

# CO-OCCURRENCES OF SARDINE AND ANCHOVY LARVAE IN THE CALIFORNIA CURRENT REGION OFF CALIFORNIA AND BAJA CALIFORNIA

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This is a report on the co-occurrences of sardine and anchovy eggs and larvae in the collections of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) during 1951-60. More important, it is also a study of the interaction between two species of fish—both filter-feeders on planktonic organisms—occupying the same trophic level. This study leads further into the problem of whether there is a limit to the biomass of sardines plus anchovies that can be accommodated in the environment and whether one species increases in abundance only at the expense of the other.

During the period of the CalCOFI surveys, which began in 1949, the population of the Pacific sardine (*Sardinops caerulea*) as determined from the distribution and abundance of eggs and larvae, decreased markedly, especially since 1954. In contrast, the population of the northern anchovy (*Engraulis mordax*), as determined from the distribution and abundance of larvae, increased spectacularly. This relation brings up the question of whether the anchovy is moving into the ecological niche previously occupied by the sardine.

CalCOFI survey cruises have been made off California and Baja California for more than 15 years. Coverage was fairly intensive in 1949-60, when cruises were made at approximately monthly intervals. In 1961-64, cruises were spaced at quarterly intervals. Temporal coverage, consequently, was much better during the decade 1951-60, the years dealt with particularly in this report.

One of the difficulties in working up the observations on sardine and anchovy eggs and larvae is the massiveness of the data. Even the data for the 10-year period, 1951-60, are based on more than 16,000 separate collections. Anchovy larvae occurred in 6,755 collections, or 42.1 percent of the total, and sardine larvae in 2,133, or 14.3 percent. These data can be examined in many different ways. For example, the sardine and anchovy larvae from all collections are measured by 1-millimeter intervals, for abundance and survival studies. Was survival of larvae better in samples where anchovy and sardine larvae co-occurred, or in samples where the larvae of one species occurred alone? What was the relation of co-occurrences to the temporal and areal distributions of the larvae of the two species or to their relative abundances per haul? What was the influence of changing environmental conditions on the frequency with which sardines and anchovies co-occurred?

The CalCOFI survey cruises initially were planned to delimit and assay the distribution and abundance of the planktonic eggs and larvae of the Pacific sardine to determine indirectly the distribution and abundance of the adult population at time of spawning and to obtain information on the factors affecting

the survival of year classes. Sardine spawning was found to have an extensive and variable areal distribution and to take place during much of the year, especially off Baja California. Consequently, we tried to cover systematically a rather large area of the ocean off California and Baja California.

The CalCOFI station pattern is illustrated in Figure 1. Inasmuch as I plan to discuss the distribution and abundance of eggs and larvae in different parts of the CalCOFI region, I have subdivided it into 7 areas—three off California and four off Baja California. The station lines included in each area are as follows:

Area	Station Line
Northern California .....	40- 57
Central California .....	60- 77
Southern California .....	80- 93
Northern Baja California .....	97-107
Upper central Baja California .....	110-120
Lower central Baja California .....	123-137
Southern Baja California .....	140-157

Not all areas were covered on each cruise. Four were consistently worked—those lying between station lines 80-137. The majority of cruises also included the central California area. Usually only 1 or 2 cruises per year were made off northern California and southern Baja California. With rare exceptions, only a single plankton haul was taken at each station occupied during a cruise.

In the course of obtaining information about sardine eggs and larvae, we also obtained information about many other fishes with planktonic young. Even at the beginning of the surveys, sardine larvae were outnumbered by larvae of northern anchovy (*Engraulis mordax*), hake (*Merluccius productus*), rockfish (*Sebastes* spp.), and usually jack mackerel (*Trachurus symmetricus*).

The occurrence of numerous species of larvae led to a decision to identify and enumerate all the kinds in the collections. This decision posed problems in identification, but these were solved with perseverance. It became evident that surveys of eggs and larvae constituted one of the indispensable methods of resource evaluation. Most pelagic fishes have planktonic stages that can be sampled more simply and quantitatively than the adults.

Larvae of the Pacific sardine and northern anchovy occur mainly off southern California and off most of Baja California. The sardine also occurs throughout the Gulf of California. The northern anchovy, a somewhat more temperate species, does not occur in the Gulf, and its larvae seldom occur south of Magdalena Bay. It ranges farther north, however, than the sardine. In recent years there has been little spawning off central California (north of Pt. Conception) by either anchovies or sardines, although

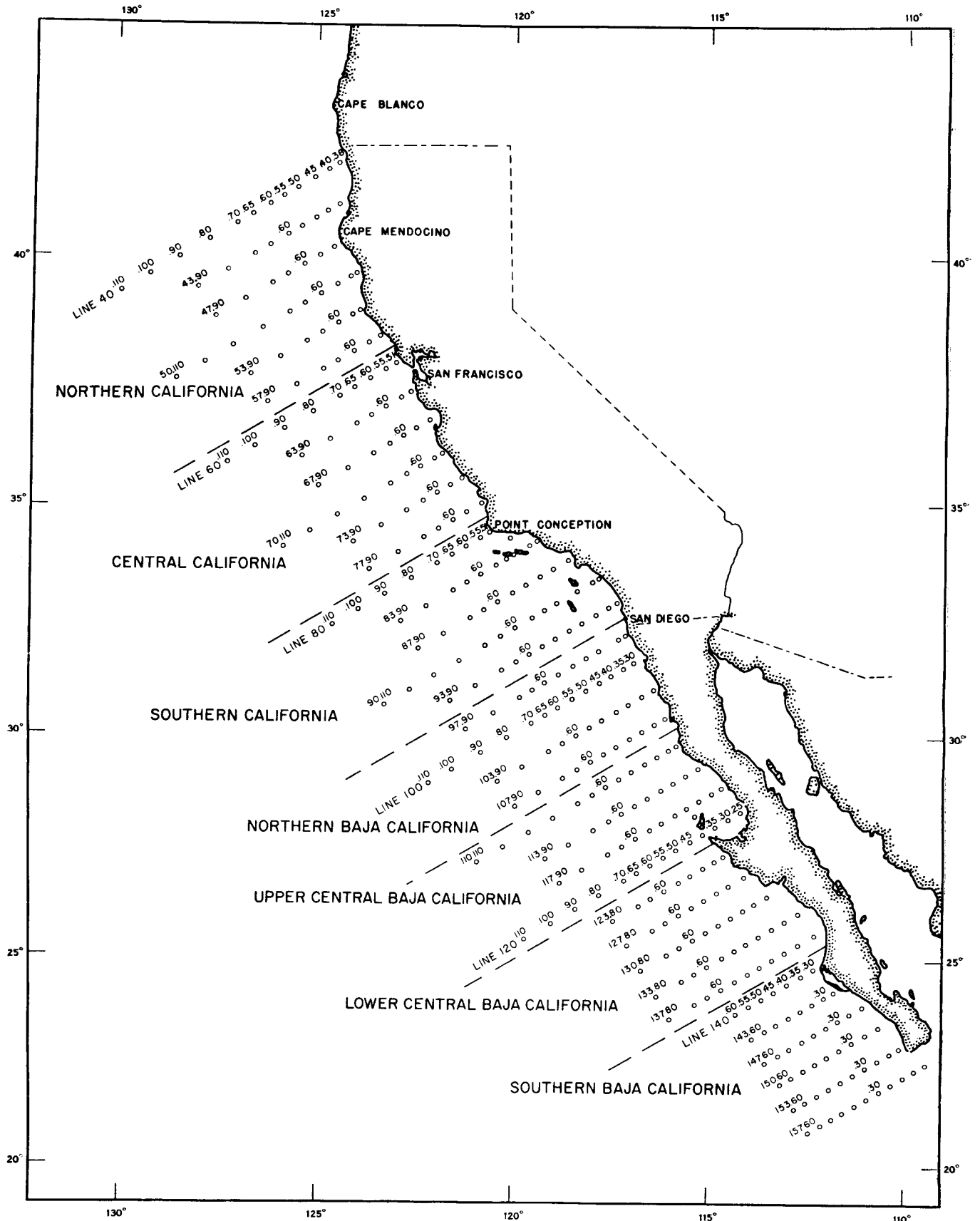


FIGURE 1. Basic CalCOFI station grid off California and Baja California (station lines 40-157); divisions into areas are indicated.

anchovy spawning was common during 1958 and 1959. Some anchovies spawn as far north as British Columbia.

A most important consideration of the data of 1951-60 is that we could define no such thing as an "average" distribution or abundance of either species. Each year differed from every other year. The distributions of both species changed from year to year; the changes reflected their response to the varying oceanic environment. The changes in abundance of the two species, however, were more systematic, as is noted later.

Examples of changing distributions are pointed out here. One of the most marked changes in the distribution of sardine eggs and larvae occurred in the 1953 and 1954 season. In 1953, nearly all sardine spawning was off central Baja California; only about 1 percent was to the north. In 1954, spawning spread distinctly northward, and was widespread off both northern Baja California and southern California. The spawning in these "northern" areas increased to more than 38 percent of the season's total.

Variations in the spawning may be temporal as well as areal. A marked temporal change in sardine spawning occurred off southern California in 1958. During the preceding years which were characterized by below-average temperatures in winter and early spring off southern California, most spawning was in May and June. In 1958, after temperatures had been above average in the eastern North Pacific since mid-1957, the peak of sardine spawning was in January 1958, and spawning extended over a 7-month period, from January to July.

Changes in the distribution of anchovy eggs and larvae were less spectacular, but nonetheless real. In 1956, one of the colder years in the California Current region during the 1950's, anchovy larvae were much more numerous off southern Baja California (lines 140 and south) than in previous years. In most years less than 1 percent of the anchovy eggs and larvae collected were from this area, but in 1956 the area contributed nearly 20 percent of the season's total. This change, in effect, indicated a southward extension of anchovy spawning of some 40 to 80 miles. In contrast, anchovy spawning spread northward in 1958 and 1959. During the 7 years before 1958, less than 1 percent of anchovy larvae were from CalCOFI stations off central California (north of Pt. Conception); the larvae were collected at only 58 of 803 stations occupied. The number of occurrences of anchovy larvae off central California rose to 101 in 1958 and 133 in 1959. In 1959 anchovy larvae occurred at more than half of the stations occupied off central California and constituted more than 10 percent of the total larvae from all areas. With the return of normal temperatures in 1960, the number of occurrences of anchovy larvae off central California dropped to 48.

Two markedly contrasting years, 1954 and 1962, illustrate changes in the areal distributions of the two species that also reflect changes in abundance. The areal distribution and relative abundance of sardine and anchovy larvae in 1954 are shown in

Figure 2. During this year, sardine larvae were even more widely distributed than anchovy larvae. Note particularly that even in the offshore waters of southern California, sardine larvae were more abundant and more widely distributed than anchovy larvae. This distribution of sardine larvae (and eggs) was the most extensive ever encountered during CalCOFI surveys.

The distributions of anchovy and sardine larvae during 1962 are shown in Figure 3. Anchovies were widely distributed; they were collected at nearly one-half of the stations (454 of the 919 occupied). Sardine larvae occurred at 58 stations, or in only slightly more than 6 percent of the stations occupied during the year. Most occurrences of sardine larvae (38 of the 58) were in the summer and fall cruises, mostly from off central Baja California. Anchovy larvae outnumbered sardine larvae in 1962 collections by more than 90 to 1.

