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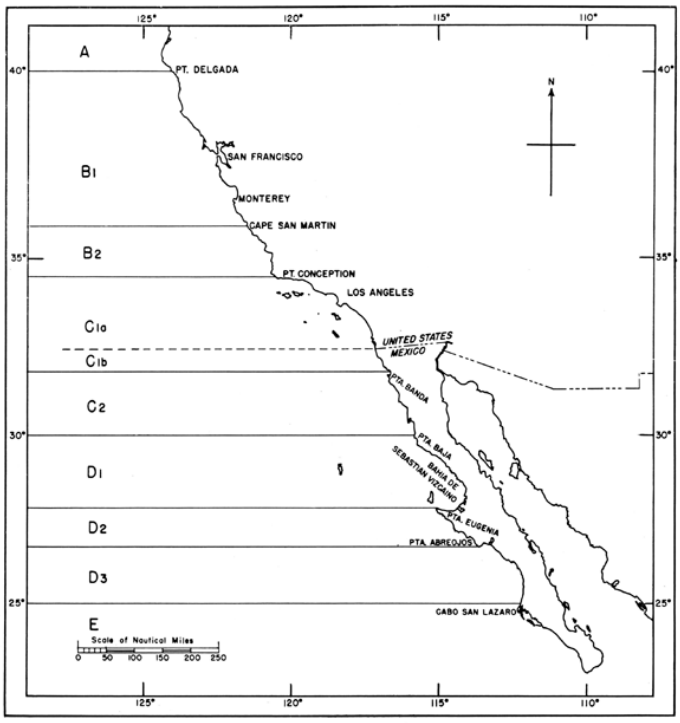
Surveys Through 1951 of the Distribution and Abundance of Young Sardines (Sardinops caerulea)

By
JULIUS B. PHILLIPS
and
JOHN RADOVICH
1952



Geographic boundaries of the areas covered by the young sardine surveys

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ACKNOWLEDGMENTS

Throughout all the surveys much assistance has been received from many members of the staff of the Bureau of Patrol and the Bureau of Marine Fisheries. The authors were accompanied on all cruises by one or more biologists and the work could not have been carried out without their help. Age determinations of sardines collected in 1950 and 1951 were made by the biologists carrying on the routine age analyses of sardines in the commercial catch. Robert C. Wilson supervised the experimental cruises in 1949 and part of the 1950 survey. His work laid the foundation for the routine program now established.

Thanks are also due to the crews of the various vessels used in the studies, especially the masters, Walter Engelke of the BLUEFIN, Lars Weseth of the ALBACORE and the N. B. SCOFIELD, Paul Petrich of the YELLOWFIN. The many weary hours spent at sea have yielded much greater returns because of the knowledge possessed by these men of the coast line, of the ocean and of the fishes contained therein.

JULIUS B. PHILLIPS
JOHN RADOVICH
April, 1952

1. THE YOUNG SARDINE SURVEYS OF 1938, 1939, 1940, 1950 AND 1951

By

JULIUS B. PHILLIPS and JOHN RADOVICH

The sardine population along the Pacific Coast of North America is subject to large fluctuations in the survival of sardines from each season's spawning. This results in some very abundant year classes, some very sparse and some of intermediate strengths. The relative abundance of each year class can be measured in its second or third year when it is first taken in the commercial fishery but it is of material help to the industry and to the biologist to know the abundance of each year class as early as possible. The California Department of Fish and Game has attempted to measure such abundance by surveys along the coast in the late summer and fall months when a new year class of sardines is about six months old.

The first exploratory surveys were conducted in California and Mexican waters during the fall months of 1938, 1939 and 1940. These were discontinued because the correlation between the observed abundance of young fish on the nursery grounds and the subsequent abundance of these fish in the commercial catch was not in good agreement. This was due in part to lack of certain equipment, such as recording echo-sounders, which were not in general use at that time, and in part to an exceptional spawning in 1939 north of the area covered by the survey. This resulted in a serious underestimate of the abundance of the 1939 year class.

Since the earlier survey, the need for a knowledge of the strength of incoming age groups has become even greater. The older sardines, which acted as a buffer against wide fluctuations in the strength of individual year classes, are no longer on the fishing grounds. As a result the industry is dependent upon younger fish, and a weakened fishery now exists which yields a widely fluctuating harvest, varying as varies the abundance and distribution of young sardines one to three years old.

There have been many new developments since the earlier surveys that aid in collecting and compiling the data. The evaluation of the strength of year classes is now possible through the development of a method of age determination (Walford and Mosher, 1943). The relative abundance of a year class can now be traced from its first appearance in the commercial catch until it is no longer taken in the fishery. During the surveys sardines of all age groups can be collected and their estimated abundance checked against similar estimates from the commercial catch.

The California Cooperative Sardine Research Program under the auspices of the Marine Research Committee is collecting data regarding concentrations of sardine eggs and larvae throughout the distribution of the sardine. This information about the location of sardine spawn is collected each season prior to the beginning of the young fish survey and the range of the survey can be established thereby. This should prevent omission from the survey of the nursery grounds to the north or south of the usual spawning area as occurred for a major part of the 1939 year class.

New tools are also most useful. The development of radar has been of great help in allowing the vessel to work closer inshore at night. It also makes it possible to define more accurately the locations where fish are found. The echo-sounder aids in finding schools which cannot be located visually.

TABLE 1

Number of Schools of Young Sardines Observed During the Fall Months of 1938, 1939, 1940, 1950, 1951

Area	Number of schools by year class				
	1938	1939	1940	1950	1951
Central California (B-1, B-2)	4	31	62	4	1
Southern California (C-1a)	745	1	46	3	6
Baja California (C-1b-E)	69	31	96	17	21
Totals	818	63	204	24	28

TABLE 1

Number of Schools of Young Sardines Observed During the Fall Months of 1938, 1939, 1940, 1950, 1951

Although the earlier surveys are not directly comparable with the later, some marked differences in the two time periods are evident. The most striking is the greater abundance of young sardines in all areas in 1938–40 than in 1950–51 (Table 1). Although this is most apparent in Central and Southern California it is also true for the Baja California region. There is no indication that lack of sardines in California waters in the later years has been compensated by an increase in abundance off Baja California.

The maximum surface temperatures where sardine schools were found are similar for both time intervals. The 1938, 1939 and 1940 surveys were extended farther south than the 1950 and 1951 cruises but sardines were not found at temperatures greater than 26.1° C. In the later surveys the highest temperature at which sardines were found was 25.7° C. The maximum surface temperature encountered on all cruises was 28.3° C. The later cruises recorded minimum temperatures as low as 10.4° C. but no sardines were located at temperatures below 11.4° C. The lowest temperature on the earlier cruises was 11.7° C.

1.1. REFERENCES

Walford, Lionel A., and Kenneth H. Mosher 1943a. Studies on the Pacific pilchard or sardine (Sardinops caerulea). 2. Determination of the age of juvenile by scales and otoliths.
U. S. Dept. Int. Fish and Wildlife Service, Special Scientific Rpt. No. 20, p. 1–17, 32 figs.

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2. REPORT ON THE SURVEY FOR YOUNG SARDINES, SARDINOPS CAERULEA, IN CALIFORNIA AND MEXICAN WATERS, 1938–40

By JULIUS B. PHILLIPS

2.1. METHODS

2.1.1. Time and Area Surveyed

The work of Scofield (1934) on the eggs and larvae of the sardine showed that general spawning can be expected from Cape San Lucas, at the tip of Baja California, northward to San Francisco, but with the main spawning region off Southern California from Pt. Conception to San Diego. Temperature conditions in the California current, which seasonally ranges off the coasts of Washington, Oregon and California, are favorable for sardine spawning. But since this current is somewhat weak and variable during the spring and summer months, any spawning north of San Francisco would appear to be fortuitous.

During surveys conducted in 1931 and 1932, Scofield found that the youngest larvae, ranging in size from those just hatched to 10 mm. in length, occur in about the same region as do the eggs. There was a slight indication of a southern movement. The intermediate-sized larvae, from 10 to 20 mm. in length, were variable in their distribution. During 1931, they showed a marked inshore movement, but from the 1932 data they appeared to spread to some extent. The main movement, however, was to the southeast, that is, inshore. The largest larvae, from 20 to 35 mm. in length, occurred in a very narrow strip along the mainland south of Pt. Conception and around the Channel Islands. This was especially true in 1931. In 1932, although the same distribution was prevalent, there was more of a scattering of these largest larvae. Some were taken well offshore and others were taken north of Pt. Conception, but the great bulk was taken inshore below Pt. Conception. A varied distribution of larvae can be expected from year to year; however, the region of maximum abundance should lie between Pt. Conception, California and Magdalena Bay, Baja California.

Godsil (1930) reported that in the region adjacent to San Diego Bay during July, swarms of recently metamorphosed sardines, approximately 45 mm. in length, appear on the shallow flats. In our work along the Baja California coast during October and November, 1938 and 1940, we obtained a few recently metamorphosed sardines in the shallow portions of Turtle, Thurloe and Asuncion Bays.

In the region to the northward of Pt. Conception, particularly at Monterey, it appears that more time is consumed by the larvae in their shoreward movements. Data gathered in the Monterey area in August and September of 1939 and 1940, indicate that the young sardines do not ordinarily gain the comparative safety of inshore flats until they attain a standard length of about 55 mm. or larger. On the other hand, young sardines, 36 to 75 mm. standard length, were obtained from the stomachs of albacore caught offshore in the Monterey region, during August and September of 1939 and 1940, previous to the inshore appearance. After the young sardines made their appearance on the inshore nursery grounds, there was a corresponding decrease in the quantities found in albacore stomachs.

The initial survey for the 1938 season was planned for the fall period of September-November. If the investigation were started too soon after the period of main spawning, it might result in not obtaining the fullest representation of the surviving young, while, if the investigation were started too late, early winter storms might interfere with the completion of the survey.

The territory between Pt. Reyes, California (Lat. 38° 00' N.), on the north and Magdalena Bay, Baja California (Lat. 24° 20' N.), on the south was chosen for the first season's work. During the following two seasons, this territory was extended to Bodega Head (Lat. 38° 20' N.) on the north, and to Cape San Lucas at the tip of Baja California (Lat. 22° 50' N.) on the south. This southern extension embraced the lower portion of the Gulf of California, adjacent to the Baja California coast. This territory readily separates into the Central California, Southern California, Baja California and Gulf of California regions. The dividing line between Central and Southern California is Pt. Conception, and the United States-Mexico boundary separates Southern California from Baja California.

Because our information indicated that young sardines are apt to be tardy in appearing in inshore areas of Central California, it was decided to work the southern regions first. The schedule of cruises followed during the first season's survey proved to be satisfactory and so this plan was followed during the succeeding two seasons of work. Accordingly, the Southern California region was surveyed first, about September, then the Mexican waters about October, and lastly the Central California region, about November.

2.1.2. Vessels Used

The State Fish and Game motor vessel, ALBACORE, was used in this investigation during the first cruise in the fall of 1938, in Southern California waters. The remaining two cruises in the fall of 1938, in Baja California and in Central California waters, were carried out with the State Fish and Game motor vessel, BLUEFIN. For all cruises in the fall of

1939, and of 1940, the State Fish and Game motor vessel, N. B. SCOFIELD, was used.

The ALBACORE, built in 1916, was 60 feet long, 12½ feet of beam and had a draft of 5 feet. She was originally equiped with a 65-horsepower gasoline engine, but this was later replaced with a 60-horsepower diesel engine, and still later with a 90-horsepower diesel engine. Her cruising speed was about nine knots with the latter engine. The normal crew complement was three men, including the captain. This ship was decommissioned and sold several months after the N. B. SCOFIELD was launched in 1938.

The BLUEFIN was 86 feet long, 18½ feet of beam and had a draft of 7¾ feet. She was powered with a 200-horsepower diesel engine. Her cruising speed was about 9½ knots. The normal crew complement was five men, including the captain. This vessel was lost during World War II.

The N. B. SCOFIELD, launched December 17, 1938 is 100½ feet long, 24 feet of beam and has a draft of 13¾ feet. She is powered with a 350-horsepower diesel engine, with a supercharger that gives an additional 70 horsepower. Her cruising speed is 10½ knots. The normal crew complement is nine men, including the captain. This vessel was expressly designed and built to carry on marine fisheries research.

2.1.3. Gear

In the course of the young sardine surveys, several types of gear were used to capture fish. A small lampara net, 100 fathoms long and 10 fathoms deep, at the bag, was successful in shallow water. A larger lampara net, 150 fathoms long and 20 fathoms deep, at the bag, was required in somewhat deeper water. These two lampara nets were of standard design with the bag in the middle and gradually tapering wings on either side. The mesh in the bag portion of each net was of ½-inch mesh, while the mesh in the wings graduated to eight inches at the ends. These nets were operated from a skiff towed behind a launch. Two men were required to pull on each end of the small lampara, and three men on each end of the large lampara. In either case, two additional men were necessary, one to operate a "scare," to keep the fish back toward the net while the net was being hauled, and the other man was needed to maneuver the launch (Figures 1 and 2).

A small purse net of light construction, and referred to as a ringnet, was tried, not with the object of sampling schools but in an attempt to encompass entire schools, to determine the amount of fish in a school. However, this did not prove practical. The ringnet was built along the lines of a regular purse seine, being rectangular in outline and with the bag at one end. The net was pursed by means of a pursing line that ran through rings attached to the leadline. The main body of the net consisted of ½-inch webbing. When used on the ALBACORE the ringnet was 95 fathoms long and 18 fathoms deep. When the ALBACORE was replaced by the N. B. SCOFIELD, the length of the net was doubled and the depth increased to 25 fathoms. The ringnet was operated directly from the ship (Figure 3).

As a possible aid in obtaining samples of fish quickly, a large metal tow net was tried during the 1938 work. This did not prove satisfactory because it could not be towed fast enough through the schools. The metal

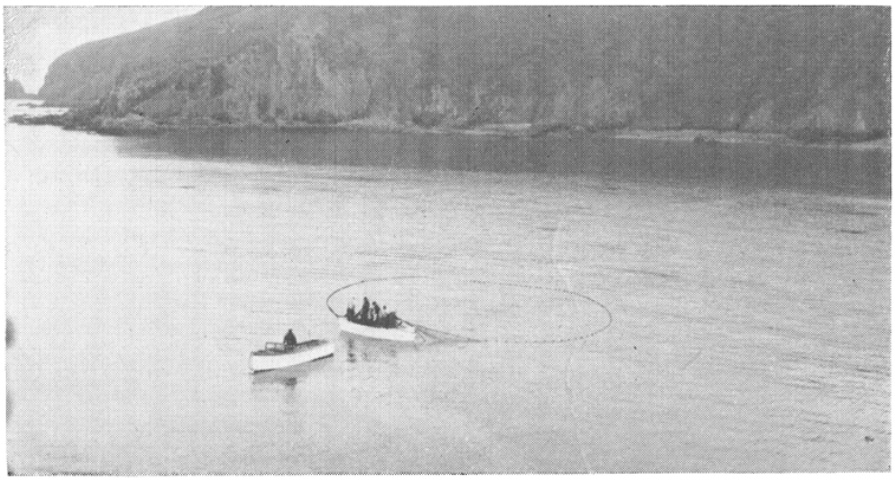

FIGURE 1. Lampara net hauled in Drakes Bay, Central California, for young sardines. November, 1940. *Photograph by Edward F. Dolder.*

FIGURE 1. Lampara net hauled in Drakes Bay, Central California, for young sardines. November, 1940. Photograph by Edward F. Dolder.

