFI area.

Knaggs (1973) estimated the total population off southern California available to the wetfish fleet, based on tag returns. This estimate was 0.7 to 1.5 million tons, but must be considered tentative because sample size was very small and many assumptions underlying tagging estimates could not be met.

Pashchenko (MS) used an acoustic-trawl survey to estimate the jack mackerel biomass outside the CalCOFI area in the spring of 1978. Using the assumption that all fish in the path of the net were caught, he obtained a biomass of 430,000 $\pm$ 110,000 short tons. If a portion of the fish in the trawl path were escaping capture, his estimate should be increased accordingly.

A new estimate of jack mackerel abundance is developed here. The approach is similar to Ahlstrom's, but assumptions regarding fecundity can be improved in light of recent work on other species (see below). Also, the methodology is changed slightly, and additional factors are considered in estimating egg production rates.

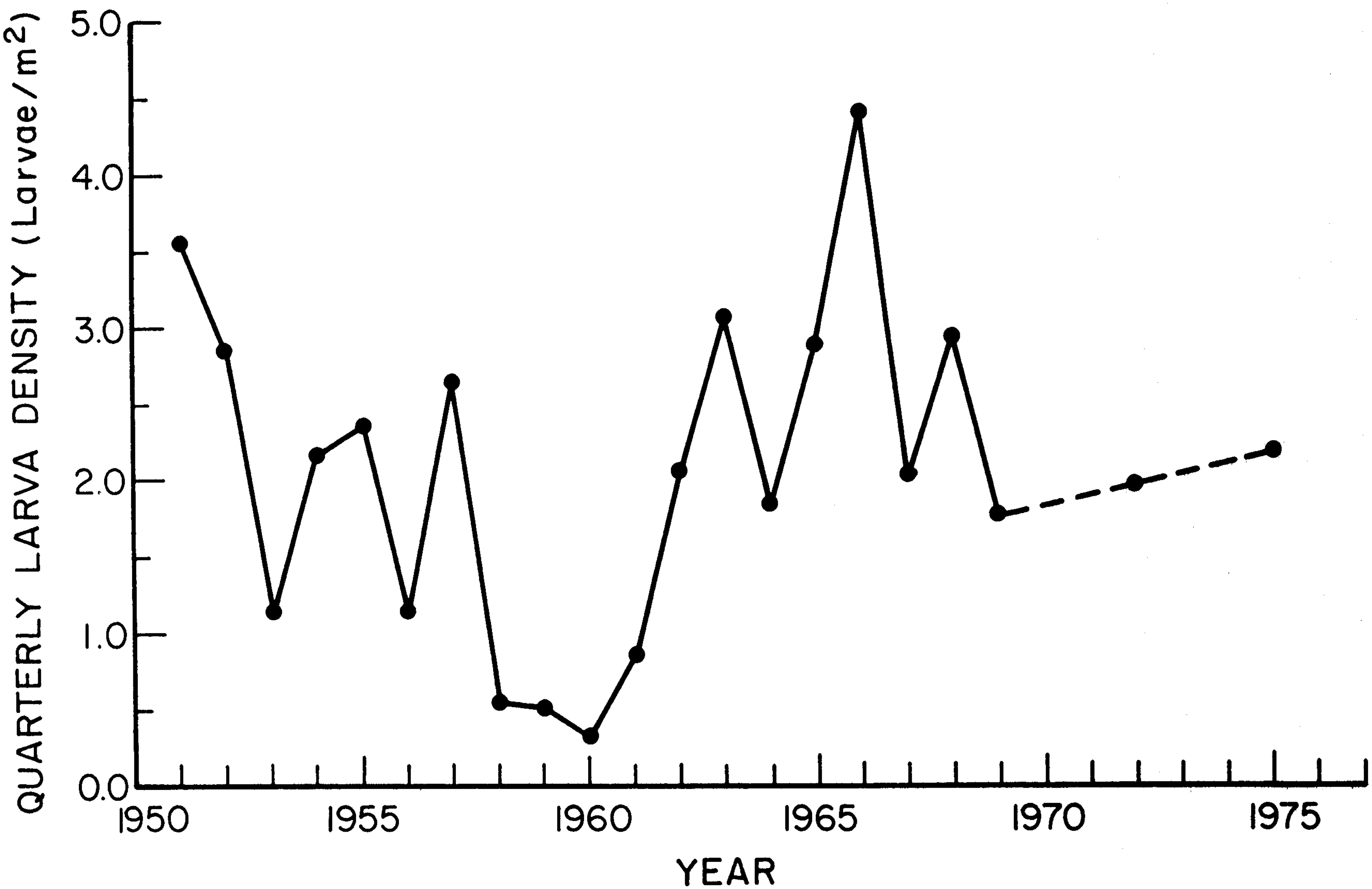

Figure 9.3-1. Density of jack mackerel larvae in selected areas of CalCOFI surveys.

Egg production can be expressed by the following equation:

$$E = Brfp$$

where E is daily egg production,
B is spawning biomass,
r is fraction of the spawning population that is female,
f is fecundity in eggs per body weight per spawning, and
p is fraction of females spawning per day.

The above equation can be rearranged to

$$B = E/rfp$$

in order to produce an estimate of spawning biomass.

Egg production in the CalCOFI region for the years 1951-54 was estimated by Farris (1961). As was shown above, there is no visible trend in jack mackerel abundance since that time, so Farris' data are appropriate for estimating present biomass. Farris corrected his egg production estimates for a 3-day duration to hatching; however, he ignored the effects of natural mortality. Due to losses of eggs before hatching, the duration of an average egg would be somewhat less than 3 days. Paul Smith[1] (unpublished data) has calculated approximate numbers of jack mackerel eggs surviving to each stage of development at 15°C. Time to hatching at 15°C is 86.4 hours, whereas mean duration of eggs is 53.2 hours, eggs being terminated either by mortality or by hatching. Thus the mean duration is 0.62 of the time to hatching. Farris' eggs were in an environment averaging 15.5°C, which is reasonably close to the above temperature. This change in assumed residence time requires that Farris' egg production estimate be multiplied by 0.62^{-1}, or 1.62.

Peak egg production extends from March to June in the CalCOFI area, during which period 82.6% of the total year's spawning products are released. Average egg production for March through June is 5.5×10^{14} eggs, or 4.5×10^{12} eggs/day (Farris, 1961). With the above mortality correction, the latter value is increased to 7.3×10^{12} eggs/day.

Ahlstrom (1968) used a fecundity estimate of 306 eggs/gram/spawning, based on a single fish examined by MacGregor (1966). MacGregor (1976) gives fecundities of 30 fish, including 15 fish longer than 40 cm. The mean fecundity of these large fish was 153.2 advanced eggs/gram body weight, or about one-half the earlier estimate. This biomass estimate will use MacGregor's fecundity estimates. However, it is likely that they are low. Pashchenko (MS) examined 18 large female jack mackerel taken 390 miles west of San Diego in the spring of 1978. These fish were larger (mean 54.0 cm FL) than MacGregor's fish, and had a mean fecundity (362.6 eggs/gram) over twice that obtained by MacGregor. If Pashchenko's data are used, or are averaged with MacGregor's observations, resulting biomass estimates would be considerably lower.

Little is known of spawning rates of pelagic fish, and nothing is known for jack mackerel. Ahlstrom (1968) used a minimum estimate of two spawnings per year, there having been two modes of egg diameters in the single fish examined; and he used 3.3 spawnings per year as a high estimate, assuming 30 days is necessary to mature each batch of eggs. In comparison, similar spawning rates were suspected for the northern anchovy (Engraulis mordax), for essentially the same reason.

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[1] Paul Smith, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, Ca.

However, recent work on anchovy gonad histology (Hunter and Goldberg, In Press) has strongly indicated that 15% of the mature female anchovy population is spawning per day during the peak spawning months. This spawning rate translates as approximately one spawning per week, and indicates that a batch of eggs may require less than 7 days to be produced. Because jack mackerel gonad morphology and the protracted spawning season are similar to those for anchovy, we assume that spawning rates are similar to those for anchovy. The present estimate of jack mackerel abundance will use 15% spawning per day as an upper limit, and 7.5% spawning per day as a lower limit. Lower percent spawnings could be considered; the biomass estimate changes inversely with this parameter which is a major source of imprecision. It is assumed that males exist in equal weight to females, so the proportion of females is 0.5.