The two species have somewhat different seasonal distributions. This difference is illustrated in Figure 4, which shows for each species the percentage of the yearly total that was taken in each month during 1952-59. The peaks of abundance of the two species and the yearly patterns of abundance show little correspondence. Anchovy larvae tended to be markedly less abundant during the last half of each year, whereas sardine larvae usually had a second peak of abundance in August-September. This late-season abundance was confined to Sebastian Viscaïno Bay and adjacent waters off central Baja California, and represents the spawning of the southern sub-population.

Anchovy larvae outnumbered sardine larvae in the California Current region even at the time of high abundance of the sardine, as was the situation during spawning surveys off southern California in 1940 and 1941. The ratio of larval anchovies to sardines was 1.18: 1 in 1940 and 1.66: 1 in 1941. These values are ratios of numbers of larvae, not the biomass of the two respective populations. An adult anchovy weighs only about one-fifth as much as an adult sardine and has a shorter life span. John MacGregor (personal communication) has estimated that an anchovy produces about twice as many eggs per unit of weight as does a sardine. If survival is even roughly similar during the egg and larval stages of sardines and anchovies, then larvae can be converted to adult biomass by equating one sardine larva to two anchovy larvae.

Stations are not equally spaced in the CalCOFI survey pattern, but tended to be more closely spaced nearshore than offshore on all cruises and to be spaced closer throughout the survey area during the peak periods of spawning. It is necessary therefore to adjust for such unequal spacing when deriving estimates of abundance. This adjustment is accomplished by integrating collection data over area. Such a treatment of data on abundance yields what we term a "census estimate." The estimates are derived for individual cruises, and each yearly estimate is simply the summation of monthly cruise estimates. Tables

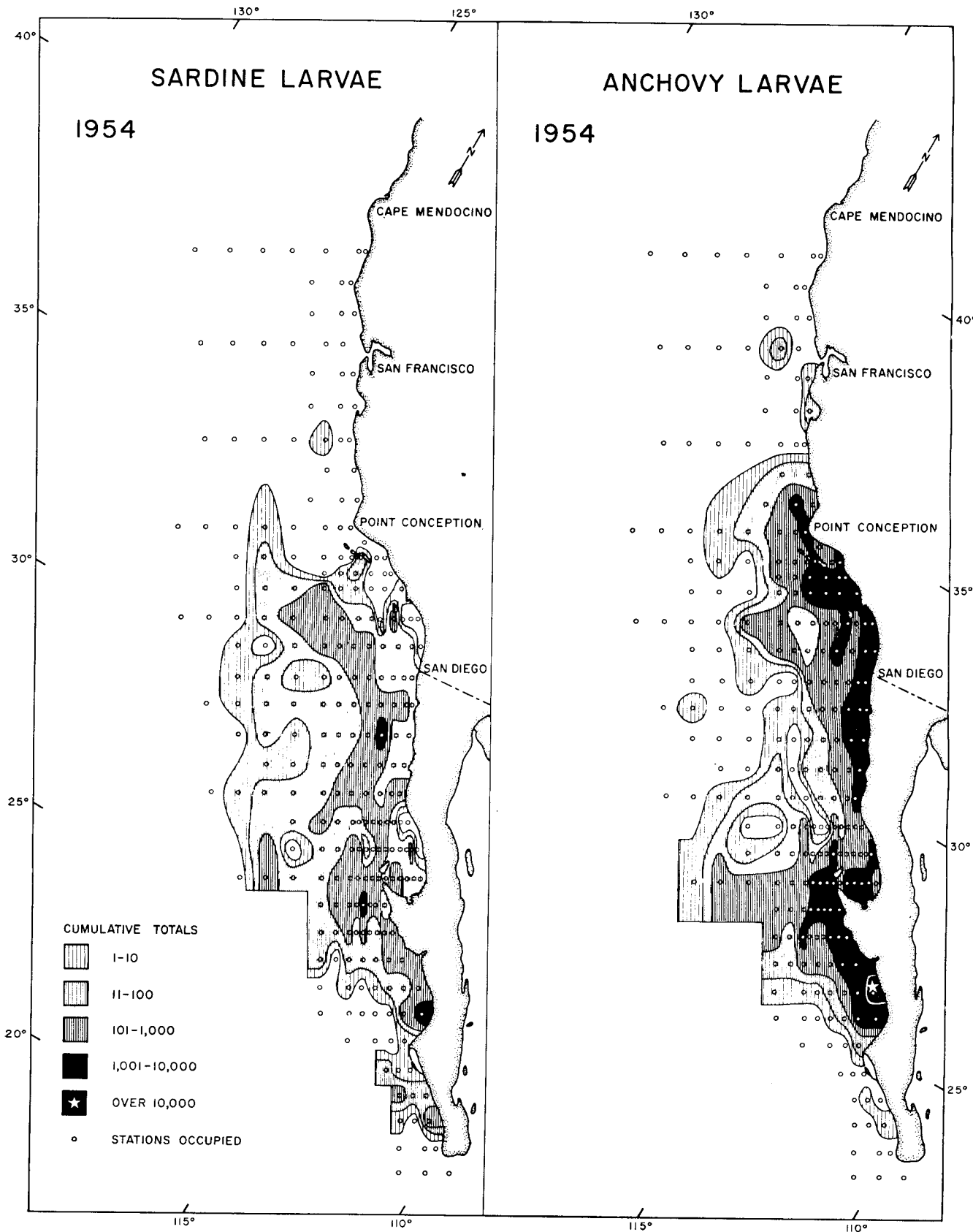


FIGURE 2. Distribution and relative abundance of sardine and anchovy larvae in the CalCOFI survey area in 1954.

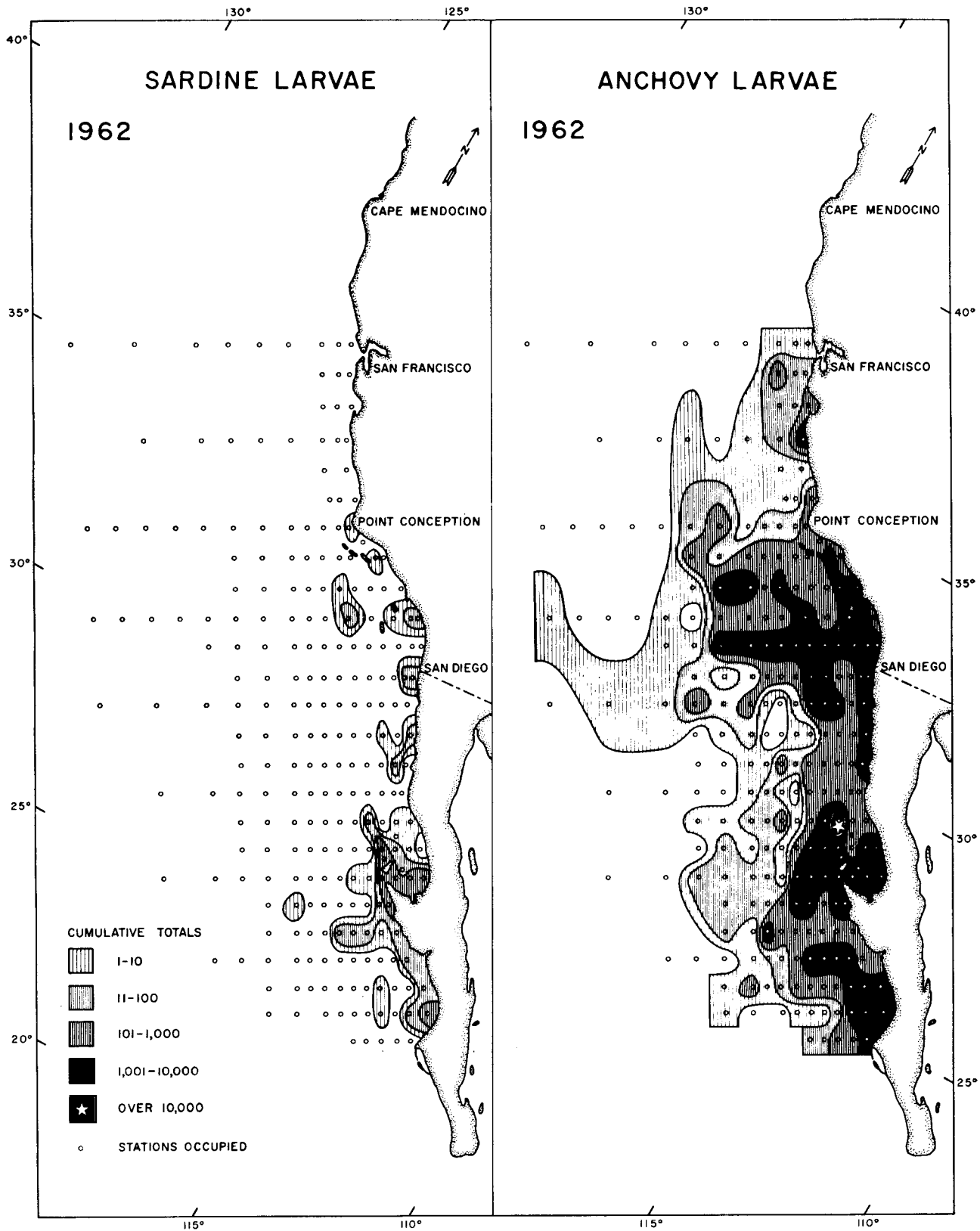


FIGURE 3. Distribution and relative abundance of sardine and anchovy larvae in the CalCOFI survey area in 1962.

