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VERTICAL DISTRIBUTION OF PELAGIC FISH EGGS AND LARVAE OFF CALIFORNIA AND BAJA CALIFORNIA

By Elbert H. Ahlstrom

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ABSTRACT

Information is given on the vertical distribution of 46 kinds of fish larvae and 8 kinds of fish eggs, as determined from 22 series of hauls made at 15 stations off southern California and central Baja California. Each series consisted of 6 to 11 hauls taken with a closing net at successively deeper levels.

Most fish eggs and larvae were found to occur in the upper mixed layer and in the upper part of the thermocline between the surface and approximately 125 meters deep. All of the more common kinds of larvae showed marked differences in vertical distribution from series to series.

Replicate vertical distribution series were taken at seven stations, one in daylight, the other during darkness. Larvae of sardine, anchovy, and *Leuroglossus stilbius* were four to five times as abundant in night series as in day. The night-to-day ratio for all larvae was 2 to 3.

Supplementary information on vertical distribution of larvae was obtained on Norpac, where two levels (131–0 meters and 262–131 meters) were fished at most stations.

VERTICAL DISTRIBUTION OF PELAGIC FISH EGGS AND LARVAE OFF CALIFORNIA AND BAJA CALIFORNIA

By ELBERT H. AHLSTROM, *Fishery Research Biologist*

BUREAU OF COMMERCIAL FISHERIES

A prerequisite to any program of quantitative sampling of plankton organisms, such as the pelagic eggs and larvae of fishes, is a knowledge of their depth distributions. We have been interested primarily in quantitative sampling of sardine eggs and larvae, and a number of studies have been made to determine their vertical distributions (Silliman 1943, Ahlstrom 1948, Ahlstrom et al. 1958). Simultaneously, information has been obtained on the vertical distributions of various other fish eggs and larvae. For some species the information is limited to one or a few observations, for others it is complete enough to fairly well delimit their vertical ranges.

METHODS AND MATERIALS

Twenty-two series of hauls were made at 15 stations to study the vertical distribution of fish eggs and larvae (fig. 1). Each series consisted of 6 to 11 hauls taken with a closing net at successively deeper levels. In the nine series made in 1941, each haul covered a limited depth stratum, such as 0–4 meters, 10–15 meters, and 25–30 meters. In the 13 series made in 1952 through 1955, horizontal hauls were taken at a number of depths. Despite these minor differences in obtaining hauls, the series taken during the two periods are roughly comparable. A record of haul data for the 206 hauls that comprise the 22 vertical series is contained in the appendix and the average depths of hauls are summarized in table 1.

Replicate series were made at seven stations, one during the night, the other during daylight, in order to study diurnal changes in vertical

NOTE.—Approved for publication, July 28, 1958. Fishery Bulletin 161.

TABLE 1.—*Average depths of hauls in 22 series of closing-net tows made to study vertical distribution of fish eggs and larvae*

Station series	Average depth (m.) of haul No. —										
	1	2	3	4	5	6	7	8	9	10	11
4104-91.54	3	8	18	24	37	54	72	----	----	----	----
4105-89.38	3	8	18	25	36	56	73	----	----	----	----
4105-92.39	3	10	20	28	40	58	76	112	----	----	----
4106-94.37N	3	9	20	27	41	58	69	100	----	----	----
4106-94.37D	3	9	19	30	41	58	73	105	139	----	----
4106-94.47N	3	10	21	27	44	59	76	107	141	----	----
4106-94.47D	3	9	21	28	42	60	76	110	141	----	----
4106-97.43N	3	10	21	27	43	57	79	106	142	----	----
4106-97.43D	3	10	20	28	42	60	77	104	133	----	----
5206-90.28N	2	7	17	27	42	57	73	107	142	206	286
5206-90.28D	2	7	18	29	44	56	71	105	134	216	286
5208-120.35	3	10	18	27	36	51	----	----	----	----	----
5303-91.38N	2	7	18	29	41	54	68	106	150	211	291
5303-91.38D	2	7	18	28	42	56	72	92	139	206	----
5305-93.50N	2	6	21	29	43	57	70	106	138	222	276
5305-93.50D	2	7	16	25	33	46	63	103	138	239	----
5403-94.80N	2	7	17	27	42	52	64	101	127	200	----
5403-94.80D	2	7	18	28	41	53	68	102	135	201	----
5504-107.80	2	8	20	31	45	57	*70	111	142	----	----
5504-110.60	2	7	18	29	44	58	*73	105	----	----	----
5504-120.50	2	7	18	27	44	60	*74	110	137	225	----
5504-130.60	2	8	17	28	42	56	*72	102	136	215	----
Average	2	8	19	28	41	56	72	105	138	215	285
Standard deviation	0.5	1.3	1.5	1.6	3.1	3.4	4.0	4.6	5.1	12.1	----
Meters of depth represented by haul	5	8	10	11	14	16	24	33	55	73	70

*Hauls taken at approximately 88 meters depth on cruise 5504 are omitted from this tabulation.

distribution and abundance of larvae. Night series at these stations are designated with an "N," day series with a "D." The differences between night and day series will be discussed in a latter section of the paper.

