SEASONAL AND GEOGRAPHIC CHARACTERISTICS OF FISHERY RESOURCES

California Current Region--VII. Pacific Sardine

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The fishery for the Pacific sardine, Sardinops caeruleus, was, during the 1930s and early 1940s, the largest in the western hemisphere; it produced nearly 25% of all fish caught in the United States.

Research on this resource had been going on for about 25 years, when its decline in the 1940s triggered the most intensive fishery study ever mounted in the world--the California Cooperative Oceanic Fisheries Investigations (CalCOFI). During the decade 1951-60, surveys were carried out each year almost on a monthly basis. Their data have been used as a base for analysis of the sardine and other pelagic resources in the California Current region. For this series of reports, the data have been used to summarize trends in densities of spawning populations by season and geography off the coasts of California and Baja California (Kramer and Smith, 1970a, b, c, d, 1971a, b). The agencies of the CalCOFI, their area of survey, and the methods of treating the data were described in our first report.

One reason given for the decline of the sardine was the intensive fishing pressure brought on by the profitable reduction of whole fish to meal and oil; from 1936 through 1945, tonnage for reduction exceeded tonnage for canning. Landings reached a high of 791,000 tons in the 1936-37 season and, from 1937-38 through 1944-45, fluctuated from 493,000 to 680,000 tons. The northern fishery off Canada, Washington, and Oregon was one of pressure on older fish that migrated from the subpopulations off California. The northern fishery collapsed as intensive fishing off California reduced the age structures of the sardine populations on that coast. In a population biology study of this species, Murphy said in 1966 that the pre-1949 population had a maximum sustainable yield of 471,000 tons at a spawning population of 1 million tons.

As reported by the California Department of Fish and Game (Frey, 1971), sardine numbers in the variable environment of the California Current region were dependent on an age structure which contained seven or eight significant reproductive classes. The intensive fishery lowered sardine life expectancy so that the population began to approach single-class reproduction. Thus, with its inherent resiliency stripped away, the northern subpopulation (off central California) collapsed following two highly unsuccessful spawnings in 1949 and 1950.

In our report on the northern anchovy (Kramer and Smith, 1971a), we discussed briefly two other possible reasons for the failure of the sardine to recover its former abundance. One was the taking over of the sardine's ecological niche by the anchovy; the other was the possibility of natural fluctuation wherein the two species may have been independent of one another in different periods over the last 2,000 years (Soutar, 1967; Soutar and Isaacs, 1969).

Seasonal and Geographic Distributions

At one time the sardine ranged from southern Alaska to the Gulf of California. Tagging studies (Clark, 1945) conducted by Canada and the States of Washington, Oregon, and California (California also tagged sardines off central Baja California) indicated that the fish moved from every region to all of the others. Returns from those tagged on Baja California showed migration northward only as far as southern and central California.

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Attempts to differentiate subpopulations have been made on the basis of 1) differences in vertebral counts (Clark, 1947; McHugh, 1950)--indicating heterogeneity but not necessarily significant differentiation; 2) differences in temporal and areal spawning (Ahlstrom, 1960)--indicating fairly distinct subpopulations, "northern" off California and northern Baja California, "southern" off central Baja California, and "gulf" in the Gulf of California. (These differences can be seen in a 1970 atlas by Kramer which depicts the relative abundance of sardine eggs and larvae collected on every survey by the CalCOFI from 1951 through 1966); and 3) differences in blood systems (Sprague and Vrooman, 1962; Vrooman, 1964) which substantiated those subpopulations of Ahlstrom's analyses. The serological studies further demonstrated the movements evidenced by the tagging studies. These showed northern and southern subpopulations moving northward in spring and summer, and south in fall and winter.

Summarized data for 1951-60, used to predict the times and locations of adult sardine spawning, are shown in Figures 1 and 2. The relative distributions of all eggs and larvae collected by the CalCOFI for all cruises from 1951 through 1966 were depicted in an atlas by Kramer (1970). As for the anchovy (Kramer and Smith, 1971a), the summarized data on eggs and larvae are used to depict the occurrences for January through July and for October. The distributions for 5-mm larvae only are used because they are most abundant in plankton hauls.

