THE SARDINE FISHERY ALONG THE WESTERN COAST OF BAJA CALIFORNIA, 1981 TO 1994

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ABSTRACT

Catch data (3,416 MT during 1984 and 56,350 MT during 1994) indicate that abundance of Pacific sardine (*Sardinops sagax*) along the west coast of Baja California has increased dramatically. Increases were closely related to abundant year classes in 1984, 1989, and 1993. The abundant year classes in 1984 and 1993 followed El Niño events. Seasonal patterns in catches lead us to hypothesize that sardine migrate seasonally between Magdalena Bay and Ensenada, moving northward during the summer and fall and southward during winter and spring. The period of highest abundance after 1989 was associated with a northern shift in the distribution of sardine and increased catches in Ensenada. Peak catches occurred in a bimodal pattern at 17° and 20°C near Ensenada in the north, at 17° and 21° near Cedros Island, and at 19° and 24° near Magdalena Bay in the south. This pattern suggests the possibility of three stocks along the west coast of Baja California.

INTRODUCTION

In Mexican waters, Pacific sardine is harvested commercially along the western coast of Baja California and in the Gulf of California. The first recorded catches of Pacific sardine (*Sardinops sagax*) along the western coast of Mexico were in Ensenada during 1951. As the sardine fishery collapsed in California, the Mexican fishery moved progressively southward (figure 1), arriving at Cedros Island in 1961 and Magdalena Bay in 1972 (Murphy 1966).

In this paper we describe some aspects of the Pacific sardine fishery along the western coast of Baja California, emphasizing the period from 1981 to 1994, and three fishing zones: Ensenada in the north, Cedros Island, and Magdalena Bay in the south (figure 1). The principal species in the commercial fishery along Baja California is Pacific sardine, but the fleet also harvests thread herring (*Opisthonema* spp.), chub mackerel (*Scomber japonicus*), and, to a lesser extent, round herring (*Etrumeus teres*), anchoveta (*Cetengraulis mysticetus*), and jack mackerel (*Trachurus symmetricus*) (Hernández-Vázquez 1983; Félix-Uraga 1986). At Magdalena Bay and Cedros Island, around 80% of the catch is used for fish meal, and approximately 20% is canned for human consumption.

The number of canneries and size of the fleet in Magdalena Bay have been relatively constant since 1981. There are two canneries with fish meal plants, one in Port San Carlos and the other in Port Lopez Mateos (figure 1). The number of boats in the Magdalena Bay zone ranges between 5 and 7 per year, with capacities between 60 and 120 MT per boat. The fleet operates mostly within the bay and leaves only occasionally to fish outside near the mouth of the bay.

On Cedros Island there is only one cannery with a fish meal plant and only one boat (150 MT capacity) that catches sardine. The boat operates near the island. Detailed information about canneries and fleet size has not been compiled for Ensenada.

DATA AND METHODS

Data about catch and fishing effort for ports in Lopez Mateos, San Carlos, and on Cedros Island during 1981–94 were obtained from canneries' business records by Centro Interdisciplinario de Ciencias Marinas personnel (table 1). Catch data for Ensenada (table 1) were