Coverage was most intensive in the upper 100-meter stratum: Five hauls were taken above 50 meters with average depths of 2, 8, 19, 28, and 41 meters; two hauls were made between 50 and 100 meters with average depths of 56 and 72 meters.

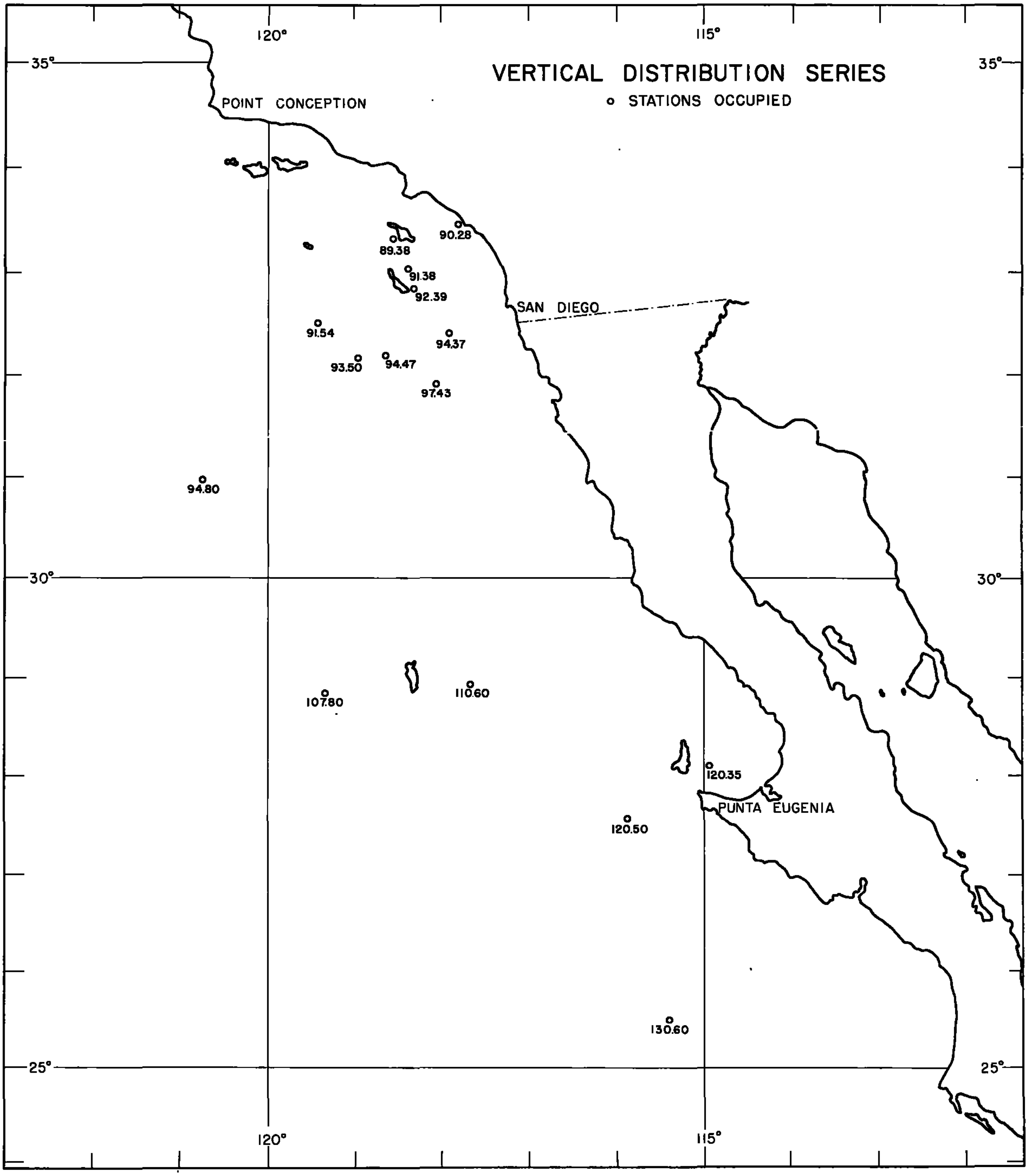

Figure 1.—Location of stations at which vertical distribution series were made.