Eggs and larvae show only slight differences in extent of their distributions in each of the same months for which they are illustrated. The lack of similarly shaded areas, for larvae as for eggs, 20% or more occurrences in plankton hauls, is attributed to the escapement, not absence, of small larvae through the meshes of the standard 1-m CalCOFI net (personal communication, William H. Lenarz, NMFS, La Jolla, California). The major centers of spawning (shaded areas) are evident first in January in small areas off central Baja California and southern California. These are the northern and southern subpopulations described above. With the passage of time, the southern group spreads northward and seaward; then, in May and June, it intermixes with the northern group, which spreads somewhat southward. In July, the two groups are separate again and, in October, heavy spawning occurs only off central Baja California. This is the off-season spawning group described by Ahlstrom (1960, p. 420), which he defined as the southern subpopulation.

The Fishery

The California Department of Fish and Game, in its report on the State's living marine resources (Frey, 1971), concluded its history of the sardine fishery: "Prior to 1967, management of the sardine resource in California almost entirely was limited to (1) control of tonnage of whole fish used for reduction, (2) case pack requirements (set number of cases of canned fish per ton of whole fish), and (3) restriction of the fishing season to the time of year when fish were most available and in prime condition for processing. A moratorium on sardine fishing in California was in effect during the 1967-68 and 1968-69 seasons. The moratorium limited the quantity of sardines which could be taken incidentally with other fish to 15% by weight of a mixed load. California landings for the 1967-68 season were 71 tons, while 52 tons were landed during the 1968-69 season.

"An extremely lucrative bait market for sardines has developed in the San Francisco Bay area in recent years. Sardines landed in California for this market bring the fishermen $400 to $500 per ton. During 1968, there were 323 tons of sardines imported from Mexico for use as bait. A bill (AB 564) enacted by the California Legislature in 1968 permitted the taking of 250 tons annually for bait. At present, the San Francisco-Delta bait market appears to be the most significant economic factor responsible for continued fishing mortality of the California sardine resource."

In its final discussion on the pelagic wetfish (packed in a "wet" condition, then cooked--hence wetfish), the Department stated:

"Landings of pelagic wetfish have been sizable in the past but have declined in more recent years. This decline is due to several factors: (1) the decline of sardine and Pacific mackerel stocks; (2) prohibiting the fishing industry from harvesting abundant anchovy stocks at a level indicated reasonable by scientific evidence; and (3) failure of the fishing industry to harvest greater

