

SUMMARY OF BIOLOGICAL INFORMATION ON THE NORTHERN ANCHOVY *ENGRAULIS MORDAX GIRARD*

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INTRODUCTION

The northern anchovy has long been recognized as one of the most abundant fishes in the northeastern Pacific Ocean and a sizable latent resource (Croker, 1942; Chapman, 1942). In recent years the anchovy population has increased dramatically. Egg and larva surveys by the U.S. Bureau of Commercial Fisheries show that the population trebled between 1951 and 1958 and has increased even further since (Ahlstrom, 1965). Despite its great abundance the anchovy has never been the object of a large-scale fishery.

DISTRIBUTION

Adult northern anchovies occur from the Queen Charlotte Islands, British Columbia to Cape San Lucas, Baja California. They are most common from about San Francisco to Magdalena Bay, chiefly in coastal waters. Eggs and larvae have been taken as far as about 300 miles offshore.

Hubbs (1925) described a separate subspecies (*E. m. nanus*) which inhabits San Francisco Bay and tolerates much-reduced salinities. In both mean and modal number of vertebrae the bay subspecies has two fewer than the ocean subspecies. It is a much smaller fish, the largest found by Hubbs measured 99 mm TL. Its head averages longer, the body deeper and more compressed. The early development is also apparently more accelerated and transformation from postlarval to juvenile stages occurs at a much smaller size.

Similar brackish-water forms also are known for the European anchovy (*E. encrasicolus*) and Australian anchovy (*E. australis*) (Blackburn, 1950).

Subpopulations

McHugh (1951) delineated three northern anchovy subpopulations on the basis of differences in numbers of dorsal, anal, and pectoral fin rays; vertebrae; and gill rakers. The three subpopulations occur from British Columbia to central California, off southern California and northern Baja California, and off central and southern Baja California.

Miller (1956), on the basis of age and size compositions of central and southern California commercial and live bait catches, aerial surveys, and sea surveys, gave possible evidence of "local" stocks of fish. Work currently is underway by the U.S. Bureau of Commercial Fisheries using serological techniques to delineate possible genetically distinct stocks of northern anchovies.

Habitat

Anchovies are pelagic schooling fishes, generally found in coastal waters. During recent years, their offshore occurrence has expanded markedly as the population has increased. Like their congeners, northern anchovies exhibit some seasonal movements. During fall and winter they apparently move offshore and return inshore in spring. Fall surveys by the Department's R/V ALASKA indicate that anchovies occur well below the surface during the day and move to the upper layers of the ocean at night. The European anchovy (*E. encrasicolus*) makes similar diurnal movements at this time of year. Off the coast near Santa Barbara during November, 1964, anchovies were noted on the depth recorder in a thin band along the bottom during the day, but at night they rose toward the surface to form a band 20 to 50 feet thick. Our sampling also indicates that large fish are less available in inshore waters during winter.

During periods of warmer-than-average water temperatures, adult anchovies become less available in the inshore waters. Fish-of-the-year apparently tolerate somewhat higher water temperatures than adults. Our sampling program has shown that 0-age-group fish predominate in inshore live bait catches during periods of warm water. During the 1957-59 "warm-water years" our research vessel surveys showed that large anchovies no longer frequented inshore areas but were more numerous offshore. While live bait fishermen were experiencing difficulty in catching large fish, vessels conducting seismic oil exploration occasionally were killing large anchovies well offshore from usual areas of abundance.

On Department sea surveys for the years 1955 through October, 1964, samples of anchovies were caught in water temperatures ranging from 8.5° to 25.0°C. between northern California and Magdalena Bay, Baja California (Table 1). Of 617 samples caught where surface temperatures were recorded, 75.9 percent of the catches occurred in waters having surface temperatures between 14.5° and 20.0°C. Off California and northern Baja California (north of lat. 31°N.) 340 samples were taken in temperatures ranging from 8.5° to 21.5°C. Of these, 72.5 percent occurred between 14.5° and 18.5°C. Off central and southern Baja California 277 anchovy samples were taken in water temperatures ranging from 13.0° to 25.0°C., 65.0 percent between 17.0° and 21.5°C.