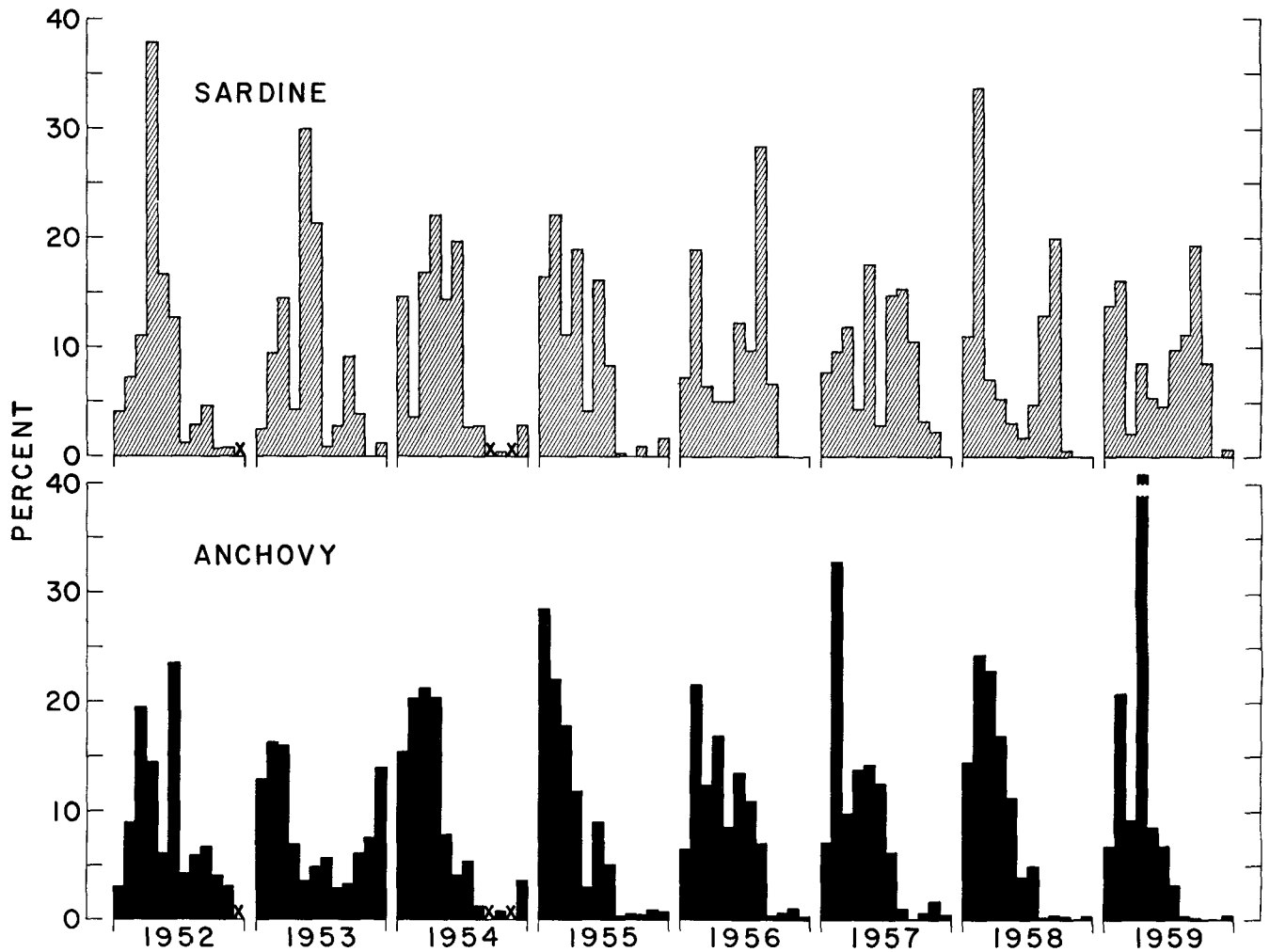


FIGURE 4. Percentages of the yearly total of sardine larvae (upper panel) and anchovy larvae (lower panel) taken in each monthly cruise, 1952-59. Spaces for each year on the abscissa depict a total of 12 months. X indicates no cruise was made.

TABLE 1  
CENSUS ESTIMATES OF ABUNDANCE OF SARDINE LARVAE, BY YEAR AND AREA, 1951-59  
(Estimates in Billions)

Area and station lines	Year								
	1951	1952	1953	1954	1955	1956	1957	1958	1959
<b>Estimated number of larvae</b>									
Northern California (40-57)-----	0	0	0	0	0	0	0	0	0
Central California (60-77)-----	3	0	0	2	0	0	47	7	7
Southern California (80-93)-----	146	189	2	1,691	528	433	569	491	427
Northern Baja California (97-107)-----	391	95	29	1,379	997	379	176	137	89
Upper central Baja California (110-120)-----	1,857	1,792	2,539	1,410	1,970	1,848	1,070	1,486	306
Lower central Baja California (123-137)-----	3,317	3,234	1,363	2,136	368	846	402	531	286
Southern Baja California (140-157)-----	60	156	87	679	478	389	168	179	44
<b>Total</b> -----	<b>5,774</b>	<b>5,466</b>	<b>4,020</b>	<b>7,297</b>	<b>4,341</b>	<b>3,895</b>	<b>2,432</b>	<b>2,831</b>	<b>1,159</b>
<b>Percentage of yearly totals taken in each area</b>									
Northern California (40-57)-----	0	0	0	0	0	0	0	0	0
Central California (60-77)-----	0.05	0	0	0.03	0	0	1.93	0.25	0.60
Southern California (80-93)-----	2.53	3.45	0.05	23.17	12.16	11.12	23.40	17.34	36.84
Northern Baja California (97-107)-----	6.77	1.74	0.72	18.90	22.97	9.73	7.24	4.84	7.68
Upper central Baja California (110-120)-----	32.16	32.78	63.16	19.32	45.38	47.44	44.00	52.49	26.40
Lower central Baja California (123-137)-----	57.45	59.17	33.91	29.27	8.48	21.72	16.53	18.76	24.68
Southern Baja California (140-157)-----	1.04	2.85	2.16	9.31	11.01	9.99	6.91	6.32	3.80
<b>Total</b> -----	<b>100.00</b>	<b>99.99</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.01</b>	<b>100.00</b>	<b>100.00</b>

**TABLE 2**  
**CENSUS ESTIMATES OF ABUNDANCE OF ANCHOVY LARVAE, BY YEAR AND AREA, 1951-59**  
 (Estimates in Billions)

Area and station lines	Year								
	1951	1952	1953	1954	1955	1956	1957	1958	1959
<b>Estimated number of larvae</b>									
Northern California (40-57)-----	12	9	--	0	--	0	--	30	0
Central California (60-77)-----	371	140	2	962	20	205	71	3,196	5,750
Southern California (80-93)-----	2,112	1,769	5,203	10,295	7,450	4,673	21,010	21,853	25,529
Northern Baja California (97-107)-----	825	1,279	2,460	4,536	8,425	1,944	3,261	7,415	3,633
Upper central Baja California (110-120)-----	4,015	6,972	10,755	7,122	17,914	15,395	7,628	12,733	13,167
Lower central Baja California (123-137)-----	7,671	6,867	5,260	15,491	3,828	8,858	8,437	11,439	6,055
Southern Baja California (140-157)-----	95	35	--	9	21	7,433	34	262	34
<b>Total</b> -----	<b>15,101</b>	<b>17,071</b>	<b>23,680</b>	<b>38,415</b>	<b>37,658</b>	<b>38,508</b>	<b>40,441</b>	<b>56,928</b>	<b>54,168</b>
<b>Percentage of yearly totals taken in each area</b>									
Northern California (40-57)-----	0.08	0.05	--	0	--	0	--	0.05	0
Central California (60-77)-----	2.46	0.82	>.01	2.50	0.05	0.53	0.18	5.62	10.61
Southern California (80-93)-----	13.98	10.36	21.97	26.80	19.78	12.14	51.95	38.39	47.13
Northern Baja California (97-107)-----	5.46	7.49	10.39	11.81	22.37	5.05	8.06	13.02	6.71
Upper central Baja California (110-120)-----	26.59	40.84	45.42	18.54	47.57	39.98	18.86	22.37	24.31
Lower central Baja California (123-137)-----	50.80	40.23	22.21	40.33	10.17	23.00	20.86	20.09	11.18
Southern Baja California (140-157)-----	0.63	0.20	--	0.02	0.06	19.30	0.09	0.46	0.06
<b>Total</b> -----	<b>100.00</b>	<b>99.99</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

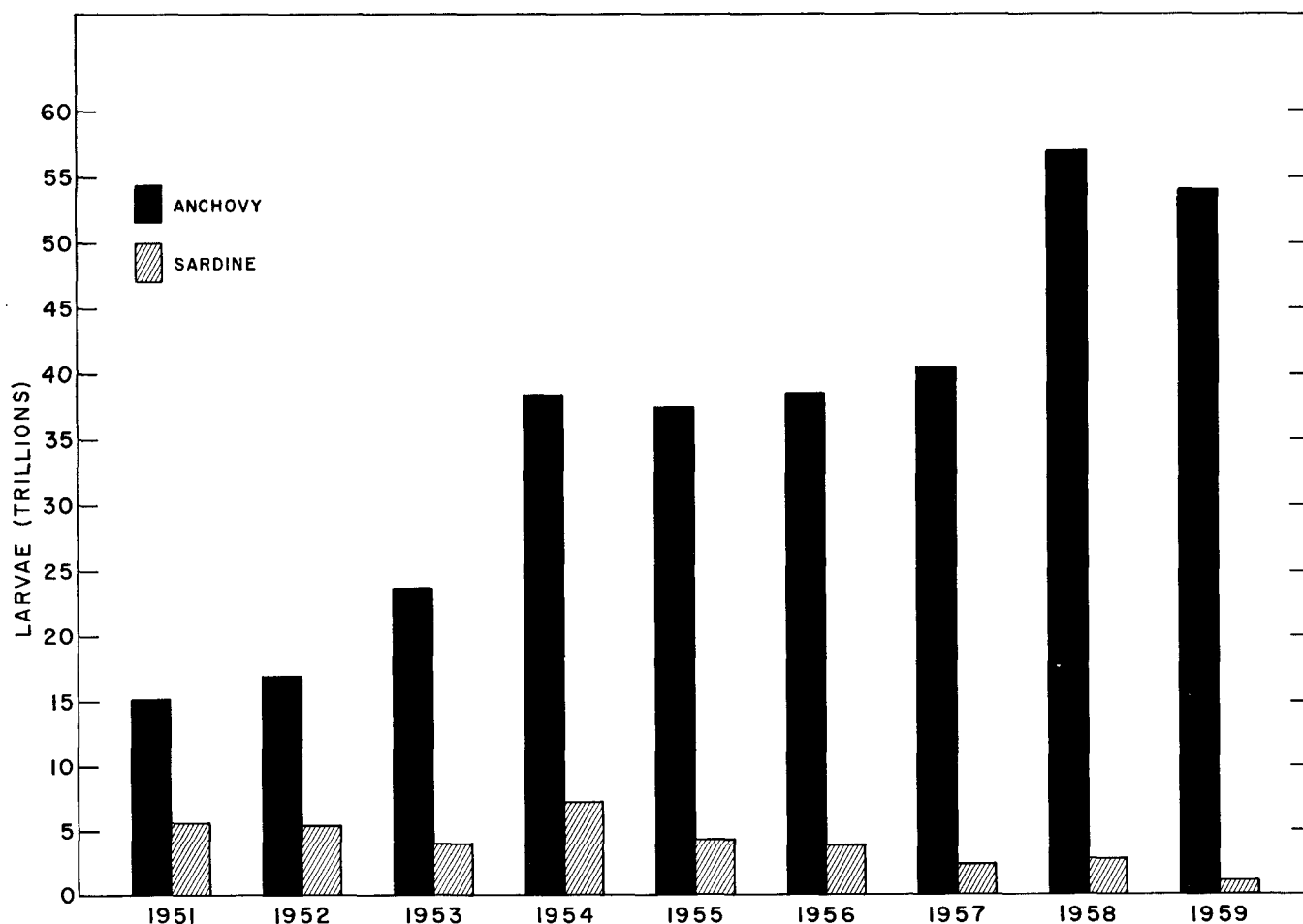


FIGURE 5. Annual census estimates for the total CalCOFI survey area of sardine and anchovy larvae, 1951-59.

