Sardines and "Substitute Sardines"

With a declining catch, the sardine industry has been forced to seek and use more of those species which are usually mixed in with sardine schools, the anchovy, the jack mackerel, the Pacific mackerel. We call these fish "substitute sardines" because being less profitable to can or process than sardines, they are being fished extensively at present only in lieu of the sardine. These fish have always been taken in some numbers, but only recently have they played much of a part in the total California catch. For the 26 years preceding the 1946-47 season, in fact, the sardine dominated all California marine fisheries in numbers caught (Fig. 21), and in dollar value amounted at times to 40 percent of the total value of California landings (Fig. 22).

During the 1952-53 fiscal year, the work of the Marine Research Committee was supported by a special tax on anchovy, jack mackerel, and Pacific mackerel, as well as sardine landings. The additional tax support did not require extensive reorientation of the research program, for inevitably in the study of sardines we have collected much information on those fish which are competitors and sometimes predators of the sardine. It was not until 1952 that the catch of these "substitute sardines" exceeded the sardine catch itself (Fig. 23).

The "substitute sardines" are collected as eggs and larvae (Figs. 24 through 26) and are sampled during the young-fish surveys. Comparative data on the feeding habits of larval sardines, jack mackerel, and anchovy have been collected (Fig. 27). Figure 28 shows observations made on all four species during the young-fish surveys.

In the following sections, we shall summarize in turn what we have learned of each of the "substitute sardine" species.

ANCHOVY

The Catch

Anchovies taken in the California fishery have two major uses, bait and canning. Formerly bait, both live and dead, exceeded canning in importance and still does in Southern California. In this region the live-bait fishery used 7,000 tons in 1952, and the Central California canneries brought the total anchovy catch to 34,500 tons.

Age Composition

Preliminary analyses of the 1952 catch indicate that in Central California the 1950 and 1949 year classes each contributed about 30 percent of the fish and the 1948 year class about 25 percent. The remaining 15 percent came from older age groups. In the Southern California fishery the 1951 and 1952 year classes were taken in considerable numbers and the catch in general consisted of anchovies one or two years younger than in the Central California catch. Anchovies in the Southern California fishery ranged in length from 2.5 to 7.5 inches and in Central California from 4.5 to 8.0 inches.

Distribution

Anchovies are found along the Pacific coast of North America from British Columbia south to the lower tip of Baja California. Off California and Baja California the 1950-52 surveys indicate that greatest abundance is reached in Southern California waters (Fig. 28). Throughout California they exceeded the abundance of the sardine during these three years but off Baja California in the young-fish surveys the anchovies were considerably less abundant than the sardine.

JACK MACKEREL

The Catch

Jack mackerel did not become of great importance in the California fishery until the 1947-48 season when slightly over 71,000 tons were caught. In the succeeding seasons the catch has fluctuated between 25,000 and 65,000 tons. The landings have varied in general with the successes and failures of the sardine and Pacific mackerel fisheries. Jack mackerel serve as a substitute canning fish when the latter two species are not obtainable in sufficient quantities to meet the canned fish demand. Over three-fourths of the catch has been taken in Southern California waters and landed in the Los Angeles region.

Age Composition

Preliminary studies of the ear bones of the jack mackerel have shown that these fish attain an age of over 25 years. Most of the fish in the commercial catch have been less than six years old with the majority either two, three, or four years. On rare occasions catches have been made of extremely large individuals ranging in age from 10 to over 25 years. These largest fish are between two and two and one-half feet long and weigh over four pounds. The majority of the jack mackerel in the catch were from 8 to 15 inches in total length.

Distribution

Only one species of jack mackerel occurs along the Pacific coast of North America. It ranges from Acapulco, Mexico, northward to British Columbia and offshore over 500 miles. A superficially similar fish, the Mexican scad, which is rather abundant off Baja California and has been taken off San Clemente Island, California, could be confused with the jack mackerel.