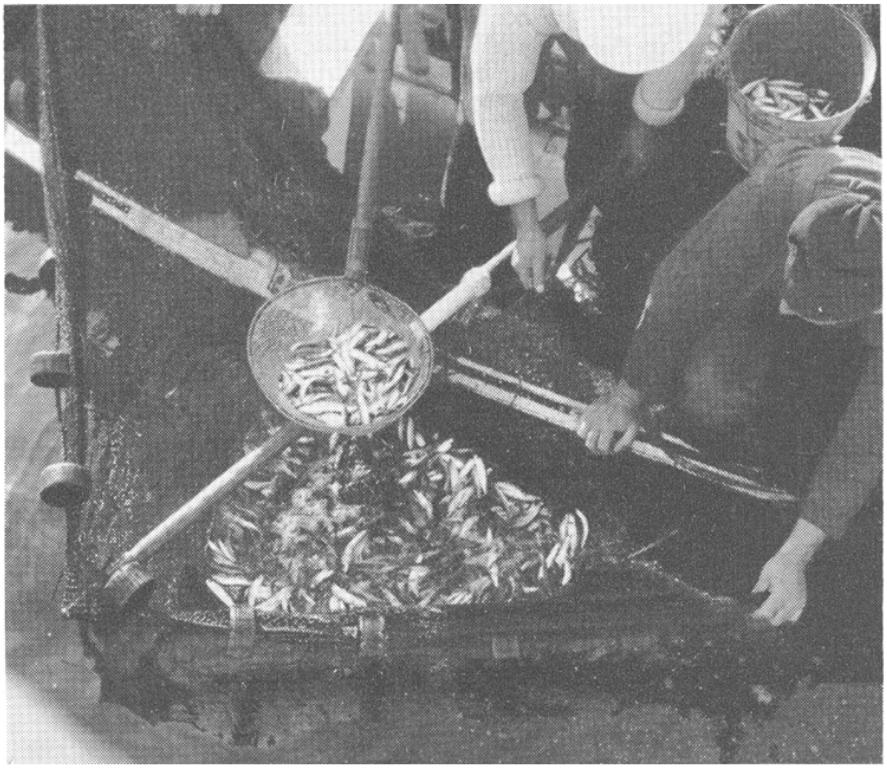

FIGURE 2. Sample of young sardines from lampara net haul in Drakes Bay, Central California. November, 1940. *Photograph by Edward F. Dolder.*

FIGURE 2. Sample of young sardines from lampara net haul in Drakes Bay, Central California. November, 1940. Photograph by Edward F. Dolder.

net had the shape of a truncated cone, six feet in length, one meter in diameter at the larger, mouth end and 10 inches in diameter at the small end. The pipe framing was covered with 18-gauge, ¼-inch bar mesh. Fitted into the mouth of the net was a two-foot long funnel section that was 10 inches in diameter at the posterior end. This metal net was tried also with short sections of webbing lashed on the sides of the mouth to act as wings. This latter addition hardly improved the effectiveness of the net.

FIGURE 3. Six-ton catch of young anchovies in ringnet haul off Santa Cruz Island, Southern California. October, 1938. *Photograph by J. B. Phillips.*

FIGURE 3. Six-ton catch of young anchovies in ringnet haul off Santa Cruz Island, Southern California. October, 1938. Photograph by J. B. Phillips.

In bodies of fresh water and in estuaries and tide-pools, that have relatively narrow confines, powdered derris root is successful, since it impairs respiratory functions of fish so that they can be collected. A section of stovepipe was used to drop this material below the surface of the ocean near schools of fish in open water, but the fish simply moved away from the vicinity where the substance was introduced.

In some cases, samples of fish were obtained by means of dynamite. This was usually used offshore, and when water conditions made netting difficult. One-quarter to one-half a stick of ordinary stumping dynamite was usually sufficient, when properly placed in a school, inasmuch as we did not require more than a hundred fish for a sample. Sometimes we missed obtaining fish because the school veered away when the charge was thrown, but in general the results were satisfactory. The use of explosives, when judiciously handled in small quantities, is not more wasteful than netting operations. The dynamite was exploded by lighting the fuse and then throwing the charge at the mark.

In 1939 and 1940, we sampled some schools of bait by shooting an occasional feeding pelican and examining its stomach contents. The contents of a pelican's stomach can be ejected readily by first slitting the stomach and then forcing water down the gullet. When a water hose is not available, water scooped into the pouch and compressed into the throat will serve as well.

On some occasions, samples of sardines were obtained from commercial bait boats and bait receivers encountered in the course of our field work.

While anchored in coves and bays along the coast at night, an electric light was suspended over the side of the ship to attract fish for identification. Some recently metamorphosed sardines were taken by this means

in Baja California. A method that is successful with larval and postlarval fishes is to lower a silk plankton net below the surface for a fathom or so. After the fish have collected above the mouth of the net, the light is extinguished and at the same instant the net is hoisted quickly to the surface. Greater speed can be attained in the hoisting by reeving the pull rope through a block on a boom. Somewhat larger fish can be taken with a dip net or by snagging with small gang hooks.

2.2. SCHOOLING HABITS

Young sardines exhibit signs of their gregarious habit from the time they cease to be larvae. However, it is not until a standard length of about 55 mm., or 2½ inches total length, has been attained that the young fish unmistakably display the schooling habits associated with the fish in later life. The tiny fish are apt to be found mixed with other tiny fishes in shallow waters. As the sardines grow into young fish, they tend to school by themselves to a greater degree. But, if the sardines in a certain district are scarce and anchovies abundant, sardines may be found scattered throughout some of the schools of anchovies and vice versa. In some cases, we have found schools of sardines in close proximity to schools of anchovies without apparent intermingling, but in other cases we have found varying proportions of mixing. In addition, in Central California, young sardines were sometimes mixed with similar sized jack smelt and top smelt (family Atherinidae). In Baja California, in addition to anchovies, young sardines were on some occasions found mixed with schools of similar sized round herring (family Dussumeridae) and thread herring (family Clupeidae).

When the young sardine survey was initiated in the fall of 1938, the field operations were conducted at night. The schools of fish were located by the luminescence resulting from their movements in the water. Before long we discovered that the field operations could be conducted during daylight hours with greater success. The chief disadvantage of night work is the restricted visibility, which confines observations to schools not far removed from the vicinity of the boat. Also the handling of gear is hampered by darkness. In the daylight operations we depended upon visual observations when fish were at or near the surface. Many times the activities of sea birds indicated the presence of bait. When other boats were found working on bait in any area, the crews were contacted for information or for samples (Figure 4).

During the early summer and fall months, schools of young sardines and anchovies will often be observed at or near the surface from day-break until midmorning and again from late afternoon until dark. When there is little or no wind and the sky is overcast, schools may be in evidence throughout the day. When the surface of the ocean becomes choppy, the detection of schools becomes difficult.

During our daylight surveys, we have had to examine carefully a great many schools, especially to differentiate between anchovies and sardines. Many times, we have noted the fish in these schools definitely going through the motions of feeding. In fact, in many cases we have been able to ascertain if the schools contained sardines by the characteristic individual feeding motion.

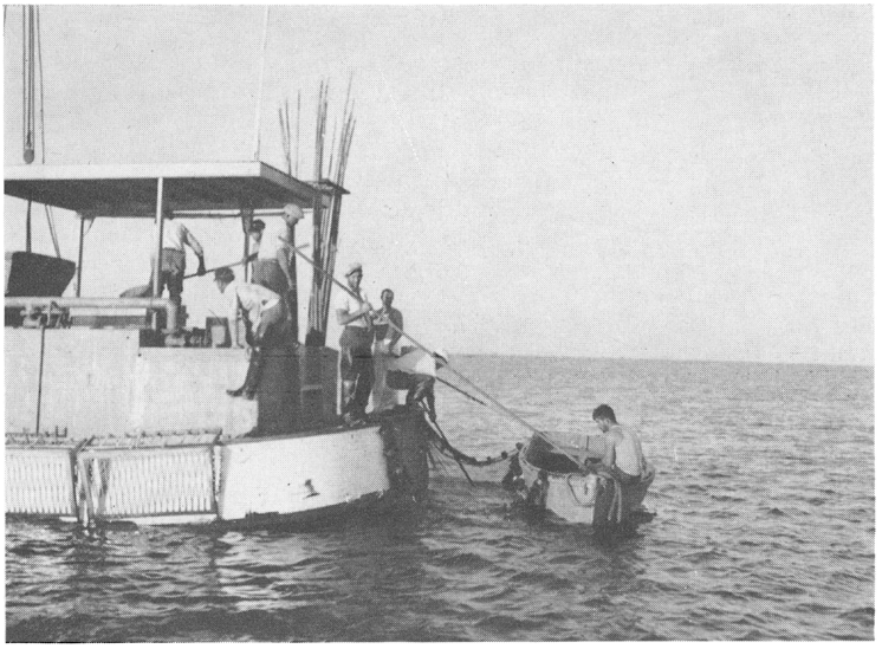

FIGURE 4. Crew of tuna boat SEA WOLF transferring young sardines to bait tank from haul in Magdalena Bay, Baja California. November, 1938. *Photograph by J. B. Phillips.*

FIGURE 4. Crew of tuna boat SEA WOLF transferring young sardines to bait tank from haul in Magdalena Bay, Baja California. November, 1938. Photograph by J. B. Phillips.

Schools of young sardines and bait fish in general are continually menaced by their natural enemies. The close schooling of sardines and a number of other pelagic fishes is a protective reflex that has served innumerable generations of these species, as a defensive response to predatory fishes. A school may split up a number of times, but this results in several smaller schools rather than a wild scattering of individuals of which fish predators would make short work. On one occasion, in Baja California waters, we observed about fifteen barracuda harassing a small school of anchovies that had collected under a light hung over the side of the ship at night. The anchovies were feeding on planktonic organisms and apparently paying little attention to the grim activities of the barracuda. The barracuda could be seen darting at the fringes of the school and occasionally through it. It was surprising how infrequently an anchovy was captured. When a barracuda charged through the school, the school split along this path and reunited like a well-drilled unit. The straggler anchovies paid the penalty.

On another occasion, after we had netted a sample of fish from a school of young sardines off the Southern California coast, we noticed a small pod of sardines that had become separated from the main body of fish. This group was stationary and was being held at the surface by the harassing activities of a number of Pacific mackerel beneath. We backed the boat down and with one sweep of a dip net captured most of the pod. However, before the remaining sardines could reform into a school, the mackerel boiled into the disorganized remnants and made short work of nearly all of the fish.

2.3. RELATION TO SURFACE TEMPERATURES

Inshore water temperatures were taken during all cruises of the young sardine survey. The three seasons' surface temperature increased from 53° F. (11.7° C.) off Point Reyes, California, at latitude 38° 00' N. in November, to 83° F. (28.3° C.) off Cape San Lucas, Baja California at latitude 22° 52' N. in October–November. Traveling up the Gulf of California, on the Baja California side, we found a gradual decrease in surface water temperatures. In the fall of 1939, we made our longest trip up the gulf, going as far as Santa Inez Bay at latitude 27° 00' N. The water cooled from 83° F. at Cape San Lucas to 81.5° F. at Santa Inez Bay. On the return from Santa Inez Bay to Cape San Lucas, we went out toward the middle of the gulf and encountered high temperatures in the vicinity of the thousand fathom curve, temperatures in keeping with those in the neighborhood of Cape San Lucas and the open ocean in that vicinity. Apparently oceanic conditions are associated with the intrusion of the tongue-like thousand fathom contour into the gulf.

In the fall of 1938 the southward cruise into Mexican waters ended at Magdalena Bay, 150 miles north of Cape San Lucas. In the fall of 1939 and 1940, the cruises were continued south of Magdalena Bay to Cape San Lucas, thence up into the lower gulf region. In the two fall periods that the investigation was carried southward and into the gulf, no sardines were found beyond Magdalena Bay. No doubt the most important factor that limits the range of sardines to the southward is high water temperatures. The warmest water in which we found sardines was 79° F. (26.1° C.). This occurred at Santa Maria Bay, adjacent to Magdalena Bay, on October 9, 1939. These were not fish of the year but fish of the previous year's spawning. The above temperature is most likely close to the upper limit tolerated by sardines. Whereas, we found but one school of fish in a water temperature of 79° F., we found several schools at 73° F.

It should not be inferred, on the basis of the data presented, that sardines are not to be found to the southward of Magdalena Bay, nor in the lower Gulf of California region, at other times of the year. The young sardine survey cruises along the Baja California coast were made during the months of October–November, at which time surface water temperatures are apt to be at their highest. Sardines have been found in the Gulf of California on some cruises made in the late winter and the spring months, when water temperatures are lower, by other members of the staff. Tuna fishermen have also reported encountering young sardines in their bait hauls, as far up the gulf as Concepcion Bay, latitude 26° 53' N., during the winter and spring months.

In the course of a cruise up the Gulf of California, along the Baja California side, in May, 1939, H. C. Godsil, while engaged in tuna work aboard the California Fish and Game Research vessel, N. B. SCOFIELD, reported the taking of small sardines in bait hauls made at San Lucas Bay (Lat. 22° 53' N.), at Espiritu Santo Island (Lat. 24° 34' N.) and at San Carlos Bay (Lat. 25° 15' N.). The latter locality was as far up the gulf as the vessel traveled on this cruise.

During another cruise southward to Cape San Lucas, and then up into the gulf, along the Baja California side to Concepcion Bay, January 14–February 13, 1940, D. H. Fry, Jr., and J. F. Janssen, Jr., while

engaged in a mackerel survey aboard the vessel, N. B. SCOFIELD, reported taking some small and large sardines and also sardine larvae in a few localities as far up as Mangles Pt. (Lat. 26° 17' N.). A sample of 30 sardines of 139–240 mm., standard length, the gonads of which were well toward maturity, were taken at Muertos Bay (Lat. 23° 55' N.). Some of these fish were maturing at a size smaller than that noted for sardines in California waters.

Although the territory covered in the Gulf of California in the above mentioned late winter and early spring cruises, was the same as during the young sardine surveys in the fall months, still the surface water temperatures were notably less than those encountered during the fall cruises. None of the temperatures encountered in the late winter and early spring cruises were too high to be tolerated by sardines. During the May, 1939, cruise, surface water temperatures varied from 61.0° F. in Southern California to 79.3° F. off Cape San Lucas. During the January–February, 1940, cruise, the temperatures varied from 61.5° F. in Southern California to 73.0° F., at Cape San Lucas. Progressing up the gulf, on this latter trip, the water became cooler and at Concepcion Bay the temperature had decreased to 66.0° F., more nearly in keeping with Southern California water temperatures, in the fall months.

From data complied to date, it appears that the Gulf of California contributes but little to the main stock of sardines along the Pacific Coast of North America. The greatest proof of this is found in an analysis of the vertebral counts (Clark, 1936, 1947).

2.4. THE 1938 SURVEY

During the 1938 season, the Southern California region was surveyed first in the period September 13th–October 3d. Operations commenced in the southern portion of the region and continued northward through the mainland districts to Pt. Conception. The waters around the northern islands, which include Anacapa, Santa Cruz, Santa Rosa and San Miguel Islands, were investigated, as well as the waters around Santa Catalina Island. Next, the Baja California region was surveyed in the period October 20th–November 18th. These operations were conducted southward along the coast to Magdalena Bay, and included the islands adjacent to the coast. Lastly, the Central California region from Pt. Conception to Pt. Reyes, was investigated in the period December 5th–12th.

In the entire territory covered during the fall of 1938, a total of 818 schools of young sardines was observed. Four schools, or about one percent of the total were found in the Central California region; 745 schools, or 91 percent of the total, in the Southern California region; and 69 schools, or 8 percent of the total, in the Lower California region (Table 1).