Using the following values,

$E = 7.3 \times 10^{12}$ eggs/day,
$r = 0.5$,
$f = 152.3$ eggs/gram of large female fish,
$p_1 = 15\%$ female fish spawning/day,
$p_2 = 7.5\%$ female fish spawning/day,

we obtain spawning biomass estimates of 0.7 and 1.4 million short tons in the CalCOFI region. If the fish migrate extensively, with virtually all fish spawning in the CalCOFI region and then dispersing, these may be direct abundance estimates. If the fish are less migratory and only a fraction of the population spawns in the CalCOFI region, total abundance will be greater. Ahlstrom (1968) assumed that one-half of the total jack mackerel spawning biomass resides outside the CalCOFI area. Pashchenko (MS) also feels that one-half of the resource may be spawning outside the CalCOFI area. While the exact fraction of the resource outside the CalCOFI area cannot be quantified, we will assume the total spawning biomass to be 1 to 2 million short tons, with 1.5 million tons as the working estimate.

This working estimate of 1.5 million short tons of spawning biomass is considerably lower than Ahlstrom's (1968) range of 2.1 to 4.8 million tons. However, it is more consistent with current knowledge of the spawning frequency of pelagic fishes. This working estimate would suggest available southern California biomasses smaller than estimated by Knaggs (1973). However, Knaggs' estimate may be high due to emigration, and this estimate gives total biomasses approaching Knaggs' lower range of 0.7 million tons (see Section 9.6.1, Table 9.6-3).

9.4. Habitat

In southern California waters, schools located over rocky banks and shallow rocky coastal areas often remain near the bottom or under kelp canopies during daylight hours and venture into deeper surrounding areas at night. All southern California commercial fishing for jack mackerel occurs in this type of bottom habitat; thus, availability relies solely on occurrence of schools in such areas. The nearness to shore and association of kelp and shallow rocky bottoms often poses a physical hazard to fishing and prevents safe operation of large research vessels.

The occurrence of small schools of young juvenile fish beneath floating kelp and debris in the open sea is a common schooling behavior which is most prevalent in the late summer and fall months. Jack mackerel aggregate and concentrate around drilling platforms. Thus in normal "barren" waters where jack mackerel occur, but not in commercially fishable concentrations (i.e., the Santa Barbara Channel), drilling platforms concentrate fish. The concentration would make these fish suitable for capture by fishermen using roundhaul gear; but unless the schools drift away from the platform, they cannot be captured. Drilling platforms have been proposed for Tanner and Cortez Banks, areas of very large jack mackerel catches. Present fishing on these banks tends to be very concentrated over a few shallow spots, spots so localized that presence of a platform could eliminate their fishability altogether. Experience of fisheries in other areas where offshore drilling has taken place has shown that abandoned undersea wellheads may cause serious losses of fishing gear. There appear to be both potential benefits and hindrances as a result of presence of these platforms. Whether the final outcome is improvement or deterioration of fishing conditions awaits future evaluation.

Artificial reefs are valuable in concentrating young jack mackerel. Once known and marked by buoys, the reefs are fished successfully by recreational anglers in boats.

9.5. Ecological Relationships

9.5.1. Food habits

Carlisle (1971) reports on stomach contents of jack mackerel taken off southern California and northern Baja California in 1951 through 1952. Most food items could be classified as macroplankton, with copepods (33%), pteropods (30%), and euphausiids (27%) together accounting for 90% of all food items by number. Euphausiids (krill) appeared to be the most significant food item, accounting for approximately 70% by volume of organic matter. Fitch (1956) reports that general observations of fish unloaded at the cannery unloading docks indicate that at time jack mackerel feed heavily and almost exclusively upon juvenile squid (Loligo opalescens) and anchovies (Engraulis mordax). Jack mackerel larvae feed almost entirely on copepods (Arthur, 1976).

Little is known of the food habits of the larger offshore fish. Fitch (1966) has observed some of these offshore fish to have stomachs filled with lanternfishes (Myctophidae), but he suspects that this may have resulted from both species having been attracted to the night-light onboard the vessel. Carlisle reported that inshore jack mackerel feed heavily on euphausiids, and Brinton (1967, 1973) indicates dense concentrations of the euphausiids, Euphausia pacifica, Nematoscelis difficilis and Thysanoessa gregaria, extending far offshore and to the north, corresponding closely to the distribution of large jack mackerel. It appears highly likely that euphausiids contribute to the food supply of large offshore jack mackerel.

9.5.2. Predators

Pinkas, Oliphant and Iverson (1971) found only one jack mackerel in 905 albacore (Thunnus alalunga) stomachs. Jack mackerel contributed 1.2% by volume of food found in 1,498 bonito (Sarda chiliensis) stomachs. Jack mackerel contributed 2.1% by volume of food in 1,073 bluefin tuna (Thunnus thynnus) stomachs, but for the southern California area, this portion was 5.1%. Baxter (1960) reports that less than 1% of the volume of food in 131 yellowtail (Seriola dorsalis) stomachs was jack mackerel. However, Baxter also reports on food contents of yellowtail stomachs from three schools captured near Cedros Island, Baja California. Jack mackerel occurrence by volume was 4.5%, 27.4% and 74.6%, respectively. Evans and Wares (1972) and Eldridge and Wares (1974) have reported major amounts of jack mackerel in the diets of striped marlin (Tetrapturus audax) off San Diego, California. Percent stomach contents by volume were 27% and 62%, respectively. Thus it appears that jack mackerel may be a major source of forage to billfish, but a relatively minor source to smaller predators. However, jack mackerel may be a major food item at specific times and places for any predators sufficiently large to eat them.

Adult jack mackerel presumably do not contribute significantly to food supplies of marine birds. The fish are too large to be ingested by most bird species, and tend to school deep (Mais, 1974, p.60), making them inaccessible to surface feeders. Brown pelicans (Pelecanus occidentalis californicus) have been observed feeding upon fish presumed to be jack mackerel (William Nott[1], personal communication), but studies of stomach contents have not encountered jack mackerel remains (Daniel Anderson[2], personal communication). It is unlikely that abundance of jack mackerel significantly influences brown pelican populations (ibid).

Little information is available on predation of jack mackerel by marine mammals. Food analyses of the California sea lions, Zalophus californianus, and northern fur seal, Callorhinus ursinus, indicate that jack mackerel occur infrequently in their diet (Ainley et al., 1977; Marine Mammal Research Laboratory, 1969). Future studies on the feeding habits of other pinnipeds and small crustaceans will undoubtedly observe some jack mackerel in their diets, but the incidence will probably be low.

The larvae of jack mackerel are likely prey of a variety of planktivores. Because larvae grow at a rapid rate, they are exposed to a gantlet of predators, each for a short period of time. An adult fish, on the other hand, may be exposed to the same predators most of its adult life. In general, fish larvae make up a small fraction of the zooplankton biomass. Furthermore, jack mackerel are found to make up only 3% of the fish larvae taken in CalCOFI plankton surveys (Ahlstrom, 1968). Consequently, it is unlikely that jack mackerel larvae are critical to the existence of any one planktivore.

9.6. Quantitative Fishery Analysis

9.6.1. Population model

A simple piece wise dynamic pool model can be used to represent the long-term average or steady state population structure. Two models are presented, based on alternative natural mortality rate schedules (Tables 9.6-1 and 9.6-2). Natural and fishing mortality rates (Section 9.6.2) and weights at age are input to estimate relative biomass at age. Under the assumptions discussed in Section 9.6.3, we have derived a working estimate of 1.5×10^6 short tons spawning biomass. The total spawning biomass is allocated among the ages according to the relative contributions calculated above. The biomass of young of the year (age 0.5) was calculated by the ratio of cohort weights at age 0.5 and age 1.

As discussed in Section 9.1.3, it is likely that young jack mackerel have a lower batch fecundity and may spawn fewer times than do older mature fish. Spawning biomass, being based on egg censuses, is expressed in terms of body weight equivalents of fully mature spawning females (see Section 4.3). Total fishable biomass is therefore likely to be greater than spawning biomass.

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[1] William A. Nott, Sportfishing Association of California, Long Beach, Ca.

[2] Daniel Anderson, University of California, Davis, Ca.