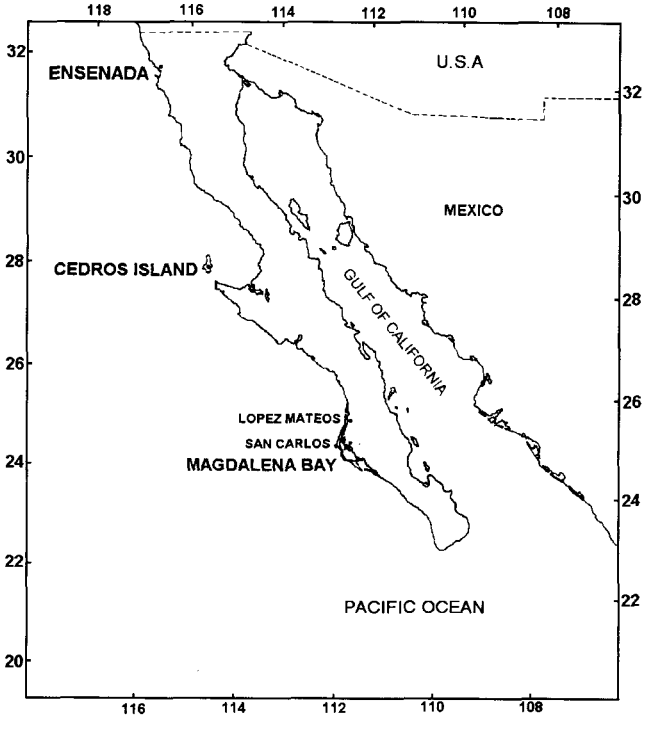

Figure 1. Baja California and its three main fishing grounds for Pacific sardine.

TABLE 1
Annual Landings (MT), Fishing Effort (Trips), and Average Sea-Surface Temperatures (SST) for Three Fishing Zones along the Western Coast of Baja California

	Cedros Island				Magdalena Bay				Ensenada	
Year	Catch Pacific sardine	Catch all species	Fishing effort	SST	Catch Pacific sardine	Catch all species	Fishing effort	SST	Catch Pacific sardine	SST
1981	1,704.6	4,267.3	133	18.8	10,557.0	14,689.1	550	21.4		17.7
1982	2,401.4	6,761.5	176	18.1	9,392.0	12,585.7	364	21.2		17.3
1983	1,595.8	2,824.1	89	19.2	2,386.2	4,945.5	174	22.9	273.6	18.2
1984	962.1	2,401.9	82	18.7	2,453.8	4,604.3	197	21.6	0	17.9
1985	1,023.4	3,356.1	96	17.9	10,979.2	13,278.3	322	20.6	3,722.3	17.2
1986	2,808	4,708.8	128	17.9	14,203.3	15,723.6	364	20.8	242.6	17.3
1987	2,856.1	3,956.7	94	18.2	8,599.3	10,486.3	241	21.3	2,431.6	17.3
1988	846.1	1,257.1	42	18.0	12,080.5	14,248.4	286	20.3	2,034.9	17.2
1989	2,344.3	3,957.9	89	18.2	7,746.1	10,087.5	239	20.9	6,222.2	17.3
1990	2,085.6	2,816.1	80	18.6	16,975.3	22,844.5	449	21.8	11,375.3	17.7
1991	551.3	1,081.0	36	18.8	15,893.5	27,331.8	511	22.8	31,391.8	17.6
1992	348.4	992.3	22	19.8	5,026.0	19,754.4	501	23.2	34,648.2	18.8
1993	1,504.6	1,966.4	36	18.8	7,543.6	18,566.8	501	22.6	32,044.9	18.2
1994	1,685.3	2,329.0	27	18.8	33,787.0	35,921.1	646	22.0	20,877	17.5

TABLE 2
Catch-at-Age data (10^6 Fish) for Pacific Sardine Caught in Magdalena Bay, 1981–1994

	Age groups						
Year	0	1	2	3	4	5	6+
1981	14.824	51.542	64.515	13.058	0.000	0.000	0.000
1982	25.355	50.965	56.860	7.607	2.582	0.000	0.000
1983	0.171	8.162	16.725	1.289	0.215	0.071	0.000
1984	5.879	7.016	17.694	9.748	0.283	0.000	0.000
1985	15.380	119.604	43.722	0.252	0.000	0.000	0.000
1986	3.929	37.047	96.494	52.135	3.863	0.000	0.000
1987	0.000	10.931	53.981	21.107	5.459	0.000	0.000
1988	7.129	34.532	48.205	37.201	3.093	0.218	0.663
1989	31.752	37.307	15.521	6.186	2.311	0.075	0.000
1990	5.195	55.485	57.292	37.047	13.267	11.352	0.102
1991	9.730	61.080	67.911	24.244	8.389	2.042	1.264
1992	1.458	37.689	30.402	5.053	0.679	0.237	0.000
1993	4.980	79.866	56.118	5.663	0.000	0.000	0.000
1994	46.294	341.263	147.834	26.358	9.737	0.000	0.000

provided by Walterio García (Centro Regional de Investigaciones Pesqueras, Ensenada, pers. comm.), but effort data were not available.