1 and 2 show census estimates for sardine and anchovy larvae, respectively, for 1951-59, summarized by year and area. Census estimates for 1960 are not included, simply because they have not been worked up as yet. The estimates of sardine larvae ranged from a high of about 7.3 trillion in 1954 to a low of about 1.2 trillion in 1959. Anchovy larvae increased from 15.1 trillion to more than 38 trillion between 1951 and 1954, remained at this level through 1957,

and then increased further to about 55 trillion in 1958 and 1959 (Figure 5). Anchovy abundance appears to have almost quadrupled during the 1950's, while sardine abundance progressively decreased after 1954. Whereas anchovy larvae outnumbered sardine larvae by less than 3:1 in 1951, the ratio had increased to more than 45: 1 by 1959. Abundance of anchovy larvae increased further from 1960 to 1965. Although this change is not shown or expressed in

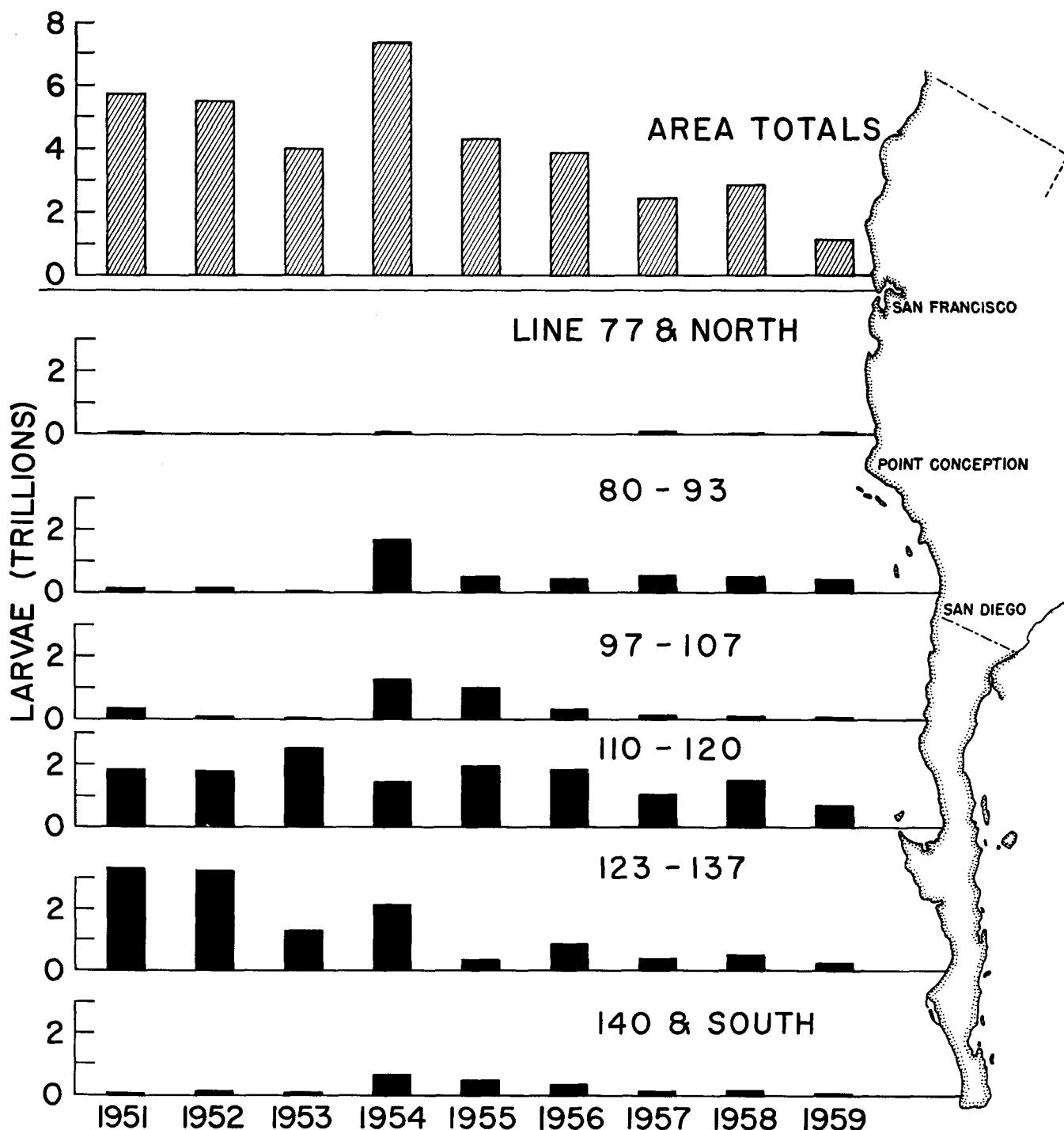


FIGURE 6. Sardine larvae: Annual census estimates by area, 1951-59.



terms of census estimates (only four cruises were made per year after 1960, rather than 10 to 12), other methods of evaluating the increase indicate that abundance more than doubled between 1958 and 1965.

The census estimates permit a better evaluation of abundance of sardine and anchovy larvae in the 7 areas of the CalCOFI region during 1951-59.

As already noted, sardine eggs and larvae were obtained more consistently off central Baja California (lines 110-137) than off northern Baja California and southern California (Figure 6). Sardine larvae were

proportionately more abundant, however, off lower central Baja California (station lines 123-137) during 1951-54 than later. Off northern Baja California (lines 97-107) and southern California (lines 80-93) abundance was low in 1951-53 but proportionately higher during 1954-59.

Throughout the decade only negligible numbers of sardine larvae were taken off central California (lines 60-77) and none off northern California. The numbers taken off southern Baja California (lines 140-157) undoubtedly would have been higher if this area had

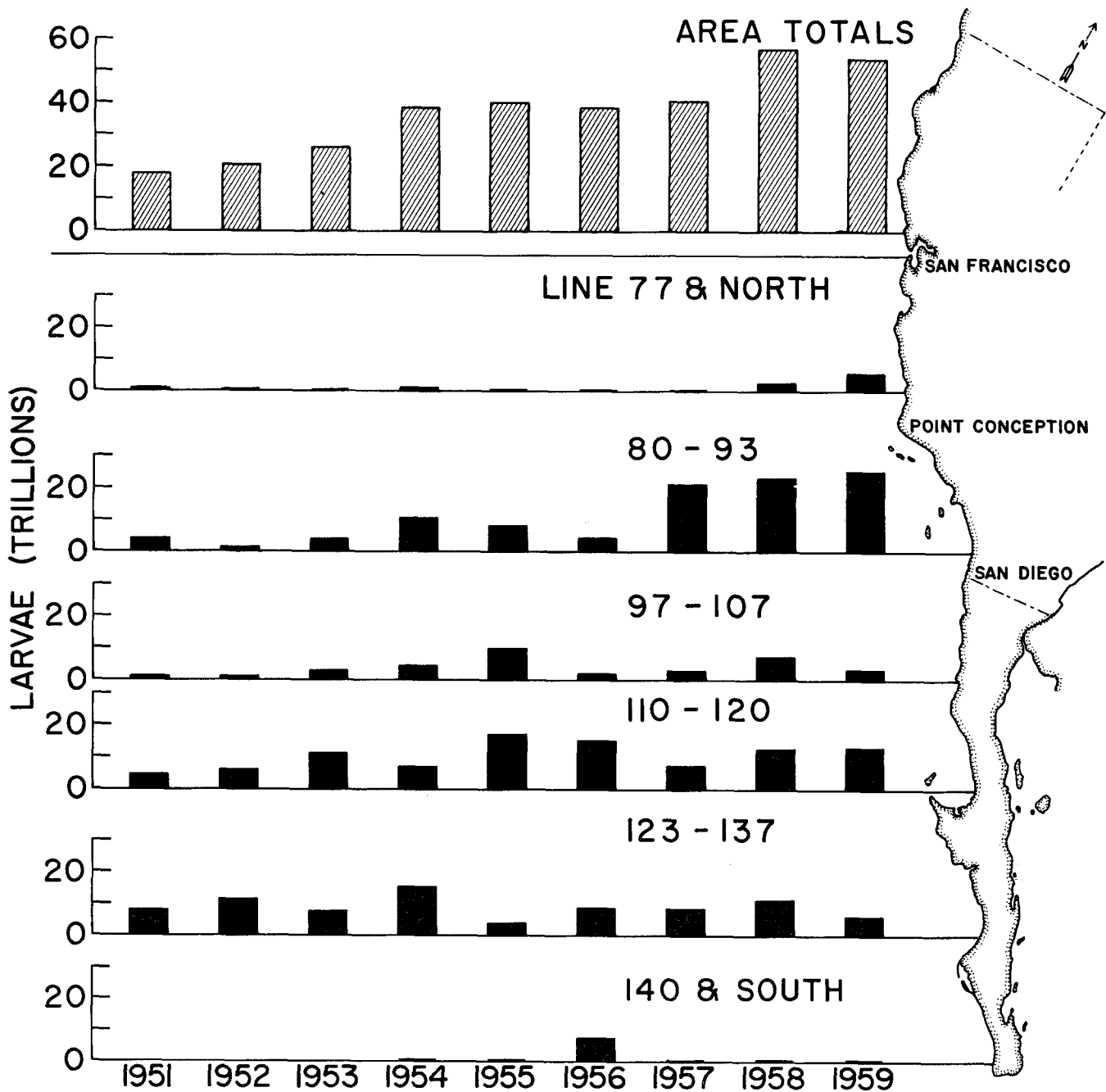


FIGURE 7. Anchovy larvae: Annual census estimates by area, 1951-59.

TABLE 3

**SARDINE LARVAE<sup>1</sup>: SUMMARY OF TOTAL OCCURRENCES, CO-OCCURRENCES WITH ANCHOVY LARVAE, AND OCCURRENCES IN HAULS WITHOUT ANCHOVY LARVAE IN THE CALCOFI SURVEY PATTERN, BY AREA AND YEAR, 1951-63**  
(Station lines given below each area<sup>2</sup>)

Year	Total occurrences of sardine larvae							Co-occurrences of sardine and anchovy larvae							Occurrences of sardine larvae alone							
	Cent. Calif. 60-77	So. Calif. 80-93	No. Baja Calif. 97-107	Upper cent. Baja Calif. 110-120	Lower cent. Baja Calif. 123-137	So. Baja Calif. 140-157	Total	Cent. Calif. 60-77	So. Calif. 80-93	No. Baja Calif. 97-107	Upper cent. Baja Calif. 110-120	Lower cent. Baja Calif. 123-137	So. Baja Calif. 140-157	Total	Cent. Calif. 60-77	So. Calif. 80-93	No. Baja Calif. 97-107	Upper cent. Baja Calif. 110-120	Lower cent. Baja Calif. 123-137	So. Baja Calif. 140-157	Total	
<b>Monthly cruises</b>																						
1951.....	1	23	26	55	55	9	169	0	10	12	47	46	3	118	1	13	14	8	9	6	51	
1952.....	0	25	21	101	109	6	262	0	12	9	65	79	2	167	0	13	12	36	30	4	95	
1953.....	0	3	8	110	91	7	219	0	3	2	72	74	0	151	0	0	6	38	17	7	68	
1954.....	1	42	92	132	96	11	374	0	22	42	86	79	4	233	1	20	50	46	17	7	141	
1955.....	0	26	72	94	47	17	256	0	12	34	79	32	3	160	0	14	38	15	15	14	96	
1956.....	0	22	39	61	38	11	171	0	3	15	55	32	4	109	0	19	24	6	6	7	62	
1957.....	6	21	22	83	31	12	175	2	9	16	60	20	3	110	4	12	6	23	11	9	65	
1958.....	2	71	26	53	30	13	195	2	67	23	44	26	6	168	0	4	3	9	4	7	27	
1959.....	5	68	16	53	25	5	172	5	66	15	43	20	3	152	0	2	1	10	5	2	20	
1960.....	0	40	26	46	18	10	140	0	39	21	39	14	8	121	0	1	5	7	4	2	19	
<b>Total.....</b>	<b>15</b>	<b>341</b>	<b>348</b>	<b>788</b>	<b>540</b>	<b>101</b>	<b>2,133</b>	<b>9</b>	<b>243</b>	<b>189</b>	<b>590</b>	<b>422</b>	<b>36</b>	<b>1,489</b>	<b>6</b>	<b>98</b>	<b>159</b>	<b>198</b>	<b>118</b>	<b>65</b>	<b>644</b>	
<b>Quarterly cruises</b>																						
1961.....	0	16	6	16	13	1	52	0	12	6	16	10	1	45	0	4	0	0	3	0	7	
1962.....	0	9	6	22	21	0	58	0	8	6	20	18	0	52	0	1	0	2	3	0	6	
1963.....	3	19	25	28	20	1	96	3	16	23	24	19	1	86	0	3	2	4	1	0	10	

<sup>1</sup> No sardine larvae were obtained off northern California (station lines 40-57).

<sup>2</sup> Includes additional closely spaced stations on inshore ends of station lines.