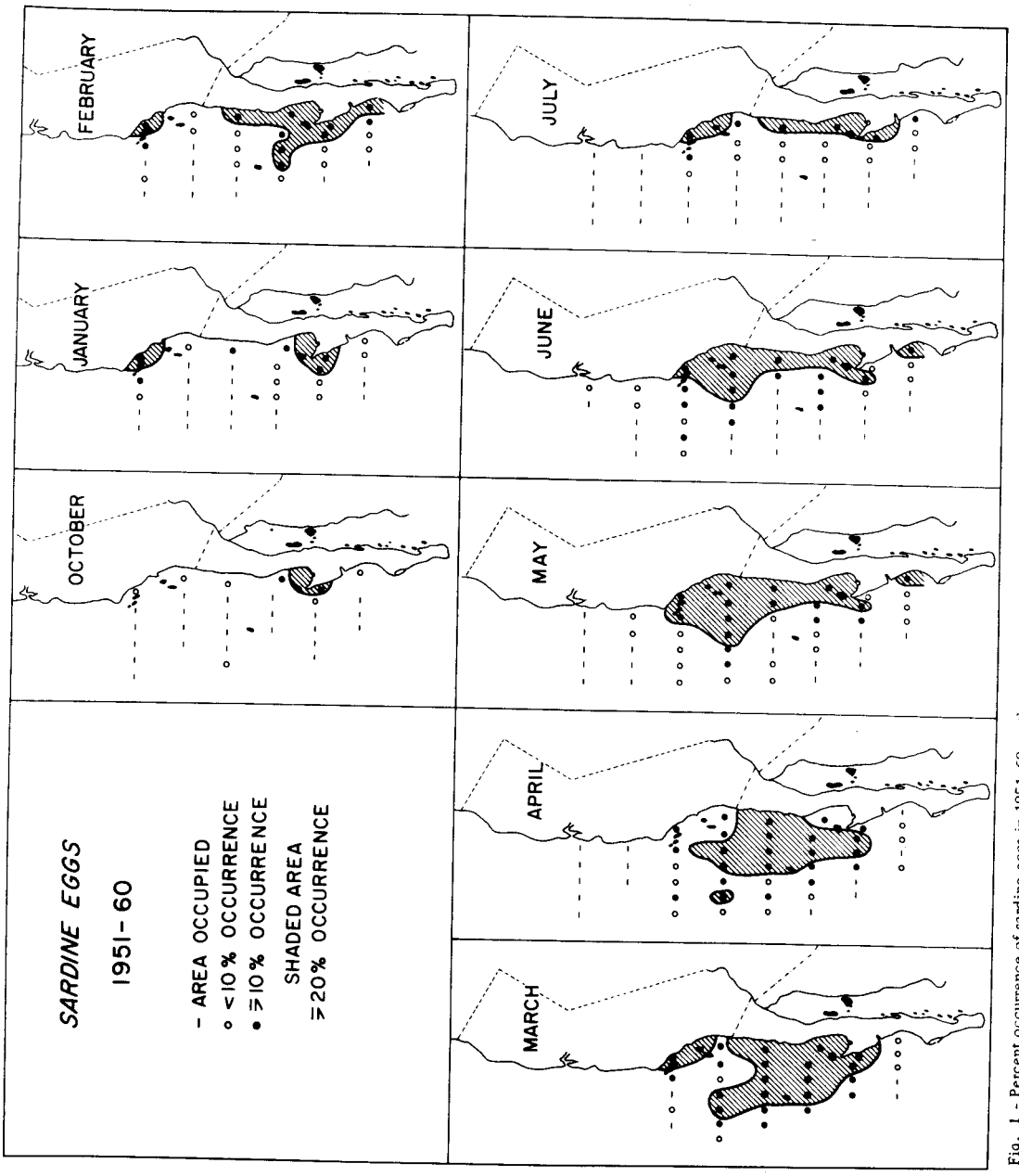

Fig. 1 - Percent occurrence of sardine eggs in 1951-60 on the survey pattern of the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Each circle, line or dot represents a pooled statistical area (see Kramer and Smith, 1970a).