In the Central California region, the few schools observed were confined within the 10-fathom contour in the southern portion of Monterey Bay. In the Southern California region, the bulk of the schools were found in the mainland area between Oceanside and Hueneme. About one-half of the total schools in this region were found inside the 15-fathom contour, and the remainder out to the 200-fathom curve. There

TABLE 1

Number of Schools of Young Sardines Observed During Fall Months of 1938, 1939 and 1940

Regions from north to south	Number of schools		
	1938	1939	1940
Central California Region			
Bodega Bay	--	6	--
San Francisco	--	9	19
Halfmoon Bay	--	4	--
Pigeon Point	--	4	--
Monterey Bay	4	8	2
Point Sur	--	--	--
Cape San Martin	--	--	16
Estero Bay	--	--	23
San Luis Obispo Bay	--	--	2
Region totals	4	31	62
Southern California Region			
Gaviota	--	--	2
Santa Barbara	--	--	3
Northern Islands	41	--	1
Hueneme	75	--	13
Santa Monica Bay	106	--	13
San Pedro	194	--	12
Santa Catalina Island	2	--	--
Newport	130	1	2
Oceanside	186	--	--
San Diego	11	--	--
Region totals	745	1	46
Baja California Region			
Point Descanso	1	--	15
Todos Santos Bay	33	2	18
Santo Tomas	--	--	--
Colnett Bay	--	--	--
San Quintin Bay	2	25	16
Point Canoas	--	--	35
Blanca Bay	--	--	3
Sebastián Vizcaíno Bay	--	--	1
Cedros Island	12	1	5
Turtle Bay	3	2	1
Asuncion Bay	--	--	2
Ballenas Bay	--	--	--
Pequena Bay	--	--	--
Magdalena Bay	18	1	--
Region total*	69	31	96
Grand totals	818	63	204

* No schools of sardines were observed southward of Magdalena Bay to Cape San Lucas, nor in the Gulf of California in the fall of 1939 and 1940.

TABLE 1

Number of Schools of Young Sardines Observed During Fall Months of 1938, 1939 and 1940

were three main areas of concentration in the Baja California region: at Todos Santos Bay, at Cedros Island, and at Magdalena Bay. The bulk of the fish in this region were found north of Pt. Santa Eugenia.

The length frequencies of sardines obtained during the course of the 1938 work are shown by districts and regions in Table 2 and in Figure 5.

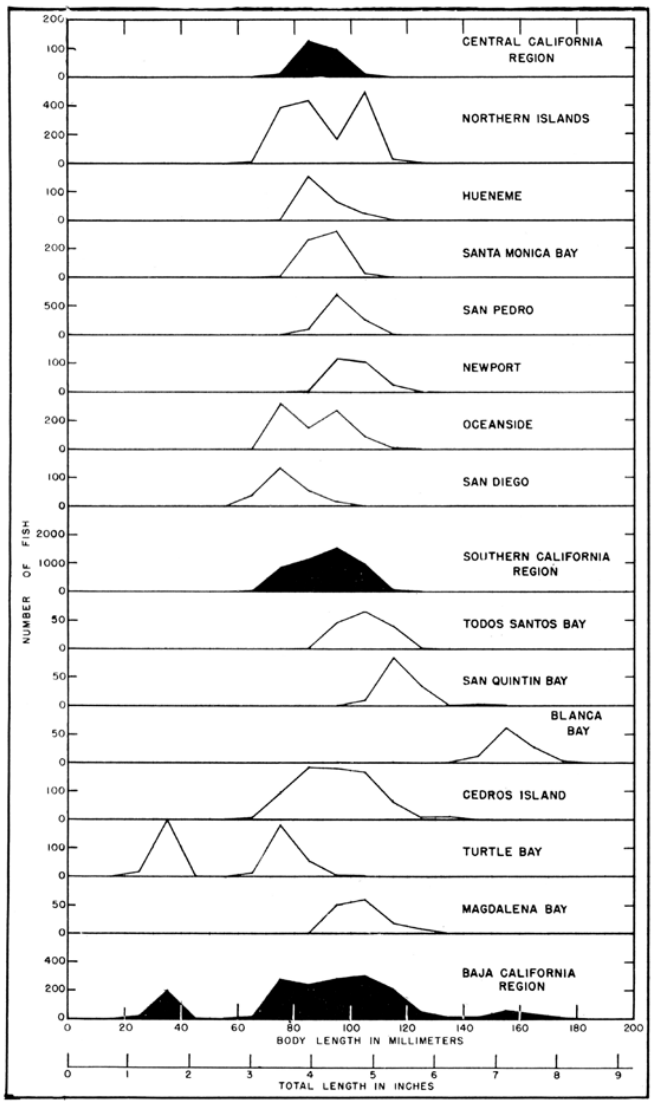

FIGURE 5. Percent of sardines at each length for regions sampled during 1938 young sardine survey

3—63995

FIGURE 5. Percent of sardines at each length for regions sampled during 1938 young sardine survey

TABLE 2

Size Distribution of Sardines Sampled During 1938 Young Sardine Survey by Regions

Body length mm.	Central California Region	Southern California Region							
	Monterey Bay	Northern Islands	Hueneme	Santa Monica Bay	San Pedro	Newport	Ocean-side	San Diego	Total
21-30									
31-40									
41-50									
51-60									
61-70		16					4	41	61
71-80	12	386	2	9	2		321	135	855
81-90	127	436	155	265	81	1	147	56	1,141
91-100	99	168	67	324	560	116	273	17	1,525
101-110	12	500	25	27	211	107	93	1	964
111-120		31	1	3	4	24	8		71
121-130		5				1	1		7
131-140									
141-150					1				1
151-160						1			1
161-170									
171-180									
Totals	250	1,542	250	628	859	250	847	250	4,626

Body length mm.	Baja California Region						
	Todos Santos Bay	San Quintin Bay	Blanca Bay	Cedros Island	Turtle Bay	Magda-lena Bay	Total
21-30					17		17
31-40					199		199
41-50					2		2
51-60							
61-70				8	6		14
71-80				96	182		278
81-90	1			184	56	1	242
91-100	46		1	179	5	51	282
101-110	66	10		167	1	60	304
111-120	40	84	1	63		19	207
121-130	1	35		9		8	53
131-140			1	10			11
141-150		1	12				13
151-160			61				61
161-170			27				27
171-180			4				4
Totals	154	130	107	716	468	139	1,714

TABLE 2
Size Distribution of Sardines Sampled During 1938 Young Sardine Survey by Regions

The size frequencies of samples of young sardines taken at the fresh fish markets in the ports of San Diego, San Pedro and Monterey, over a period of years, indicate that the average size attained by sardines at completion of the first year's growth is about 125 mm., standard length, or 5¾ inches, total length. This size was selected as representing the upper limit of modes for the first year fish. Methods for determining the age of sardines, by means of scales, had not been developed at this time. The modes of all samples, except those for Blanca Bay and a few other scattered fish, fell within this range (Figure 5). No attempt was made to search out schools that were not young fish of the year.

2.5. THE 1939 SURVEY

During the 1939 season, the first and second cruises were made in the Southern California region. The first cruise lasted but 12 days, August 22d–September 2d, because sardines of the year were exceedingly scarce. Inasmuch as this cruise included the full moon period, a second cruise that included the new moon period was undertaken, to determine if this factor had anything to do with the apparent lack of young sardines. The second cruise, September 11th–16th, also revealed an apparent paucity of young sardines.

Scouting during the above two cruises in the Southern California region was conducted along the mainland area from the Mexican boundary northward to Pt. Conception. The waters around the Northern Channel Islands, Santa Catalina Island and San Nicolas Island were investigated, also. Next, the Baja California region was surveyed in the period September 27th–October 30th. This cruise was conducted southward along the coast to Cape San Lucas, at the tip of Baja California, thence into the Gulf of California for about 280 miles along the Baja California side to Santa Inez Bay. Lastly, the Central California region was examined, from Pt. Conception to Bodega Head in the period November 8th–18th.

In the entire territory covered during the fall of 1939, a total of 63 schools of young sardines was found. of these, 31 schools, or 49 percent of the total, were found in the Central California region; 1 school, or 2 percent, was found in the Southern California region, and 31 schools, or 49 percent, in the Baja California region (Table 1).

The one school of young sardines in the Southern California region was taken in the Newport district. The bulk of the schools in the Baja California region was located in San Quintin Bay. All of the schools in the Central California region were found from Monterey northward to Bodega Head (Lat. 38° 17' N.), which was as far north as the investigation extended. Just how far northward of Bodega Bay the young fish occurred could not be determined at the time. Subsequent reports indicated that there was a greater than usual abundance of young sardines of the year north of Bodega Head. British Columbia and Washington State biologists noted, in the summer of 1940, an unusual abundance of young sardines, referrable to a 1939 spawning, in inlets and bays around Vancouver Island and in Puget Sound (Walford and Mosher, 1941). In January–March, 1941, fisheries biologists in the Pacific Northwest noted a considerable mortality among sardines referrable to a 1939 spawning (Pacific Fisherman, 1941; Foerster, 1941). This mortality

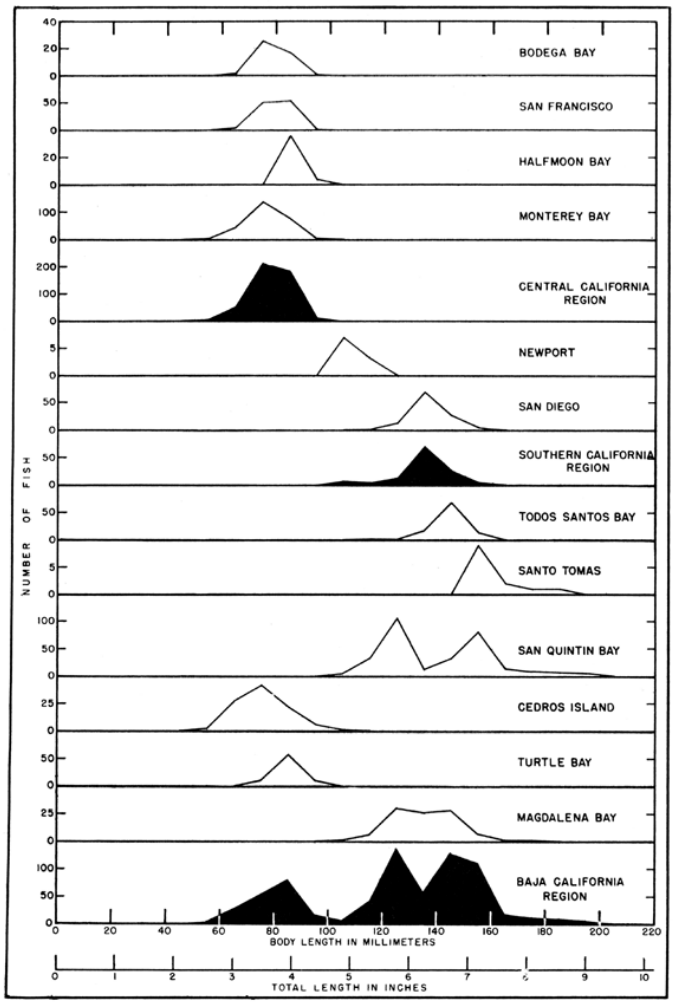

FIGURE 6. Percent of sardines at each length for regions sampled during 1939 young sardine survey

FIGURE 6. Percent of sardines at each length for regions sampled during 1939 young sardine survey

TABLE 3

Size Distribution of Sardines Sampled During 1939 Young Sardine Survey by Regions

Body length mm.	Central California Region					Southern California Region		
	Bodega Bay	San Francisco	Halfmoon Bay	Monterey Bay	Total	Newport	San Diego	Total
51-60				4	4			
61-70	2	5		45	52			
71-80	25	51		137	213			
81-90	17	53	36	77	183			
91-100	1	2	4	4	11			
101-110						7		7
111-120						3	1	4
121-130							13	13
131-140							70	70
141-150							26	26
151-160							4	4
161-170								
171-180								
181-190								
191-200								
201-210								
211-220								
Totals	45	111	40	267	463	10	114	124

Body length mm.	Baja California Region						
	Todos Santos Bay	Santo Tomas	San Quintin Island	Cedros Island	Turtle Bay	Magdalena Bay	Total
51-60				2			2
61-70				27			27
71-80				42	11		53
81-90				22	58		80
91-100				6	10		16
101-110			4	1		1	6
111-120	1		33			6	40
121-130	1		106			30	137
131-140	17		13			26	56
141-150	68		32			28	128
151-160	13	9	81			7	110
161-170		2	14			1	17
171-180		1	9			1	11
181-190		1	7				8
191-200			5				5
201-210							
211-220			1				1
Totals	100	13	305	100	79	100	697

TABLE 3
Size Distribution of Sardines Sampled During 1939 Young Sardine Survey by Regions

was confined to sardines in small bays and inlets. Uncommonly low water temperatures and a somewhat starved condition were noted in these fish.

The length frequencies of sardines obtained during the course of the 1939 work are shown, by districts and regions, in Table 3 and in Figure 6. As with the 1938 survey, the main effort was concentrated on the fish of the year, that is the 1939 year class. Samples of fish of previous year classes that were taken incidentally, are included.

Sardines of the 1939 year class were almost completely absent in Southern California waters during the 1939 survey. Records from the bait fisheries in Southern California also indicated that bait boats were finding very few fish of the 1939 year class. In Baja California waters, the abundance of young sardines of the 1939 year class was about one half as great as that of the 1938 year class observed the previous year. In Central California waters, there were about eight times as many schools of the 1939 year class as of the 1938 year class found the previous year. An equal number of schools of young sardines were observed in 1939 in the Central California and the Baja California regions. However, as pointed out previously, our survey of abundance north of Pt. Conception terminated at Bodega Head, and later evidence indicated that there was an abundance of the 1939 year class as far north as Vancouver Island, British Columbia.

2.6. THE 1940 SURVEY

During the 1940 season, the Southern California region was surveyed first in the period of September 16th–30th. Operations commenced in the southern portion of the region and continued northward along the mainland to Pt. Conception. The waters around the Northern Islands as well as those around Santa Catalina Island were investigated also. Next, the Baja California region was covered in the period October 11th–November 12th. Operations were conducted along the Baja California coast to Cape San Lucas, thence into the Gulf of California for about 100 miles, along the Baja California side, to Espiritu Santo Island. Lastly, the Central California region was examined in the period November 22d–30th. These operations were conducted from Pt. Conception northward to Bodega Head.

In the entire territory covered during the fall of 1940, a total of 204 schools of young sardines of the year were observed. of this total 22 percent were found in the Southern California region, 48 percent in the Baja California region, and 30 percent in the Central California region (Table 1).

In the Southern California region, the greatest concentration of fish occurred between Newport Beach and Hueneme, with a scattering of schools north of Hueneme and around the Northern Channel Islands. In the Baja California region, the schools were found scattered between Pt. Descanso, about 15 miles south of the Mexican border, to Asuncion Bay, about 50 miles south of Pt. Santa Eugenia. In the Central California region, about two-thirds of the total number of schools were encountered in the area between San Luis Obispo Bay and Cape San Martin. Nearly all of the remainder of the schools in the Central California region were found in the San Francisco area.