TABLE 1
 NUMBER OF STATIONS WHERE ANCHOVY SAMPLES WERE CAUGHT
 BY DEPARTMENT OF FISH AND GAME RESEARCH VESSELS,
 1955-1964 BY SEA SURFACE TEMPERATURE

Temperature °C.	North of Lat. 31°N.	South of Lat. 31°N.	Total
8.5	1	--	1
9.0	1	--	1
9.5	2	--	2
10.0	1	--	1
10.5	2	--	2
11.0	2	--	2
11.5	4	--	4
12.0	5	--	5
12.5	5	--	5
13.0	12	1	13
13.5	6	2	8
14.0	11	4	15
14.5	38	7	45
15.0	23	10	33
15.5	31	10	41
16.0	35	7	42
16.5	28	10	38
17.0	32	27	59
17.5	22	29	51
18.0	20	20	40
18.5	17	21	38
19.0	13	17	30
19.5	13	13	26
20.0	10	15	25
20.5	4	15	19
21.0	1	9	10
21.5	1	14	15
22.0	--	8	8
22.5	--	8	8
23.0	--	15	15
23.5	--	8	8
24.0	--	5	5
24.5	--	1	1
25.0	--	1	1
Total	340	277	617

Anchovy larvae have been taken in water temperatures ranging from 10.0° to 19.7°C.; approximately 95 percent were taken between 14.0° and 17.4°C. (Ahlstrom, 1959). Ahlstrom also found that, on the average, the larvae occurred mostly between 24 and 48 m although they also were abundant in the upper 23 m.

Anchovy eggs were sampled in 1953 and 1954 in temperatures ranging from 9.9° to 23.3°C. (Ahlstrom, 1956). He used water temperatures at 10 meters as representative of the upper mixed layer where anchovy eggs occurred. Most eggs were taken in temperatures between 13.0° and 17.5°C.; however, 10 percent of the spawning sampled in these years occurred at temperatures below 13.0°C.

REPRODUCTION

Maturity (age and size)

A few northern anchovies first reach sexual maturity at about 90 to 100 mm SL at the end of their first year of life. About 50 percent are mature at 130 mm SL when they are between 2 and 3 years old. All are

mature when 150 mm long or 4 years old (Clark and Phillips, 1952).

Fecundity

Although little has been published on the fecundity of the northern anchovy, each large female spawns an estimated 20 to 30 thousand eggs annually and spawns two or three times each year. There is always a reservoir of maturing eggs in the ovary of an adult female in spawning condition.

Spawning

Anchovy spawning, although recorded from British Columbia to below Magdalena Bay, Baja California, is heaviest between Point Conception, California and Point San Juanico, Baja California. Most spawning has occurred within 60 miles of the coast, although it has been recorded to about 300 miles offshore. In waters north of Point Conception spawning intensity has been variable. During some years such as 1950 and 1954, heavy spawning has occurred in the area while in others such as 1953 and 1955 there has been very little (Ahlstrom, 1956). Ahlstrom also noted that in the area south of Point Conception there are two major spawning areas, one off southern California and northern Baja California, and the other off central and southern Baja California. The southern sector, between 1951 and 1955, consistently had the most eggs and larvae. From 54 to 85 percent of the larvae were taken there.

Spawning has been noted in every month of the year particularly in the southern part of the anchovy's geographical distribution. The peak spawning period is during late winter and spring. Bolin (1936) noted that most spawning takes place in Monterey Bay from December to June; however, he also noted that eggs have been taken in the southern portion of Monterey Bay during each month of the year.

The eggs and larvae of anchovies are pelagic and float passively in the upper layers of the ocean. According to Bolin (1936) anchovies spawn regularly at 10 PM. Spawning takes place in the upper mixed layer in temperatures ranging from 9.9° to 23.3°C. with most eggs occurring in temperatures between 13.0° and 17.5°C. (Ahlstrom, 1956). The threshold temperature for anchovy spawning is about 11.5° or 12.0°C. Fertilization of the eggs takes place in the water immediately after spawning and is so successful that an unfertilized egg is rare (Ahlstrom, 1956). The eggs are ovoid, as is typical of all engraulids, and float with the major axis perpendicular to the surface of the water. As the embryo grows the egg rolls over on its side so the major axis becomes horizontal and the embryo hangs underneath (Bolin, 1936).