Sea-surface temperature (SST) data for Magdalena Bay, Cedros Island, and Ensenada during 1981–90 were obtained from COADS (Comprehensive Ocean Atmosphere Data Set; Roy and Mendelssohn 1994; table 1). SST data for 1991–94 were from Anonymous 1991–1994. The SST data from COADS were average temperatures in 2° latitude × 2° longitude squares. Squares along the coast at 24°–26° N., 28°–30° N., and 30°–32° N. Lat. were used for Magdalena Bay, Cedros Island, and Ensenada. Data from IATTC (Inter-American Tropical Tuna Commission) reports were the temperature at the isothermal nearest each fishing zone. Average annual temperatures were calculated for each region.

Catch-at-age data (number of fish in each age group caught during each year) during 1981–94 were available for Magdalena Bay, but not for Cedros Island and Ensenada. Catch-at-age data for Magdalena Bay in Félix-Uraga 1992 were updated (with the methods of Holden and Raitt 1975) to 1994 (table 2). A recruitment index for sardine in the Magdalena Bay fishery was estimated from catch-at-age data by summing the catch at each age for each year class.

For 1991 to 1994, we estimated a seasonal index of relative catch for each fishing zone (catch increased considerably in Ensenada during this period). The seasonal catch was the catch during a season divided by the catch for the entire year. Seasons were winter (January–March), spring (April–June), summer (July–September), and fall (October–December). To determine temperature preferences for sardine, we summed monthly catches by 1°C intervals and plotted the results.

RESULTS

Catch and Effort

The total catch of sardine along the western coast of Baja California increased from about 12,000 MT in 1981 to about 56,000 MT in 1994 (table 1, figure 2). From 1985 to 1989, total landings averaged 16,000 MT annually, and catch in Magdalena Bay was greater than at Cedros Island or Ensenada. After 1989, the average catch was more than 40,000 MT annually, and catches were greatest in Ensenada, except for 1994, when the catch was higher (34,000 MT) in Magdalena Bay. Thus the period of highest abundance after 1989 seems associated with a northern shift in the distribution of sardine.

The sardine catch at Cedros Island has averaged 1,600 MT annually and has been relatively constant since 1981. In most years, the Cedros Island fishery was the least important in terms of total landings.

Total fishing effort (number of fishing trips) and catch by the sardine fleet at Magdalena Bay and Cedros Island is related to the availability of sardine and other species (table 1). When fish are available, fishing trips and catches increase. The correlation (r) between fishing effort and total landings (all species) at Magdalena Bay and Cedros Island during 1981–94 was $r = 0.88$ ($P < 0.00$) and $r = 0.94$ ($P < 0.00$). The correlation between fishing effort and Pacific sardine landings was $r = 0.66$ ($P = 0.001$) for Magdalena Bay and $r = 0.64$ ($P = 0.01$) for Cedros Island.

Year-Class Abundance Index

The year-class index (figure 3) indicates that sardine recruitment increased continuously after 1981, with particularly strong recruitments during 1984, 1989, and 1993. The 1994 year class appears weak, but this is probably due to limited data for the most recent recruitment.

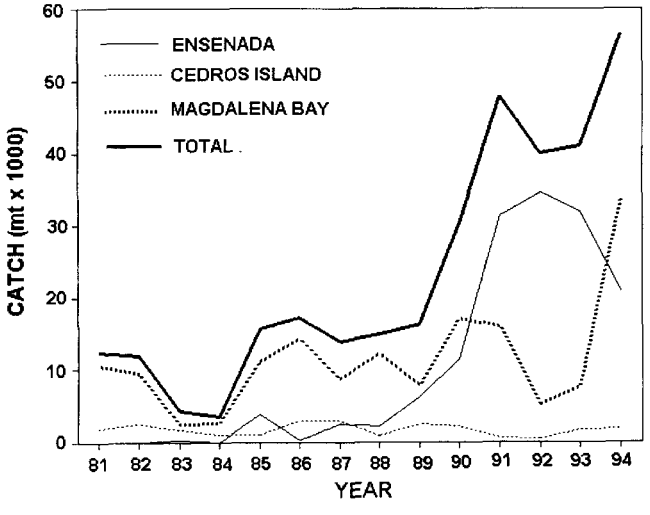

Figure 2. Pacific sardine landings (MT) along the west coast of Baja California.