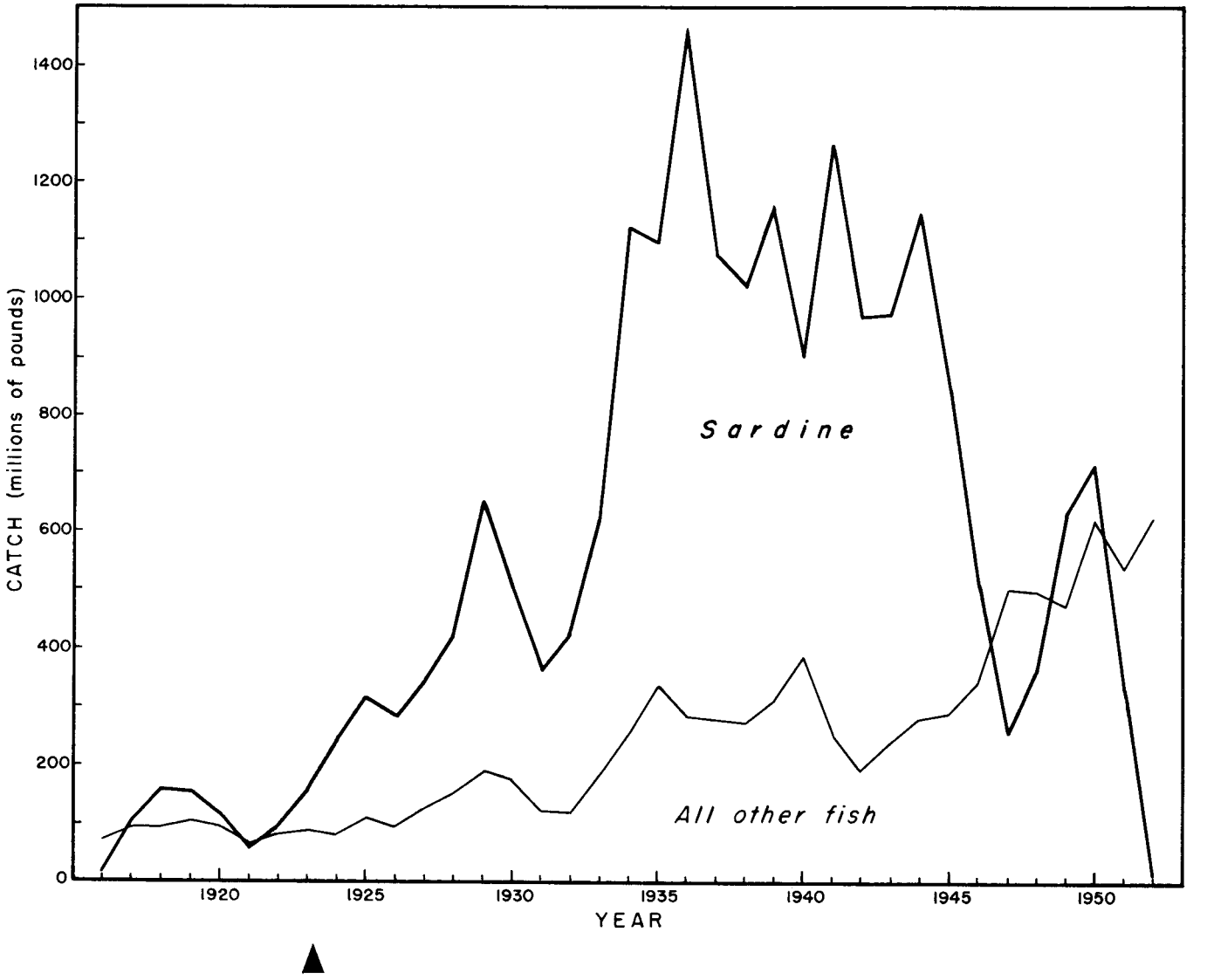


FIGURE 21. From 1922 to 1946, the catch of Pacific sardines exceeded in weight that of all other California fisheries combined, particularly so during the 1930's.

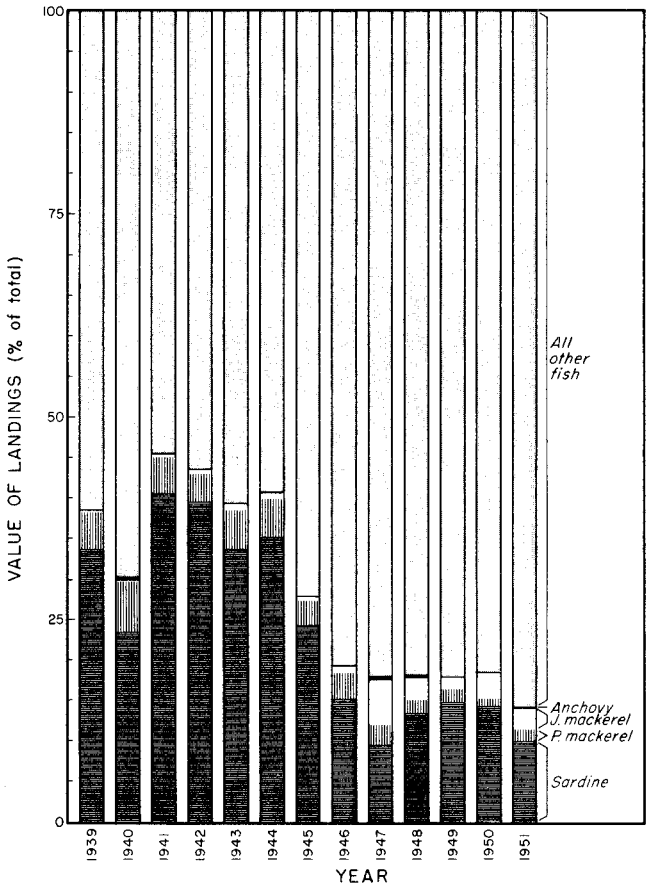
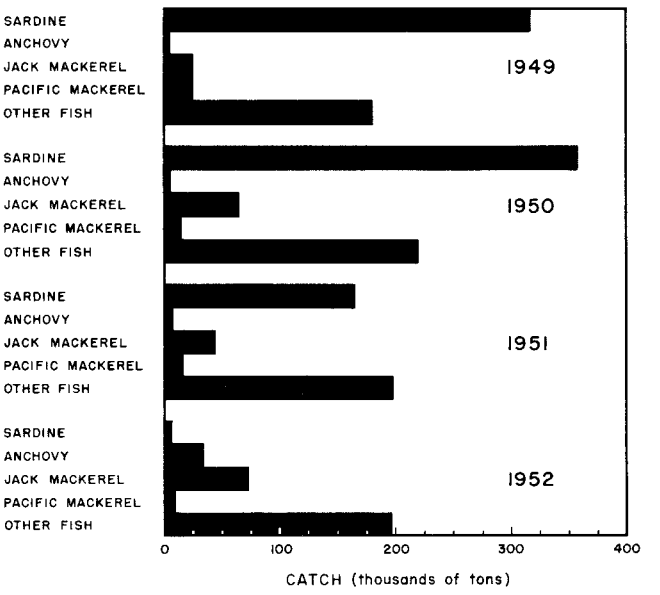


FIGURE 22. In the 13 years, 1939 through 1951, the sardine accounted at times for almost half the total dollar value of all California landings and shipments of fish, mollusks, and crustaceans. But recent years have shown sharp decreases in the sardine percentages, sharp increases in those of the "substitute sardines," Pacific mackerel, jack mackerel, and anchovy. There has been an increasing dependence on jack mackerel and anchovy as the sardine catch has declined.

FIGURE 23. Catches of sardines and Pacific mackerel have shown a downward trend since 1949. Landings of anchovy, jack mackerel, and other species have increased.