Development

The egg and early larval stages were first described by Bolin (1936). The ovoid eggs are 1.23 to 1.55 mm along the major axis and 0.65 to 0.82 mm along the minor axis. They are clear and translucent and require from 2 to 4 days to hatch depending on the temperature of the water. Bolin noted that in the

Monterey Bay area hatching takes place about 62 hours after spawning.

Newly-hatched larvae are 2.5 to 3 mm long. The yolk sac is rather large and elongated, tapering to a point posteriorly. The yolk sac is absorbed entirely within 36 hours. The larvae are elongated, transparent and threadlike. In the early stages the mouth is terminal and they do not begin to look like the adult form until they are about 1 inch long.

AGE AND GROWTH

Clark and Phillips (1952) first determined the age and rate of growth for the northern anchovy. Miller (1955) studied the validity of scales for determining the ages of anchovies and concluded that scales mounted dry between two glass slides were satisfactory. He also concluded that annual rings were formed on the scales during the early winter and spring months and all fish showed new annuli by the middle of April. Growth rates decreased during late summer and fall (August–November).

Clark and Phillips (1952) presented a growth curve for anchovies taken in southern and central California and determined average sizes through age VII (Table 2, Figure 1).

TABLE 2
AVERAGE LENGTH AT EACH AGE OF THE ANCHOVY IN THE CALIFORNIA FISHERY (CLARK AND PHILLIPS, 1952)

Age	Standard length (mm)	Total length (mm)	Total length (inches)
1	92	108	4.3
2	120	142	5.6
3	139	163	6.4
4	152	178	7.0
5	161	188	7.4
6	167	195	7.7
7	171	200	7.9

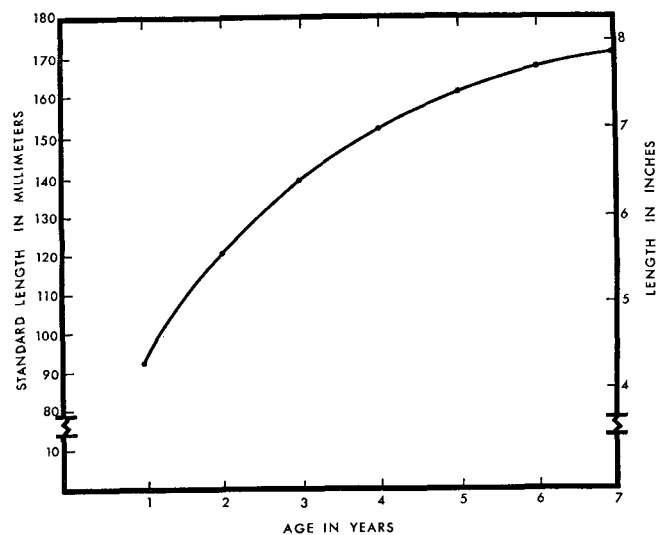


FIGURE 1. Growth curve for the northern anchovy in California.

In general the anchovy is short-lived; individuals over 7 inches long and 4 years of age are rare, although anchovies 9 inches long and 7 years old have been taken.

FOOD

Although statements that adult northern anchovies feed on zooplankton have been common, no definitive study of their food habits has been published as yet. Such studies of anchovy food are only now in their early stages. Some work has been done on the food of larvae. Berner (1959) found that larvae collected in 1954 ate chiefly crustaceans, mostly copepods in various developmental stages.

Anchovies are apparently indiscriminate filter feeders and are chiefly daytime feeders. They have been observed to be predatory on small fish at times, even their own kind. We have observed this several times. We have also noted 1½-inch fish in the stomachs of 5½-inch anchovies.

COMPETITORS

The chief competitor of the northern anchovy is almost certainly the Pacific sardine (*Sardinops caeruleus*). Competition begins in the larval stages and probably continues through life. Sardines and anchovies eat about the same foods and both occur in greatest abundance between Point Conception, California and Magdalena Bay, Baja California.