Two alternative fecundity models are used here. The first model simply assumes that all fish are equally fecund on a unit body weight basis (Tables 9.6-1 and 9.6-2). The second model assigns partial fecundities to young fish. If mature fecundity is given a relative value of 1.0, ages 1 through 4 are assigned relative fecundities of 0.2, 0.4, 0.6 and 0.8, respectively (Tables 9.6-3 and 9.6-4).

The above method of allocating biomass among age categories is subject to considerable imprecision. Both assumed rates of natural mortality and relative fecundity of young fish have strong influences on the age structure and total biomass of the model population. The two alternative natural mortality rate schedules indicate that the biomass assigned to the small fish (ages 0-8) changes inversely to the biomass assigned to the large fish (ages 15-30). When we compare Tables 9.6-1 and 9.6-2, the small fish biomass fell to 43%, the large fish biomass increased to 285%. The effect of assuming lower fecundity of young fish is minor for the lower mortality rate schedule because a relatively small fraction of the population is assigned to the affected age groups. However, the effect on the model using the higher natural mortality rates is large. When we compare Tables 9.6-1 and 9.6-3, biomasses rise by 22%. The biomass available to southern California fishermen given in Table 9.6-3 is consistent with Knaggs' (1973) lower estimate of 0.7 million tons (see Section 9.3).

9.6.2. Fishing mortality rate

The dynamic pool model was used to estimate fishing mortality rates by an iterative process. Fishing mortality rates at age (F_j) are given by

$$F_j = C_j / \overline{B}_j \tag{1}$$

where C_j is catch of age j fish, and $\overline{B}_j$ is mean biomass. Mean biomass was approximated by

$$\overline{B}_j = (B_j + B_{j+1}) / 2 \tag{2}$$

The iterative process is as follows: Initially, fishing mortality rates of 0 are input to the dynamic pool model, and biomasses are estimated. Estimates of F_j are then made by equations (1) and (2), given the mean catch of fish at age for the 1952-53 through 1971-72 fishing seasons (Fleming and Knaggs, 1977, p.32). These fishing mortality rates are then input into the dynamic pool model to produce new biomass estimates for the second iteration. The estimates of F converge to two significant digits with three iterations.

Estimates of F are given in Tables 9.6-1 through 9.6-4, and reflect a southern California fishery of approximately 27,000 short tons per year, which is the average San Pedro catch for the 1952-1971 period. Fishing mortality on older fish due to incidental catches and to the foreign trawl fishery has been ignored, due to lack of information on magnitude and age composition. Foreign trawl catches of up to 2,000 tons per year are not large enough to significantly affect the model.

Table 9.6-1. Dynamic pool model of jack mackerel population and estimates of potential yield, using schedule of higher natural mortality rates.

Age	Assumed natural mortality rate	Fishing mortality rate	Relative number	Length (mm-FL)	Mean[1] weight (g)	Initial biomass (10^3 short tons)	Mean[2] catch (10^3 short tons)	Potential yield (10^3 short tons) Low X=0.3	Potential yield (10^3 short tons) High X=0.5
0	(0.5)	-	1,000	-	-	-	-		-
0.5[3]	(0.5)	0.018	779	-	60	(135.9)	2.601	10.2[4]	17.0[4]
1	0.5	0.043	602	198	85	148.8	6.314	22.3	37.2
2	0.45	0.046	350	234	140	142.5	6.243	19.2	32.1
3	0.4	0.058	213	267	207	128.4	6.989	15.4	25.7
4	0.35	0.032	135	297	285	111.5	3.333	11.7	19.5
5	0.3	0.012	92	324	370	98.9	1.155	8.9	14.8
6	0.25	0.004	67	349	461	90.2	0.371	6.8	11.3
7	0.2	0.002	52	372	556	84.4	0.137	5.1	8.4
8	0.2	0.001	43	392	653	81.0	0.028	4.9	8.1
0-8	-	-	-	-	-	1021.6	27.171	104.5	174.1
9-15	0.2	-	145	411-493	959	404.5	-	24.3	40.5
16-30	0.2	-	45	503-576	1598	209.8	-	12.6	21.0
0-30						1500.0 (spawning)		141.0	235.6
						1635.9 (total)			

[1] Weight is based on length-weight relationship with correction for σ_L = 21.5 mm (Pienaar and Ricker, 1968)

[2] Catch only includes San Pedro landings.

[3] Age 0 fish are assumed to be unavailable for the first half year, mean weight is approximate, and biomass does not spawn.

[4] Potential yield reduced by 1/2 because fish are only available for 1/2 year.

Table 9.6-2. Dynamic pool model of jack mackerel population and estimates of potential yield, using low natural mortality rates.

Age	Assumed natural mortality rate	Fishing mortality rate	Biomass (10^3 short tons)	Potential yield (10^3 short tons) X=0.3	X=0.5
0.5	(0.5)	0.119	43.6	3.3	5.5
1	0.25	0.131	45.3	3.4	5.7
2	0.225	0.119	51.1	3.4	5.7
3	0.20	0.132	53.5	3.2	5.4
4	0.175	0.062	52.8	2.8	4.6
5	0.15	0.021	54.1	2.4	4.1
6	0.125	0.006	56.8	2.1	3.6
7	0.10	0.002	60.1	1.8	3.0
8	0.10	0.001	63.7	1.9	3.2
0-8	-	-	437.4	24.3	40.8
9-15	0.10	-	463.7	13.9	23.2
16-30	0.10	-	598.9	18.0	29.9
0-30			1500.0 (spawning)	56.2	93.9
			1543.6 (total)		

Table 9.6-3. Dynamic pool model of jack mackerel population and estimates of potential yield, using high natural mortality rates and partial fecundity of young fish.

Age	Assumed fecundity	Assumed natural mortality rate	Fishing mortality rate	Biomass (10^3 short tons)	Potential Yield (10^3 short tons) X=0.3	Potential Yield (10^3 short tons) X=0.5
0.5	0	(0.5)	0.032	163.4	12.3	20.4
1	0.2	0.5	0.036	177.5	26.6	44.4
2	0.4	0.45	0.038	171.0	23.1	38.5
3	0.6	0.4	0.048	155.3	18.6	31.1
4	0.8	0.35	0.026	136.2	14.3	23.8
5	1.0	0.3	0.010	121.6	10.9	18.2
6	1.0	0.25	0.003	111.1	8.3	13.9
7	1.0	0.2	0.001	104.0	6.2	10.4
8	1.0	0.2	0.001	99.9	6.0	10.0
0-8	-	-	-	1240.0	126.3	210.7
9-15	1.0	0.2	-	498.8	29.9	49.9
16-30	1.0	0.2	-	258.6	15.5	25.9
0-30				1500.0 (spawning)	171.7	286.5
				1997.4 (total)		

Table 9.6-4. Dynamic pool model of jack mackerel population and estimates of potential yield, using low natural mortality rates and partial fecundity of young fish.

Age	Assumed fecundity	Assumed natural mortality rate	Fishing mortality rate	Biomass (10^3 short tons)	Potential yield (10^3 short tons) X=0.3	X=0.5
0.5	0	(0.5)	0.114	45.5	3.4	5.7
1	0.2	0.25	0.125	47.4	3.6	5.9
2	0.4	0.225	0.113	53.7	3.6	6.0
3	0.6	0.20	0.124	56.6	3.4	5.7
4	0.8	0.175	0.058	56.2	3.0	4.9
5	1.0	0.15	0.020	57.9	2.6	4.3
6	1.0	0.125	0.006	60.9	2.3	3.8
7	1.0	0.10	0.002	64.4	1.9	3.2
8	1.0	0.10	0.001	68.3	2.0	3.4
0-8	-	-	-	510.9	25.8	42.9
9-15	1.0	0.10	-	496.9	14.9	24.8
16-30	1.0	0.10	-	641.7	19.3	32.1
0-30				1500.0 (spawning)	60.0	99.8
				1649.5 (total)		

9.6.3. Yield per recruit

Yield per recruit was evaluated by the piece-wise "Ricker method" (Ricker, 1975, p.238), using the FORTRAN program MGEAR (Lenarz et al., 1974). Four yield per recruit tables were calculated (Tables 9.6-5 through 9.6-8) respectively based on the M and F vectors given in Tables 9.6-1 through 9.6-4 of the preceding section. Changes in fishing intensity were modeled by applying constant multiples to the fishing mortality rates of age (F vector). Yields are based on recruitment at age 0.5 years. Yield per recruit generally increases with increased fishing intensity. The analysis does not support a minimum size limit as a means of increasing yield, mainly due to the high rates of natural mortality that have been assumed for the youngest ages. However, if the optimum fishery requires a high exploitation rate, a minimum size limit may be worth considering for the purpose of maintaining sufficient spawning biomass per recruit to decrease risk of protracted reproductive failure.