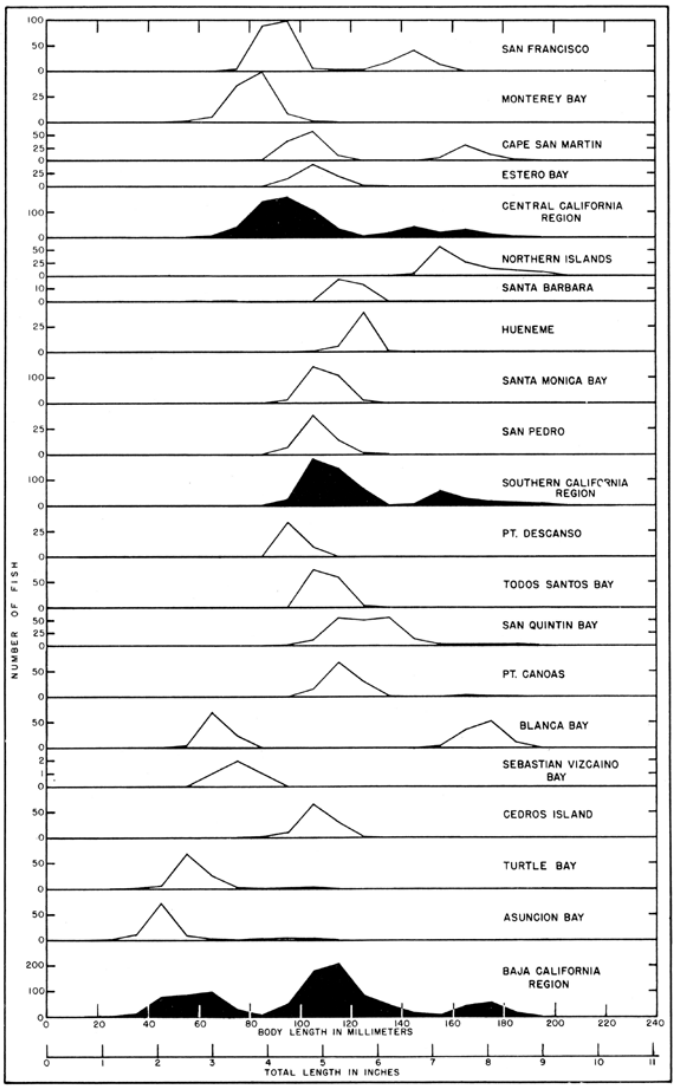

FIGURE 7. Percent of sardines at each length for regions sampled during 1940 young sardine survey

FIGURE 7. Percent of sardines at each length for regions sampled during 1940 young sardine survey

TABLE 4
Size Distribution of Sardines Sampled During 1940 Young Sardine Survey by Regions

Body length mm.	Central California Region					Southern California Region					
	San Francisco	Monterey	Cape San Martin	Estero Bay	Total	Northern Islands	Santa Barbara	Hueneme	Santa Monica Bay	San Pedro	Total
21– 30											
31– 40											
41– 50											
51– 60		1			1						
61– 70		5			5		1				1
71– 80	4	36			40						
81– 90	89	49	2		140						
91–100	98	8	38	14	158				14	7	21
101–110	6	1	57	43	107	1		1	141	38	181
111–120	3		10	19	32	1	17	6	107	14	145
121–130	3			2	5		13	39	11	1	64
131–140	18				18			1			1
141–150	41				41	4					4
151–160	13		6		19	55					56
161–170			30		30	27					27
171–180			12		12	14					14
181–190			2		2	11					11
191–200						7					7
201–210						1					1
Totals	275	100	157	78	610	122	31	47	273	60	533

TABLE 4
Size Distribution of Sardines Sampled During 1940 Young Sardine Survey by Regions

Body length mm.	Baja California Region									
	Point Descanso	Todos Santos Bay	San Quintin Bay	Point Canoas	Blanca Bay	Sebastian Vizcaino Bay	Cedros Island	Turtle Bay	Asuncion Bay	Total
21– 30									1	1
31– 40								1	10	11
41– 50								5	72	77
51– 60					6			68	9	83
60– 70					70	1		25	1	97
71– 80					24	2		1		27
81– 90						1	1		2	4
91–100	33		2				10	1	3	49
101–110	9	73	11	15			66	2	3	179
111–120		58	54	67			30			209
121–130		3	50	29			1			83
131–140			55	1						56
141–150			13							13
151–160			3		4					7
161–170			3	3	35					41
171–180			3	1	51					55
181–190			3	1	10					14
191–200										
201–210										
Totals	42	134	197	117	200	4	108	103	101	1,006

TABLE 4—Cont'd.

Although in the Central California region the main concentration of schools was in the southern portion of the area, there was a strong enough showing in the San Francisco area to indicate that there may have been spawning, and resultant young fish, to the northward of San Francisco, as was the case for the 1939 season.

The sample frequencies obtained during the course of the 1940 survey are shown, combined by districts and regions, in Table 4 and in Figure 7. As with the 1938 and 1939 surveys, the main effort was concentrated on young fish of the year. Samples of fish of previous year classes that were taken incidentally are included.

Sardines of the 1940 year class were more abundant in Southern California waters than were sardines of the 1939 class in the previous fall. Nevertheless, the abundance of the 1940 class in Southern California waters was only about one-fifteenth that of the 1938 class, as determined in the fall of 1938. In the Baja California region, the abundance of the 1940 class was about triple that of the 1939 class, as determined in the previous year's survey, and about 40 percent greater than that of the 1938 class, as determined in the fall of 1938. In Central California waters, the 1940 class was twice as abundant as the 1939 class was in the previous year's survey, and 15 times as abundant as the 1938 class in the fall of 1938.

British Columbia biologists noted young sardines around Vancouver Island in 1941 probably referrable to the 1940 year class. These fish were more sporadic in their appearance, however, than those noted the previous year for the 1939 year class (Canada, Fisheries Research Board, 1941). It appears that spawning and resultant survival of young for 1939 and 1940 was significantly greater than normal in Pacific Northwest waters and perhaps southward to Central California waters.

2.7. OBSERVATIONS ON YOUNG ANCHOVIES

During the three seasons' work, the relative abundance of anchovies in the California waters surveyed was noted. The dominant species of anchovy in the California waters is the northern anchovy, Engraulis mordax. This species is also found in Baja California waters, to some extent, but the estimates of abundance in these waters is complicated by the presence of several other species of anchovies, as well as the round herring (Etremeus othonops), thread herring (Opisthonema libertate), and Sardinella, farther south.

During the 1938–40 surveys, the young of the northern anchovy was found to be much more abundant in Southern California than in Central California waters. In 1938 there was a moderately good showing of young anchovies in Southern California. In 1939 there were about half as many schools of young anchovies as observed in the fall of 1938. In 1940 there was a great abundance of young anchovies—about six times that observed in 1938. During these three years, there was only a scattering of schools of young anchovies in Central California waters.

Where young anchovies and young sardines were found in the same areas, the anchovies were usually found closer to shore than sardines, and in somewhat less clear water. At times we found varying proportions of mixture of the two species in the same school. This was particularly true when one or the other species was scarce.

2.8. CONCLUSIONS

Ten years after completion of the 1938–40 young sardine surveys, the 1938, 1939 and 1940 year classes have passed through the commercial fishery and, for all practical purposes, completed their life span in the ocean.

From the results of the young fish surveys, in the territory in which the surveys were conducted, the 1938 class was considered about 10 times as abundant as the 1939 class, and four times as abundant as the 1940 class. In actual numbers and poundage of fish taken along the Pacific Coast, during the life span of the above year classes, the 1939 class proved to be very strong and the 1938 and 1940 classes moderately strong. Roughly, the commercial fishery took about 800,000 tons from the 1939 class, and about 500,000 tons each from the 1938 and 1940 classes.

Why then did not the young sardine surveys conducted during the fall months of 1938, 1939 and 1940 detect the true magnitude of these respective year classes in the first year of their existence?

The 1938 class, which turned out to be a moderately strong group, was found in its first year of life to be abundant in Southern California waters, less abundant in Baja California waters, and poor in Central California waters. The 1939 class, which turned out to be a very strong group, was very scarce in Southern California waters in its first year, more abundant in Baja California, and especially so, in Central California waters. The 1940 class, which turned out to be moderately strong, was in its first year, least abundant in Southern California waters, more abundant in Central California and most abundant in Baja California waters.

From the foregoing, it would appear that the 1938 class resulted from a fairly successful spawn survival in Southern California waters, whereas the 1939 and 1940 classes were deficient in Southern California. On the other hand, the apparent survival of the 1939 and 1940 classes was greater in Central California and in Baja California waters than in Southern California waters. In fact, in 1939 and in 1940, the indications are that north of Bodega Bay, beyond our surveys, some spawning and survival of young occurred as far as Pacific Northwest waters. Walford and Mosher (1941) noted an extension of sardine spawning to North Pacific waters in 1939. Canadian biologists reported young fish of the 1939 and 1940 year classes in two successive years. It appears that the cruises to the southward of California, to Cape San Lucas, include the southern limit of any nursery grounds for young sardines, but that the northern limit should be projected northward of Bodega Bay, as far as Vancouver Island, in years when conditions are favorable for spawning in the northern waters.

2.9. SUMMARY

1. Surveys of the relative abundance of young sardines were made in 1938, 1939 and 1940.

2. The coastal area between Bodega Head, California, and Cape San Lucas, Lower California, and the southern section of the Gulf of California was covered by the surveys.

3. Fish schools were sampled with roundhaul nets and occasionally with small dynamite charges and by examining the contents of pelican stomachs. At times fish were dipped under a light at night.

4. No sardines were found in waters with a surface temperature higher than 79° F. (26.1° C.) or lower than 53° F. (11.7° C.).

5. In 1938, 818 schools of young sardines were observed of which 1 percent was found off Central California, 91 percent off Southern California and 8 percent off Lower California.

6. In 1939, only 63 schools were found, of which 49 percent were in Central California, 2 percent in Southern California and 49 percent in Lower California. Subsequent information demonstrated extensive spawning in 1939 well to the north of the area surveyed.

7. In 1940, 204 sardine schools were observed, 30 percent in Central California, 22 percent in Southern California and 48 percent in Lower California. As in 1939 there were indications that the 1940 spawning extended northward beyond the area surveyed.

2.10. REFERENCES

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3. REPORT ON THE YOUNG SARDINE, SARDINOPS CAERULEA, SURVEY IN CALIFORNIA AND MEXICAN WATERS, 1950 AND 1951

By JOHN RADOVICH

3.1. INTRODUCTION

The young sardine surveys of 1950 and 1951 were planned primarily to assess the relative abundance of incoming age groups prior to their availability on the commercial fishing grounds. This information is necessary before accurate predictions of the commercial catch can be made. In addition the data collected on these cruises give some information on relative abundance of all year classes, on fishing mortality, on growth differences between areas, on temperatures in which sardines are found, and some measure of the abundance and distribution of other species.

3.2. METHODS

3.2.1. Areas

For convenience, the entire area populated by the sardine was divided into five major areas called A, B, C, D, and E. Area A is the area north of Bodega Head extending to British Columbia. Area B extends from the vicinity of Bodega Head to Pt. Conception, area C from Pt. Conception south to Punta Banda and includes Southern California and northern Baja California. Area D is central Baja California from Punta Banda to Cabo San Lazaro, and area E, southern Baja California (Frontispiece).

Areas B, C and D, the areas covered by the survey at the present time, are further divided. The area around Morro Bay sustained a limited fishery during the past two seasons, 1950–51 and 1951–52, while the San Francisco-Monterey area did not, especially in 1951–52. Since these differences existed, the area in B including the San Francisco and Monterey region was called B-1 and the region around Morro Bay was called B-2. Area C was divided into C-1 and C-2, because the water in region C-2, from Punta Banda to Punta Baja, seemed to be colder, which suggested that environmental conditions might be different. Area D was divided into D-1, Sebastian Vizcaino Bay; D-2, Punta Eugenia to Punta Abreojos; and D-3, Punta Abreojos to Cabo San Lazaro. These divisions were made because of temperature differences and of differences in distribution of the year classes in these regions. In order to compare the commercial catch of Southern California with the survey in Region C-1, it was necessary to further divide C-1 into C-1a and C-1b, with the Mexican boundary being the line separating the two regions. Table 1 and Frontispiece show the latitudinal and geographic boundaries for the areas and regions.

TABLE 1

Locality Divisions of the Sardine Survey

Area	Geographic range	North latitude
B-1	Delgada Point-Cape San Martin	39°59.9′-35°53.0′
B-2	Cape San Martin-Point Conception	35°52.9′-34°30.0′
C-1a	Point Conception-Mexican Boundary	34°29.9′-32°32.0′
C-1b	Mexican Boundary-Punta Banda	32°31.9′-31°50.0′
C-2	Punta Banda-Punta Baja	31°49.9′-30°00.0′
D-1	Punta Baja-Punta Eugenia	29°59.9′-27°51.0′
D-2	Punta Eugenia-Punta Abreojos	27°50.9′-26°43.0′
D-3	Punta Abreojos-Cabo San Lazaro	26°42.9′-25°00.0′

TABLE 1
Locality Divisions of the Sardine Survey

3.2.2. Vessel

The vessel used for the 1950 and 1951 young fish surveys was the M. V. YELLOWFIN. It is a former army interisland, freight carrying vessel converted to a research vessel and is 114 feet long with a 27-foot beam and a cruising radius of 6,000 miles. A crew of 10 is carried with additional room for three scientists. There are two laboratories on the main deck, one forward and one aft. The vessel is suitable for the sardine survey work and has proved to be quite useful for oceanographic work. Wilson (1951) gives a detailed description of the YELLOWFIN.

3.2.3. Sampling Techniques

According to the California Cooperative Sardine Research Program (1950), there was, in 1949 and 1950, a northward progression of spawning as the season advanced, beginning in the region from Punta Eugenia to Punta Abreojos and gradually moving northward. This same progression occurred again during the 1951 investigations. Consequently the surveys began in the south and worked northward, covering each area from four to six months after the main spawning had occurred. So far work has been started in area D and extended northward to include areas

C and B. If spawning conditions warrant it, however, future surveys can be extended to cover either area A or area E.

The area surveyed was from as close to shore as safety permitted to approximately 20 miles offshore. When surveying banks and islands, however, the coverage was farther offshore. Previous studies have indicated that young sardines tend to be concentrated in shallow water and are sparse if not completely absent in offshore waters (Scofield, 1934; Godsil, 1930). In addition during the fall and winter adult sardines are also confined to coastal waters (Clark, 1936, 1937). When surveying offshore banks and islands sardines were not found in the intervening deeper waters. For these reasons it is felt that the survey covered the major areas where both young and adult sardines occur during the fall and winter months.

Some preliminary work was done with different sampling devices in order to obtain a consistent sampling technique that would yield uniform results. Gill nets were tried, but it was found that a maximum of one sample per night was all that could be collected, since the nets were set at dusk and hauled at dawn. The efficiency was much lower in areas of small concentrations of sardines and many unsuccessful sets were made. The nets were very selective as to the size of the fish taken. It was difficult to determine the exact location where the fish were caught since the nets might have drifted as much as eight miles during the night. It was impractical to set close to shore for fear of running aground. Much time was spent drifting with the nets, cutting down on the area surveyed per night.

A mid-depth trawl consisting of a 12-foot diameter hoop with a bag was tried. It was cumbersome and dangerous to use, except in calm weather, and was not successful in sampling sardines.

Bait nets were not used, since not more than 100 fish were needed for a sample. It was thought that many more fish would be taken than necessary, and the time required to set and haul would cut down on scouting time.

A small charge of dynamite proved to be the best method of collecting samples. It was not as size-selective as gill nets. Small samples of fish were taken; quite often fewer than 100 fish. Less time was consumed in sampling with dynamite than with the other methods, therefore more area could be covered and more samples could be obtained per night.

Scouting was done at night and the fish were located either by visual observation of the schools, by indications of fish on the recording echo-sounder (Figure 2), or by attracting them with a 750-watt light suspended above the surface of the water. Sardine schools are observed visually at night by the bioluminescence, which is the glow caused by the agitation of micro-organisms in the water by the school of fish. Scouting was started each night at dark and continued until daylight.