PREDATORS

The list of anchovy predators would certainly include almost every predatory species in our waters. Although the list of anchovy predators in our waters includes a great many species of fishes, birds, and mammals, we know very little of the actual quantities of anchovies consumed or what percentage of the predator diet is made up of anchovies in relation to other forage species. Available quantitative studies show that anchovies constituted 12.8 percent by volume of the diet of California yellowtail (*Seriola dorsalis*) (Craig, 1960) and 29.1 percent by volume of the diet of king salmon (*Oncorhynchus tshawytscha*) off San Francisco (Merkel, 1957). Qualitative studies have shown anchovies to be an important constituent in the diets of all of the large predatory game fish off California. It is interesting to note that the Pacific bonito (*Sarda chiliensis*) population has blossomed concurrent with the tremendous growth of the anchovy population. Between 1951 and 1963 the bonito catch by party boats increased from 6,300 fish in 1953 to a high of 1,200,000 fish in 1960. Since then, the bonito catch has dropped from 850,000 in 1961 to 775,000 in 1963. Suffice to say, the anchovy is probably the number one forage species in the inshore waters of California and Baja California at the present time. Despite this apparent forage demand the anchovy population has still continued to grow in size at a phenomenal rate (Ahlstrom, 1965).

FISHERY

The California anchovy fishery is in reality two distinct fisheries, the commercial fishery and that for live bait. Both are quite modest compared to anchovy fisheries in other parts of the world. In fact, the amount of anchovies consumed by the guano birds of Peru (an estimated $3\frac{1}{4}$ million tons annually) approximates a large portion of the entire population size of our species (see Jordán, this volume).

Commercial Fishery

The commercial fishery in California is carried on exclusively with roundhaul nets, and except for the

period from 1952 through 1957 when the failure of California's sardine fishery forced the purse-seine fleet to turn to other species, most catches have been made by small boats employing lampara nets.

Commercial Catch

Under commercial catch are included fish used in canning for both human consumption and pet foods; fresh, frozen, and salted fish sold at fresh fish markets; dead bait used by both sportsmen and commercial fishermen; fish used for feeding at fish hatcheries and mink farms; and offal used for reduction into meal and oil.

The Department of Fish and Game has tabulated the amounts of fish and fishery products landed in California since 1916 (Table 3). From 1916 to 1938 between 30 and 973 tons were landed annually, mostly for dead or salted bait. In general, less than 200 tons were landed annually during this period. Slightly increased tonnages were landed between 1918 and 1921 for reduction into meal and oil in central California. Legislation requiring a special permit from the Fish and Game Commission to reduce whole fish stopped this activity in 1922.

In 1939 increased catches of anchovies were made for grinding into "chum" for use in the southern California "scoop" fishery for Pacific mackerel (*Scomber diego*). With the decline of sardines and Pacific mackerel in the years immediately following World War II varying amounts of anchovies were packed to supply foreign and domestic markets for canned wetfish. The period of greatest activity in the anchovy fishery was between 1952 and 1957 when from 20,273 to the all time high of 42,917 tons were landed. Most of this was canned either "sardine style" for export or for pet food. Since 1957 the commercial catch has varied between 1,400 and 5,800 tons chiefly due to a lack of demand by canners.

Live Bait Fishery

This unique fishery is carried on expressly to supply fishermen with live fish for use as bait or chum. Fishing for live bait was introduced locally in 1910 by Japanese albacore fishermen who used blanket nets; lampara or bait nets, as used now, were introduced into the live-bait fishery in 1912.

The mainstay of the live-bait fishery is the northern anchovy which comprises up to 98 percent of the total live-bait catch. Other species included in the catch are Pacific sardines, white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), Pacific mackerel, jack mackerel (*Trachurus symmetricus*), and Pacific herring (*Clupea pallasii*).

Bait nets are usually 120 to 140 fathoms long by 20 to 30 fathoms deep and are generally constructed of synthetic fibers such as nylon. Mesh sizes vary from 6 to 8 inches in the wings to $\frac{1}{2}$ inch in the bag.