Table 9.6-5. Jack mackerel yield (g) per recruit, based on higher natural mortality rate schedule (Table 9.6-1).

Age at entry	0.2	0.5	1.0	2.0	3.0	4.0	6.0	8.0	10.0
4.0	1	1	3	5	8	10	14	18	21
3.0	1	3	6	11	16	20	28	34	39
2.0	2	4	9	16	22	28	37	43	48
1.0	2	6	11	20	28	34	44	50	55
0.5	2	6	12	21	29	35	45	51	56

Multiplier of present fishing intensity

Table 9.6-6. Jack mackerel yield (g) per recruit, based on low natural mortality rate schedule (Table 9.6-2).

Age at entry	0.2	0.5	1.0	2.0	3.0	4.0	6.0	8.0	10.0
4.0	2	6	11	21	30	38	52	63	73
3.0	5	12	23	41	55	66	82	91	97
2.0	7	17	31	52	66	76	87	92	94
1.0	9	21	36	57	70	76	81	81	80
0.5	10	22	38	58	69	73	76	74	72

Multiplier of present fishing intensity

Table 9.6-7. Jack mackerel yield (g) per recruit, based on high natural mortality rate schedule and partial fecundity of young fish (Table 9.6-3).

Age at entry	0.2	0.5	1.0	2.0	3.0	4.0	6.0	8.0	10.0
4.0	1	1	2	4	6	8	12	15	18
3.0	1	2	5	9	13	17	24	29	34
2.0	1	4	7	13	19	24	32	39	44
1.0	2	5	9	17	24	30	39	46	51
0.5	2	5	10	19	26	32	41	48	53

Multiplier of present fishing intensity

Table 9.6-8. Jack mackerel yield (g) per recruit based on low natural mortality rate schedule and partial fecundity of young fish (Table 9.6-4).

Age at entry	0.2	0.5	1.0	2.0	3.0	4.0	6.0	8.0	10.0
4.0	2	5	10	20	28	36	50	61	71
3.0	5	11	22	39	53	64	80	90	96
2.0	7	16	29	50	64	74	86	91	93
1.0	8	20	35	56	68	75	81	81	80
0.5	9	21	36	57	67	73	76	75	73

Multiplier of present fishing intensity

9.6.4. Potential yield

There is insufficient information on the jack mackerel resource and fishery to estimate maximum sustainable yield (MSY) or equilibrium yield (EY). Estimation of these quantities will require many years of fishery data, including fishing intensities above present levels.

The potential yield estimator of Gulland (1970, p.2) is intended to provide a reasonable limit to exploratory expansion of a fishery. It is not meant to be an estimate of MSY, but is an interim limit to catches while data sufficient to estimate MSY are being accumulated. Thus it should not be treated as a goal for fishery development. In some cases it may be considerably in excess of true MSY, but we cannot know for the case of the jack mackerel fishery until more fishery information is gained.

The potential yield estimator is given by

$$Y_{pot} = X\ M\ \overline{B}_o \tag{3}$$

where Y_{pot} is potential yield, M is natural mortality rate, $\overline{B}_0$ is mean virgin biomass. and X is a coefficient based on M, Von Bertalanffy growth parameter K, and c, the ratio of length at first capture to asymptotic length. The present biomass is only very lightly fished, and can be used for $\overline{B}_0$. A value of X=0.5 is commonly used and will be used here for a "high" estimate. The value obtained from Gulland (1970) for M/K = 2.5 to 5.0, and relative length at first capture c = 0.3, is X = 0.3, providing a "low" estimate of potential yield. Gulland's estimator assumes a constant mortality rate, but M varies with age in the dynamic pool model. Therefore, the Gulland estimator is applied to each age separately, and potential yields are summed afterward (Tables 9.6-1 through 9.6-4).

The sensitivity of potential yield estimates to different assumed rates of natural mortality (compare Tables 9.6-1 and 9.6-2) is somewhat different than sensitivity of biomass estimates (9.6.1). For the large fish segment, decreases in natural mortality rate (M) result in offsetting increases in estimated biomass ($\overline{B}_0$), making potential yield estimates relatively constant (cf. equation 3). However, the sensitivity is compounded for the small fish segment, where decreased overall rates of mortality result in a decreased portion of the total biomass being allocated to the small fish segment, and potential yield drops considerably. Without good estimates of biomass and mortality rates, these estimates of potential yield must remain only tentative.

Potential yield is estimated for three segments of the resource. Ages 0.5 through 8 represent the inshore small fish fishery, and have a potential yield of 24 to 210 thousand short tons. The historical fishery has exploited fish aged 1 through 4 years more heavily than the other ages in the small fish fishery. Based on yield per recruit considerations, there would be no detriment in obtaining an equivalent total yield from younger fish (e.g., ages 1-4) rather than in proportion to their biomasses over the entire range of ages. This argument does not extend to the large fish segment, which is harvested independently. Potential yield of large fish ranges from 13 to 30 thousand short tons. The intermediate group of ages 9 to 15 years has a potential yield of 14 to 50 thousand tons. The total stock has a potential yield of 56 to 290 thousand short tons.

By assuming various forms of the spawner-recruit relationship, yield per recruit calculation (Section 9.6.3) can be used to evaluate potential yield in terms of increase in fishing intensity. If recruitment is assumed to be constant (on the average) over a wide range of spawning biomasses, then harvests equivalent to potential yield would require an annual exploitation rate of approximately 15%. This fishery would be equivalent to F values 6 to 8 times larger than present, using the higher natural mortality rate schedule (Tables 9.6-1 and 9.6-5), but for the case of the lower natural mortality rate schedule (Tables 9.6-2 and 9.6-6), the current fishery would be harvesting potential yield. If mean recruitment is distinctly not constant, but more nearly proportional to spawning biomass, then harvest of quantities approaching calculated potential yield would require extreme fishing intensity, while spawning biomass would decline to low levels. Under such a spawner recruit relationship, calculated potential yield would not be sustainable and therefore MSY would also have to be a smaller quantity.

9.6.5. Maximum sustainable yield (MSY)

The estimates of potential yield given in Tables 9.6-1 through 9.6-4 cover a wide range. These estimates are built upon scanty data and many assumptions, which means the true uncertainty is even greater than the range of potential yields would suggest. The spawning biomass estimate is dependent on the assumed spawning rate (unknown) and the fraction of the stock in the CalCOFI area (unknown). The total biomass estimate is dependent on the spawning biomass estimate, the natural mortality rate (unknown), and the relative fecundity of young fish (partially known). If the potential yield estimate is to provide a good estimate of true MSY, the total biomass estimate and natural mortality rate estimates must be good (see above), and jack mackerel population dynamics must conform to an implicit model, including assumptions that MSY occurs at one-half the virgin abundance, and that recruitment at this reduced level is near or above that of the virgin stock (neither quality has been demonstrated).

MSY is not known. MSY is likely to fall within the range of estimated potential yields (56 to 290 thousand short tons), but, based on the above uncertainties and experience with other fisheries, there is a distinct possibility that MSY may fall outside the range of estimated potential yield.

A major objective of this plan is to develop a more precise estimate of MSY through controlled expansion of the fishery. For this purpose, potential yield can partially replace MSY as a reference quantity for determining optimum yield, but must not be treated with the degree of certainty ascribed to MSY in the FCMA.

9.6.6. Acceptable biological catch (ABC)

There are presently no known features of the resource requiring special limitations on the jack mackerel catch. Conflict with the Pacific mackerel fishery in southern California (see Section 8.6.3) may result in occasional reduction in fishing effort directed at jack mackerel, but it is not presently necessary to impose limits on the jack mackerel catch to reduce conflict with Pacific mackerel.

The jack mackerel is a long-lived fish. Its age structure, geographic distribution and reproductive strategy will all be affected by the additional mortality due to a fishery. Previous experience in other fisheries has shown that overly rapid fishery expansion may interact with the life strategy of the fish in unexpected and often deleterious ways. Slow and methodical expansion of the fishery is the only biologically acceptable course of development.