Sonar was tried but was not successful in locating schools of fish in most of the area covered by the survey. Much of the scouting was done in water depths of less than 300 feet and at this depth the bottom return was indistinguishable from schools of fish. Much time was spent checking on what was thought to be fish only to find that the "return" was caused by irregularities in the ocean floor. The equipment used was Model WEA-2a sonar, with a maximum range of 5,000 yards, and although it was

FIGURE 1. Brailing sardines after stunning with a small explosive charge.
Photograph by Daniel J. Miller, March, 1952.

FIGURE 1. Brailing sardines after stunning with a small explosive charge. Photograph by Daniel J. Miller, March, 1952.

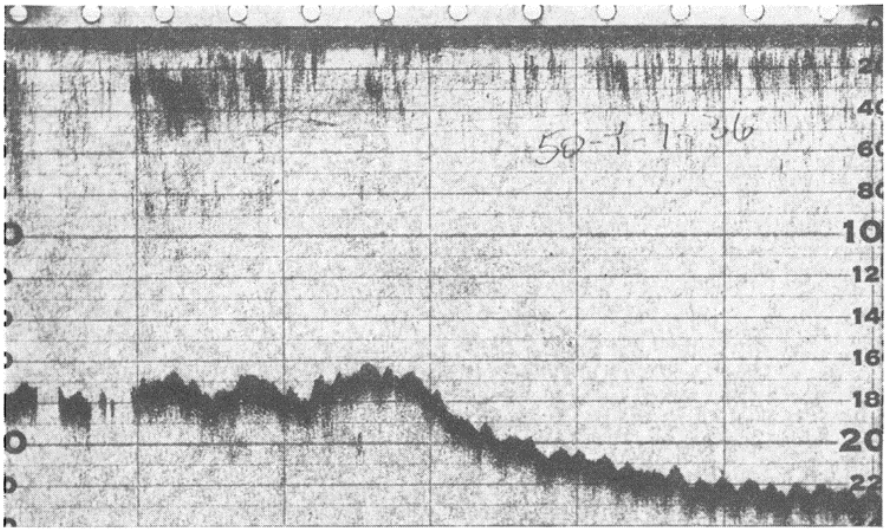

FIGURE 2. Example of the use of the recording echo-sounder as an aid in locating fish. The light trace near the top was made by a school of sardines, the heavier lower trace by the bottom

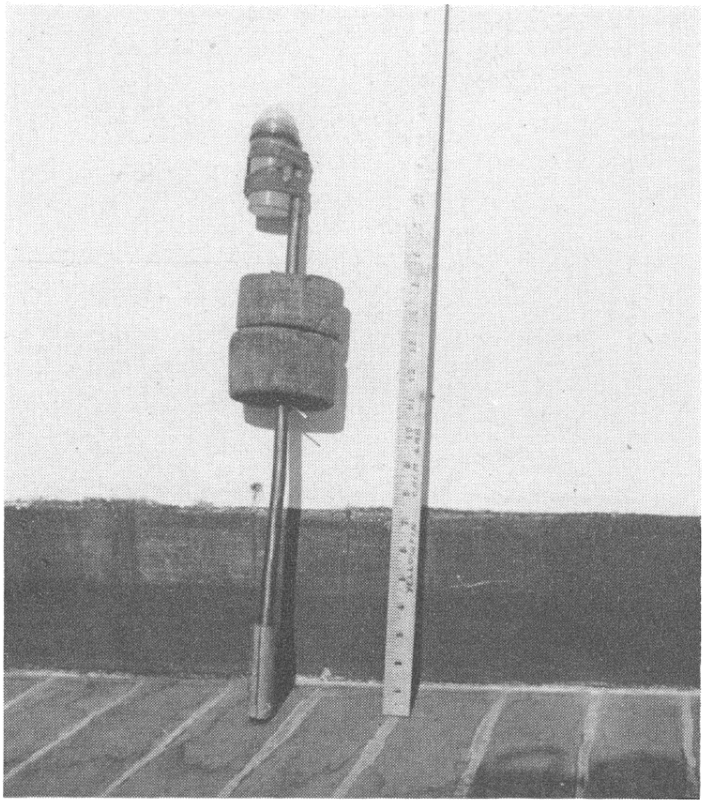

FIGURE 3. A float used as a marker buoy to aid in picking up samples of fish. Photograph by Leo Pinkas, March, 1951.

obsolete war surplus equipment, not designed for fishing, it did pick up fish in deeper water offshore. New echo ranging equipment specifically designed for fishing could prove to be very useful in locating schools.

When a school was sighted either visually or on the echo-sounder, the captain would bring the vessel around and one man would go to the flying bridge, where he would turn on the fuse lighter (an electrical heating element), take a small charge of dynamite in his hand, and wait to come upon the fish again. When the vessel was within range of the fish, the fuse was lighted and the dynamite thrown as close as possible to the fish. At this time, a float with a waterproof flashlight attached (Figure 3) was also thrown over the side to mark the spot. The vessel would then again come around to the light and the fish, if any were killed, were picked up with a long-handled brail. Up to 100 sardines were collected, constituting a sample. When visual scouting was poor, at regular intervals the vessel would be stopped and a light put out for one hour.

Each attempt at sampling was called a station. At each station, water samples were taken for salinity determinations, surface temperatures were taken, and with a bathythermograph continuous temperatures were taken down to the bottom, or to 900 feet if the bottom was deeper than

FIGURE 4. Plankton net used in collecting food organisms of sardine. Photograph by Kramer Adams, October, 1949.

900 feet. At each station records were made of barometric pressure, depth, wind direction and force, and height of sea.

Sex and body length (standard length) to the nearest millimeter were recorded for each fish. In addition, scales for use in age determination were taken from 1 to 10 sardines selected at random from the sample. Stomachs and gonads as well were removed from these fish and placed in 5 percent formalin buffered with borax.

At each station where sardines were sampled, in addition to the regular observations, plankton tows were taken to obtain microscopic organisms that might be used as food by the sardine. The stomach samples, together with the plankton samples, were sent to Scripps Institution of Oceanography where food studies of the sardine are being conducted. The gonads were sent to U. S. Fish and Wildlife Service for fecundity studies.

3.2.4. Processing the Data

For each region, the recorded lengths of each sample of fish were grouped into one centimeter class intervals, and the frequencies were weighted to 100 fish per sample. This was done because the number of sardines collected from a school bore no relation to the number of fish in the school. It, therefore, seemed better to give each sample equal weight. The fish aged in each region were also grouped into one centimeter class intervals and the percentage of each year class was determined for each centimeter size group. The age composition of measured fish weighted to 100 fish per sample was then determined by multiplying the frequency of each class interval of the measured fish by the percentage of each year class of the same class interval determined from the fish aged.

At times, bad weather curtailed the survey so that fewer nights might be spent in a given area than was originally planned. In other areas fish were more abundant so that more time was consumed in taking samples, and consequently more nights spent in an area than was previously planned. Since the effort expended in each area was not uniform, total numbers of fish sampled did not give an accurate measure of abundance. A scouting night was selected as a unit of effort, and the concentration of any year class, in any region, was expressed as the number of fish measured, weighted to 100 fish per sample, per scouting night. A comparison of this relative concentration, by regions or from one year to another, should indicate the distribution and relative strength of year classes.

3.3. THE 1950 SURVEY

3.3.1. Relative Abundance of Year Classes

The 1950 survey was conducted in four cruises. The first cruise, July 18 to August 4, surveyed regions D-3, D-2, and D-1; the second, August 14–24, surveyed regions C-2 and the southern part of C-1; the third, September 5–22, surveyed the northern part of C-1; the fourth cruise, October 2–19, surveyed regions B-1 and B-2.

The 1948 year class was by far the strongest, averaging 88.2 fish measured per night or 48.3 percent of all the fish measured (Table 2). The 1950 year class was second, averaging 37.7 fish measured per night or 20.7 percent of the fish measured. The 1947 year class made up 14.1 percent of all the fish measured and the 1949 year class 10.5 percent.

TABLE 2

Numbers of Sardines of Each Year Class Measured per Scouting Night for Each Region Covered During the 1950 Survey

The Numbers Are Weighted to 100 Fish per Sample

Region	Number of nights	Year class								
		1950	1949	1948	1947	1946	1945	1944	1943	Totals
B-1	9	33.3								33.3
B-2	3	33.3		11.3	17.3	4.7				66.6
C-1	20	14.4	8.3	113.0	48.1	13.0	11.0	2.2		210.0
C-2	6	83.0	5.3	130.1	26.8	3.3			1.5	250.0
D-1	7	28.7	61.3	167.6	13.4	0.4				271.4
D-2	5	14.4	74.6	67.2	14.8	5.2	3.8			180.0
D-3	2	250.0								250.0
All areas combined	52	37.7	19.2	88.2	25.8	6.2	4.6	0.8	0.2	182.7
Percentage		20.7	10.5	48.3	14.1	3.4	2.5	0.4	0.1	100.0

TABLE 2

Numbers of Sardines of Each Year Class Measured per Scouting Night for Each Region Covered During the 1950 Survey

The Numbers Are Weighted to 100 Fish per Sample

Fish three years old and older (year classes 1944 to 1947) were more abundant off Southern California than elsewhere. The 1948, 1949 and 1950 year classes were most abundant in Mexican waters (Table 2 and Figure 5). The 1950 year class was stronger than the 1949, although neither seemed to be exceptionally numerous.

3.3.2. Comparison With the 1950–51 Fishing Season

During the 1950–51 fishing season (August 1950-January 1951) the 1948 year class was numerically more abundant than any other. The order of the abundance of year classes was the same as in the California portion of the young fish survey, except that the 1949 and 1950 year classes were not available to the fishery. This is to be expected, however, for the fish do not normally become available to the fishermen on the California fishing grounds until they are two years old. They usually are not fully available until they are three years old.

To compare numbers of fish of each year class in the commercial catch with numbers of fish of each year class taken in California by the young fish survey, it was necessary to convert one set of numbers to the other. The numbers of fish in each age group of the commercial catch was multiplied by 1/1,011,000 (see footnote Table 3) This made the total of all age groups three years and older equal to the same total as in the survey data. The results of this conversion (Table 3 and Figure 6) indicate that the 1948 year class in California was not fully available to the fishermen and that the 1947 and older year classes were sampled in about the same proportions by the fishermen as by the young fish survey.

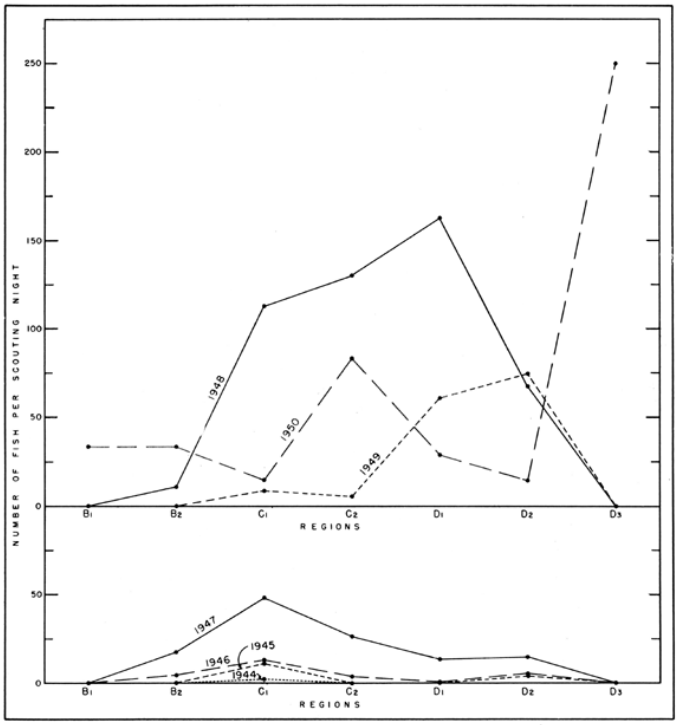

FIGURE 5. Relative concentration by region of the year classes sampled during the 1950 survey. The numbers of fish represent numbers of sardines measured per scouting night weighted to 100 fish per sample.

FIGURE 5. Relative concentration by region of the year classes sampled during the 1950 survey. The numbers of fish represent numbers of sardines measured per scouting night weighted to 100 fish per sample

TABLE 3

Numbers of Sardines of Each Year Class From the Commercial Catch and From the 1950 Survey in California
The Survey Numbers Are Weighted to 100 Fish per Sample
The Numbers in the Commercial Catch Are Given in the Thousands, i.e., 000 Omitted

	Year class									
	1950	1949	1948	1947	1946	1945	1944	1943	Older	Totals
1950 Survey										
Central California	400	.....	34	52	14	.....	.....	.....	.....	500
Southern California	68	136	1,810	888	257	198	43	.....	.....	3,400
All California	468	136	1,844	940	271	198	43	.....	.....	3,900
All California 1947 year class and older	.....	.....	.....	940	271	198	43	.....	.....	1,452
1950-51 Commercial Catch										
Central California	.....	.....	43,976	116,061	87,429	14,775	7,949	362	79	270,631
Southern California	.....	.....	1,077,389	873,712	300,947	59,185	7,705	.....	.....	2,318,938
All California	.....	.....	1,121,365	989,773	388,376	73,960	15,654	362	79	2,589,569
All California 1947 year class and older	.....	.....	.....	989,773	388,376	73,960	15,654	362	79	1,468,204
All California[1] ÷ 1,011	.....	.....	1,109.2	979.0	384.1	73.1	15.5	0.4	0.1	2,561.4

[1] The conversion factor 1/1011 comes from dividing 1,468,204 by 1,452. This converts the numbers of the commercial catch to the same magnitude as the numbers from the survey based on fish three years old and older.

TABLE 3
Numbers of Sardines of Each Year Class From the Commercial Catch and From the 1950 Survey in California The Survey Numbers Are Weighted to 100 Fish per Sample The Numbers in the Commercial Catch Are Given in the Thousands, i.e., 000 Omitted

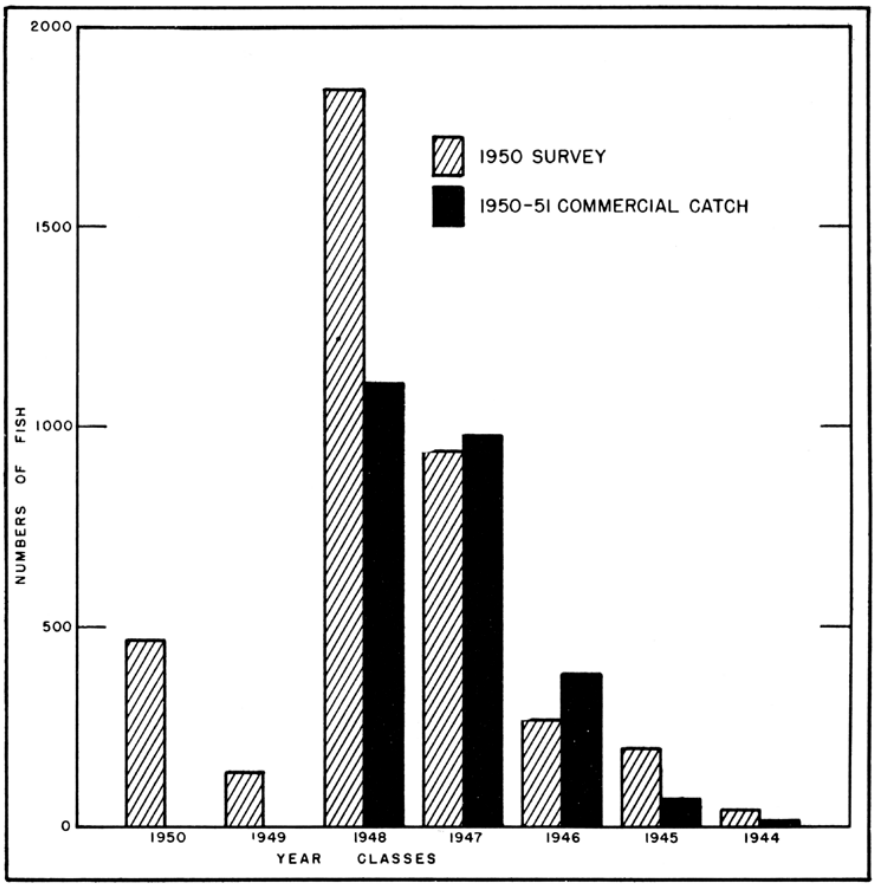

FIGURE 6. Numbers of sardines of each year class at 100 fish per sample taken in California by the 1950 survey and numbers of sardines of each year class from 1950-51 commercial catch converted to the survey numbers based on fish three years of age and older

FIGURE 6. Numbers of sardines of each year class at 100 fish per sample taken in California by the 1950 survey and numbers of sardines of each year class from 1950–51 commercial catch converted to the survey numbers based on fish three years of age and older

3.4. THE 1951 SURVEY

3.4.1. Relative Abundance of Year Classes

The 1951 survey was conducted in three cruises. The first cruise, August 20th-September 12th, surveyed regions D-3, D-2, and D-1; the second, September 23d-October 12th, regions C-2 and the southern part of C-1; the third, October 19th–November 8th, regions B-1, B-2, and the northern part of C-1.