The live-bait fishery is carried on at most coastal ports between San Francisco and San Diego. Los Angeles-Long Beach Harbor is the most important fishing area, supplying over 80 percent of the live bait used in southern California in recent years. Although live bait taken in coastal areas is located

TABLE 3
CALIFORNIA ANCHOVY LANDINGS BY PORT, 1916-1964
(IN TONS)

Year	Eureka	San Francisco	Monterey	Santa Barbara	Los Angeles	San Diego	Total
1916	--	119.8	125.7	--	20.1	--	265.6
1917	--	50.1	187.8	--	26.4	--	264.3
1918	--	134.2	270.2	--	24.7	4.9	434.0
1919	--	153.0	352.5	--	288.4	10.8	804.7
1920	--	110.6	156.9	--	2.3	15.1	284.9
1921	--	87.6	741.4	--	5.2	139.1	973.3
1922	--	75.4	68.2	--	182.4	0.2	326.2
1923	--	92.0	42.5	--	19.0	--	153.5
1924	--	5.3	148.5	1.7	17.9	--	173.4
1925	--	13.0	0.7	--	32.8	--	46.5
1926	--	1.7	24.3	--	4.1	--	30.1
1927	--	139.1	28.3	--	16.1	0.6	184.1
1928	--	62.8	87.7	--	27.9	0.3	178.7
1929	--	119.8	41.0	--	30.4	--	191.2
1930	--	130.9	21.7	--	5.2	1.9	159.7
1931	--	82.3	52.4	--	18.9	0.1	153.7
1932	--	73.8	60.0	--	15.8	--	149.6
1933	--	92.5	45.4	--	20.7	--	158.6
1934	--	33.5	63.7	--	31.5	--	128.7
1935	--	37.2	38.2	--	14.0	--	89.4
1936	1.0	66.5	15.1	--	14.9	--	97.5
1937	--	51.0	22.1	--	40.0	--	113.1
1938	--	125.9	17.0	--	224.6	--	367.5
1939	--	107.4	6.0	--	960.5	--	1,073.9
1940	--	6.9	18.7	--	3,125.9	7.3	3,158.8
1941	--	0.3	16.6	16.6	2,019.1	--	2,052.6
1942	--	2.7	74.5	--	769.7	0.2	847.1
1943	--	39.4	99.2	--	646.8	--	785.4
1944	--	55.0	424.0	--	1,465.1	1.4	1,945.5
1945	0.2	146.0	63.9	--	598.3	--	808.4
1946	--	131.9	124.0	2.5	702.2	0.2	960.8
1947	2.2	195.1	7,747.9	99.7	1,423.5	1.8	9,470.2
1948	6.8	190.1	3,627.8	102.1	1,486.2	4.9	5,417.9
1949	--	108.2	741.4	240.8	566.6	4.1	1,661.1
1950	0.4	169.3	1,273.3	145.9	850.1	0.3	2,439.3
1951	--	142.0	2,525.0	100.8	703.2	6.4	3,477.4
1952	--	2,915.5	19,867.8	3,516.8	1,578.7	12.6	27,891.4
1953	--	1,536.3	6,847.5	17,367.6	17,164.9	1.4	42,917.7
1954	0.7	130.9	122.6	8,403.7	12,546.0	1.2	21,205.1
1955	--	103.3	3,441.8	1,630.8	17,166.7	3.2	22,345.8
1956	--	194.0	4,829.2	278.7	23,158.4	--	28,460.3
1957	0.5	5.1	742.9	77.5	19,440.5	7.2	20,273.7
1958	--	1.4	271.2	313.5	5,212.9	2.3	5,801.3
1959	--	15.0	186.4	404.9	2,979.7	0.9	3,586.9
1960	--	0.3	645.3	12.8	1,870.9	--	2,529.3
1961	--	114.8	1,893.7	27.1	1,820.2	--	3,855.8
1962	--	5.7	594.0	14.9	767.2	0.2	1,382.0
1963	--	13.9	1,680.1	5.7	585.5	--	2,285.2
1964	--	15.1	1,416.6	0.5	1,053.6	1.7	2,487.5

most commonly either visually or with fathometers, the most successful method is to attract the bait schools at night with lights. This latter method, developed in the Los Angeles-Long Beach Harbor area, employs a small skiff with a gasoline-powered generator which supplies 500- to 1000-watt lights. The light both attracts and holds bait schools so that they can be netted.

After being caught, the bait is either sold directly from the bag of the net or transferred to one of the various holding facilities for sale later.