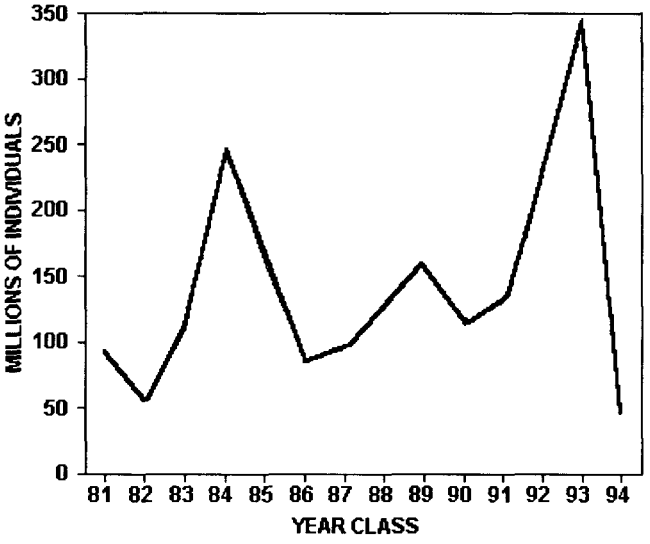

Figure 3. Recruitment index (sum of catch at age for each year class) for Pacific sardine in the Magdalena Bay fishery.

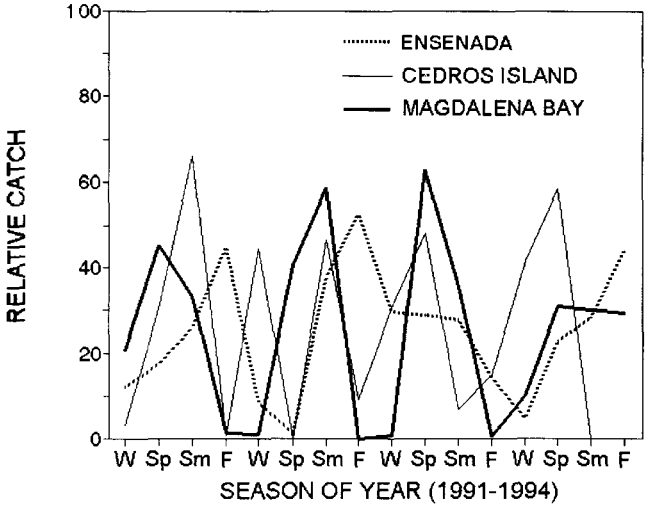

Figure 4. Relative Pacific sardine catch by year, season, and fishing zone, 1991–1994. W = winter; Sp = spring; Sm = Summer; and F = fall.

Seasonal Catch

Seasonal catch during 1991 to 1994 (figure 4) shows that the fishery in Magdalena Bay occurred mainly during spring and summer. In most years, the fishery at Cedros Island also occurred during the spring and summer. During 1991, however, there were peaks during both the summer and winter. In the Ensenada fishery, except for 1993, only one peak occurred in each year, mainly in the fall.

Catch and Temperature Relationship

Annual average SST along the western coast of Baja California was relatively warm in 1983 and 1992 and relatively cool during 1985–90 (figure 5). Trends in temperature at different zones were similar, but Magdalena

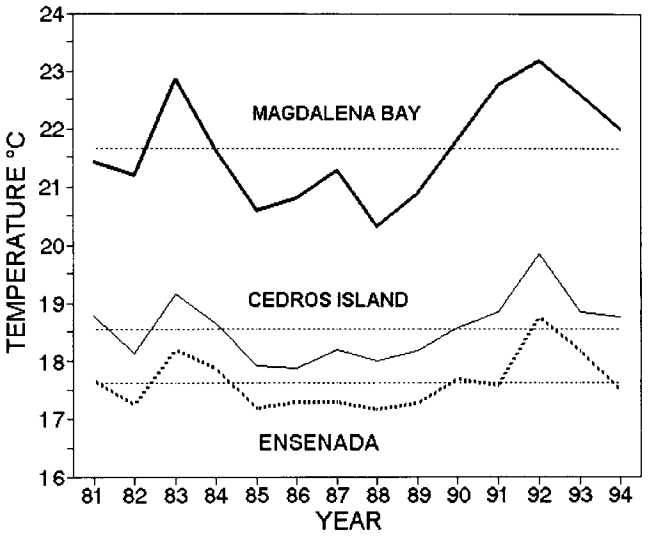

Figure 5. Annual average sea-surface temperatures near Ensenada, Cedros Island, and Magdalena Bay.