The 1948 year class was still the strongest throughout the area surveyed except in regions D-2 and D-3. It comprised 39.6 percent of all the fish measured, the 1951 year class contributed 27.0 percent, the 1950 year class 15.4 percent, and the 1949 year class 10.7 percent. All other year classes made up 7.3 percent (Table 4).

The 1951 year class was stronger than the 1950, but about the same magnitude as 1950 was in the 1950 survey (Figure 7). The 1950 year class had, in 1951, about the same concentration and distribution as the 1949 year class had in 1950. There have been no numerically abundant year classes

TABLE 4

Numbers of Sardines of Each Year Class Measured per Scouting Night for Each Region Covered During the 1951 Survey

The Numbers Are Weighted to 100 Fish per Sample

Region	Number of nights	Year class							
		1951	1950	1949	1948	1947	1946	1945	Totals
B-1	7								0
B-2	4	1.5	11.3	3.7	24.8	6.2	2.5		50.0
C-1	18	20.3	7.0	8.4	55.9	10.3	2.1	1.6	105.6
C-2	6	50.0	4.7	15.6	92.8	15.5	4.7		183.3
D-1	9	64.0	63.7	41.5	89.8	7.7			266.7
D-2	4	108.5	60.0	18.0	36.8	1.7			225.0
D-3	1	100.0							100.0
All areas combined	49	36.3	20.7	14.4	53.4	7.8	1.5	0.6	134.7
Percentage		26.95	15.37	10.69	39.64	5.79	1.11	0.45	100.0

TABLE 4

Numbers of Sardines of Each Year Class Measured per Scouting Night for Each Region Covered During the 1951 Survey

The Numbers Are Weighted to 100 Fish per Sample

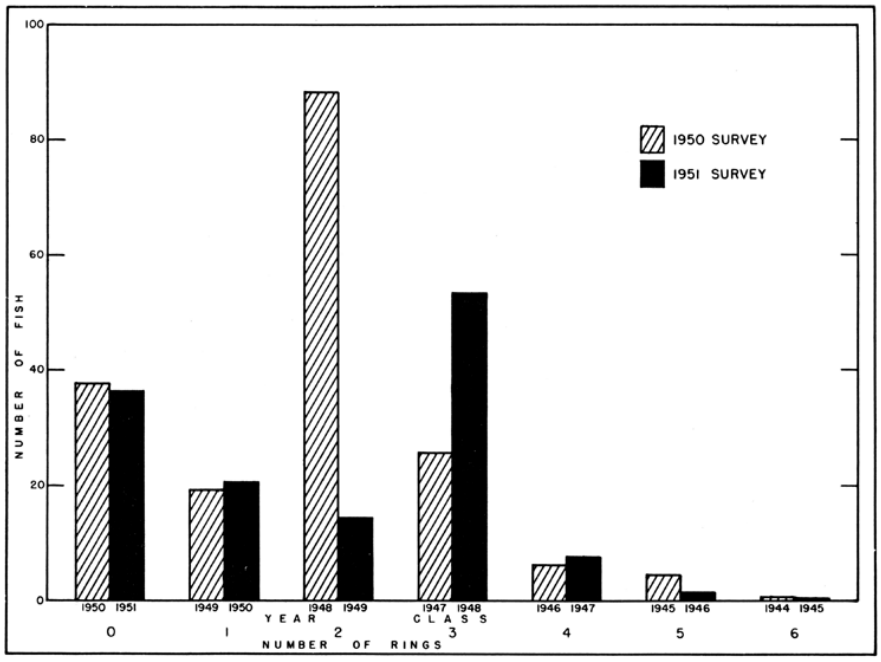

FIGURE 7. Comparison of concentrations of sardines by age for the 1950 and 1951 surveys in numbers of fish per scouting night

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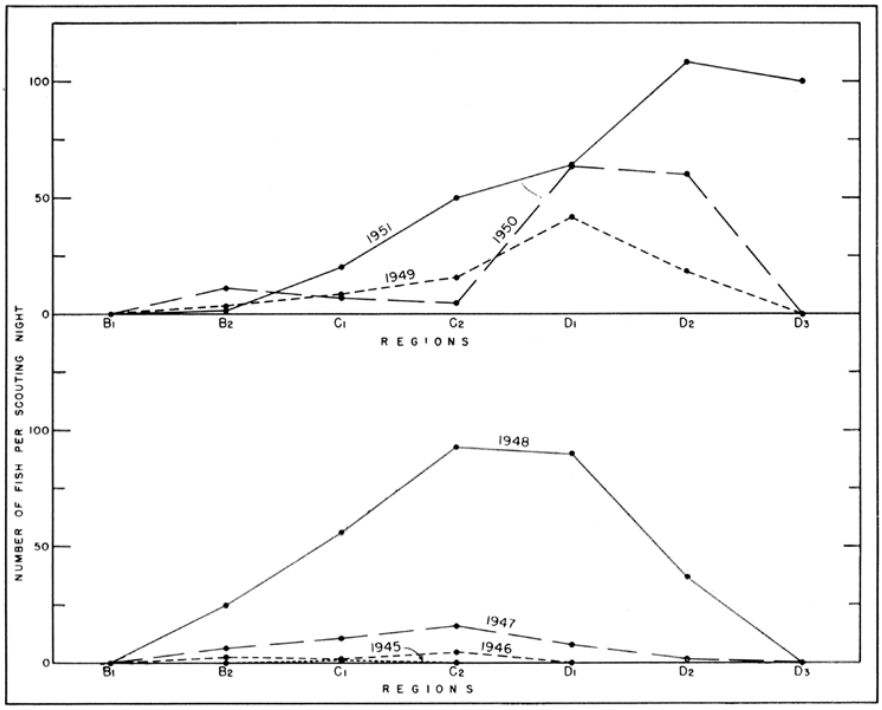

FIGURE 8. Relative concentration by region of the year classes sampled during the 1951 survey. The numbers of fish represent numbers of sardines measured per scouting night weighted to 100 fish per sample.

FIGURE 8. Relative concentration by region of the year classes sampled during the 1951 survey. The numbers of fish represent numbers of sardines measured per scouting night weighted to 100 fish per sample

since 1948. The 1951 year class seems to be stronger in regions D-1 and D-2 than was the 1950 year class when a few months old (Table 4, Figure 8). The older fish, which were more aboundant in Southern California than elsewhere in 1950, were greatly diminished in strength throughout their distribution. They had apparently suffered heavy mortality between the time of the two surveys. The 1948 year class although still the most abundant group had also declined in numbers throughout all areas.

3.4.2. Comparison With the 1951–52 Fishing Season

The 1948 year class comprised 77 percent of all fish three years and older taken in the California portion of the survey and made up 72 percent of the same age classes in the commercial catch during the 1951–1952 fishing season. Older year classes were slightly more available to the commercial fishery than to the California portion of the young fish survey, whereas fish two years old and younger were not as available.

A comparison of numbers of fish of each year class taken on the 1951 survey with numbers of fish of each year class in the commercial catch weighted by the factor 1/754,000 (see footnote Table 5) to survey numbers, based on fish three years of age and older (Table 5 and Figure 9), indicates that the 1948 year class is the dominant group throughout.

TABLE 5

Numbers of Sardines of Each Year Class From the Commercial Catch and From the 1951 Survey in California
The Survey Numbers Are Weighted to 100 Fish per Sample
The Numbers in the Commercial Catch Are Given in the Thousands, i.e., 000 Omitted

	Year class									
	1951	1950	1949	1948	1947	1946	1945	1944	1943	Totals
1951 Survey										
All California	204	167	138	914	206	47	24	0	0	1,700
All California, 1948 year class and older				914	206	47	24	0	0	1,191
1951-52 Season Commercial Catch										
All California		10,378	49,122	643,212	175,735	61,552	14,580	2,560	274	957,413
All California, 1948 year class and older				643,212	175,735	61,552	14,580	2,560	274	897,913
All California[1] ÷ 754		13.8	65.1	853.1	233.1	81.6	19.3	3.4	0.4	1,269.8

[1] The conversion factor 1/754 comes from dividing 897,913 by 1,191. This converts the numbers of the commercial catch to the same magnitude as the numbers from the survey based on fish three years old and older.

TABLE 5
Numbers of Sardines of Each Year Class From the Commercial Catch and From the 1951 Survey in California The Survey Numbers Are Weighted to 100 Fish per Sample The Numbers in the Commercial Catch Are Given in the Thousands, i.e., 000 Omitted

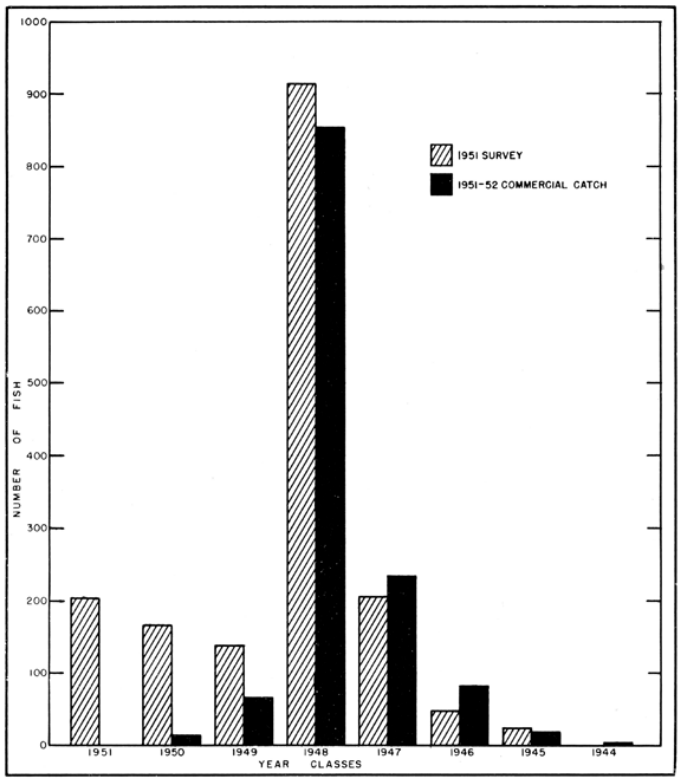

FIGURE 9. Numbers of sardines of each year class at 100 fish per sample taken in California by the 1951 survey and numbers of sardines of each class from the 1951-52 commercial catch converted to survey numbers based on fish three years of age and older

FIGURE 9. Numbers of sardines of each year class at 100 fish per sample taken in California by the 1951 survey and numbers of sardines of each class from the 1951–52 commercial catch converted to survey numbers based on fish three years of age and older

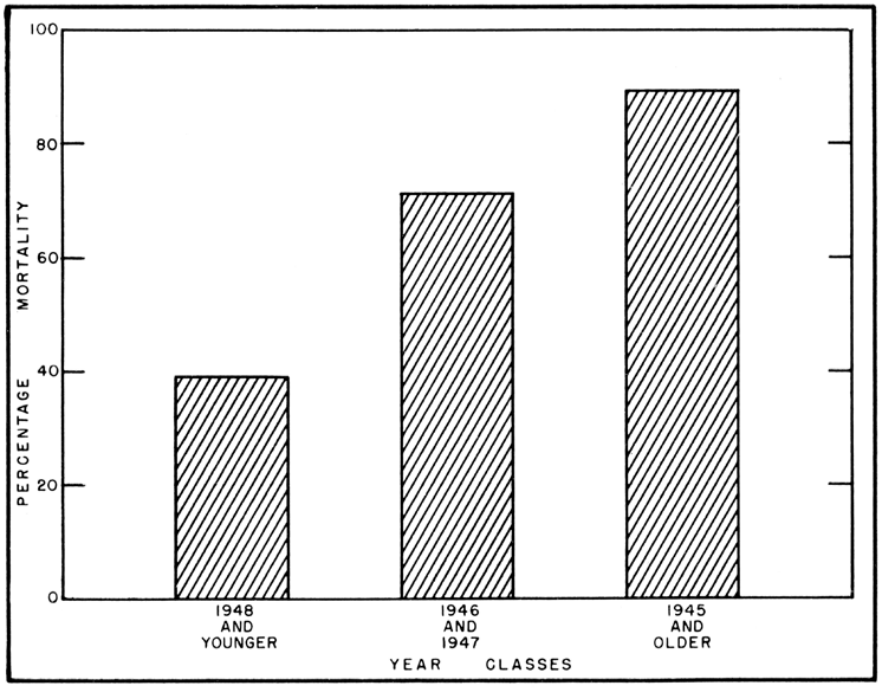

FIGURE 10. The mortality rates of sardines between the 1950 and the 1951 surveys

FIGURE 10. The mortality rates of sardines between the 1950 and the 1951 surveys

3.5. MORTALITY OF YEAR CLASSES

By determining the percentage decline of each year class in numbers per scouting night from the 1950 to the 1951 survey its mortality during the year elapsed between surveys was measured (Table 6).

The 1950 year class had a mortality of 45.1 percent, and the mortality of the 1949 and 1948 year classes was 25.0 percent and 39.5 percent, respectively. The 1948, 1949 and 1950 year classes combined, which represented fish that were two years old and younger in 1951, experienced a mortality of 39.0 percent. The fish that were three and four years old, 1946 and 1947 year classes, suffered a mortality of 70.9 percent, and the fish over five years of age 89.3 percent (Figure 10).

During the fall of 1950, fish of the 1947 year class, and older, were most heavily concentrated in the Southern California area (Figure 5). This was the area where fishing intensity was the greatest in the 1950–51 season. These older sardines, subjected to heavy fishing pressure, declined from 70 to 90 percent between 1950 and 1951. The younger age groups not yet fully available to the fishery experienced a decline of less than 40 percent.

TABLE 6

Mortality of Sardines by Year Classes Between the 1950 and the 1951 Survey

	Year class								
	1950	1949	1948	1947	1946	1945	1944	1943	Totals
1950 Survey numbers of fish per night	37.7	19.2	88.2	25.8	6.2	4.6	0.8	0.2	182.7
1951 Survey numbers of fish per night	20.7	14.4	53.4	7.8	1.5	0.6			98.4
Decline in numbers of fish per night	17.0	4.8	34.8	18.0	4.7	4.0	0.8	0.2	84.3
Percentage decline (mortality)	45.09	25.00	39.46	69.77	75.81	86.96	100.0	100.0	46.14
Percentage mortality, 1948 year class and younger	39.01								
Percentage mortality, 1946 and 1947 year classes				70.94					
Percentage mortality, 1945 year class and older						89.29			

TABLE 6

Mortality of Sardines by Year Classes Between the 1950 and the 1951 Survey

3.6. SIZE DIFFERENCES OF THE SARDINE BETWEEN SOUTHERN CALIFORNIA AND SEBASTIAN VIZCAINO BAY

Sardines of the same year class average larger off Monterey and northward than they do in Southern California (Felin et al., 1948, 1949, 1950, 1951; Phillips, 1948). The surveys make possible a further comparison of the sizes of sardines in the Southern California area, region C-1, with the sizes of sardines to the south.