TABLE 4

**ANCHOVY LARVAE: SUMMARY OF TOTAL OCCURRENCES, CO-OCCURRENCES WITH SARDINE LARVAE, AND OCCURRENCES IN HAULS WITHOUT SARDINE LARVAE IN THE CALCOFI SURVEY PATTERN, BY AREA AND YEAR, 1951-63**  
(Station lines given below each area)

Year	Total occurrences of anchovy larvae							Co-occurrences of sardine and anchovy larvae							Occurrences of anchovy larvae alone									
	No. Calif. 40-57	Cent. Calif. 60-77	So. Calif. 80-93	No. Baja Calif. 97-107	Upper cent. Baja Calif. 110-120	Lower cent. Baja Calif. 123-137	So. Baja Calif. 140-157	Total	No. Calif. 40-57	Cent. Calif. 60-77	So. Calif. 80-93	No. Baja Calif. 97-107	Upper cent. Baja Calif. 110-120	Lower cent. Baja Calif. 123-137	So. Baja Calif. 140-157	Total	No. Calif. 40-57	Cent. Calif. 60-77	So. Calif. 80-93	No. Baja Calif. 97-107	Upper cent. Baja Calif. 110-120	Lower cent. Baja Calif. 123-137	So. Baja Calif. 140-157	Total
<b>Monthly cruises</b>																								
1951.....	6	43	89	59	107	95	11	410	0	0	10	12	47	46	3	118	6	43	79	47	60	49	8	292
1952.....	1	11	110	92	169	134	2	519	0	0	12	9	65	79	2	167	1	11	98	83	104	55	0	352
1953.....	--	2	228	91	199	165	0	685	--	0	3	2	72	74	0	151	--	2	225	89	127	91	0	534
1954.....	0	15	259	124	187	169	4	758	0	0	22	42	86	79	4	233	0	15	237	82	101	90	0	525
1955.....	0	7	218	120	178	94	7	624	0	0	12	34	79	32	3	160	0	7	206	86	99	62	4	464
1956.....	0	5	168	82	151	107	23	536	0	0	3	15	55	32	4	109	0	5	165	67	96	75	19	427
1957.....	--	17	187	94	172	98	12	580	--	2	9	16	60	20	3	110	--	15	178	78	112	78	9	470
1958.....	5	96	272	145	164	85	11	778	0	2	67	23	44	26	6	168	5	94	205	122	120	59	5	610
1959.....	0	133	311	116	197	120	11	888	0	5	66	15	43	20	3	152	0	128	245	101	154	100	8	736
1960.....	0	48	280	193	256	173	27	977	0	0	39	21	39	14	8	121	0	48	241	172	217	159	19	856
<b>Total.....</b>	<b>12</b>	<b>377</b>	<b>2,122</b>	<b>1,116</b>	<b>1,780</b>	<b>1,240</b>	<b>108</b>	<b>6,755</b>	<b>0</b>	<b>9</b>	<b>243</b>	<b>189</b>	<b>590</b>	<b>422</b>	<b>36</b>	<b>1,489</b>	<b>12</b>	<b>368</b>	<b>1,879</b>	<b>927</b>	<b>1,190</b>	<b>818</b>	<b>72</b>	<b>5,266</b>
<b>Quarterly cruises</b>																								
1961.....	--	30	115	84	102	69	1	401	--	0	12	6	16	10	1	45	--	30	103	78	86	59	0	356
1962.....	--	26	129	91	105	92	11	454	--	0	8	6	20	18	0	52	--	26	121	85	85	74	11	402
1963.....	--	40	171	97	133	97	4	542	--	3	16	23	24	19	1	86	--	37	155	74	109	78	3	456

been sampled as consistently as the others off Baja California.

The distribution of anchovy larvae was somewhat different than that of sardines (Figure 7). Anchovy larvae were important in the area off central California (lines 60-77) only during 1958 and 1959, and in the southernmost area (lines 140-157) only during 1956; they were taken in only a few hauls off northern California (lines 40-57). In the remaining areas, they were more consistently represented throughout the 10-year period than sardine larvae. Anchovy larvae, like sardine larvae, were more abundant off California during the warm years, 1957-59. In these years, the center of anchovy abundance shifted from central Baja California to southern California.

I wish now to deal more specifically with occurrences and co-occurrences of larvae and eggs of the

two species. Information concerning occurrences and co-occurrences of the two species in the seven areas are summarized in Tables 3 and 4. For completeness, I have included information on occurrences and co-occurrences of both species for 1961-63, as well as for 1951-60. The total number of stations occupied on CalCOFI cruises during each year, 1951-63, are summarized by area in Table 5. These summations are not limited to regular CalCOFI stations, but include extra occupancies and special cruises (Table 6). However, the analysis that follows is based on the data for 1951-60.

Throughout the CalCOFI survey period, anchovy larvae always have occurred in more collections than sardine larvae (Figure 8). In the 1950's as a whole, anchovy larvae occurred in 3.1 times as many hauls as sardine larvae. The disparity was lowest in 1952

TABLE 5  
SUMMARY OF STATIONS OCCUPIED ON CalCOFI SURVEY CRUISES, BY YEAR AND AREA, 1951-63  
(Station lines given below each area)

Year	Northern California 40-57	Central California 60-77	Southern California 80-93	Northern Baja Calif. 97-107	Upper central Baja Calif. 110-120	Lower central Baja Calif. 123-137	Southern Baja Calif. 140-157	Total
Monthly cruises								
1951.....	45	243	337	258	263	201	89	1,436
1952.....	29	164	350	287	352	277	14	1,473
1953.....	0	119	478	249	319	267	13	1,445
1954.....	13	109	418	274	352	271	36	1,473
1955.....	7	95	403	302	353	212	79	1,451
1956.....	54	112	395	280	308	182	76	1,407
1957.....	0	101	364	287	360	267	114	1,493
1958.....	41	230	459	352	391	274	105	1,852
1959.....	22	232	572	419	473	345	119	2,182
1960.....	62	165	439	341	420	286	113	1,826
Total.....	273	1,570	4,215	3,049	3,591	2,582	758	16,038
Quarterly cruises								
1961.....	0	128	237	183	209	191	5	953
1962.....	0	85	243	185	210	182	15	920
1963.....	0	81	266	206	218	226	12	1,009

TABLE 6  
STATIONS OCCUPIED ON REGULAR CalCOFI CRUISES AND SPECIAL CRUISES, INCLUDING EXTRA OCCUPANCIES, 1951-64

Year	Regular occupancies	Late March cruise	Extra occupancies of regular stations	Special tows	Additional inshore stations	Multiple occupancies (not included)	Total
Monthly cruises							
1951.....	1,436	0	0	0	0	0	1,436
1952.....	1,376	63	34	0	0	0	1,473
1953.....	1,346	63	36	0	0	0	1,445
1954.....	1,473	0	0	0	0	0	1,473
1955.....	1,425	0	26	0	0	(166)	1,451
1956.....	1,399	0	8	0	0	0	1,407
1957.....	1,493	0	0	0	0	0	1,493
1958.....	1,851	0	1	0	0	(34)	1,852
1959.....	2,180	0	2	0	0	0	2,182
1960.....	1,810	0	1	15	0	(24)	1,826
Total.....	15,789	126	108	15	0	(224)	16,038
Quarterly cruises							
1961.....	944	0	9	0	0	0	953
1962.....	919	0	1	0	0	0	920
1963.....	881	0	3	0	125	0	1,009
1964.....	877	0	7	0	319	0	1,203

<sup>1</sup> Includes 54 stations occupied on Norpac.

and 1954, when they were collected only twice as often as sardine larvae, but increased yearly in 1955-60; in the 1960 collections, anchovy larvae occurred seven times as often as sardine larvae. A corresponding increase appeared in the co-occurrences of anchovy larvae in the collections containing sardine larvae, from 62 percent in 1954 to about 87 percent in 1960.

Obviously, as one species becomes more abundant and more widespread than another, it will occur alone more frequently, and thus be free from possible competition. When anchovy larvae are collected in seven times as many hauls as sardine larvae, as in 1960, the possible co-occurrences with sardine larvae would be only 14 percent. In fact, sardine larvae co-occurred with anchovy larvae in one haul out of eight (12.4 percent), while anchovy larvae co-occurred with sar-

dine larvae in six hauls out of seven (86.5 percent).

For the decade as a whole, anchovy larvae co-occurred in 1,489 (69.8 percent) of the 2,133 hauls that contained sardine larvae, whereas sardine larvae occurred in only 1,489 (22.0 percent) of the 6,755 hauls that contained anchovy larvae. Thus, anchovy larvae were present in two of every three hauls that contained sardine larvae, whereas sardine larvae occurred in little more than one of five hauls containing anchovy larvae. If interspecies competition is a factor in the survival of larvae, and co-occurrence is a measure of competition, then the anchovy should have had a decided advantage over the sardine.

Another factor must be considered: sardine larvae are less likely to occur with anchovy larvae in some areas of the CalCOFI grid than in others (Tables 7 and 8). Anchovy larvae have had decidedly less com-

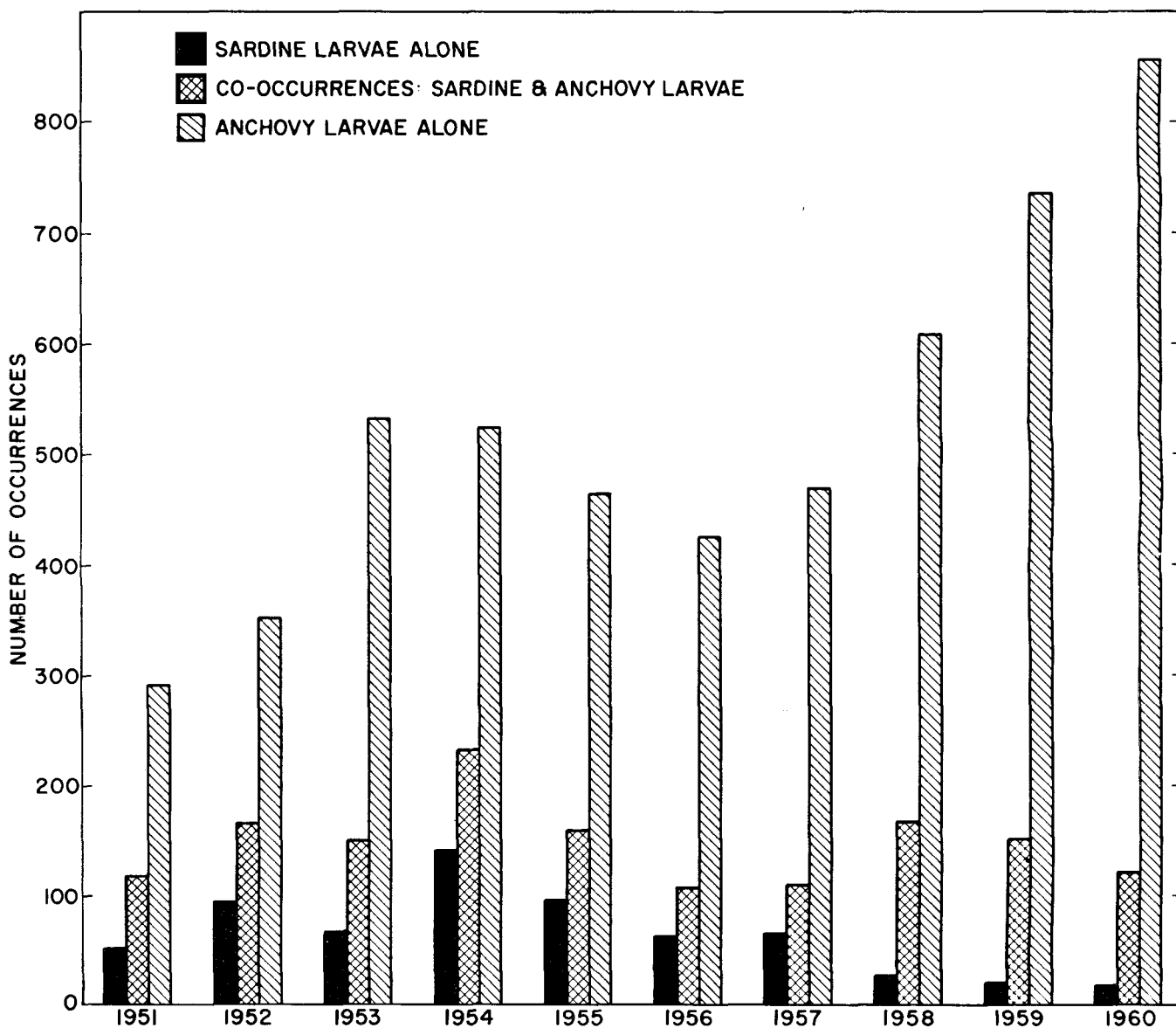


FIGURE 8. Graphic presentation, by year, of the number of CalCOFI plankton collections containing 1) sardine larvae alone, 2) both sardine and anchovy larvae, and 3) anchovy larvae alone, 1951-60