Live Bait Catch

In 1935, California initiated a program of personal interviews with live-bait fishermen to obtain information about the extent of the fishery. Since 1939, the Department has collected fishing logs. The present version of the logs is combined with personal interviews and sampling to determine the amount of fish sold as live bait, the species composition of the catch localities of catch, and fishing effort. Catches are recorded by the fishermen in "scoops" which are converted into pounds by Department personnel.

Live-bait catches have fluctuated between 4,000 and 7,000 tons annually since 1950 (Table 4). In recent years, sales have been estimated at about 1.5 million dollars per year.

POPULATION

Age Composition

The Department routinely sampled the commercial anchovy catch from 1952 through 1957 and has sampled the live bait catch since 1955. Age compositions have been determined cooperatively with the U.S. Bureau of Commercial Fisheries. The commercial anchovy season extends from April 1 through March 31.

In central California, particularly, the age composition of the catch has been somewhat variable. From 1952-53 through 1953-54, ages II, III, and IV predominated the landings. Beginning in 1954-55, following increased anchovy fishing, the 1954 year-class began to dominate the landings. In 1954-55, 80.4 percent was fish-of-the-year; in 1955-56, 79.0 percent was 1954 year-class fish as 1-year-olds and in 1956-57, this time as 2-year-olds, the 1954 year-class contributed 73.8 percent of the catch. Fish up to 6 years old were sampled. The central California fishery seems to depend upon sporadic good year classes from a localized population. This agrees with the report of Ahlstrom (1956) that good spawning success is intermittent in the area north of Point Conception.

The commercial catch off southern California between 1952 and 1957 was comprised chiefly of 1- and