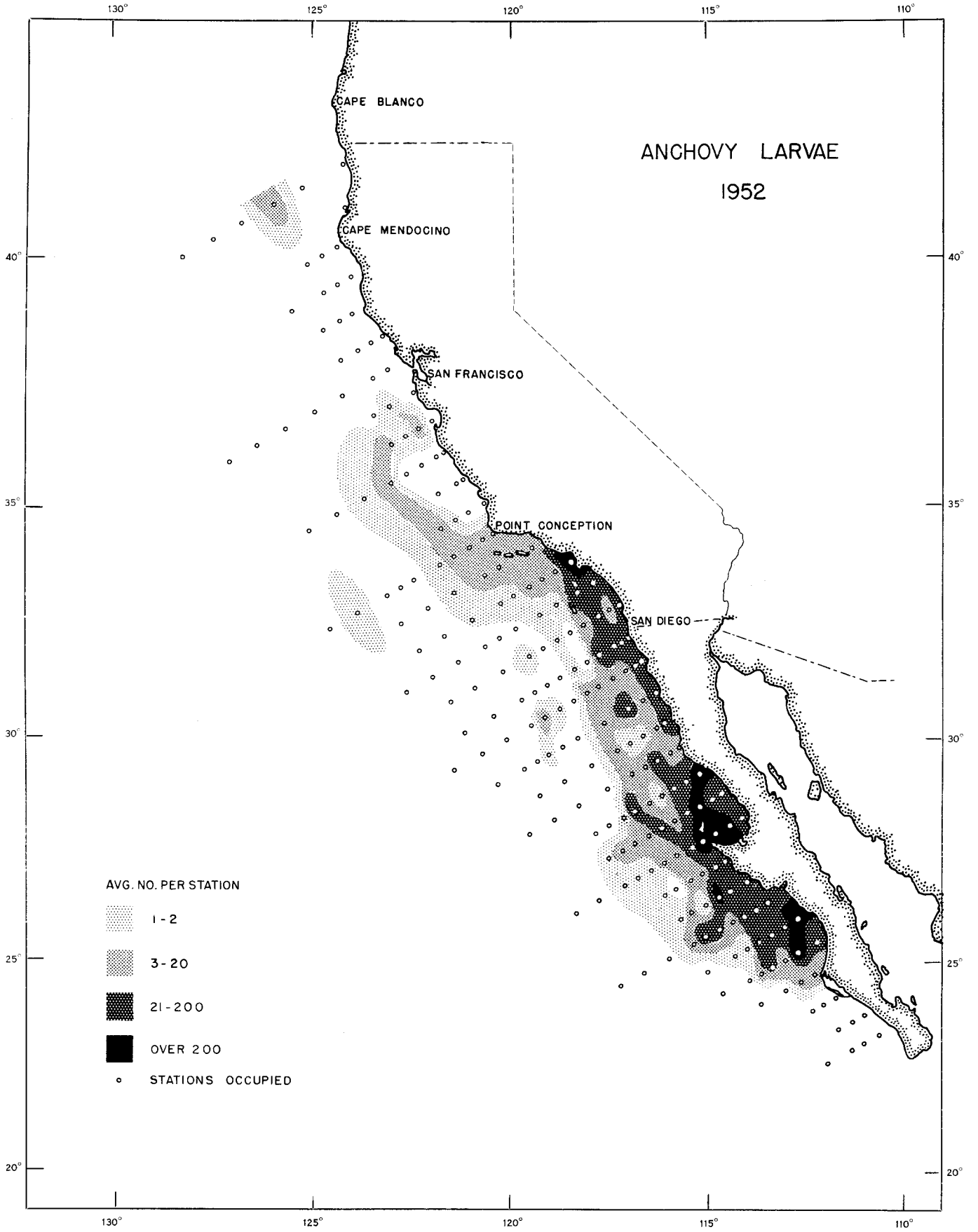

ANCHOVY LARVAE
1952
CAPE BLANCO
CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
130°
125°
120°
115°
110°
40°
35°
30°
25°
20°
AVG. NO. PER STATION
1-2
3-20
21-200
OVER 200
STATIONS OCCUPIED

FIGURE 24. During both 1951 and 1952, we have found anchovy larvae second in abundance in our collections, being exceeded only by hake larvae. (The hake is not fished commercially on this coast.) Although anchovies are known to spawn from British Columbia to Cape San Lucas, the larvae are taken in greatest abundance to the south of Point Conception. The larger concentrations of anchovy larvae occurred in a coastal band seldom more than 100 miles wide and usually much narrower, but some larvae were taken as far as 200 miles offshore during 1952. However, a noticeable difference between the distribution of anchovy larvae in 1952 as compared to the preceding year was the concentration of the larvae closer to shore.

To the north of Point Conception, anchovy larvae were obtained during a three-month period, July through September, though never in large numbers. Off Southern California and adjacent Baja California, on the other hand, anchovy larvae were taken on every cruise.

Anchovy larvae were approximately four times as abundant off central Baja California as off Southern California and adjacent northern Baja California. The largest concentration of larvae—over 200 per haul on the average—was obtained in Sebastian Vizcaino Bay. Collections made within 50 miles of the coast in other areas off central Baja California averaged approximately 140 larvae per haul, as compared to approximately 35 larvae per haul off Southern California.

Approximately 60 percent of the larvae taken off Southern California were collected within 25 miles of shore, and 83 percent within 50 miles of the coast. In the central Baja California area, larvae were equally abundant out to 50 miles from shore, 77 percent being contained in this zone. Only about 1 percent were taken farther offshore than 100 miles in Southern California waters, while nearly 7 percent occurred at distances greater than 100 miles off central Baja California.