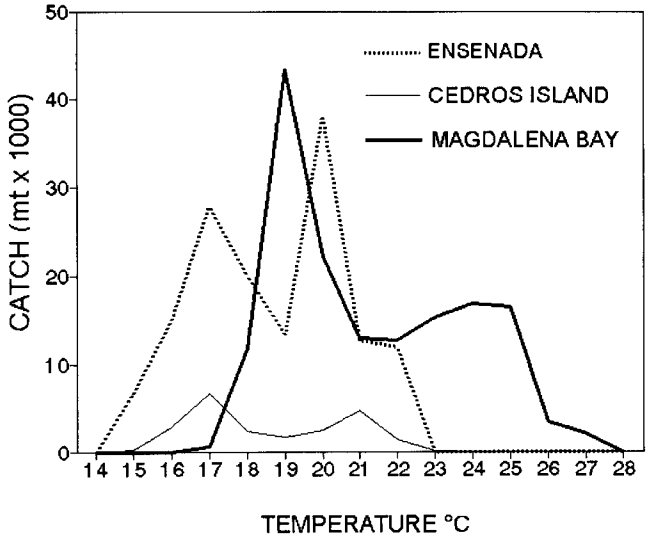

Figure 6. Pacific sardine catch by temperature at Ensenada, Cedros Island, and Magdalena Bay, 1981–1994.

Bay was consistently warmest (average 21.7°C compared to 18.5° at Cedros Island and 17.6° at Ensenada). The difference in average temperature during 1981–94 between Ensenada and Cedros Island was only about 1°, whereas the difference between Cedros Island and Magdalena Bay was about 3°.

Peak catches in the three fishing regions occurred at different temperatures, and there were two peaks at each location (figure 6). At Ensenada, the first peak in sardine catch was at 17°, the second at 20°. The first peak at Cedros Island was also at 17°, but the second was at 21°. For Magdalena Bay, the first peak was at 19°; the second was between 24° and 25°.

DISCUSSION

Increases in total catch (a crude index of abundance for sardine; e.g., Lluch-Belda et al. 1989) during 1985, 1990, and 1994 (figure 2) were associated with strong year classes during 1984, 1989, and 1993 (figure 3). The strong year classes in 1984 and 1993 may be due to El Niño events during 1983 and 1992 (Murphy 1960; Huato-Soberanis and Lluch-Belda 1987; Félix-Uraga 1992).

Increased catches at Ensenada during 1992 coincided with decreased catches at Magdalena Bay in the same year (figures 2 and 5). This could be due to the 1992 El Niño event, which caused northward movements of sardine from Magdalena Bay.

The pattern of highest relative catch by season (spring–summer in the south, and fall in the north) during 1991–94 (figure 4) indicates seasonal migrations of sardine between Ensenada, Cedros Island, and Magdalena Bay. Seasonal migrations may amplify or contribute to increases in abundance of sardine in northern areas when the population is growing (Lluch-Belda et al. 1989, 1991).

Pacific sardine are caught over a wide range of temperatures along the western coast of Baja California (figure 6). Peak catches occurred at three different temperatures: 17°, 20°–21°, and 24°–25°. This pattern suggests the possibility of three different stocks along the coast of Baja California.

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EGG PRODUCTION OF PACIFIC SARDINE (*SARDINOPS SAGAX*) OFF OREGON IN 1994

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ABSTRACT

Since the late 1970s, the Pacific sardine (*Sardinops sagax*) population off the west coast of the United States has been increasing. In 1994, an ichthyoplankton survey to assess anchovy biomass was conducted off the Oregon coast from the Columbia River to the Coquille River (just north of Cape Blanco) and out to 190 km offshore. Samples collected during the survey contained numerous Pacific sardine eggs and larvae, which were used to estimate daily egg production (0.42 eggs/0.05 m^2/day) and egg mortality (0.13/day). The spawning biomass of Pacific sardine was calculated to be about 50,000 MT.