TABLE 7

**SUMMARY OF TOTAL STATION OCCUPANCIES, OCCURRENCES OF SARDINE LARVAE, AND CO-OCCURRENCES WITH ANCHOVY LARVAE, BY AREA, 1951-60**

Area and station lines	1951-60 total occupancies	Occurrences of sardine larvae	Percentage of positive hauls	Co-occurrences with anchovy larvae	Percentage of co-occurrences
Northern California (40-57).....	273	0	0	0	0
Central California (60-77).....	1,570	15	1.0	9	60.0
Southern California (80-93).....	4,215	341	8.1	243	71.3
Northern Baja California (97-107).....	3,049	348	11.4	189	54.3
Upper central Baja California (110-120).....	3,591	788	21.9	590	74.9
Lower central Baja California (123-137).....	2,582	540	20.9	422	78.1
Southern Baja California (140-157).....	758	101	13.3	36	35.6
Totals.....	16,038	2,133	13.3	1,489	69.8

TABLE 8

**SUMMARY OF TOTAL STATION OCCUPANCIES, OCCURRENCES OF ANCHOVY LARVAE, AND CO-OCCURRENCES WITH SARDINE LARVAE, BY AREA, 1951-60**

Area and station lines	1951-60 total occupancies	Occurrences of anchovy larvae	Percentage of positive hauls	Co-occurrences with sardine larvae	Percentage of co-occurrences
Northern California (40-57).....	273	12	4.4	0	0
Central California (60-77).....	1,570	377	24.0	9	2.4
Southern California (80-93).....	4,215	2,122	50.3	243	11.5
Northern Baja California (97-107).....	3,049	1,116	36.6	189	16.9
Upper central Baja California (110-120).....	3,591	1,780	49.6	590	33.1
Lower central Baja California (123-137).....	2,582	1,240	48.0	422	34.0
Southern Baja California (140-157).....	758	108	14.2	36	33.3
Totals.....	16,038	6,755	42.1	1,489	22.0

petition in the northern part of the CalCOFI survey area. Off central California (station lines 60-77) sardine larvae occurred in less than 1 percent of the collections, while anchovy larvae occurred in 24 percent. In this area the percentage of co-occurrence of sardine with anchovy larvae was only 2.4 percent. Off southern California, anchovy larvae occurred in more than 50 percent of all collections made during the 1950's, and sardine larvae in only 8.1 percent. Hence, even though the co-occurrence of anchovy larvae with sardine larvae was 71.3 percent, sardine larvae occurred in only 11.5 percent of the collections that contained anchovy larvae. Off southern California the anchovy must have had a decided advantage.

The region in which the two species might have competed most intensely was off central Baja California. In this region sardine larvae occurred in one of every three hauls containing anchovy larvae; anchovy larvae occurred in three of every four hauls containing sardine larvae.

The occurrences of eggs in our plankton hauls were less frequent than occurrences of larvae. Probably a major reason for this lower frequency is that eggs of both the Pacific sardine and the northern anchovy hatch in only 2 to 4 days, depending on water temperature; consequently the eggs in any given haul represent a relatively short time span. A sample of larvae, on the other hand, can contain specimens accumulated during a span of perhaps 30 days or more. Sardine eggs, on the average, occurred in only about

70 percent as many collections as sardine larvae. Anchovy eggs, which are not fully retained by the standard CalCOFI net, occurred in little more than a third as many hauls as anchovy larvae. Hence, the frequency of occurrence and, as it happens, co-occurrence of eggs is less than for larvae. In only 1958 and 1959 did sardine eggs co-occur in more hauls with anchovy eggs than they occurred alone. For the decade as a whole, anchovies spawned in the same waters with sardines only about 30 percent of

TABLE 9

**COMPARISON OF AVERAGE NUMBER OF LARVAE PER HAUL OF "CO-OCCURRENCES," WITH SAMPLES CONTAINING SARDINE OR ANCHOVY LARVAE ALONE**

	Sardine larvae			Anchovy larvae		
	All hauls	Alone	Co-occurring	Co-occurring	Alone	All hauls
1951.....	65.5	21.4	84.5	124.5	50.9	72.1
1952.....	93.8	82.5	99.9	192.2	88.2	121.8
1953.....	68.8	63.3	71.2	186.4	142.4	152.1
1954.....	72.0	47.9	86.5	304.0	172.3	212.7
1955.....	55.6	47.5	60.4	302.2	201.6	227.5
1956.....	90.7	57.2	109.9	329.0	232.0	251.8
1957.....	56.2	67.9	49.3	315.7	238.1	252.8
1958.....	58.9	27.0	64.0	610.4	169.5	264.0
1959.....	31.2	34.4	30.7	473.4	183.7	233.7
1960.....	60.6	17.8	67.3	494.9	271.5	299.1
Average.....	65.3	46.7	72.4	333.3	175.0	208.7

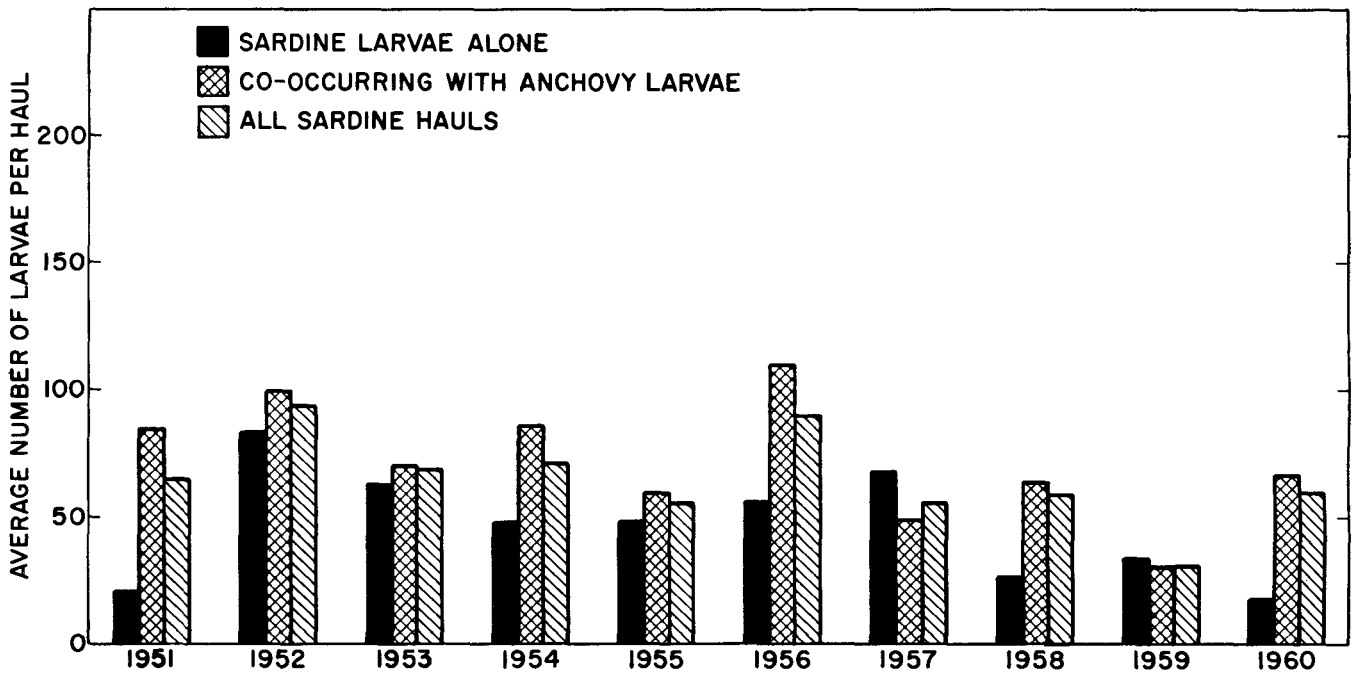


FIGURE 9. Comparison of the annual average number of sardine larvae obtained per haul, 1) in hauls containing sardine larvae alone, 2) in hauls in which sardine larvae co-occurred with anchovy larvae, and 3) in all hauls containing sardine larvae, 1951-60.