Sebastián Vizcaíno Bay, region D-1, is an area in which large numbers of fish were found during the 1950 and 1951 surveys. It is separated from region C-1, Southern California and northern Baja California, by approximately 100 miles. The length frequencies of fish aged from regions D-1 and C-1 during the 1950 survey and the lengths of fish, by year class, taken in Southern California by the commercial catch in the 1950–51 season are given in Table 7, 8 and 9.

The 1948 year class yielded the largest number of samples for the two regions. These length frequencies (Figure 11) indicate that fish of the same age were larger in the Southern California region than in the Sebastián Vizcaíno Bay region.

The length frequencies of fish aged for the two regions, D-1 and C-1, during the 1951 survey and for the commercial catch in Southern California in the 1951–52 season (Tables 10, 11, and 12), and the length frequencies of the 1948- and 1949-year-class fish, for the 1951 survey (Figure 12), again show that the fish of the 1948 and 1949 year classes are larger in the Southern California area than in the Sebastián Vizcaíno Bay area. In both seasons the commercial catch in Southern California took a greater proportion of large fish from any year class than did the survey in this area.

TABLE 7

Length Frequency by Year Class of Sardines Taken in the 1950 Survey in Region D-1, Sebastian Vizcaino Bay, for Which Ages Were Determined

Body length mm.	Year class					
	1950	1949	1948	1947	1946	Totals
131-140	1	--	--	--	--	1
141-150	--	1	--	--	--	1
151-160	--	3	1	--	--	4
161-170	--	10	20	--	--	30
171-180	--	8	23	--	--	31
181-190	--	2	36	3	--	41
191-200	--	--	5	1	--	6
201-210	--	--	1	1	--	2
211-220	--	--	--	1	--	1
221-230	--	--	1	2	1	4
231-240	--	--	--	1	--	1
Totals	1	24	87	9	1	122

TABLE 7
Length Frequency by Year Class of Sardines Taken in the 1950 Survey in Region D-1, Sebastian Vizcaino Bay, for Which Ages Were Determined

TABLE 8

Length Frequency by Year Class of Sardines Taken in the 1950 Survey in Region C-1, Southern California and Northern Baja California, for Which Ages Were Determined

Body length mm.	Year class						
	1949	1948	1947	1946	1945	1944	Totals
171–180	--	1	--	--	--	--	1
181–190	4	15	--	--	--	--	19
191–200	5	80	11	3	1	--	100
201–210	1	34	25	5	6	1	72
211–220	--	4	14	7	2	--	27
221–230	--	--	9	1	4	2	16
231–240	--	--	1	1	1	--	3
Totals	10	134	60	17	14	3	238

TABLE 8
Length Frequency by Year Class of Sardines Taken in the 1950 Survey in Region C-1, Southern California and Northern Baja California, for Which Ages Were Determined

TABLE 9

Length Frequency by Year Class of Sardines From the Commercial Catch in Southern California During the 1950-51 Season for Which Ages Were Determined

Body length mm.	Year class					
	1948	1947	1946	1945	1944	Totals
181-190	22	2	--	--	--	24
191-200	100	33	4	1	--	138
201-210	84	58	14	--	--	156
211-220	44	67	35	7	2	155
221-230	11	63	41	13	3	131
231-240	1	15	24	8	4	52
241-250	--	1	5	1	--	7
Totals	262	239	123	30	9	663

TABLE 9
Length Frequency by Year Class of Sardines From the Commercial Catch in Southern California During the 1950–51 Season for Which Ages Were Determined

TABLE 10

Length Frequency by Year Class of Sardines Taken in the 1951 Survey in Region D-1, Sebastian Vizcaino Bay, for Which Ages Were Determined

Body length mm.	Year class					
	1951	1950	1949	1948	1947	Totals
141-150	2	1	--	--	--	3
151-160	2	4	--	--	--	6
161-170	--	11	1	3	--	15
171-180	--	14	5	13	1	33
181-190	--	7	14	39	4	64
191-200	--	3	10	9	1	23
201-210	--	--	1	5	--	6
211-220	--	1	1	2	--	4
Totals	4	41	32	71	6	154

TABLE 10 Length Frequency by Year Class of Sardines Taken in the 1951 Survey in Region D-1, Sebastian Vizcaino Bay, for Which Ages Were Determined

TABLE 11

Length Frequency by Year Class of Sardines Taken in the 1951 Survey in Region C-1, Southern California and Northern Baja California, for Which Ages Were Determined

Body length mm.	Year class						
	1950	1949	1948	1947	1946	1945	Totals
161-170	3	--	--	--	--	--	3
171-180	2	--	--	--	--	--	2
181-190	5	3	1	--	--	--	9
191-200	1	2	42	2	2	--	49
201-210	1	6	24	4	--	1	36
211-220	--	--	8	4	--	1	13
221-230	--	--	7	6	1	--	14
231-240	--	--	1	3	1	--	5
Totals	12	11	83	19	4	2	131

TABLE 11
Length Frequency by Year Class of Sardines Taken in the 1951 Survey in Region C-1, Southern California and Northern Baja California, for Which Ages Were Determined

TABLE 12

Length Frequency by Year Class of Sardines From the Commercial Catch in Southern California During the 1951-52 Season for Which Ages Were Determined

Body length mm.	Year class							
	1950	1949	1948	1947	1946	1945	1944	Totals
181-190		1	3					4
191-200	4	16	157	17				194
201-210	7	16	292	47	7	1	1	371
211-220	2	7	146	60	17	6	1	239
221-230		3	88	68	27	6	4	196
231-240			20	29	11	1	1	62
241-250			2	9	4	1	1	17
251-260					1			1
Totals	13	43	708	230	67	15	8	1,084

TABLE 12
Length Frequency by Year Class of Sardines From the Commercial Catch in Southern California During the 1951–52 Season for Which Ages Were Determined

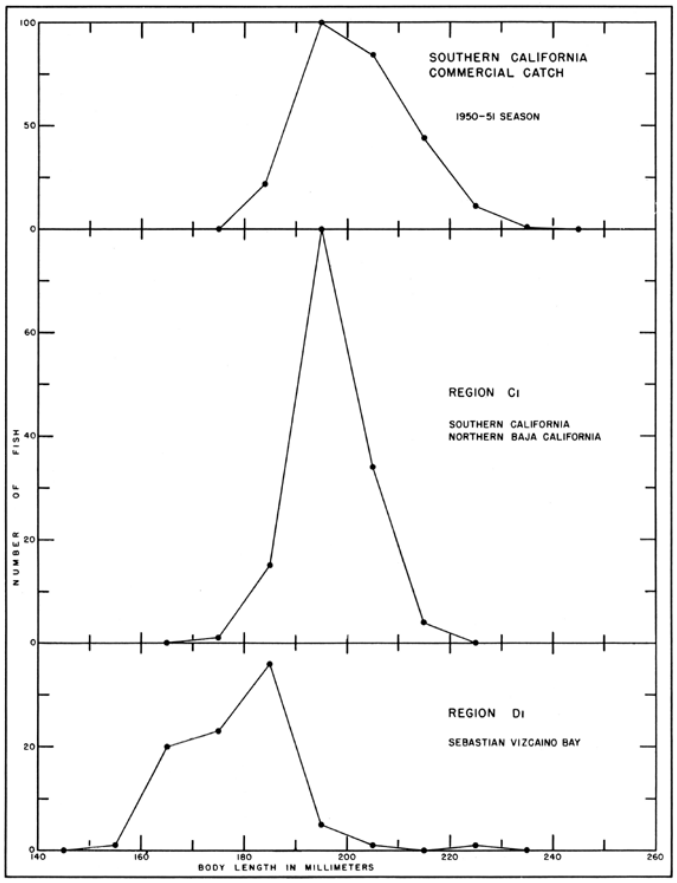

FIGURE 11. Sizes of sardines of the 1948 year class in the 1950 survey comparing regions C-1, D-1 and the 1950-51 commercial catch

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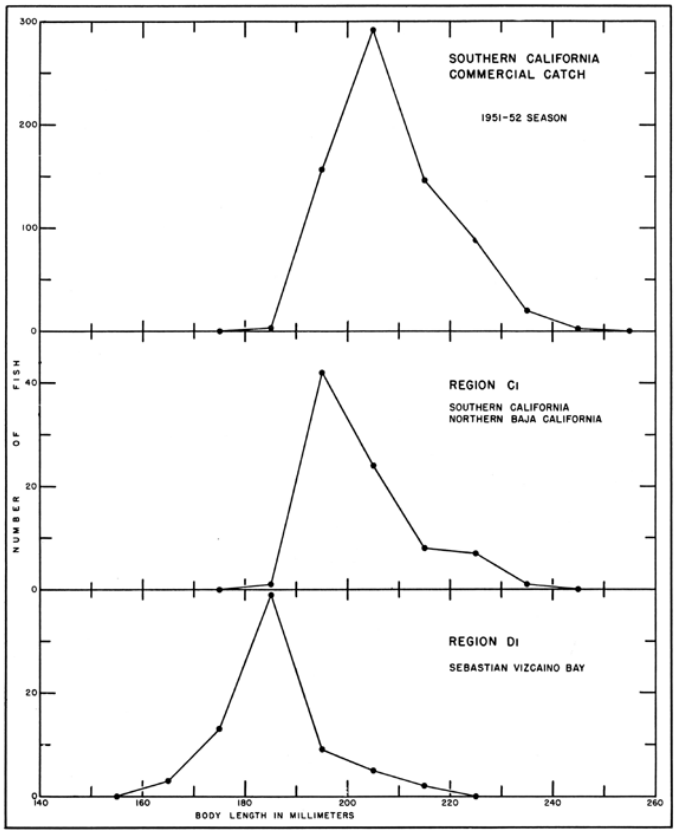

FIGURE 12. Sizes of sardines of the 1948 year class in the 1951 survey comparing regions C-1, D-1 and the 1951-52 commercial catch

FIGURE 12. Sizes of sardines of the 1948 year class in the 1951 survey comparing regions C-1, D-1 and the 1951–52 commercial catch

The mean length of the 1948-year-class fish, sampled during 1950, was 19.74 cm. in region C-1, and 17.92 cm. in region D-1, a difference of 1.82 cm. with a standard of error of 0.13 cm. The difference exceeded its standard error by 14 times. The mean length of the 1948-year-class fish, sampled during the 1951 survey was 20.32 cm. in region C-1, and 18.64 cm. in region D-1. This difference of 1.68 cm. exceeded its standard error of 0.16 cm. by 10.5 times. These statistical measures indicate that the difference in the sizes of fish in the two regions is significant. This might either be due to a differential growth rate for the two regions or to a differential size migration or to a combination of both.

It has been known for some time that sardines occur in Mexican waters although the amount that these fish contribute to the California catch has not been determined. Results of vertebral counts indicate that fish south of Sebastián Vizcaíno Bay do not contribute to the commercial catch of California, whereas fish north of the southern boundary of Sebastián Vizcaíno Bay do contribute to a certain extent to the fishery (Clark, 1947).

Tagging experiments (Clark and Janssen, 1945) demonstrated that fish from Sebastiá Vizcaíno Bay were taken in Southern California, but no recoveries were made of sardines tagged south of Punta Eugenia.

3.7. WORK IN 1949

There were five cruises conducted in 1949 during the months of September, October, November, and December. These cruises were planned to experiment with different types of sampling gear and techniques, and to collect data on the environment of the sardines along the coast. One of the cruises was designed to get information about the distributing of jack mackerel, Trachurus symmetricus, and scouting for sardines was of secondary importance. Because all of the survey regions were not covered, and because of the nature of these cruises, the unit of effort was

TABLE 13

Numbers of Sardines of Each Year Class Measured per Scouting Night for Each Region Covered by the 1949 Survey

The Numbers Are Weighted to 100 Fish per Sample

Region	Number of nights	Year class						
		1949	1948	1947	1946	1945	1944	Totals
B-1	7		10.8	2.3	1.2			14.3
B-2								
C-1	16		29.1	31.0	11.5	5.4	4.3	81.3
C-2								
D-1	5	9.0	50.8	0.2				60.0
D-2	3	33.3		33.3				66.6
D-3	2							
All areas combined	33	4.4	24.1	18.6	5.8	2.6	2.1	57.6
Percentage		7.6	41.9	32.3	10.1	4.5	3.6	100.0

TABLE 13
Numbers of Sardines of Each Year Class Measured per Scouting Night for Each Region Covered by the 1949 Survey
The Numbers Are Weighted to 100 Fish per Sample

not consistent and the results are not directly comparable to the 1950 and 1951 surveys. There were some data collected, however, that are pertinent to the present study.

The 1948 year class was the strongest, comprising 41.9 percent of the fish sampled, the 1947 year class was second with 32.3 percent, the 1946 year class contributed 10.1 percent, the 1949 year class made up 7.6 percent, and the other year classes comprised 8.1 percent (Table 13). The 1948 and 1949 year classes showed the heaviest concentration to the south, whereas the fish three years old and older were found chiefly in the area around Southern California. Fish two years old, the 1947 year class, were about evenly divided between Southern California and central Baja California. The relative strength of the 1948 year class measured when these fish were one year old and taken incidentally in the fishery was substantiated by the subsequent surveys of 1950 and 1951 and by the 1950–51 and 1951–52 commercial catch. The weakness of the 1949 year class was evident in the 1949 survey and the sparsity of this year class was also borne out by the subsequent surveys of 1950 and 1951.

3.8. TEMPERATURES WHERE SARDINES WERE FOUND

The surface temperatures encountered on the surveys, and the surface temperatures at which sardines were found, are shown in Table 14. Temperatures as low as 10° C. were encountered but no sardines were found

TABLE 14

Occurrences of Surface Temperatures Where Sardines Were Found and Occurrences of Temperatures Taken During Surveys

Temperature degrees C.	Year survey was made					
	1949		1950		1951	
	Where sardines were found	All temperatures taken	Where sardines were found	All temperatures taken	Where sardines were found	All temperatures taken
10	--	--	--	12	--	9
11	1	1	1	10	--	7
12	--	2	--	18	--	16
13	--	2	10	34	--	12
14	5	5	12	26	3	17
15	2	2	4	7	3	19
16	1	1	9	9	12	36
17	1	1	8	11	13	43
18	--	--	22	25	4	19
19	2	3	19	36	12	24
20	1	1	8	8	6	8
21	--	1	3	3	2	3
22	1	1	--	--	1	1
23	--	--	--	--	3	4
24	--	--	--	--	6	7
25	--	2	--	--	1	1
26	--	1	--	--	--	3
27	--	1	--	--	--	--
28	--	2	--	--	--	1
Totals	14	26	96	199	66	230

TABLE 14
Occurrences of Surface Temperatures Where Sardines Were Found and Occurrences of Temperatures Taken During Surveys

at temperatures below 11° C. Since the distribution of the sardine may no longer extend as far to the north as it formerly did, it is quite possible that these minimum temperatures do not represent the minimum temperatures in which sardines could live.