9.7. Present and Future Condition of the Fishery

The overall stock has not shown major changes in abundance since 1951, and there is little reason to believe any such changes will occur from natural causes in the near future. On the other hand, recruitment of young fish is highly variable, showing manyfold variations from year to year, and the southern California fishery will continue to be faced with a variable supply of fish.

The main factor influencing long-term abundance, and indirectly, average recruitment to the southern California fishery, is fishing pressure. Abundance must be expected to decline as the fisheries expand. Recruitment is very likely to be linked to abundance as a long-term average, but it will be difficult to separate trends from chance variations. Abundance estimates will be available from CalCOFI surveys every 3 years (e.g., 1975, 1978, 1981, etc.). However, any single survey is imprecise and conclusions should not be drawn from a single survey result. Thus there will be a delay of 6 or more years between an actual change in abundance and the perception of that change.

Monitoring of age composition, especially in the southern California fishery, will help determine recruitment patterns and may later be used in calculating fishing mortality rates and population sizes by cohort analysis or related methods. A major change in age composition occurred after 1952, when older jack mackerel ceased being landed in southern California. If this shift in age composition was due to the effects of fishing rather than to changes in fishing pattern or natural population variability, the resource may be more delicate than anticipated. The age composition since 1952 has been relatively consistent, but should be monitored especially if the fishery expands.

10.0. OTHER CONSIDERATIONS

The jack mackerel fishery interacts with other fisheries as has been discussed in Section 8.6. Changing fishing patterns and intensity of any of the fisheries involved may result in new considerations or conflicts. Two particular areas of concern are the southern California Pacific mackerel fishery and the trawl fishery for whiting. The Pacific mackerel appear to be successfully recovering from a depleted state. Whether recovery will continue remains to be seen. Either increased or decreased levels of Pacific mackerel may present problems to the jack mackerel fishery in the future. Also, the whiting fishery is much larger than the jack mackerel fishery, but incidental catches of jack mackerel may conceivably limit the whiting fishery. Again, the extent of this problem remains to be seen, and solutions may have to be sought in future management plans once the nature of the interactions becomes clear and quantifiable.

Jack mackerel caught incidentally in the salmon and albacore troll fisheries and the whiting trawl fishery are often discarded at sea. As such, they do not constitute landings, but are nonetheless removals from the stock (see Section 8.6.2). These unrecorded removals must be considered in establishing optimum yield quotas.

The jack mackerel resource extends well outside the 200-mile United States Fishery Conservation Zone, including Mexican waters, Canadian waters, and high seas. As of 1978 jack mackerel harvests outside the U.S. FCZ have been negligible. In the event that harvests in these areas increase, allowable catches in the U.S. FCZ will have to be altered and optimum yield may have to be redefined.

Purple coral (Allopora spp.) has at times been accidentally destroyed by the purse seine nets employed by southern California jack mackerel fishermen. Coral may be detached by the chains at the bottom of the purse seine nets, even though fishermen take elaborate precautions against allowing their nets to touch bottom because of potentially severe damage to their gear from underwater rocks. There has been public controversy between recreational divers and commercial jack mackerel fishermen regarding loss of purple coral at Farnsworth Bank, near Catalina Island. It is likely that an expanded jack mackerel fishery will continue to exploit the same fishing areas, and not spread to new locations where purple coral exists. Therefore, it is unlikely that there will be significant additional loss of purple coral due to an expanded jack mackerel fishery. For further information on purple coral and its harvesting, refer to the Environmental Analysis for Proposed Coral Harvesting (Bureau of Land Management, 1978). Purple coral is managed by the Department of the Interior, Bureau of Land Management.

11.0. CATCH AND CAPACITY

11.1. Domestic Harvesting Capacity

An estimate of the domestic harvesting capacity is based on the hold capacities of those vessels landing at least 50 tons of jack mackerel in 1975 or 1976. These vessels accounted for 98.6% of the total jack mackerel landings in 1976. There were 39 vessels that met this criterion; four of these have since sunk and were not included in this analysis of capacity. The hold capacities for 19 of these vessels were estimated by California Department of Fish and Game employees in Long Beach, California. An empirical relationship between hold capacity (short tons), vessel length (feet), and vessel net tonnage (short tons) was estimated for these vessels using ordinary least squares regression analysis.

$$\text{Capacity} = 106.65 - 2.23\ \text{length} + 0.0003\ \text{length}^3 + 0.64\ \text{net tonnage}$$
$$R^2 = 0.80\ .$$

The hold capacities for the 16 vessels not previously examined were estimated by this regression equation. The total hold capacity estimated for the 35 vessels that landed at least 50 tons of jack mackerel in 1975 or 1976 is 3,069 short tons. It is difficult to estimate the fleet's capacity to harvest jack mackerel because it fishes for several other species besides jack mackerel. The 1976 landings by these 35 vessels of six major species are presented in Table 11.1-1.

Table 11.1-1. Landings in 1976 of six major species by vessels landing at least 50 tons of jack mackerel.

	Jack mackerel	Pacific mackerel	Anchovy	Squid	Pacific bonito	Bluefin
	short tons					
landings by jack mackerel vessels:	22,125	170	102,465	1,375	1,757	1,011
total Calif. landings:	22,447	177	124,919	10,145	4,448	9,395
% of total landings made by jack mackerel vessels:	98.6%	96.0%	82.0%	13.6%	39.5%	10.8%

The total amount of these six species landed by these vessels is 149,982 short tons. Jack mackerel only make up 17% of this total, with 79% accounted for by landings of anchovies. The other 4% is accounted for by landings of bluefin tuna, bonito, Pacific mackerel and squid. These vessels also land various other species of fish during the year, but these are not included in this analysis.

The total annual fishing capacity of mackerel vessels for all species is estimated by multiplying the fleet hold capacity by the number of days that the fleet can fish. Assuming that the vessels fish 5 days a week for the whole year, the maximum annual catch is 260 x 3,069 = 797,940 short tons. Clearly, this capacity estimate ignores the fact that daily catch rates may be less than hold capacity. In the southern California jack mackerel fishery, one obvious consideration is that fishing trips to Tanner and Cortez Banks require 2 days, while 1-day trips are made when fishing closer to the canneries. It is desirable, therefore, to estimate a jack mackerel fishing capacity that is consistent with typical trip length. During 1965-1972, approximately 50% of the southern California jack mackerel harvest was caught at Tanner and Cortez Banks (see Table 5.2-4). Thus the average jack mackerel fishing trip is 1.5 days long. Given that vessels could at most fill their holds once every 1.5 fishing days, the annual jack mackerel fishing capacity is estimated to be 532,000 short tons in southern California.

11.2. Processing Capacity

An estimate of the processing capacities for jack mackerel is derived by examining the maximum yearly production of jack mackerel products by plants operating between 1970 and 1976. The majority of jack mackerel is canned for human consumption or for pet food by plants operating in southern California. Smaller canning operations have taken place in Monterey and Santa Cruz. There were seven plants canning mackerel in 1970 and four in 1976. Capacity was estimated as the sum of the maximum historic capacities for the individual canneries. Therefore, capacity is estimated to be 90,000 short tons per year, which would occur if every facility were operating at a realistic maximum rate. There have been five plants processing other jack mackerel products during the period 1970 to 1976. Small quantities have been processed fresh or frozen as bait, frozen fillets, or smoked. The estimated maximum amount of jack mackerel processed into these products is approximately 300 short tons. The total processing capacity for all jack mackerel products is estimated to be 90,300 short tons.

11.3. Expected Domestic Annual Harvest and Processing

The jack mackerel resource is biologically divided into small- and large-fish segments (see Section 9.2), which occur in different geographic areas and are fished by different fleets (see Section 5.1). The fishery is therefore divided into two zones (see Figure 6.3-1): a southern (small fish) zone, and a northern-offshore (large fish) zone.

11.3.1. Southern zone

1979 season: The southern California jack mackerel processors indicated in consultation with National Marine Fisheries Service personnel that they intend to process 55,000 tons of jack mackerel in 1979. This annual quantity of processed fish is the same as that listed in the Preliminary Management Plan for the Trawl Fishery of the Washington, Oregon and California Region, and is approximately equal to the maximum jack mackerel landings in California in recent years.