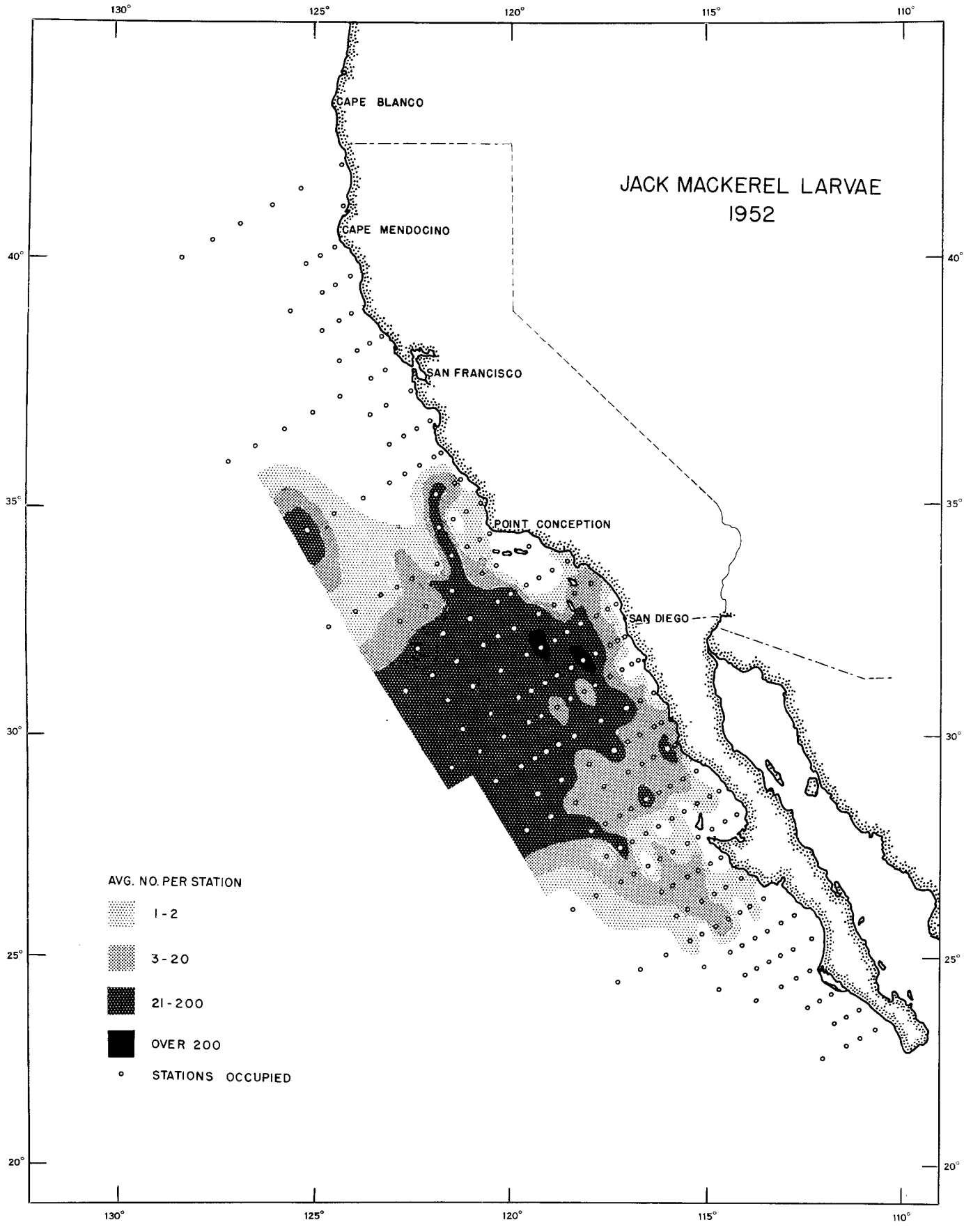

JACK MACKEREL LARVAE
1952
CAPE BLANCO
CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
130°
125°
120°
115°
110°
40°
35°
30°
25°
20°
AVG. NO. PER STATION
1-2
3-20
21-200
OVER 200
STATIONS OCCUPIED

FIGURE 25. We have found the center of abundance of jack mackerel larvae is off Southern California and adjacent Baja California, between Point Conception and Cape San Quintin. The season of greatest abundance is during the five-month period, March through July.

Jack mackerel larvae are taken farther offshore than either sardine or anchovy larvae, the largest concentrations occurring between 50 and 200 miles to sea. During 1952, the larvae were found farther offshore (160-240 miles from the coast) during the early months of the year and closer inshore (50-125 miles from the coast) during the months July through September. We are not delimiting the offshore distribution of jack mackerel larvae. This is especially true of the 1952 cruises, when offshore coverage was less extensive than during either 1950 or 1951. The distribution of jack mackerel during 1952 was rather similar to that found during 1950. Both seasons differed from 1951 in two respects: (1) the peak of abundance occurred a month later than during 1951 and (2) the larvae were not distributed as far northward. During 1952 only 2 percent of the larvae were taken to the north of Point Conception, while during 1951 nearly 15 percent of the larvae were found in this area.