There appears to be an association between geographic distribution of sardine eggs and the 14°C isotherm derived from the 1-m to 10-m depth zone. We hypothesize that the isotherm of 14°C forms a distinct boundary for spawning sardine off Oregon and may prove useful for determining boundaries for future spawning surveys.

INTRODUCTION

The Pacific sardine (*Sardinops sagax*) fishery, which ranged from Baja California, Mexico, to as far north as British Columbia, Canada, was the largest commercial fishery in the Western Hemisphere in the early 1900s (Wolf 1992). During that period, sardine evidently spawned throughout most of their range. Spawning occurred during the summer in Oregon and British Columbia waters (Walford and Mosher 1941; Ahlstrom 1948). Since the decline of the sardine population in the 1940s, no landings have been documented in waters off Oregon and Washington (Radovich 1982; Wolf 1992), and to our knowledge no spawning has been documented in waters north of California.

In 1994, the National Marine Fisheries Service (NMFS) conducted an ichthyoplankton survey off the Oregon coast to estimate northern anchovy (*Engraulis mordax*) biomass. During this survey northern anchovy eggs were rarely collected, but Pacific sardine eggs were abundant throughout the study area. Pacific sardine eggs were found as far north as Tillamook Head, Oregon, indicating that the Pacific sardine may again be using northern portions of its historical spawning range. This apparent expansion of spawning range to Oregon waters is consistent with the rates of increase in biomass and spawning area that have been observed off California since the mid-1980s (Deriso et al. 1996).

In this paper, we describe the geographic distribution of Pacific sardine eggs and larvae and estimate egg production and mortality in our study area off Oregon in July 1994. We also provide a crude estimate of Pacific sardine spawning biomass.

MATERIALS AND METHODS

Survey Description

The ichthyoplankton survey used the egg production methods of Lasker (1985) and was conducted aboard the 17.4-m research vessel *Sea Otter* during 5–26 July 1994. Sampling was conducted over a grid of 234 stations along 12 east–west transects, which encompassed an area of 69,308 km^2 (figure 1). Transects extended

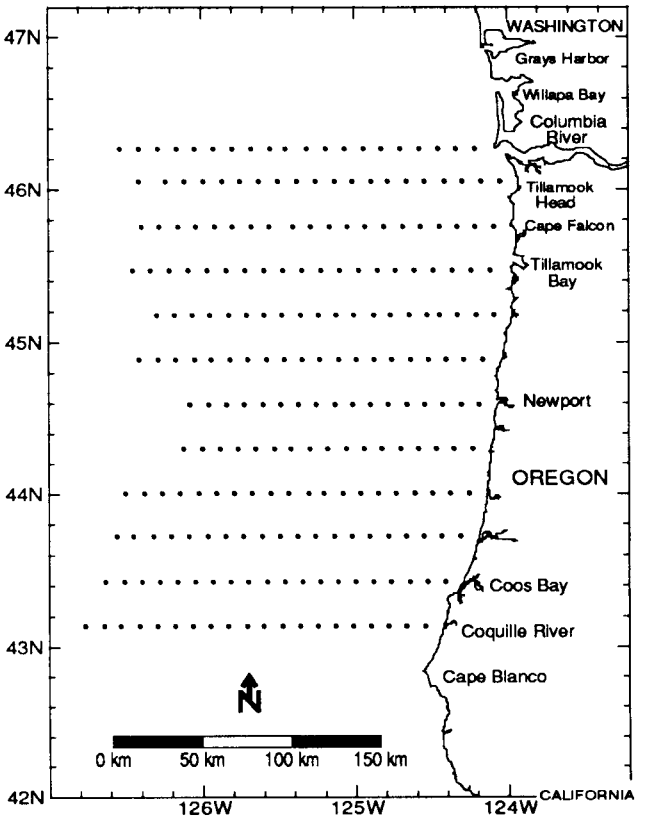

Figure 1. A grid of 234 sampling stations occupied during the ichthyoplankton survey, 5–26 July 1994.