1980 season: These southern California processors (personal communication through the Jack Mackerel Advisory Subpanel of the Pacific Fishery Management Council) intend to process up to 85,000 short tons of mackerel in 1980, optimum yield permitting. Although this level is higher than recent years, it is within estimated processing capacity (Section 11.2). Because "mackerel" refers to both jack mackerel and Pacific mackerel, the likely harvest of Pacific mackerel must be subtracted. Pacific mackerel quotas are governed by a formula based on abundance (see Section 8.6.3), and the Pacific mackerel quota for 1979-80 is expected to be 23,500 short tons. Fishery patterns, including fish behavior and geographic distribution, indicate that the Pacific mackerel quota will be taken. The expected jack mackerel processing capacity in the southern zone in 1980 is therefore 85,000 less 23,500, or 61,500 short tons. Domestic fishermen are capable of harvesting more than this amount (see Section 11.1), but will not harvest more than ordered by the processors. The domestic industry is expected to harvest and process 61,500 short tons of jack mackerel in southern California in the 1980 jack mackerel season.

Future seasons: Expected domestic annual harvesting and processing capacity cannot presently be determined for more than one season in advance. However, the following procedure specifies the expected domestic annual processing capacity. Processors will provide projections of their small-mackerel orders for the forthcoming season. The Pacific mackerel quota will be known by July 1 of each year, and will be subtracted from the above mackerel orders to give the expected jack mackerel processing capacity. As shown in Section 11.1, harvesting capacity is very large, so expected domestic harvest will be equal to expected processing capacity, except as modified by joint-venture processing. This procedure for estimating expected domestic annual harvest and processing will be modified if historical evidence indicates that it consistently provides an over- or under-estimate of the true realized capacity. The above procedure will provide expected capacities not exceeding 90,000 short tons, unless new processing equipment is installed (see Section 11.2).

11.3.2. Northern-offshore zone

Past seasons: In 1975 the Polish trawl fleet took 3,736 metric tons of jack mackerel while catching 57,000 tons of whiting, giving an incidental catch rate of 6.5%. More recent seasons have shown much lower incidental catch rates of jack mackerel by foreign trawl fleets (see Section 5.2.3.2). Landings of jack mackerel by domestic fishermen were negligible until the 1978 season, when an experimental "joint venture" Pacific whiting fishery resulted in a 3.5% incidental catch rate of jack mackerel (total catch of whiting was 895.1 metric tons).

Future seasons: The 3.5% incidental catch experienced in the 1978 experimental joint venture whiting fishery does not necessarily reflect incidental catch rates for future seasons. Biological and oceanographic conditions may cause incidental catch rates to vary. Until more experience is gained, a 5% incidental catch rate should provide domestic fishermen with an insured opportunity to catch the expected domestic annual harvest of whiting.

Expected domestic annual harvest and processing of jack mackerel by a directed fishery will be calculated by the following procedure. Processors will provide projections of their large-mackerel orders (i.e., jack mackerel as a target species) for the forthcoming season. This procedure for estimating expected domestic annual harvest and processing will be modified if historical evidence indicates that it consistently provides an over- or under-estimate of the true realized capacity. Total allowable incidental catch of jack mackerel in the whiting fishery is northern-offshore OY less expected directed harvest. The California, Oregon and Washington Groundfish Fishery FMP will allocate the incidental catch.

11.4. Domestic Sales to Foreign Buyers

A primary constraint upon the domestic fishery for small mackerel is the lack of sufficient market demand at prices high enough to cover fishing and processing costs. If foreign buyers (or processors) of fish want to take delivery of jack mackerel from U.S. vessels in the Fishery Conservation Zone, then U.S. fishermen should be given preference in catching any excess of optimum yield above the expected domestic processing capacity.

12.0. OPTIMUM YIELD

Optimum yield from the jack mackerel fishery must be a level of annual catch that provides "the greatest overall benefit to the Nation." In determining the optimum yield, the Fishery Conservation and Management Act asks that maximum sustainable yield be used as a basis, and that modifications be made to account for relevant economic, social and ecological factors. In the case of the jack mackerel resource, maximum sustainable yield is not known, but crude estimates of potential yield are offered as guidelines for fishery development (see Section 9.6.5). One objective of this plan is to determine the productivity of the resource through controlled expansion of the fishery. Potential yield should be used as an interim limit to fishery expansion, and functions much as MSY does in the wording of the FCMA. In this respect, potential yield may be exceeded if the factors determining optimum yield indicate such a yield to be appropriate.

12.1. Biological and Ecological Considerations

Information presented in Section 9.0 provides the basis for discussion of biological factors. The findings that are most pertinent to optimum yield include the following:

1. Spawning biomass of jack mackerel is estimated to be between 1 and 2 million short tons.
2. Jack mackerel are relatively long-lived fish. Although annual variability in recruitment is large, variability of the total stock biomass is relatively small.
3. Rough estimates of potential yield indicate that sustainable catches may approach the following:
    a. 24 to 210 thousand short tons for 0 to 8-year-old fish,
    b. 14 to 50 thousand short tons for 9 to 15-year-old fish,
    c. 13 to 30 thousand short tons for 16 to 30-year-old fish.

Because the stock/recruitment relationship has not been determined, the total potential yield of 56 to 290 thousand short tons may be available only if the catch is balanced among the age classes as described above.

4. Yield-per-recruit analysis suggests nothing is to be gained by increasing the age at first entry into the fishery.
5. Jack mackerel appear to feed primarily upon copepods, pteropods, euphausiids, juvenile squid and anchovies. No substantial predation upon other commercially or recreationally important fish stocks is suspected.

6. Adult jack mackerel do not appear to be major food sources for other important species like bonito, albacore, or bluefin tuna; although striped marlin and, at times, yellowtail have been found with significant quantities of jack mackerel in their stomachs.
7. Adult jack mackerel has not been found to be a major food item for marine birds or mammals.
8. Given the inexact nature of the potential yield analysis, the uncertainty about effects of fishing upon recruitment, weakness of abundance monitoring capability, and the possibility of ecological interactions with larger predator fish, controlled growth of the fishery would best serve the biological/ecological interests.

Many fishery experts prefer to determine productivity of a stock by immediately fishing it very intensely. Such an approach should also be given consideration.

12.2. Socio-Economic Factors

Jack mackerel is one of several pelagic fish species that are important to southern California purse seine fishermen. The level of employment and income specifically generated by jack mackerel is rather moderate (see Sections 8.1 and 8.5). Nevertheless, any drastic change in the level of harvest would have significant impacts. A severe reduction in jack mackerel harvests could lay idle as many as 35 vessels, and could cause the unemployment of as many as 350 fishermen. Growth in the fishery would result in more employment and higher income for existing fishermen, and would undoubtedly attract new firms into the mackerel fishing business.

As explained in Section 8.3, the canned products for both human consumption and pet food are among the lowest-priced processed fishery products. Canned mackerel sells at about half the price of bonito or sardines and at one-third the price of tuna. Although the market demand for canned mackerel is growing, this growth does not appear to be rapid, and the domestic producers must be competitive with canned Pacific mackerel imported from Japan. The extent to which the canned mackerel market develops in future years depends largely upon domestic and international marketing efforts and price competition with foreign products.

Economic factors, therefore, do not suggest that harvest volumes should be pushed to the biological limits, at least in the purse seine fishery for smaller jack mackerel. At the same time, there are no good reasons to limit the domestic fishery to less than the biologically acceptable level of harvest. The primary concern is for allowing at least the current level of jack mackerel harvest and avoiding any serious risk to the maintenance of this level of harvest in the future.

Consideration of the optimum yield of large jack mackerel in the trawl fishery must focus primarily on the interaction with the developing fishery for Pacific whiting. Although it is known that some large mackerel are caught and sold either smoked or fresh/frozen, the extent of the potential market is probably very limited. No fishermen have yet been attracted to this fishery. The incidental catch of jack mackerel by Polish trawlers and unofficial reports of catch by the developing U.S. fishery, suggests that the by-catch of large mackerel may approach the lower estimate of potential yield, 12.6 thousand short tons. A harvest quota for the large mackerel may, therefore, restrict the operation of the whiting fishery. From an economic standpoint, the loss of a few tons of large mackerel from the spawning stock is probably not a heavy price to pay for hundreds of tons of whiting. So long as the take of large mackerel does not put a severe strain upon the stock, therefore, by-catch should be allowed in the trawl fishery. Optimum yield of large mackerel would, by this reasoning, be a level sufficient to allow the whiting fishery to continue without hindrance.