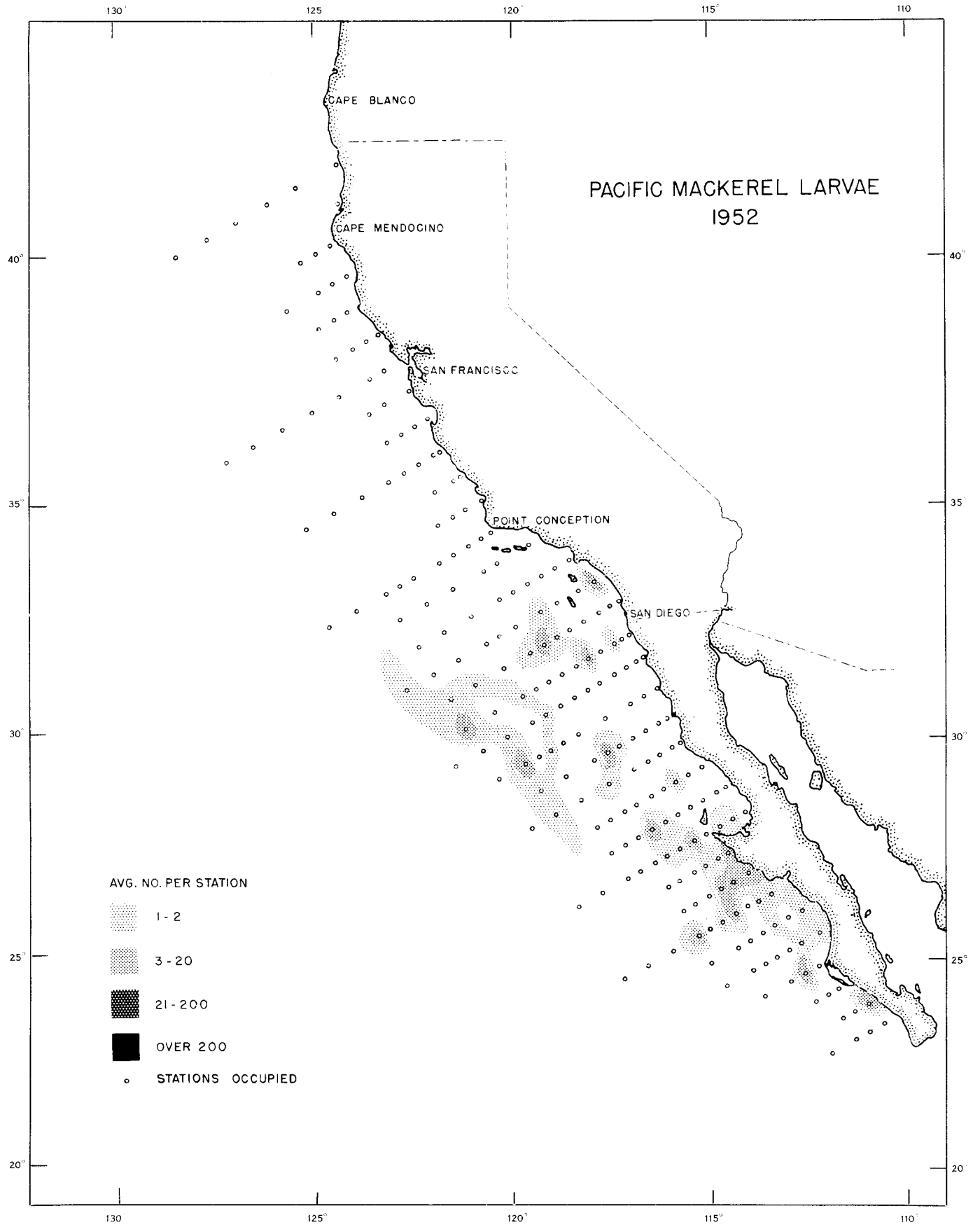
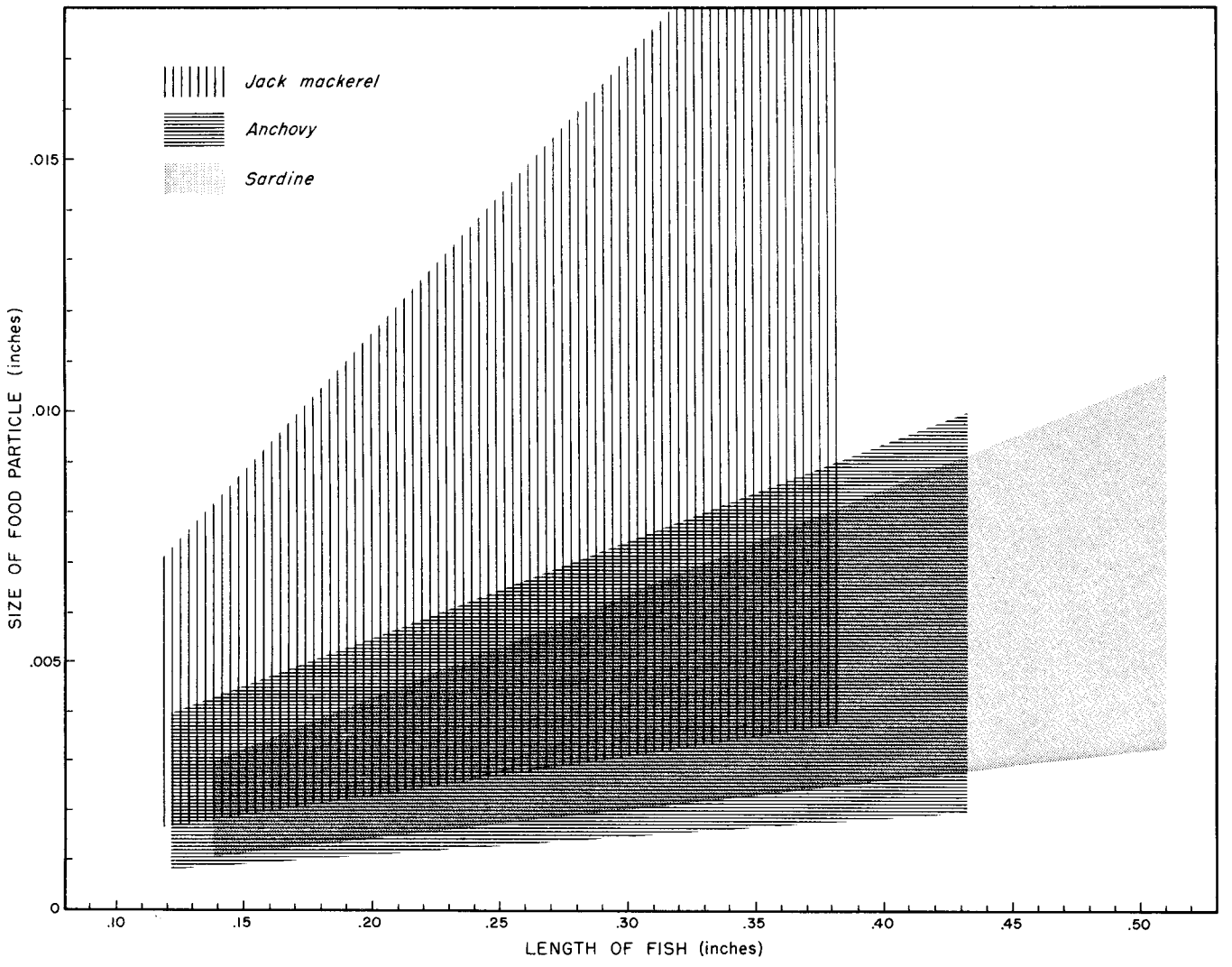

PACIFIC MACKEREL LARVAE
1952
CAPE BLANCO
CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
130°
125°
120°
115°
110°
40°
35°
30°
25°
20°
AVG. NO. PER STATION
1 - 2
3 - 20
21 - 200
OVER 200
STATIONS OCCUPIED

FIGURE 26. Pacific mackerel larvae occur off Southern California and along the length of Baja California. The larvae have a fairly widespread distribution, especially off Southern California, occurring as far seaward as 300 miles. During the 1952 season approximately 20 percent of the Pacific mackerel larvae were obtained off Southern California and adjacent Baja California, and 80 percent off central Baja California. The period of maximum occurrence off Southern California during 1952 was May through July. The season was a month later than during 1951, when the largest numbers were taken during April, May, and June. Off central Baja California the larvae have been taken during every month of the year. During 1952, the largest numbers were obtained during April and May. In many respects the distribution of Pacific mackerel larvae is similar to the distribution of sardine larvae (Fig. 9). There are two major centers of abundance, one off Southern California and adjacent Baja California, the other off central Baja California. The largest numbers of larvae of both species are taken in the southern spawning center. Even the seasons of spawning of the two species are similar, being mostly limited to April through June (or July) off Southern California, while occurring during most of the year off central Baja California. In the latter center the larvae of both species are taken farther offshore during the spring months than during the late summer or fall, when most occurrences are within 25 miles of the coast.