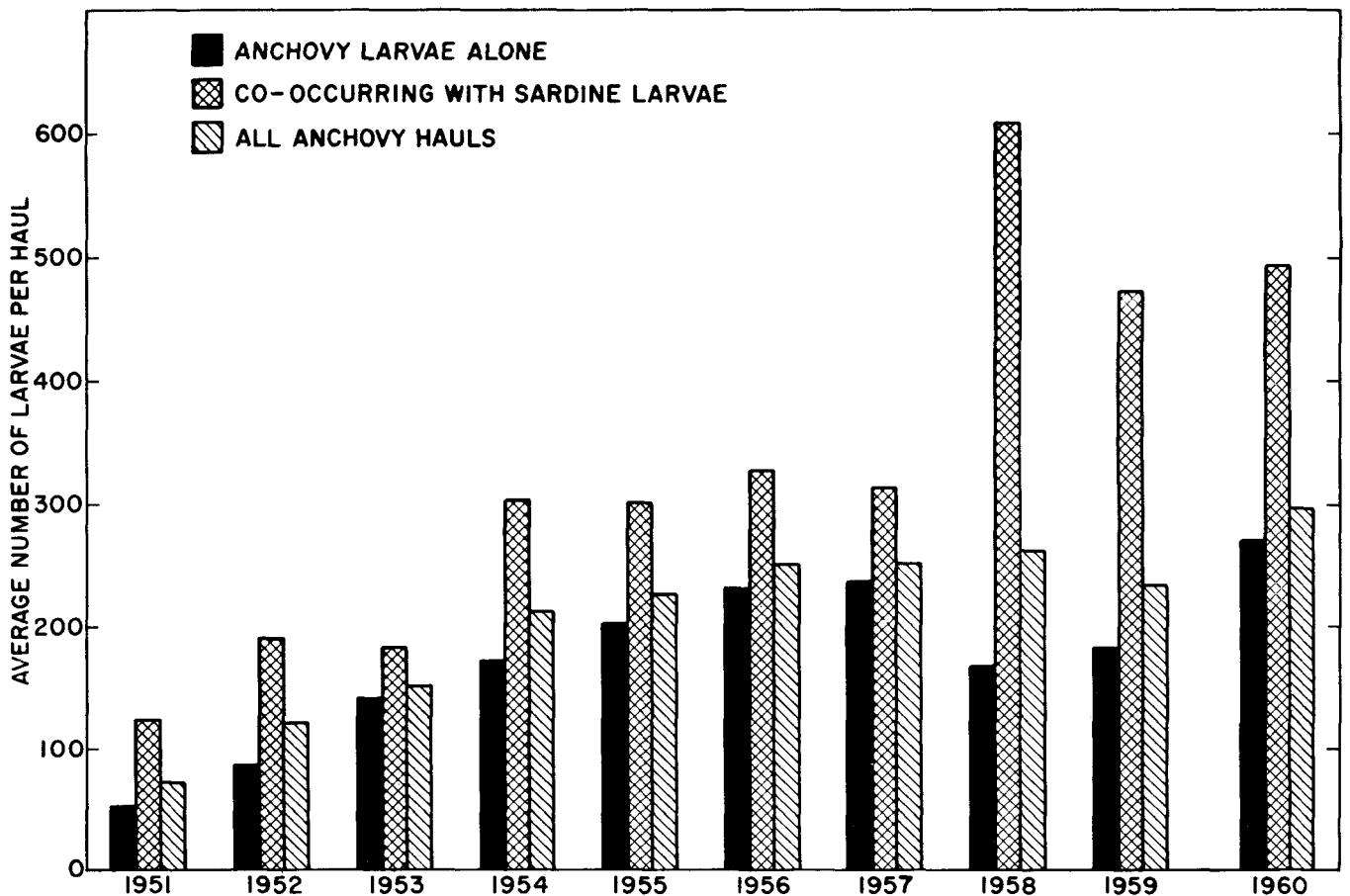


FIGURE 10. Comparison of the annual average number of anchovy larvae obtained per haul, 1) in hauls containing anchovy larvae alone, 2) in hauls in which anchovy larvae co-occurred with sardine larvae, and 3) in all hauls containing anchovy larvae, 1951-60.

the time. In contrast, the larvae of anchovies co-occurred with sardine larvae about 70 percent of the time.

The numbers of larvae in "co-occurring hauls" compared with hauls containing only one or the other species alone are summarized in Table 9 and illustrated in Figures 9 and 10. More larvae were obtained per sample in hauls where the two species co-occurred

than in hauls where they occurred alone. The consistently larger numbers of anchovies taken in hauls containing sardine larvae over numbers in hauls containing anchovies alone, usually by about 2 to 1, was especially striking. Numbers of sardine larvae in samples that contained anchovy larvae usually were also considerably larger than in hauls where they occurred alone—only two exceptions in the 10-year series.

TABLE 10

SARDINE LARVAE—ALL OCCURRENCES: AVERAGE NUMBER PER POSITIVE HAUL ( $\times 10^2$ ), SUMMARIZED BY SIZE AND YEAR, 1951-60

Size class (mm)	Year										Un-weighted average
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
3.0	1,608	2,632	1,782	2,193	1,390	3,049	1,287	1,566	1,137	1,667	1,831.1
4.75	1,388	2,580	2,489	1,992	1,799	2,316	1,086	1,419	831	1,256	1,715.6
5.75	777	968	735	822	951	837	975	875	417	798	815.5
6.75	508	698	451	408	356	508	397	606	164	563	465.9
7.75	513	580	380	337	243	490	444	626	103	376	409.2
8.75	379	414	242	262	138	479	364	301	116	388	308.3
9.75	302	322	125	238	154	400	304	177	96	328	244.6
10.75	227	260	134	253	93	260	249	87	86	199	184.8
11.75	214	196	123	179	98	155	160	75	44	190	143.4
12.75	163	166	136	152	91	145	92	49	45	102	114.1
13.75	144	122	90	134	74	90	59	27	40	43	82.3
14.75	101	95	64	110	70	85	75	20	14	33	66.7
15.75	54	47	45	54	41	98	48	28	11	10	43.6
17.25	77.5	44.0	54.0	36.0	41.6	77.1	44.5	20.3	12.4	3.6	41.1
19.25	17.4	28.4	11.4	15.5	13.7	46.2	20.6	7.8	3.5	--	16.4
21.25	25.4	13.6	4.7	3.0	3.8	32.5	6.0	1.9	1.6	1.8	9.4
23.25	18.2	9.8	2.4	5.0	--	6.7	1.9	--	--	--	4.4
25.25 and larger	--	--	--	3.8	1.1	--	2.4	--	--	2.0	0.9
Disintegrated	32	199	6	--	2	--	4	1	--	100	34.4
Total	6,548.5	9,374.8	6,874.5	7,197.3	5,560.2	9,074.5	5,619.4	5,887.0	3,121.5	6,060.4	6,531.8

TABLE 11

SARDINE LARVAE—CO-OCCURRING WITH ANCHOVY LARVAE: AVERAGE NUMBER PER POSITIVE HAUL ( $\times 10^2$ ), SUMMARIZED BY SIZE AND YEAR, 1951-60

Size class (mm)	Year										Un-weighted average
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
3.0	1,953	2,648	1,718	2,747	1,492	4,068	969	1,784	1,078	1,763	2,022.0
4.75	1,833	2,557	2,602	2,252	2,135	2,321	811	1,567	816	1,422	1,831.6
5.75	1,005	776	680	869	1,028	917	1,130	934	442	901	868.2
6.75	655	809	535	446	309	682	367	629	167	641	524.0
7.75	678	740	480	379	185	655	293	675	109	422	461.6
8.75	512	529	268	300	128	638	339	313	123	445	359.5
9.75	397	421	136	294	167	537	296	178	98	375	289.9
10.75	304	364	107	362	101	325	227	90	90	230	220.0
11.75	285	267	146	262	112	209	134	77	45	214	175.1
12.75	220	233	143	223	104	197	45	53	39	112	136.9
13.75	187	166	104	190	84	84	65	29	40	46	99.5
14.75	129	107	68	156	76	106	108	22	12	38	82.2
15.75	71	62	46	81	48	132	68	27	9	11	55.5
17.25	102.5	44.0	57.3	54.0	44.8	69.9	47.6	15.8	10.5	4.1	45.0
19.25	16.5	19.8	11.6	21.3	16.2	24.2	9.7	7.1	2.1	--	12.8
21.25	35.0	14.0	6.8	2.2	4.2	15.2	9.5	2.2	--	2.1	9.1
23.25	22.4	4.0	3.4	8.0	--	5.6	3.0	--	--	--	4.6
25.25 and larger	--	--	--	6.2	1.7	--	3.8	--	--	2.3	1.4
Disintegrated	46	232	8	0	4	0	2	2	0	106	40.0
Total	8,451.4	9,992.8	7,120.1	8,652.7	6,039.9	10,985.9	4,927.6	6,405.1	3,080.6	6,734.5	7,239.1

The problem then is to account for the higher number of each species in hauls in which they co-occurred—to determine whether they were obtained in centers of heavier spawning for both species or whether survival was better in areas of co-occurrence. If the latter were true, it would be difficult to justify any hypothesis that postulates that competition between the two species would adversely affect their survival.

The average numbers of larvae per positive haul are summarized by size and year in Tables 10 to 15. For each species these data are summarized in three ways: (1) for all occurrences, (2) for hauls in which the larvae of one species co-occurred with those of the other, and (3) for hauls in which the larvae of a species occurred alone.

A semi-log plot (Figures 11 and 12) gives a simple method of illustrating changes in abundance with

TABLE 12  
SARDINE LARVAE—OCCURRING ALONE (NO ANCHOVY LARVAE): AVERAGE NUMBER PER POSITIVE HAUL ( $\times 10^2$ ), SUMMARIZED BY SIZE AND YEAR, 1951-60

Size class (mm)	Year										Un-weighted average
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
3.0	810	2,604	1,922	1,276	1,217	1,257	1,826	222	1,580	1,059	1,377.3
4.75	357	2,619	2,237	1,562	1,236	2,306	1,552	505	952	201	1,352.7
5.75	249	1,307	859	746	820	696	712	510	228	142	626.9
6.75	166	503	266	346	436	201	448	465	140	66	303.7
7.75	129	298	158	267	340	198	699	326	62	83	256.0
8.75	72	212	183	199	154	198	407	226	57	25	173.3
9.75	83	149	101	144	132	158	318	171	82	29	136.7
10.75	48	78	192	73	78	146	286	68	57	--	102.6
11.75	51	71	72	42	74	61	204	68	38	36	71.7
12.75	31	48	120	33	69	54	173	27	91	44	69.0
13.75	47	44	61	42	58	99	50	13	42	28	48.4
14.75	34	74	56	34	59	47	18	9	26	--	35.7
15.75	13	21	43	10	29	38	14	34	28	--	23.0
17.25	19.6	43.9	46.6	6.2	36.4	89.8	39.2	48.1	27.0	--	35.7
19.25	19.6	43.6	10.7	6.0	9.5	84.8	38.9	12.2	14.0	--	23.9
21.25	3.3	13.0	--	4.5	3.3	62.9	--	--	14.0	--	10.1
23.25	8.2	20.2	--	--	--	8.7	--	--	--	--	3.7
25.25 and larger	--	--	--	--	--	--	--	--	--	--	0.0
Disintegrated	0	143	0	0	0	15	6	0	0	63	22.7
Total	2,140.7	8,291.7	6,327.3	4,790.7	4,751.2	5,720.2	6,791.1	2,704.3	3,438.0	1,776.0	4,673.1

TABLE 13  
ANCHOVY LARVAE—ALL OCCURRENCES: AVERAGE NUMBER PER POSITIVE HAUL ( $\times 10^2$ ), SUMMARIZED BY SIZE AND YEAR, 1951-60

Size class (mm)	Year										Un-weighted average
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
2.5	871	2,266	2,356	4,396	3,198	2,611	3,447	4,181	4,791	7,266	3,538.3
3.75	871	1,768	2,974	3,221	4,724	3,964	4,076	5,476	5,104	5,536	3,771.4
4.75	1,081	1,380	2,611	2,625	2,789	2,885	3,432	3,493	2,688	4,240	2,722.4
5.75	1,164	1,540	1,852	2,564	3,009	2,732	3,156	3,317	2,412	3,624	2,537.0
6.75	1,107	1,471	1,592	2,637	2,554	3,120	2,956	2,837	2,173	2,908	2,335.5
7.75	723	1,267	1,182	1,925	2,052	2,818	2,515	2,243	1,809	2,006	1,854.0
8.75	453	846	891	1,418	1,573	2,306	2,055	1,680	1,349	1,340	1,391.1
9.75	303	561	676	913	1,112	1,857	1,451	1,135	1,031	928	996.7
10.75	187	370	424	581	712	1,273	888	764	702	578	647.9
11.75	144	241	268	376	388	751	558	494	407	391	401.8
12.75	76	135	129	239	237	402	312	311	277	243	236.1
13.75	43	74	88	132	136	194	162	177	181	154	134.1
14.75	28	64	51	84	85	100	101	109	120	115	85.7
15.75	19	43	30	49	49	51	54	65	92	63	51.5
17.25	13.7	62.9	35.2	40.2	66.8	57.8	67.5	67.0	91.3	81.3	58.4
19.25	4.3	28.4	12.5	23.5	23.4	40.5	16.8	29.1	37.8	36.8	25.3
21.25	2.6	20.9	7.8	4.4	7.0	2.8	11.3	8.9	9.9	9.5	8.5
23.25 and larger	12.3	13.7	11.6	4.2	8.6	7.4	6.8	3.1	3.0	11.4	8.2
Disintegrated	106	23	21	36	27	4	13	10	88	378	70.6
Total	7,208.9	12,174.9	15,212.1	21,268.3	22,750.8	25,176.5	25,278.4	26,400.1	23,366.0	29,909.0	20,874.5



increase in size. Two curves are plotted for each species, one illustrating abundance of co-occurring larvae, the other of the species taken alone.