12.3. Objectives Specific to Management

This section expands on the general objectives stated in Section 4.2, and relates them specifically to management of the resource. The objectives of the Jack Mackerel Fishery Management Plan are:

1. To prevent overfishing of the jack mackerel resource within the United States Fishery Conservation Zone (FCZ).

   Recognizing that management information is imprecise and that maximum sustainable yield is unknown (see Sections 9.3 and 9.6), the fishery must be expanded with deliberation so that the possibility of overfishing can be anticipated. This approach will minimize the risk of overfishing while allowing the fishery to expand.

2. To allow a fishery for jack mackerel within the U.S. FCZ so as to achieve the optimum yield on a continuing basis.

   The present U.S. harvest is small relative to the apparent potential yield of jack mackerel (see Section 9.6.4). Quotas exceeding levels of harvest preceding this Fishery Management Plan will provide freedom for fishery expansion. Fuller utilization of the resource will provide greater benefits to the United States.

3. To provide a basis for developing cooperative international management of the jack mackerel resource.

   The jack mackerel resource is a transboundary stock ranging from Baja California, Mexico to the Gulf of Alaska and offshore beyond the U.S. FCZ. Resource research on an international level would facilitate monitoring the impact of an expanding fishery. These data would provide better information on which to determine optimum yield. A deliberate expansion of the fishery would approximate equilibrium conditions necessary for fishery modeling and determination of MSY.

4. To avoid conflict among user groups.

   Management measures for jack mackerel should be directed towards keeping interactions of recreational and commercial fishery interests at the current low level (Section 8.6.1).

5. To avoid interference with the Pacific whiting fishery.
   Harvest of jack mackerel should not constrain the trawl fisheries from achieving optimum yield of Pacific whiting. Domestic trawl fishermen should be given preferential catch allowances, so that development of a domestic whiting fishery is facilitated. Management regulations should be simple and consistent with the regulations promulgated by the California, Oregon and Washington Groundfish Fishery FMP.

6. To promote efficiency in the utilization of the jack mackerel resource within the FCZ, recognizing the multiple species context of the fishery both economically and ecologically.

7. To methodically explore the productivity of the resource through controlled expansion of the fishery.
   Equilibrium yield and maximum sustainable yield are not known. These quantities may be estimated in the future from data on resource abundance and fishery removals. Controlled growth of the fishery will provide data from which a more precise fishery management plan can eventually be developed.

Other categories such as time and area closures and gear restrictions are open for consideration, but are not addressed here. Some management measures regulating the trawl fishery which may take jack mackerel are addressed by the California, Oregon and Washington Groundfish Fishery FMP.

12.4. Monitoring Management Effectiveness

The following aspects of the jack mackerel fishery should be monitored to insure continuing satisfaction of the objectives discussed in Section 14.1:

1. The effect of jack mackerel harvest on the abundance and age composition of the resource.
   Long term monitoring of abundance can be aided by ongoing CalCOFI egg and larva surveys, and possibly by catch per unit effort in the trawl fisheries. Collection of length frequency data from all fishery segments will be necessary to detect changes in age composition.

2. Catches of jack mackerel by fisheries operating outside the U.S. FCZ.
   The resource may be harvested in Mexican and Canadian waters, and on the high seas independently of U.S. regulations. Management must recognize all removals of fish from the stock in determining optimum yield and total allowable catch within the U.S. FCZ.

3. Possible conflicts with the fishery for Pacific whiting.
   It is the intent of this Fishery Management Plan to encourage a domestic fishery for Pacific whiting. If jack mackerel quotas cause the domestic whiting fishery to be restrained, jack mackerel quotas and the method of their allocation should be reviewed and possibly revised.

4. Possible conflicts between the commercial fishery and the recreational fishery for jack mackerel.
   Determination of optimum yield requires due consideration of both recreational and commercial fisheries. At the time this

Fishery Management Plan was developed, no serious conflicts were in evidence or were anticpated. However, if conflicts were to arise, the management regime should be reviewed, and options should be considered whereby conflict could be reduced.

5. Possible conflicts from or with other resource management plans.
The jack mackerel fishery can be expected to interact with the management of other natural resources, for example:
a) Northern anchovy -- Pacific Fishery Management Council
b) Groundfish Fisheries -- Pacific Fishery Management Council
c) Pacific mackerel -- State of California
d) Purple coral -- Bureau of Land Management

Significant interactions may require review and possible revision of this or other management plans.

In the event that the Jack Mackerel Fishery Management Plan is not reviewed due to the above considerations, this Plan should be reviewed after having been in effect for 10 or more years. There is little benefit to be gained from more frequent review, and a 10-year period of management would be consistent with this Plan's intent of slow and deliberate fishery expansion.

13.0. RESEARCH NEEDS

The following research needs are categorized by the following codes:

u = urgent
l = long-term study, no immediate results
f = information will be gained through implementation of this FMP
q = questionable whether useful results can be obtained
e = expensive.

A. Stock Structure

1. Identification of subpopulations (u,q). Best approach would use electrophoretic techniques, supplemented by meristics and morphometrics.

2. Temporal - geographic distribution of all age groups (l). Locate the 30 cm to 50 cm length fish, and relate them to small and large segments.

3. Migratory paths and rates (l, e).

B. Population Parameters

1. Measurement of abundance (e. f?, l). While this information is very important, there is no immediately apparent method of satisfactorily determining abundance. Catch per unit effort (CPUE) from the northern fishery may be of some use, but CPUE is very often not dependable.

2. Rates of natural mortality (1, f?). This is one of the most difficult problems in fishery biology. Again, there are no immediately apparent methods to be used. Geographic structure of the population makes investigation even more difficult.

C. Resource Productivity

1. Production model (1, f). Satisfactory estimation of MSY and equilibrium yield will take very many years.

2. Recruitment/spawner relationship (1,f). Historical patterns of recruitment could possibly be inferred from annuli on otoliths of large fish (could be done in conjunction with A.1). This project will take as long as development of a production model, and probably longer.

3. Identification of environmental factors relating to reproductive success (e). This information would allow prediction of year class strengths, and may be useful to a future management regime wherein quotas are varied according to abundance.

D. Fishery

1. Rates and length frequency of incidental catches of jack mackerel in the (a) Pacific whiting fishery, (b) salmon troll fishery, and (c) albacore troll fishery (u, f). The magnitude of these catches is not known, but is important to the accounting of removals from the jack mackerel resource.

E. Processing

1. Utilization of jack mackerel; amounts of fish going to (a) canning for human consumption, (b) canning for pet food, (c) reduction to fish meal, and (d) other, including fresh, frozen, smoked, etc., (f). Economic aspects of optimum yield require knowledge of processing and marketing structure.

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Appendix 1.

California Fish and Game Code - Provisions Affecting or Potentially Affecting Southern Jack Mackerel Fisheries (Excluding Trawling).

7700. As used in this chapter:
(a) "Reduction plant" means any plant used in the reduction or conversion of fish into fish flour, fishmeal, fish scrap, fertilizer, fish oil, or other fishery products or byproducts.

7704. Except as allowed by this code, it is unlawful to use any fish, or part thereof, except fish offal, in a reduction plant or by a reduction process.

8075. The commission may grant a permit, subject to such regulations as it may prescribe, to take and use fish by a reduction or extraction process.

8076. No reduction of fish shall be permitted which may tend to deplete the species, or result in waste or deterioration of fish.

8077. No permit shall be issued except after a public hearing and a finding by the commission that the granting thereof would promote the economic utilization of the fish resources of the State in the public interest. In making such finding the commission shall take into consideration the interest of the people of the State in the utilization and conservation of the fish supply and all economic and other factors relating thereto, including the efficient and economical operation of reduction plants.

8078. A hearing pursuant to this article shall be held within 30 days after application for a permit, upon such notice as the commission shall prescribe. The commission may extend such a hearing from time to time for a total period of not more than 30 days.

8079. The commission shall, whenever necessary to prevent overexpansion, to insure the efficient and economical operation of reduction plants, or to otherwise carry out the provisions of this article, limit the total number of permits which are granted.

8750. As used in this article, "round haul nets" are circle seines, and include purse seines and ring or half ring, and lampara nets.

8751. In Districts 1, 2 and 3, round haul nets may not be possessed on any boat, except in that part of District 3 lying within the boundaries of the Moss Landing Harbor District, where round haul or any other type of nets may be possessed on any boat, and except in that part of District 2 lying within Marin County.