The lowest surface temperature in which sardines were found, in the three surveys, was 11.4° C. and the highest was 25.7° C. The lowest temperature encountered during the surveys was 10.4° C. and the highest was 28.3° C. In 1951 no sardines were found at temperatures of less than 14° C. This resulted from the lack of sardines off Central California. It is not apparent, however, that the low surface temperatures off Central California account for the paucity of sardines in this region in 1951, since fish were found in 1949 and 1950 in temperatures as low as those present off Central California in 1951.

Experiments conducted on Japanese sardines, Sardinops melanosticta, held in tanks, showed a living temperature range for these fish from about 7° C. to 29° C. (Suehiro, 1951). These experiments also demonstrated that the Japanese sardine was more resistant to sudden decreases in temperature than they were to sudden increases. The temperatures in which sardines were found, in the three surveys, fell within the limits of the living range for the Japanese species.

The temperatures that are listed for the three surveys are surface temperatures, and might be warmer in some cases than the actual temperatures in which the largest portion of the schools were located. From examinations of echo-sounder tracings, the average depth of the midpoints of sampled schools was approximately 50 feet. At the present time, not enough temperatures at a 50-foot depth have been taken to yield any conclusive results.

3.9. OTHER FISHES

It is not always possible to determine what species of fish are in a school without sampling. This is especially true when a school is mixed. Consequently, many fish other than sardines were sampled. In the areas B-1 and B-2, Pacific herring, Clupea pallasi, and osmerid smelt were fairly numerous. In area D-3, thread herring, Opisthonema libertate, and various carangids were more common in the sampling. Sauries, Cololabis saira, were quite abundant offshore along the entire coast, and atherinid smelt were numerous close to shore.

The species that occurred in large schools, and were sampled most frequently, were the sardine; the jack mackerel, Trachurus symmetricus; the Pacific mackerel, Pneumatophorus diego, and the anchovy Engraulis mordax. Sardines were sampled most often, anchovies were almost as abundant as sardines, jack mackerel were less numerous in the sampling, and Pacific mackerel were still less numerous.

The range of distribution of the other species may be somewhat different from that of the sardine and correlation of their relative abundance with that of the sardine refers only to the area surveyed. The occurrences of the principal fishes taken on the 1950 and 1951 surveys are given in Table 15.

The samples of fish taken per scouting night by region give a relative measure of the abundance of the important species (Table 16, Figure 13). During the 1950 surveys the sardines were most abundant in

TABLE 15

Numbers of Samples of the Principal Fishes Collected by Region Taken on the 1950 and 1951 Surveys

Region	1950 Survey				1951 Survey			
	Sardines	Jack mackerel	Pacific mackerel	Anchovies	Sardines	Jack mackerel	Pacific mackerel	Anchovies
B-1	3	7		6		2		3
B-2	2	2		2	2	1		2
C-1	42	40	25	48	19	25	10	25
C-2	15	12	5	12	11	8		8
D-1	19	4	2	2	24	5	3	5
D-2	9	3	3	7	9	5	7	8
D-3	5			9	1			2
Totals	95	68	35	86	66	46	20	53

TABLE 15

Numbers of Samples of the Principal Fishes Collected by Region Taken on the 1950 and 1951 Surveys

TABLE 16

Relative Abundance of the Principal Fishes Sampled During the 1950 and 1951 Young Fish Surveys as Measured by Numbers of Samples per Scouting Night by Region

Region	1950 Survey				1951 Survey			
	Sardines	Jack mackerel	Pacific mackerel	Anchovies	Sardines	Jack mackerel	Pacific mackerel	Anchovies
B-1	0.33	0.78	0.00	0.67	0.00	0.29	0.00	0.43
B-2	0.67	0.67	0.00	0.67	0.50	0.25	0.00	0.50
C-1	2.10	2.00	1.25	2.40	1.06	1.39	0.56	1.39
C-2	2.50	2.00	0.83	2.00	1.83	1.33	0.00	1.33
D-1	2.71	0.57	0.29	0.29	2.67	0.56	0.33	0.56
D-2	1.80	0.60	0.60	1.40	2.25	1.25	1.75	2.00
D-3	2.50	0.00	0.00	4.50	1.00	0.00	0.00	2.00
All regions combined	1.83	1.31	0.67	1.65	1.35	0.94	0.41	1.08

TABLE 16

Relative Abundance of the Principal Fishes Sampled During the 1950 and 1951 Young Fish Surveys as Measured by Numbers of Samples per Scouting Night by Region

Sebastián Vizcaíno Bay; the jack mackerel off Southern California and northern Baja California; the Pacific mackerel off Southern California; and the anchovies, south of Punta Abreojos.

The 1951 survey showed the heaviest concentration of sardines in Sebastián Vizcaíno Bay; jack mackerel, in Southern California and northern Baja California; Pacific mackerel, in the region from Punta Eugenia to Punta Abreojos; and anchovies in the area south of Punta Eugenia. For all regions the sardines were slightly more abundant than any other species and the anchovies next. The jack mackerel differed but little from the anchovy and sardine but the Pacific mackerel were definitely less numerous. Since the jack mackerel probably range farther off shore it is doubtful if the surveys give an accurate measure of the relative abundance of this species.

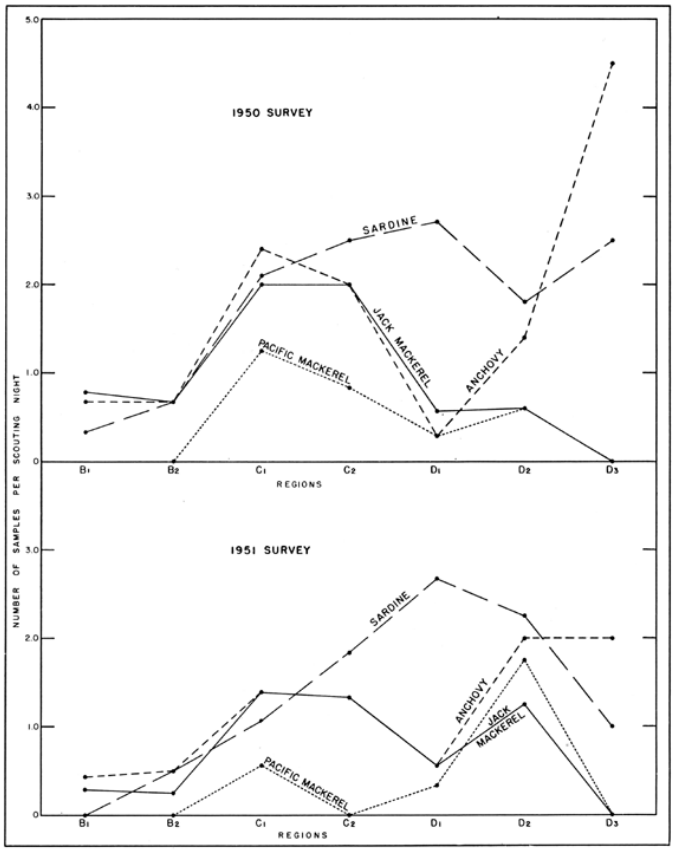

FIGURE 13. Concentration of principal fishes sampled during the 1950 and 1951 young fish surveys as measured by numbers of samples per scouting night by region

FIGURE 13. Concentration of principal fishes sampled during the 1950 and 1951 young fish surveys as measured by numbers of samples per scouting night by region

3.10. THE OUTLOOK FOR THE FUTURE

There are a great number of unknown variables which affect the random nature of the data collected, such as geographic limits of the population, size of schools, scouting efficiency, etc. These variables invalidate any detailed or complicated statistical analyses of the data and prevent attempts at calculating total population numbers or measures of availability. The value of assessing the abundance of incoming age groups is dependent, therefore, upon how well the information can be used in predicting future fishing success. In addition to knowing the relative strength and distribution of year classes, it is necessary to know in advance whether or not the young fish will eventually appear on the fishing grounds of any area before accurate predictions can be made on fishing success in that region. The factors influencing the movement of sardines have not yet been determined, therefore, any guess about the future distribution of any year class has to be based on past known movements.

The portion of the 1948 year class that was located off the coast of Southern California was heavily exploited in the 1951–52 season. It does not seem likely that the 1948 class can support a fishery by itself unless the greatest portion of the fish of this group found south of the Mexican boundary in 1951 moves up the coast to the Southern California fishing grounds by the fall of 1952. The mortality of the southern fish will reduce their numbers by the 1952–53 season and, even though a northward movement may occur, the 1948 year class should not be expected to increase in Southern California. The 1950 year class does not seem to be a strong one nor does the 1949 year class. The indications are that the 1952–53 season will be weaker than the 1951–52 season which ranks with 1947–48 as the poorest on record. Nor does it seem likely that fishing will improve in 1953–54 unless the 1951 year class proves to be much stronger than the survey indicated.

The San Francisco-Monterey area should not be expected to contribute much to the total catch. The main success should occur in Southern California. Failures north of California are expected to continue.

3.11. SUMMARY

Attempts were made by surveys to assess the relative abundance of young sardines prior to their entry into the commercial fishery. The results of these surveys indicate that this method might be used to forecast future fishing success.

1. Radar and echo-sounder aid greatly in collecting samples.
2. Age reading aids in evaluating data.
3. The 1950 survey indicated that the 1948 year class was the strongest one in the fishery at that time and that the 1949 and 1950 year classes were below average.
4. The 1951 survey also indicated that the 1948 year class was strong as compared to others at that time and that the 1949, 1950 and 1951 classes were all below average.

5. Work in 1949 showed the 1948 year class to be substantially stronger than any other year class at that time.

6. The sardines located in Mexico in 1950 and 1951 were mostly young fish.

7. The year classes concentrated, in 1950, in the area where fishing intensity was highest, suffered the highest mortality between 1950 and 1951.

8. Fish of the same year classes had a greater average length in Southern California than in Sebastían Vizcaíno Bay.

9. Distribution, as well as abundance, seems to be important in the determination of the availability of a given year class to the California fishery.

10. The 1951–52 season ranks with 1947–48 as the poorest in the past 29 years. The 1948 year class furnished 67 percent of the catch.

11. The 1952–53 catch will probably be less than in 1951–52.

12. The 1953–54 season should be still weaker than 1952–53 unless the 1951 year class is much stronger than was indicated during the 1951 survey.

TABLE 17

Length Frequency of All Sardines Sampled During the 1950 Young Fish Survey by Region

Body length mm.	Regions							
	B-1	B-2	C-1	C-2	D-1	D-2	D-3	Totals
51- 60	3		3	1	3		38	48
61- 70	37		2	5			25	69
71- 80	118	3	4	5			4	134
81- 90	60		7	2	1		3	73
91-100			28	1		3	8	40
101-110			15	14		35	28	92
111-120			2	74		16	6	98
121-130			1	19		17	5	42
131-140					1	1		2
141-150					7	1		8
151-160					91	5		96
161-170				2	286	14		302
171-180			6	11	340	40		397
181-190			105	89	326	41		561
191-200			567	152	108	60		887
201-210			411	34	25	54		524
211-220		6	164	5	10	23		208
221-230			84		9	4		97
231-240			16		2	3		21
241-250			1					1
251-260		1						1
Totals	218	10	1,416	414	1,209	317	117	3,701

TABLE 17
Length Frequency of All Sardines Sampled During the 1950 Young Fish Survey by Region

TABLE 18

Length Frequency of All Sardines Sampled by Region During the 1950 Young Fish Survey Weighted to 100 Fish per Sample

Body length mm.	Regions							
	B-1	B-2	C-1	C-2	D-1	D-2	D-3	Totals
51- 60	3		20	25	100		93	241
61- 70	51		14	60			104	229
71- 80	177	100	45	18			119	459
81- 90	69		33	125	100		84	411
91-100			122	4		3	17	146
101-110			41	53		35	59	188
111-120			10	178		16	13	217
121-130			3	35		17	11	66
131-140					1	1		2
141-150					7	1		8
151-160					226	104		330
161-170				7	357	31		395
171-180			22	49	422	181		674
181-190			308	410	487	77		1,282
191-200			1,614	440	145	182		2,381
201-210			1,380	78	30	177		1,665
211-220		86	342	18	12	66		524
221-230			194		11	5		210
231-240			51		2	4		57
241-250			1					1
251-260		14						14
Totals	300	200	4,200	1,500	1,900	900	500	9,500

TABLE 18

Length Frequency of All Sardines Sampled by Region During the 1950 Young Fish Survey Weighted to 100 Fish per Sample

TABLE 19

Numbers of Sardines of Each Year Class Sampled by Region During the 1950 Survey Weighted to 100 Fish per Sample

Region	Year class								
	1950	1949	1948	1947	1946	1945	1944	1943	Totals
B-1	300								300
B-2	100		34	52	14				200
C-1	288	165	2,259	961	261	222	44		4,200
C-2	498	32	780	161	20			9	1,500
D-1	201	429	1,173	94	3				1,900
D-2	72	373	336	74	26	19			900
D-3	500								500
Totals	1,959	999	4,582	1,342	324	241	44	9	9,500

TABLE 19

Numbers of Sardines of Each Year Class Sampled by Region During the 1950 Survey Weighted to 100 Fish per Sample

TABLE 20

Length Frequency of All Sardines Sampled During the 1951 Young Fish Survey by Region

Body length mm.	Regions							
	B-1	B-2	C-1	C-2	D-1	D-2	D-3	Totals
41– 50					1	2		3
51– 60						2		2
61– 70					6	8	13	27
71– 80					2	5	66	73
81– 90					4	4	21	29
91–100			1	1	28	12		42
101–110			6	1	56	10		73
111–120			5	8	17	13		43
121–130			4	4	2	1		11
131–140		1	9			1		11
141–150		1	4		5	2		12
151–160					14	21		35
161–170		7	3		41	72		123
171–180		10	6	8	297	74		395
181–190			52	125	454	103		734
191–200		6	259	220	180	58		723
201–210		20	184	46	43	13		306
211–220		16	90	4	11	1		122
221–230		3	37					40
231–240			13					13
241–250			2					2
Totals	0	64	675	417	1,161	402	100	2,819

TABLE 20
Length Frequency of All Sardines Sampled During the 1951 Young Fish Survey by Region

TABLE 21

Length Frequency of All Sardines Sampled by Region During the 1951 Young Fish Survey Weighted to 100 Fish per Sample

Body length mm.	Region							
	B-1	B-2	C-1	C-2	D-1	D-2	D-3	Totals
41– 50					20	5		25
51– 60						54		54
61– 70					113	124	13	250
71– 80					150	152	66	368
81– 90					4	10	21	35
91–100			3	100	28	29		160
101–110			53	8	66	24		151
111–120			140	159	135	31		465
121–130			39	33	12	2		86
131–140		3	109			1		113
141–150		3	21		36	2		62
151–160					74	27		101
161–170		21	16		275	107		419
171–180		31	19	114	459	119		742
181–190			117	191	670	127		1,105
191–200		19	579	285	290	72		1,245
201–210		63	529	205	57	13		867
211–220		50	152	5	11	1		219
221–230		10	95					105
231–240			25					25
241–250			3					3
Totals	0	200	1,900	1,100	2,400	900	100	6,600

TABLE 21
Length Frequency of All Sardines Sampled by Region During the 1951 Young Fish Survey Weighted to 100 Fish per Sample

TABLE 22

Numbers of Sardines of Each Year Class Sampled by Region During the 1951 Survey Weighted to 100 Fish per Sample

Region	Year class							
	1951	1950	1949	1948	1947	1946	1945	Totals
B-1								0
B-2	6	45	15	99	25	10		200
C-1	365	127	151	1,006	186	37	28	1,900
C-2	300	28	94	557	93	28		1,100
D-1	576	573	374	808	69			2,400
D-2	434	240	72	147	7			900
D-3	100							100
Totals	1,781	1,013	706	2,617	380	75	28	6,600

TABLE 22
Numbers of Sardines of Each Year Class Sampled by Region During the 1951 Survey Weighted to 100 Fish per Sample

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