From two to four hauls were usually made below 100 meters with average depths of 105, 138, 215, and 285 meters.

Each of the hauls in a series is assumed to be representative of the distribution within a depth zone. Since the spacing of hauls in depth was not uniform, the widths of zones are narrower for hauls taken near the surface and become progressively greater for deeper hauls.

All hauls were made with closing nets and gear patterned after that described by Leavitt (1935, 1938). Two sizes of closing nets were employed, one measuring 0.5 meter in diameter at the mouth, the other 1.0 meter in diameter at the mouth. A 0.5-meter net was used in 1941 at stations 4104–91.54 and 4105–89.38. It was constructed of No. 40xxx grit gauze with mesh openings of approximately 0.45 millimeter when new, shrinking to approximately 0.30 millimeter after use. The 1.0-meter closing net used in 1941 (series 4105–92.39, 4106–94.37N and D, 4106–94.47 N and D, and 4106–97.43N and D) was constructed of cotton scrim, with mesh openings ranging in width from 0.8 to 1.0 millimeter. The 1.0-meter nets used in taking all subsequent series were constructed of No. 30xxx grit gauze, with mesh openings of approximately 0.55 millimeter width after shrinkage.

All series are numbered according to present usage. The series made in 1941 have been reported in literature under different station numbers (Silliman 1943). To avoid confusion, the equivalents are given below:

Station No. (present usage)	Equivalent in 1941 system	Position		Date of occupancy
		N. latitude	W. longitude	
4104-91.54	2046	32°29′	119°26′	IV-30-41
4105-92.39	2043	32°50′	118°18′	V-2-41
4106-94.37N	2452N	32°23′	117°52′	VI-17, 18-41
4106-94.37D	2452D	32°17′	117°52′	VI-18-41
4106-94.47N	2454N	32°12′	118°38′	VI-18, 19-41
4106-94.47D	2454D	32°10′	118°39′	VI-19-41

We have tried to collect successive hauls of a given series in a comparable manner as regards length of haul and speed of hauling. No attempt has been made, however, to make the several series entirely comparable. Because of the uncertainty of performance of current meters when used with closing nets, they were not employed. Consequently, it has not been possible to determine the volume of water strained in taking hauls. The series taken during 1941 averaged 15 to 18 minutes per haul; those taken subsequently averaged 10 minutes, occasionally 5 minutes per haul. At station 5305–93.50, towing time was reduced to 5 minutes per haul for a number of the hauls because of the large quantity of plankton material being collected. To adjust for this, counts of larvae for 5-minute hauls were doubled, hence numbers reported for 5305–93.50N and D are comparable for all depths.

In the four series made off central Baja California in 1955, a haul was taken at approximately 88 meters deep (125 meters of wire out)—a level not sampled in previous series. This level was added in order to obtain additional information on distribution of larvae within the thermocline, which was quite deep at these stations. The larvae taken at this level are included in table 2 and in depth-distribution tables for individual species. Inasmuch as this depth was not occupied in taking other series, the data have not been used in obtaining average depth distribution values for most species. Several species occurred almost exclusively in the series made on cruise 5504, especially *Vinciguerria lucetia* and *Diogenichthys laternatus*, and in these instances this level was used.

Vertical distribution series were usually made at localities where eggs and larvae were fairly abundant. Often a large area was scouted before such a rich spot was located. More than 40 localities were sampled on cruise 5504, for example, in order to locate the 4 sites at which vertical series were taken.

The least number of larvae taken in any of the 22 vertical series was 23 in 4106–97.43D, the most was 5,862 in 5504–120.50. Less than 100 larvae were taken in 3 series, between 101 and 500 larvae were obtained in 10 series, between 501 and 1,000 larvae in 3 series, and over 1,000 larvae in 6 series. The combined total for the 22 series was 18,045 larvae.

At least 60 kinds of fish larvae were taken in the vertical series. A summary tabulation of the abundance of 46 kinds of larvae in the 22 series is given in table 2. All other kinds of fish larvae are placed in a category labeled "others." Included as others are gobies, paralepedids, cottids, trichiurids, sciaenids, most blennies, zoarcids, and eel leptocephalids—most of which were identified only to family—and a few larvae that could not

TABLE 2.—*Abundance of fish larvae in vertical distribution series taken off California and Baja California, by station*