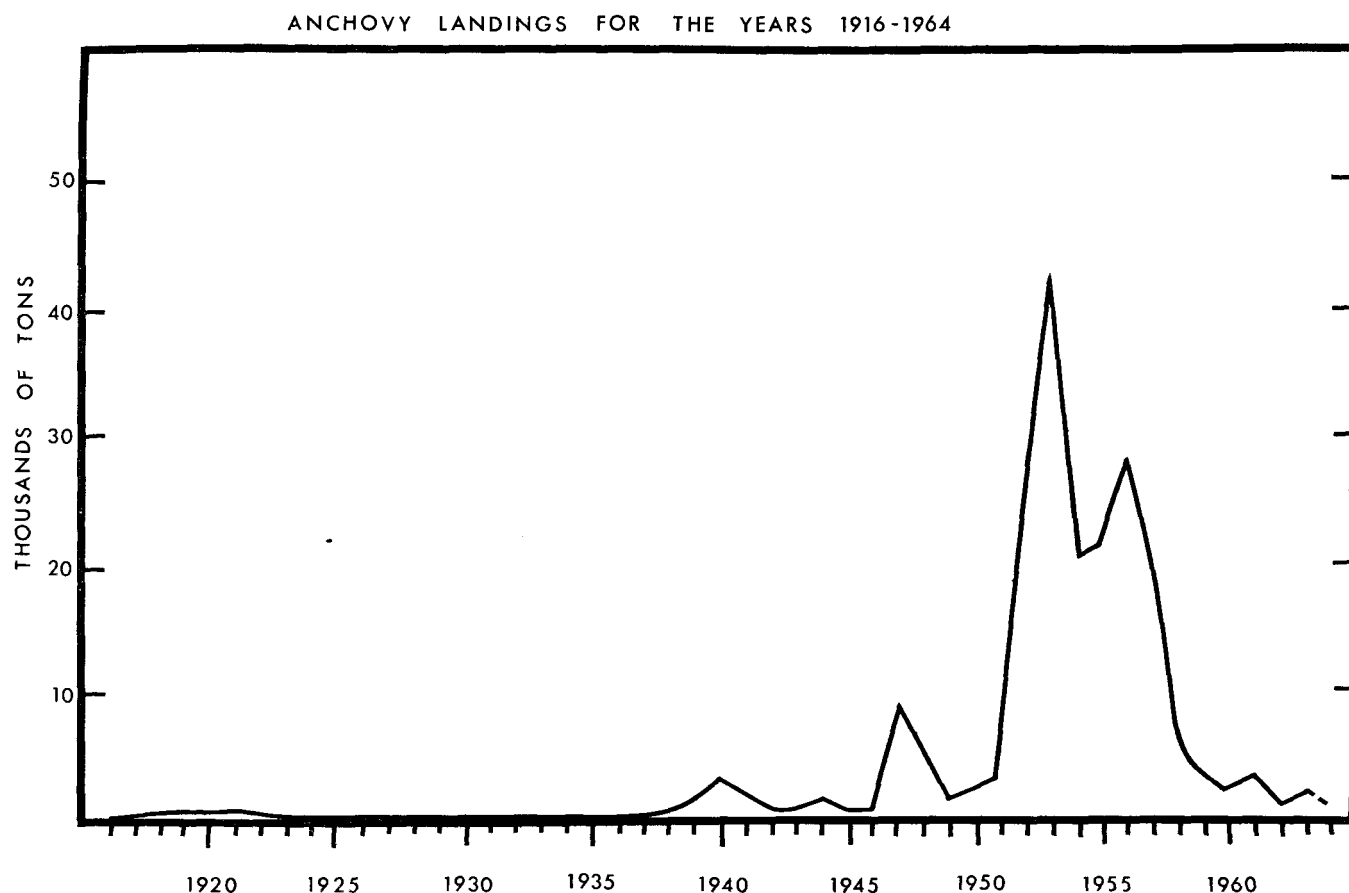


FIGURE 2. California Commercial Anchovy Landings, 1916-1964 (in tons).