FIGURE 27. Competition for food between the sardine and other species seems to be at its most intense during the larval stages when, our studies have revealed, the anchovy and sardine compete directly for microscopic food items. The jack mackerel larva, which is larger than either the anchovy or sardine larvae, also eats some particles of the same size, but feeds more on larger items which the anchovy and sardine larvae are unable to ingest. This information comes from studies of the food contents of several hundred larval sardines, anchovy, and jack mackerel.



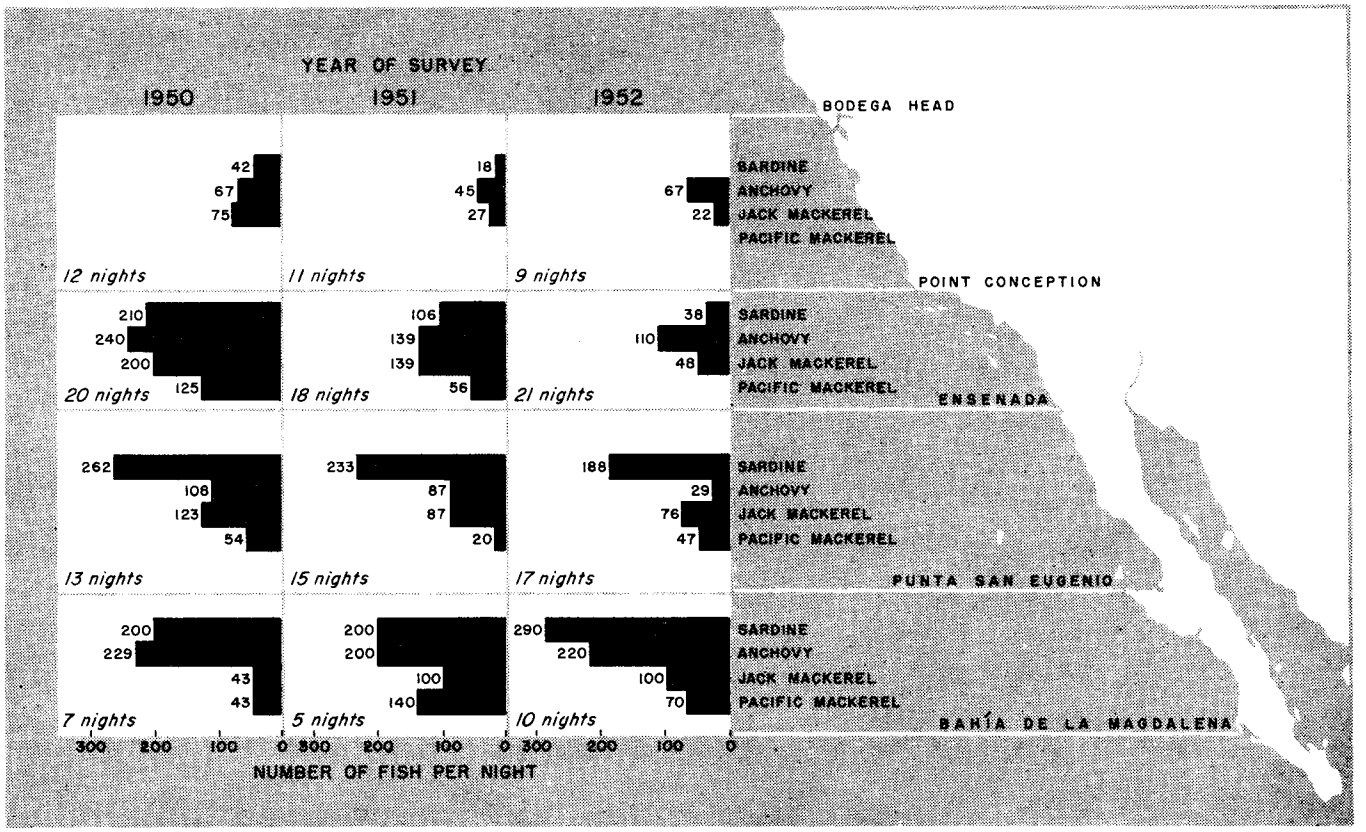


FIGURE 28. The young-fish surveys collect specimens of all four species. Here we show the numbers of sardines, anchovies, jack mackerel, and Pacific mackerel collected per night at various areas along the coast during the surveys of 1950, 1951, and 1952. In 1952 only anchovy and jack mackerel were collected north of Point Conception. The largest numbers of all species were collected off southern Baja California.

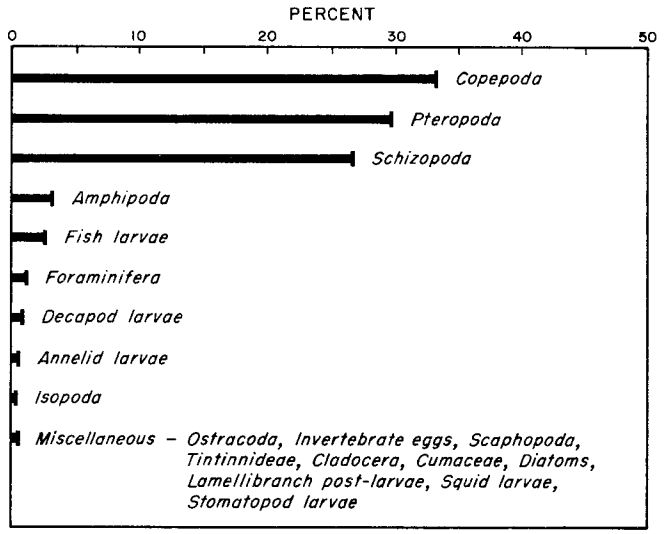


FIGURE 29. The jack mackerel feeds largely on small crustaceans, these creatures making up about 65 percent of the food items eaten by fish studied. Minute mollusks make up another large percentage of the food of the jack mackerel. Percentages are based on numbers.