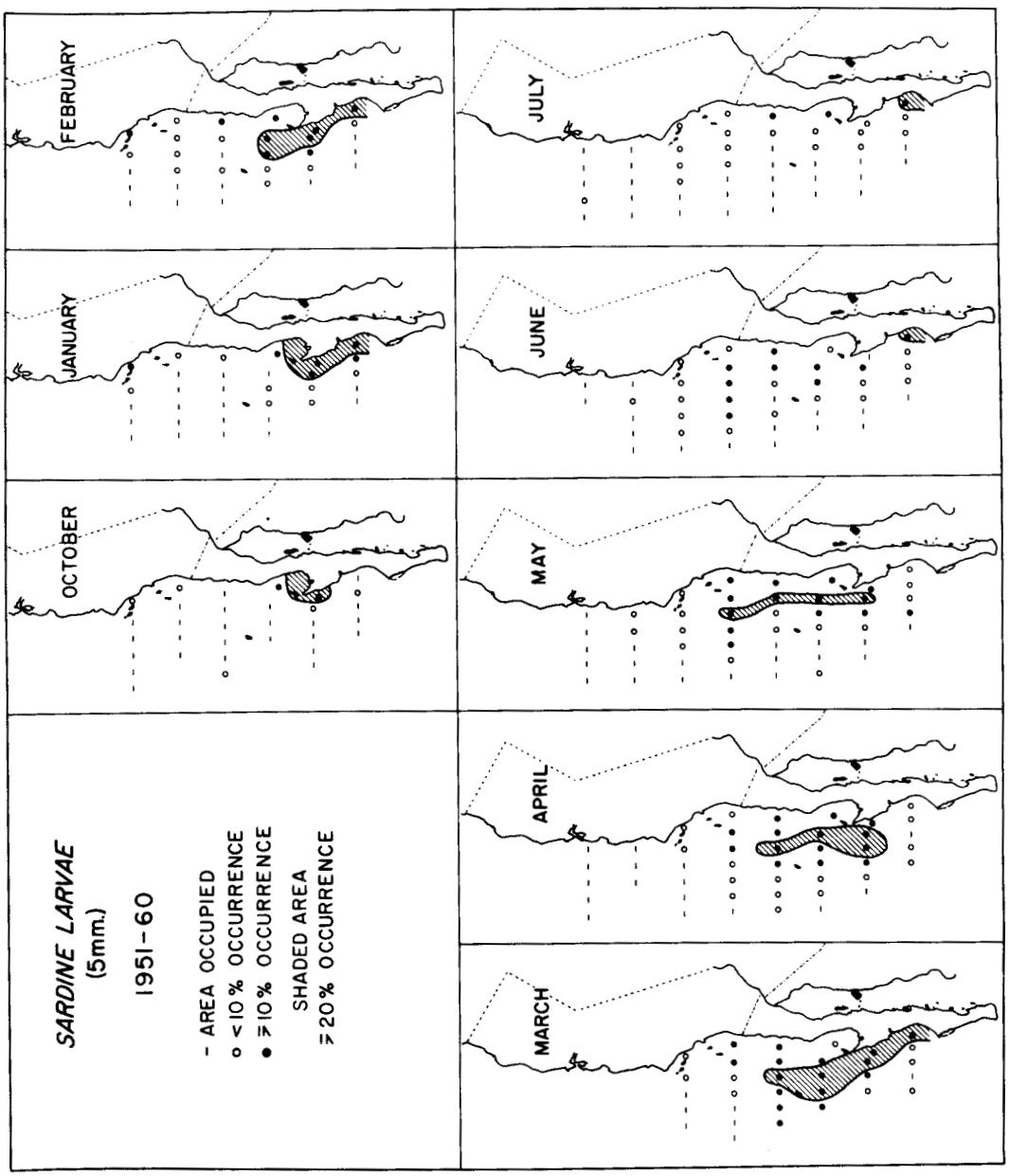

Fig. 2 - Percent occurrence of 5-mm sardine larvae in 1951-60 on the survey pattern of the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Each circle, line or dot represents a pooled statistical area (see Kramer and Smith, 1970a).

quantities of jack mackerel and squid. In 1968, pelagic wetfish resources (including squid) supported a catch of approximately 115 million pounds valued at over $3.1 million to the fishermen.

"A number of interrelationships exists in the wetfish fishery. Since the same basic fleet harvests different wetfish species, economic factors, changing abundance and variation in local availability, and fishing restrictions on one species may affect the fishing pressure placed upon others in the group. The northern anchovy is the sardine's principal competitor for food and occupies the same general geographic range. The increase of the anchovy population size followed closely the decline of sardine stocks. This indicates the possibility of increasing sardine stocks by increasing fishing pressures on anchovies and eliminating them on sardines. An experimental fishery to do this has been proposed, but only has been initiated on a partial basis because of political and sociological reasons."

The experimental anchovy fishery was a recommendation for 200,000 tons, discussed briefly by us (Kramer and Smith, 1971a) and detailed by Messersmith (1969).

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