8752. In Districts 6, 7, 8, 9, 10 and 11, purse and round haul nets may be used.

8753. In that part of District 16 lying north and west of a line drawn from the light on the end of the Monterey Breakwater magnetic east to the shore line, purse and round haul nets may be used to take fish other than squid, and lampara nets may be used to take squid.

In that portion of District 16 lying southerly of the Monterey Breakwater and south of a line drawn from the light on the end of such breakwater magnetic east to the shore line, lampara nets may be used from June 1st to August 31st for the purpose of taking squid.

8754. In Districts 17, 18 and 19, purse and round haul nets may be used, except that purse seines or ring nets may not be used in that portion of District 19 lying within three miles offshore from the line of the high-water mark along the coast of Orange County from sunrise Saturday to sunset Sunday from May 1st to September 10th, inclusive.

Purse seine or ring nets may not be used from May 1st to September 10th, inclusive, in the following portions of District 19:

(a) Within a two-mile radius of Dana Point.

(b) Within a two-mile radius of San Mateo Point.

(c) Within two miles offshore from the line of the high-water mark along that portion of the coast of Orange County lying between the northernmost bank of the mouth of the Santa Ana River and a point on such coast six miles south therefrom.

8755. In Districts 20A and 21, purse and round haul nets may be used.

(a) Purse and round haul nets may be used, except: (1) from sunrise Saturday to sunset Sunday, in that portion of District 20 from a line extending three nautical miles east magnetically from the extreme easterly end of Santa Catalina Island southwesterly and northerly to a line extending promóntory of China Point and (2) at any time during the period commencing on June 1st and ending on September 10th in each year, in that portion of District 20 from a line extending three nautical miles east magnetically from the extreme easterly end of Santa Catalina Island southerly to a line extending three nautical miles southeasterly magnetically from the United States government light on the southeasterly end of Santa Catalina Island.

(b) Subdivision (a) shall not be construed as restricting the right to use the waters therein specified for anchorage of vessels at any time.

8780. As used in this chapter, the term "bait net" means a lampara or round haul type net the mesh of which is constructed of twime not exceeding Standard No. 9 medium cotton seine twine or synthetic twine of equivalent size or strength. The net shall not have rings along the lead line or any method of pursing the bottom of the net.

In Districts 19A and 19B bait nets may be used only to take anchovies, queenfish, white croakers, and smelt for bait only. Such nets may not be used within 750 feet of Seal Beach Pier or Belmont Pier.

No other species of fish may be taken or possesed on any boat carrying a bait net in District 19A.

NOTE: District 19A is Santa Monica Bay.
District 19B is Los Angeles-Long Beach Harbor.

Appendix 2.

TITLE 14, State of California Fish and Game Commission Orders, Rules and Regulations for 1978 - Provisions Affecting or Potentially Affecting the Southern Jack Mackerel Fisheries.

Recreational fishing:

Fin Fish-Minimum Size Limits, Bag and Possession Limits and Seasons

27.60. Limit. (a) General: Twenty fin fish in combination of all species with not more than ten of any one species, except as otherwise provided. (See Sections 27.70 through 28.60 for minimum size limits and poundage restrictions for certain species.)

NOTE: This section applies to jack mackerel.

Gear Restrictions

28.65. General. Except as provided in this article, fin fish may be taken only on hook and line or by hand. Any number of hooks and lines may be used in all ocean waters and bays except: (a) San Francisco and San Pablo bays between the Golden Gate Bridge and the west Carquinez Bridge, where only one line with not more than three hooks may be used; and

(b) On public piers, breakwaters and other structures on which a fishing license is not required, no person shall use more than two rods and lines or two hand lines.

(c) No gaff hook shall be used to take or assist in landing any fin fish shorter than the minimum size limit. For the purpose of this section a gaff hook is any hook with or without a handle used to assist in landing fish or to take fish in such a manner that the fish does not take the hook voluntarily in its mouth. No person shall take fin fish from any boat or other floating device in ocean waters without having a landing net in possession or available for immediate use to assist in landing undersize fish of species having minimum size limits; the opening of any such landing net shall be not less than eighteen inches in diameter.

Appendix 3.

California Regulations Governing the Harvest of Pacific Mackerel.

California Fish and Game Code

The following Pacific mackerel legislation will remain in effect until January 1, 1981.

8388.5. It is the intent of the Legislature that the Pacific mackerel resource be enhanced. The department shall make an annual report to the Legislature, no later than July 31, on the status of the resource.

A season allowable catch equal to 20 percent of the amount of Pacific mackerel in excess of 20,000 tons total population, as determined by the department, shall be established by the director. The allowable catch may be taken mixed or unmixed with other species, under revocable permits issued by the department to boat owners or operators, under conditions prescribed by the department, to ensure that the total harvest between October 1 and September 30 does not exceed the allowable catch.

Total population means Pacific mackerel age one and over as of October 1 of each year.

The department shall keep records of the catch of Pacific mackerel, including all Pacific mackerel taken incidentally with other species of fish. The department shall estimate from the current trend of catches the date on which the allowable catch will be reached and shall publicly announce that date as the closing date of the season at least 48 hours prior thereto. After the season is declared closed, the allowable tolerance of Pacific mackerel taken with other species is 18 percent by number.

8388.6. During the course of the season, to ensure that the total season's harvest does not exceed the catch allowed under Section 8388.5, and to allow fishing for other species, the director may:

(a) Adjust a figure previously determined to represent the season allowable catch for the taking of Pacific mackerel, if additional biological data becomes available which would indicate that an earlier determined total population needs to be revised.

(b) Set an allowable tolerance for the taking of Pacific mackerel incidental to the fishing of other species of fish, taking into consideration the mixing ratios of Pacific mackerel with other species. The allowable tolerance for Pacific mackerel mixing with jack mackerel shall not be greater than 50 percent Pacific mackerel by number determined in a manner prescribed by the director, nor less than 18 percent by number. The allowable tolerance for Pacific mackerel mixing with other species of fish, shall not be greater than 50 percent Pacific mackerel by number determined in a manner prescribed by the director.

(c) Allow any load of fish weighing three tons or less to contain any amount of Pacific mackerel, without regard to the established tolerance for the taking of Pacific mackerel incidental to the fishing of any other species of fish.

NOTE: Section 8388.6 (c) has been modified by TITLE 14, Section 148 (see below) so that eight tons or less of Pacific mackerel may be landed in pure loads.

The following Pacific mackerel legislation will be in effect after January 1, 1981.

8388. Except as provided in Section 8388.2, Pacific mackerel may not be taken or possessed at any time for any purpose except loads or lots of fish may contain 18 percent or less by weight of Pacific mackerel taken incidentally to other fishing operations. Such Pacific mackerel, incidentally taken, may be used for any purpose.

8388.1. It is the intent of the Legislature that the Pacific mackerel resource be enhanced. During this process a fishery shall be allowed once the Pacific mackerel spawning population, in waters north of Punta Eugenia, Baja California, Mexico, has reached 10,000 tons as determined by the department. Such determination shall be made public in an annual report to the Legislature no later than July 31 of each year. It is also the intent that as the spawning population increases, in excess of 20,000 tons, the seasonal quota also be increased but at such a rate as to allow the continued increase in the Pacific mackerel population. This process should continue with the objective of maximizing the sustained harvest.

8388.2. Section 8388 shall remain in effect until the department determines that the estimated Pacific mackerel spawning population, in waters north of Punta Eugenia, Baja California, Mexico, exceeds 10,000 tons. When the department makes this determination, a season harvest quota equal to 20 percent of the amount of Pacific mackerel in excess of 10,000 tons spawning population, as determined by the department, shall be permitted under permits issued by the department.

When the department determines that the spawning population exceeds 20,000 tons, the harvest quota shall be increased to 30 percent of the excess over 20,000 tons.

The department shall keep records of the catch of Pacific mackerel and when it appears that the season quota will be reached, it shall notify all permitholders of the date when such limit will be reached and therefore the season closed, and shall notify, by certified mail, all permitholders of such closure.

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148.(b)(2) Load Composition. Loads of fish weighing eight tons or less may contain any amount of Pacific mackerel. Loads of Pacific mackerel in amounts over eight tons shall not contain quantities of Pacific mackerel greater than 50% by number.

NOTE: Modifications of season dates and size limits for Pacific mackerel were being considered by the California legislature at the time of publication.