The two curves for anchovy larvae tend to converge with increase in size. This convergence would be expected if survival were better in hauls in which the larvae of a species occurred alone, free from competition. It is well to remember that the upper curve

represents the average of 1,489 hauls and the lower the average of 5,266 hauls—large amounts of data.

Data on changes in relative abundance with increase in size are less consistent for sardines. The upper curve, sardine larvae in co-occurrences with anchovy larvae, necessarily is based on the same number of hauls as is its counterpart graph for anchovies (1,489), but the lower curve is based on considerably

TABLE 14

ANCHOVY LARVAE—CO-OCCURRING WITH SARDINE LARVAE: AVERAGE NUMBER PER POSITIVE HAUL ( $\times 10^2$ ), SUMMARIZED BY SIZE AND YEAR, 1951-60

Size class (mm)	Year										Un-weighted average
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
2.5	1,524	2,836	2,648	6,773	2,997	2,471	1,326	6,832	11,385	11,189	4,998.1
3.75	1,525	2,600	4,578	4,310	5,877	5,057	3,336	14,634	12,854	8,780	6,355.1
4.75	2,432	2,211	2,509	3,791	3,618	4,818	3,599	9,116	4,655	7,478	4,422.7
5.75	2,282	2,597	2,218	3,415	3,687	4,789	4,741	8,550	4,051	6,920	4,325.0
6.75	1,700	2,608	1,992	3,954	3,723	3,996	4,015	7,138	3,461	5,437	3,802.4
7.75	1,202	2,375	1,445	2,708	3,225	3,364	3,579	5,020	3,011	3,708	2,963.7
8.75	726	1,495	1,016	2,063	2,398	2,702	3,700	3,559	2,607	2,232	2,249.8
9.75	423	934	746	1,406	1,900	1,975	2,879	2,292	2,008	1,313	1,587.6
10.75	236	624	546	859	1,022	1,460	1,819	1,485	1,294	728	1,007.3
11.75	182	354	360	468	644	1,117	1,246	974	690	570	660.5
12.75	60	169	184	261	413	561	619	668	463	325	372.3
13.75	46	69	149	132	226	266	269	381	221	219	197.8
14.75	31	94	99	91	162	163	162	192	156	119	126.9
15.75	9	55	48	44	94	56	94	100	109	45	65.4
17.25	16.2	76.3	51.5	57.6	137.0	84.8	149.9	50.2	69.1	49.8	74.2
19.25	1.4	41.1	12.2	29.2	45.7	25.0	13.0	28.1	34.5	16.1	24.6
21.25	1.8	27.5	4.4	4.9	14.9	--	7.7	11.0	9.5	13.6	9.5
23.25 and larger	--	25.4	17.1	--	13.0	--	7.5	5.8	4.0	--	7.3
Disintegrated	53	27	18	30	28	0	6	5	275	343	78.5
Total	12,450.4	19,218.3	18,641.2	30,396.7	30,224.6	32,904.8	31,568.1	61,041.1	47,357.1	49,485.5	33,328.8

TABLE 15

ANCHOVY LARVAE—OCCURRING ALONE (NO SARDINE LARVAE): AVERAGE NUMBER PER POSITIVE HAUL ( $\times 10^2$ ), SUMMARIZED BY SIZE AND YEAR, 1951-60

Size class (mm)	Year										Un-weighted average
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
2.5	607	1,994	2,273	3,343	3,269	2,646	3,945	3,459	3,417	6,711	3,166.4
3.75	607	1,371	2,521	2,739	4,324	3,685	4,250	2,975	3,490	5,077	3,103.9
4.75	536	984	2,640	2,109	2,502	2,392	3,394	1,958	2,277	3,794	2,258.6
5.75	713	1,037	1,748	2,187	2,774	2,206	2,786	1,888	2,071	3,158	2,056.8
6.75	867	930	1,479	2,054	2,148	2,896	2,709	1,663	1,904	2,551	1,920.1
7.75	529	740	1,107	1,579	1,645	2,678	2,267	1,485	1,559	1,766	1,535.5
8.75	342	536	855	1,133	1,286	2,205	1,670	1,168	1,088	1,214	1,149.7
9.75	254	384	657	694	838	1,827	1,117	820	828	873	829.2
10.75	167	250	390	458	604	1,225	670	568	579	557	546.8
11.75	129	187	243	335	299	658	397	363	348	366	332.5
12.75	82	119	114	229	175	362	241	214	239	231	200.6
13.75	42	76	70	132	105	175	137	121	173	145	117.6
14.75	27	50	37	82	58	84	87	87	112	115	73.9
15.75	23	38	26	51	33	50	44	56	89	65	47.5
17.25	12.7	56.5	30.6	32.4	42.4	50.8	48.3	71.6	96.0	85.8	52.7
19.25	5.5	22.4	12.6	21.0	15.7	44.5	17.6	29.4	38.5	39.8	24.7
21.25	2.9	17.7	8.7	4.2	4.2	3.5	12.1	8.3	9.9	8.9	8.0
23.25 and larger	17.3	8.1	10.0	6.1	7.0	9.3	6.6	2.4	2.8	13.1	8.3
Disintegrated	127	22	22	38	27	5	14	12	49	382	69.8
Total	5,090.4	8,822.7	14,243.9	17,226.7	20,156.3	23,202.1	23,812.6	16,948.7	18,370.2	27,152.6	17,502.6

fewer hauls (644). Some of the irregularities in this curve, compared with the other three, may be due to fewer data.

At first glance at the two curves for sardine larvae, one gets the impression that survival may have been somewhat better in the co-occurring hauls. On closer inspection however, it is seen that larvae larger than 6.75 mm followed no consistent trend, except as noted below. The greatest difference in relative abundance was between the smaller larvae (3.0–5.75 mm long) and all larger larvae. This difference could be interpreted as poorer initial survival of sardine larvae in situations where they occur alone. An equally logical explanation for the difference, however, is based on the increasing frequency of co-occurrences of sardine and anchovy larvae with increase in size. It was noted earlier that the frequency of co-occurrence of sardine and anchovy eggs was markedly lower than for larvae. A natural corollary is that newly hatched larvae of the two species would co-occur less frequently than the larger larvae. The effect on abundance curves would be to increase the numbers of larger larvae in hauls in which the species co-occurred than in hauls in which they occurred alone. Furthermore, the two curves for sardine larvae do converge if all larger-sized larvae (17.25–25.25 mm) are taken into account. As many larger larvae were taken in

hauls in which sardines occurred alone as in hauls in which both species occurred—0.73 larvae per haul on the average.

Thus, the basic question has been answered; better survival was not indicated by the hauls in which both species were caught even though average numbers of larvae per haul were larger.

Although the analysis has been confined largely to the 1950's, the report can be brought up to date. Tables 3 and 4 include the number of occurrences and co-occurrences of sardine and anchovy larvae during the first 3 years of quarterly cruises, 1961–63. Anchovy larvae occurred in 43 percent of the hauls in 1961, 49 percent in 1962, and 54 percent in 1963. Sardine larvae occurred in 5 percent of the hauls in 1961, 6 percent in 1962, and 9.5 percent in 1963. (Data for 1963 are not closely comparable to those for other years because a number of closely spaced in-shore stations were added.) Anchovy larvae occurred in nearly 90 percent of the hauls containing sardine larvae. In contrast, sardine larvae occurred in only 13 percent of the hauls containing anchovy larvae. Co-occurrences of anchovy larvae with sardine larvae were even higher than in the late 1950's, and even a higher percentage of the collections of anchovy larvae contained no sardine larvae. Anchovy larvae now seem to be completely dominant.

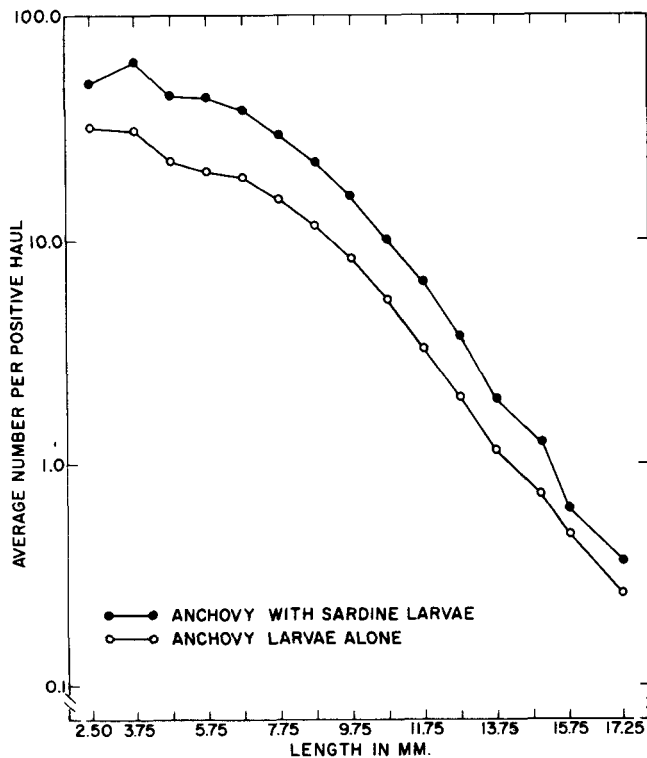


FIGURE 11. Comparisons of average number of anchovy larvae per positive haul as related to length (mm) for 1) hauls containing both anchovy and sardine larvae, and 2) hauls with anchovy larvae alone. Data for 1951–60 combined.

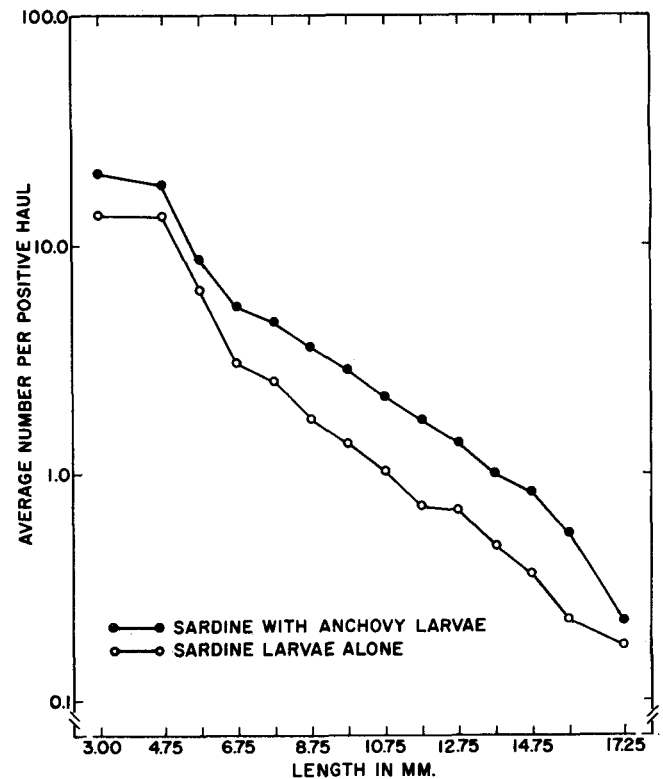


FIGURE 12. Comparisons of average number of sardine larvae per positive haul as related to length (mm) for 1) hauls containing both sardine and anchovy larvae and 2) hauls with sardine larvae alone. Data for 1951–60 combined.

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