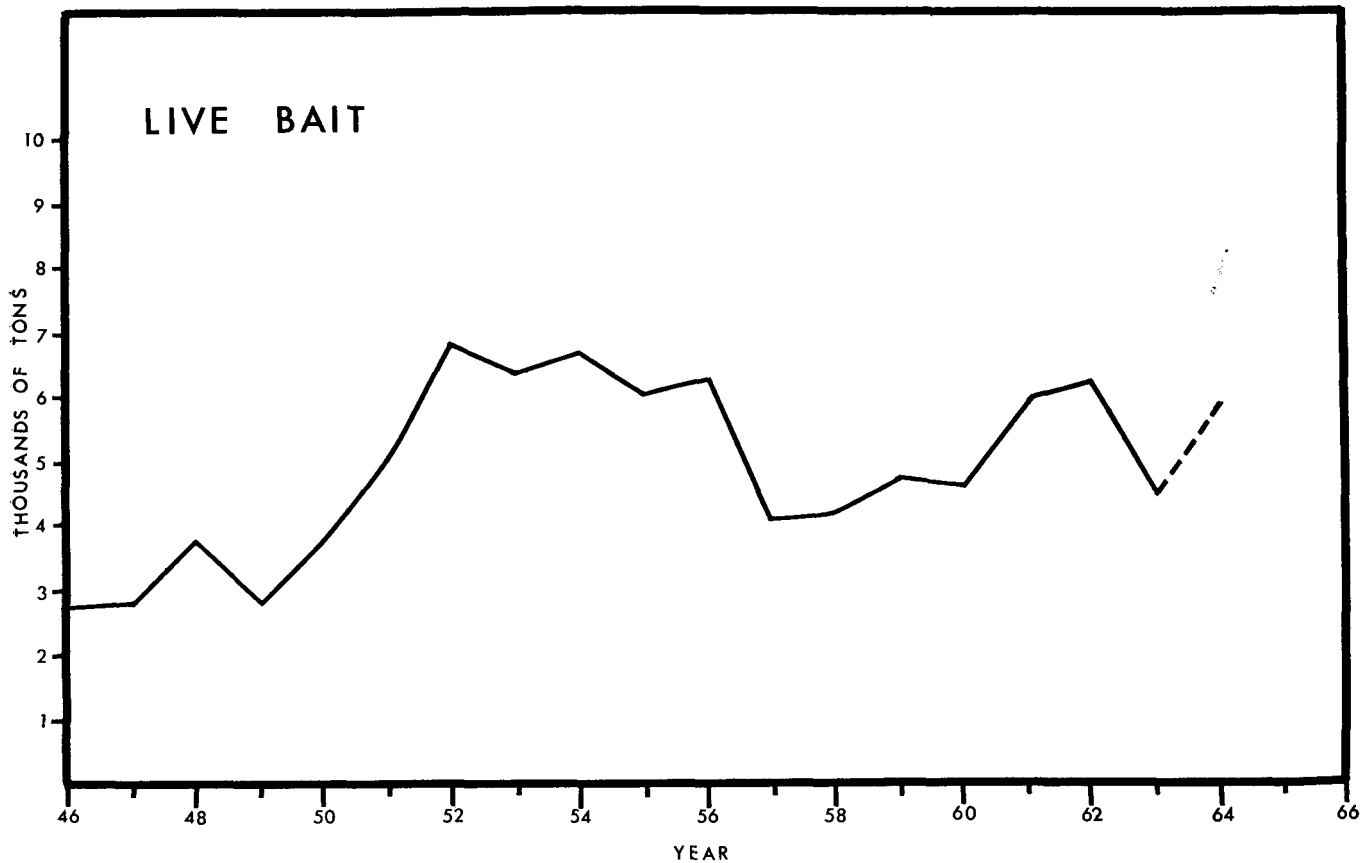


FIGURE 3. Live-bait catch of anchovies in California, 1939-1964 (in tons).

TABLE 4
LIVE-BAIT CATCH OF ANCHOVIES IN SOUTHERN CALIFORNIA,
1939-1964 (CATCH FROM 1942-45 NOT RECORDED)

Year	Catch (tons)
1939	1,503.2
1940	2,006.0
1941	1,587.7
1942	257.5
1943	--
1944	--
1945	--
1946	2,748.1
1947	2,854.0
1948	3,725.5
1949	2,802.4
1950	3,823.8
1951	5,141.9
1952	6,810.4
1953	6,391.5
1954	6,686.0
1955	6,125.4
1956	6,331.8
1957	4,110.1
1958	4,235.9
1959	4,737.5
1960	4,657.5
1961	5,912.5
1962	6,166.5
1963	4,442.0
1964	5,191.0

2-year-old fish with varying amounts of fish-of-the-year. The 1954 year-class also dominated this catch; however, not so completely as in central California. The oldest fish sampled in the southern California commercial fishery was 5 years old (Table 5).

The live bait catch between 1955 and 1962 was consistently dependent upon 1- and 2-year-old fish each year. One-year-olds contributed 38.9 to 56.3 percent of the catch and 2-year-olds, 30.6 to 51.5

TABLE 5
AGE COMPOSITION OF THE COMMERCIAL NORTHERN ANCHOVY
CATCH FOR THE SEASONS 1952-53 THROUGH 1956-57

	Percentage composition by age						
	0	1	2	3	4	5	6
Central California							
1952-53	1.9	6.9	31.6	33.3	19.7	6.2	0.4
1953-54	7.7	9.8	35.8	28.5	14.5	2.9	0.8
1954-55	80.4	5.5	4.8	4.0	5.0	0.3	--
1955-56	10.1	79.0	8.1	2.3	0.3	0.2	--
1956-57	6.0	9.5	73.8	8.5	2.1	0.1	--
Southern California							
1952-53	38.3	19.9	30.6	18.0	13.1	0.1	--
1953-54	17.2	32.0	34.8	13.4	2.3	0.3	--
1954-55	10.7	52.9	29.5	5.6	1.2	0.1	--
1955-56	4.3	49.5	36.2	10.0	--	--	--
1956-57	1.4	18.8	61.8	16.1	1.7	0.2	--

percent. Very few fish over 3 years old are taken in the live-bait fishery (Table 6).

TABLE 6
AGE COMPOSITION OF THE NORTHERN ANCHOVY LIVE-BAIT CATCH FOR THE YEARS 1955-1962

Season/Year	Percentage composition by age					
	0	1	2	3	4	5
1955.....	8.8	43.0	41.8	6.4	--	--
1956.....	2.1	39.9	51.5	5.9	0.6	--
1957.....	3.2	35.5	37.1	19.7	4.3	0.3
1958.....	4.8	56.3	33.6	4.5	0.8	--
1959.....	2.5	53.9	40.5	2.8	0.3	--
1960.....	4.4	38.4	47.8	9.4	--	--
1961.....	6.5	38.9	37.9	14.9	1.8	0.1
1962.....	9.6	46.2	30.6	10.4	3.6	0.2

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