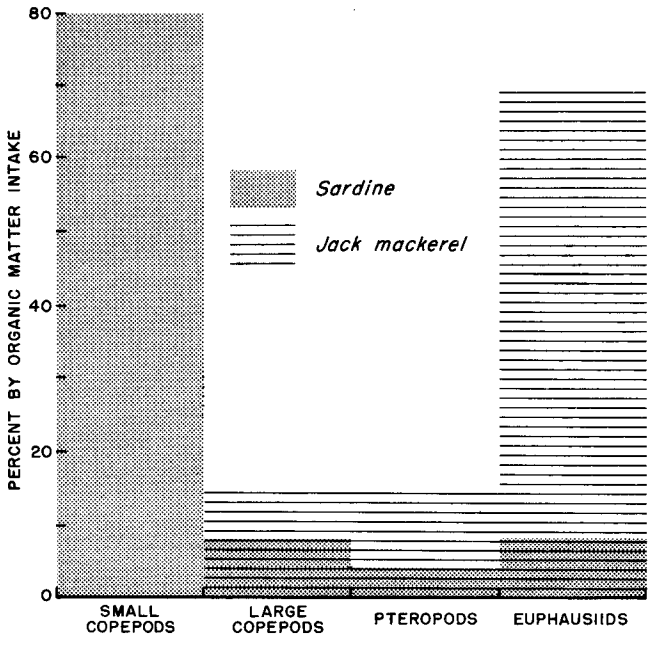


FIGURE 30. Competition for food hardly exists between the adult sardines and jack mackerel. Here we show the percentage by volume of organic matter intake of several food items important in the diet of both species. The overlap of the two shaded areas shows the amount of competition.

Jack mackerel occur farther offshore than other species and our surveys only reflect the relative abundance of these fish in the inshore waters.

The 1950 and 1951 surveys indicate that jack mackerel were most abundant off Southern California and northern Baja California but in 1952 a somewhat greater proportion was found in central Baja California. Off southern Baja California the numbers of jack mackerel declined in all surveys (Fig. 28).

Food

Food studies of 150 juvenile and adult jack mackerel showed 51 percent with some identifiable food present. Over 90 percent by numbers of all food consisted of small crustaceans (copepods), larger shrimp-like crustaceans (euphausiids) and minute mollusks (pteropods) (see Fig. 29). Crustaceans alone made up 65 percent of all food eaten. Among the juvenile fish copepods were a more important food item than among the adults. These crustaceans and mollusks are among the most common animals in the plankton and it seems probable that food does not limit the distribution of jack mackerel to any particular area.

Samples of planktonic food taken from the waters where the jack mackerel were found indicate that most of the food utilized by the jack mackerel is taken by a definite act of capture. In any given stomach, only a few at most of all the different organisms present in the plankton were found. Were the jack mackerel, like the sardine, a filter-feeder, merely swimming about, mouth open, the gill rakers would strain out many more types of organisms than are ever found in the stomach analyses. In addition, many stomachs have certain organisms present in far greater proportion than in the plankton collected at the time the fish were caught. This is particularly noticeable for those fish in which the stomach was greatly distended by large quantities of euphausiids with no other food present. Jack mackerel frequently can be taken on feathered and other artificial lures, on strikers and on cut bait, which is further evidence of a particulate feeding habit.

Since the sardine and jack mackerel sometimes occur together in schools, spawn in part on the same grounds, and occupy in part the same waters off our coast, it is of interest to see how much competition there is between these species for food.

A comparison (Fig. 30) indicates that here too there may be competition, but perhaps even to a lesser extent than between their larvae. The sardine is an omnivorous filter-feeder which at times may exercise its ability to select particular items from the plankton, while the jack mackerel is entirely a selective particulate feeder eating the larger planktonic animals. Over 90 percent by numbers of the food of the jack mackerel consists of three types of animals, euphausiids, large copepods, and pteropods (small

mollusks), whereas by numbers the minute phytoplankters make up more than 99 percent of the diet of the sardine. On a basis of the volume of the actual organic matter (nutritive material) the phytoplankters in the food of the sardine assume a relatively minor role, while copepods become the most important single item, they alone being accountable for at least 80 percent of the nutritive intake of the fish. It should be emphasized here that the copepods eaten by the sardine are for the most part small, while those eaten by the jack mackerel are large. If we consider the diet of the jack mackerel in terms of nutritive value we discover it has quite a different aspect than the presentation by numbers might suggest. On a basis of organic matter the euphausiids become the most significant single food item, accounting for approximately 70 percent, while the large copepods and pteropods together make up most of the remaining 30 percent. The euphausiids which appear to be so important to the jack mackerel account for only 3-4 percent of the total food of the sardine and therefore very little competition exists for this food item. Also, owing to the differences in sizes of copepods used by the two fish, little competition exists here, and the same is true for the pteropods, of which the sardine eats about one-eighth the amount of the jack mackerel. The percentages in Figure 30 are based on the assumption that the four food groups included make up 100 percent of each fish's diet. From the figure it appears obvious that very little direct competition for food exists between these fish and that they may better be spoken of as complementary feeders than as competitors.

PACIFIC MACKEREL

The Catch

For the 23 seasons 1930-31 through 1952-53 the catch of the Pacific mackerel totaled 713,570 tons. Of this 92 percent was landed in the Los Angeles region (Fig. 31). Since the peak season, 1935-36, the total catch has trended downward with a marked acceleration after 1944-45.

Age Composition

Although Pacific mackerel may live to be at least 12 years old, fish over eight years are extremely uncommon in the commercial catch. Pacific mackerel attain a length of about 10 inches and a weight of a quarter of a pound during their first year. A 12-inch mackerel is nearly three years old and weighs three-fourths of a pound. The largest Pacific mackerel on record was 24.8 inches and weighed 6½ pounds. In general two- and three-year-old mackerel have made up the bulk of the catch. In the past few seasons, however, conditions have paralleled those of the

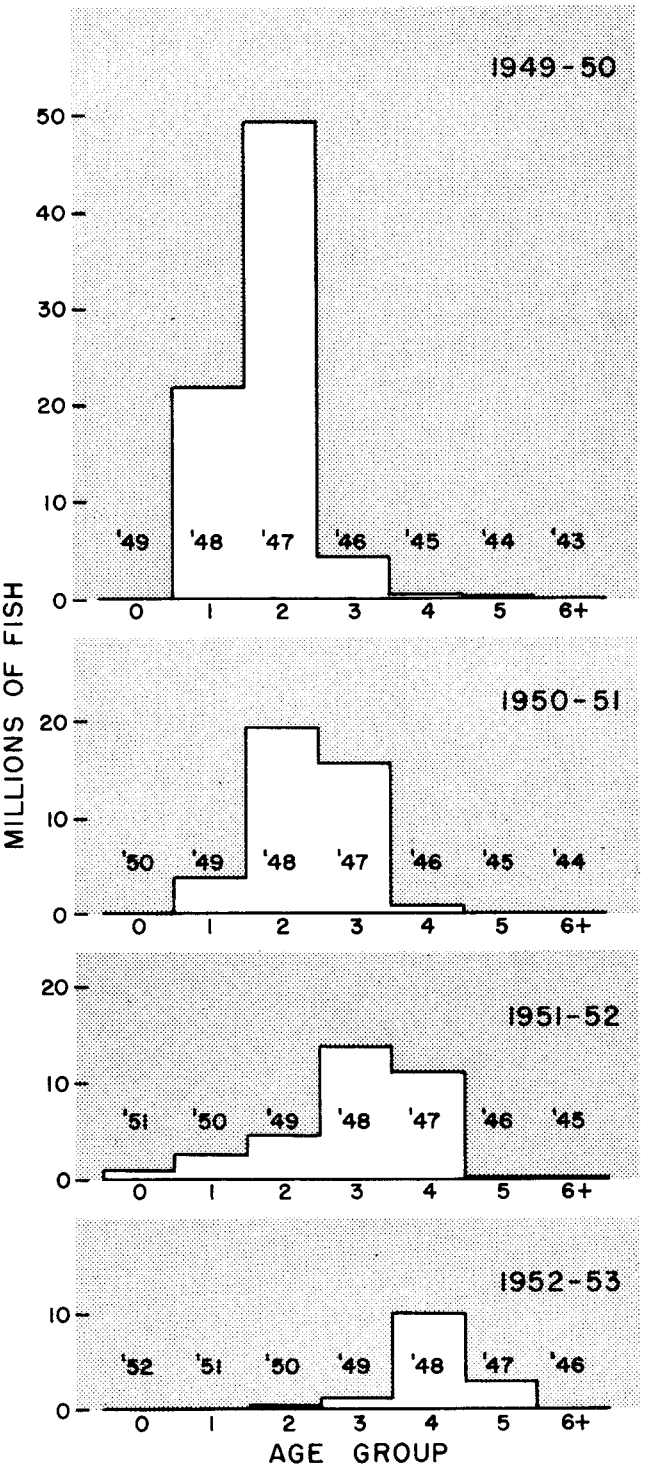


FIGURE 31. The Pacific mackerel catch in the past few years has consisted chiefly of fish from the 1947 and 1948 year classes. Total catch has declined.

sardine. Younger year classes have not appeared on the fishing grounds to replace the older mackerel as the latter disappear from the fishery. As a result the declining fishery has been supported by three-, four- and five-year olds, now few in number.

Three year classes, 1938, 1941, and 1947, have made outstanding contributions to the fishery. Over 125,000,000 fish were taken from each of these groups. The smallest contributions were made by the 1946 and 1949 classes, furnishing only about 10,000,000 fish each. Thus, as with the sardine, Pacific mackerel year-class sizes are variable, some being as much as 12.5 times as abundant as others. Preliminary estimates indicate that the 1950, 1951, and 1952 year classes may not supply even 5,000,000 fish before they are exhausted.

Distribution

The range of the Pacific mackerel extends from the Gulf of Alaska southward into the Gulf of California and off the tip of Baja California at Socorro and San Benedicto Islands in the Revillagigedo group. Racial analyses indicate that within this range there might be as many as five reasonably distinct populations among which little mingling occurs. However, tagging experiments demonstrate that many of the fish from the northern and some from the central Baja California groups ultimately enter the California fishing grounds. San Roque Bay, 60 miles south of Punta San Eugenio, represents the southern point along the Baja California coast from which such recoveries were made.

Data from the surveys of 1950, 1951, and 1952 indicate that Pacific mackerel were the least abundant of the four principal species sampled (Fig. 24). In 1950 Pacific mackerel were most common off Southern California and northern Baja California. In 1951 they were in greatest abundance in the area between Punta San Eugenio and Punta Abreojos. In 1952 these fish were about equally distributed over the areas off central Baja California; none were found north of Ensenada.

Food

The usual diet of the Pacific mackerel includes anything that can be swallowed, from fish, squid, and tunicates several inches long down to copepods smaller than fleas. Although as a rule mackerel are exceedingly voracious, there are times when they appear decidedly "choosy" about their food.

SUMMARY: THE STATUS OF THE SUBSTITUTE FISH POPULATIONS, 1 JULY 1953

1. Landings of anchovies, especially in central California, would indicate that this population is satisfactorily abundant, although the appearance of the anchovies on the fishing grounds is somewhat sporadic and seasonal. The same seems to be true of the jack mackerel population in Southern California. Pacific mackerel catches, on the other hand, indicate a low abundance of these fish throughout all California waters.
2. Young-fish surveys, designed primarily to sample sardines, also sample anchovies, jack and Pacific mackerel. With the exception of jack mackerel these surveys give an estimate of the relative abundance of the four species and their distribution along the coast from Northern California to southern Baja California. Jack mackerel schools occur farther offshore than do the other species and the surveys only reflect the relative abundance of these fish in the inshore waters. This was evident in the 1952-53 season when jack mackerel were scarce on the Southern California fishing grounds but the fishermen were able to bring in good tonnages from the offshore banks. This offshore fishery, however, did not yield any appreciable tonnages of sardine or Pacific mackerel.
3. The lowest abundance of all species occurred off central California. The numbers of Pacific and jack mackerel declined steadily in the Southern California waters throughout the three years of the surveys but showed a slight increase off Baja California. Anchovies were more abundant off Southern California and Baja California than off central California. Off California their greatest abundance occurred in 1950. They were slightly more abundant in 1952 than in 1951.
4. From 1950 to 1952 the decline of sardines on California grounds was steady and rapid. Pacific mackerel, at a lower level at the beginning, disappeared almost completely by 1952. Anchovy and jack mackerel also declined but at a slower rate. Throughout the three years their abundance exceeded that of sardines.
5. In Baja California waters, jack mackerel decreased slightly and anchovies more markedly. Pacific mackerel did not decline and showed a minor increase in 1952. They were the least abundant of all species, however, on the Baja California grounds as well as off California.

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