	4104–91.54	4105–89.38	4105–92.39	4106–94.37N	4106–94.37D	4106–94.47N	4106–94.47D	4106–97.43N	4106–97.43D	5206–90.28N	5206–90.28D	5208–120.35	5303–91.38N	5303–91.38D	5305–93.50N	5305–93.50D	5403–94.80N	5403–94.80D	5504–107.80	5504–110.60	5504–120.50	5504–130.60	Total
Sardinops caerulea	734	34	676	40	6	89	24	1	0	5	3	114	0	0	0	0	10	4	35	59	7	1	1,842
Engraulis mordax	342	169	577	27	4	217	10	12	0	612	151	125	12	0	10	20	0	0	543	15	5,144	1	7,991
Trachurus symmetricus	4	0	21	0	1	7	0	0	0	26	2	0	0	0	4	2	52	210	72	297	86	0	784
Pneumatophorus diego	0	0	62	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	147	0	217
Merluccius productus	36	21	22	3	0	8	0	1	0	0	0	0	20	5	0	0	1,753	707	214	2	100	0	2,892
Sebastodes spp	97	39	67	20	46	41	65	0	1	48	33	0	225	46	124	144	0	0	15	40	216	0	1,267
Citharichthys spp	7	2	8	0	2	3	3	1	0	1	0	102	17	6	4	4	0	0	0	0	21	0	181
Lyopsetta exilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10
Paralichthys californicus	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Pleuronichthys decurrens	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	8
Symphurus atricauda	0	0	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	39
Lampanyctus leucopsarus	35	18	25	0	4	6	7	1	0	158	4	0	119	60	51	112	10	9	0	0	0	0	619
Lampanyctus mexicanus	0	1	15	5	1	19	2	27	14	3	0	0	0	0	2	0	5	0	88	36	22	33	273
Lampanyctus ritteri	5	2	19	1	2	1	0	4	6	1	2	0	9	5	10	4	19	21	38	11	13	0	173
Tarletonbeania crenularis	0	0	0	0	0	0	0	0	0	13	34	0	1	1	11	6	0	0	0	0	0	0	66
Diogenichthys laternatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	108	110
Diogenichthys atlanticus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	5
Electrona spp	1	0	0	2	0	5	0	0	0	1	0	0	1	0	0	0	4	1	3	0	2	0	20
Lampanyctus regalis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Loweina rara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Myctophum californiense	0	0	2	0	1	2	0	2	0	0	0	0	0	0	0	0	1	0	9	0	1	0	18
Myctophum margaritatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Leuroglossus stilbius	18	0	70	2	1	22	1	1	0	60	30	0	460	74	25	7	0	1	0	5	61	0	838
Bathylagus wesethi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5	66	4	6	0	84
Argentina sialis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	4
Bathylagus alascanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Bathylagus sp	5	0	14	2	1	6	2	1	0	3	0	0	8	1	0	2	0	0	1	0	1	0	47
Microstoma sp	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	3	0	0	0	0	0	5
Nansenia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Vinciguerria lucetia	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	16	25	5	112	159
Argyropelecus spp	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	2	6
Aristostomias scintillans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Chauliodus macouni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2
Cyclothone spp	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	7	7	3	11	30
Ichthyococcus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Idiacanthus antrostomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Stomias atriventer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Brosmophycis marginata	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	3
Chromis punctipinnis	0	0	0	0	0	0	5	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	11
Cololabis saira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	3
Icichthys lockingtoni	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	1	0	0	0	0	5
Melamphaes spp	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	3	6	2	0	0	0	14
Palometa simillima	0	3	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5	0	13
Sphyraena argentea	0	3	0	0	0	0	0	0	0	4	10	0	0	0	0	0	0	0	0	0	0	0	17
Trachypterus rexsalmonorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
Labrids	0	4	8	0	0	2	11	0	0	57	1	0	1	0	0	4	0	0	0	0	1	0	89
Others	3	1	5	1	0	5	1	0	0	23	7	38	50	6	3	14	4	0	7	0	6	5	179
Total	1,288	297	1,592	103	70	444	132	53	23	1,023	281	424	928	208	245	323	1,875	966	1,124	502	5,862	282	18,045

be identified with certainty. A total of 179 larvae are included in this category, slightly less than 1 percent of the total.

It is interesting to note that despite the fact that most vertical series were taken off southern California in areas where sardine spawning might be taking place, the series do reflect fairly well the abundance of fish larvae in the California Cooperative Oceanic Fisheries Investigations (CCOFI) survey area. The relative abundance of the 15 most common kinds of larvae taken in vertical series is compared with their relative abundance in the CCOFI area during 1955 and 1956 in table 3. Fourteen of these ranked among the 15 most common kinds of larvae taken during the 1955 survey cruises, and 12 ranked among the 15 most common kinds of larvae taken in 1956.

Anchovy larvae ranked first in abundance, hake larvae second in the three tabulations. The conscious selection for sardine larvae when taking vertical series raised them to third place in abundance in the vertical series, but sardine larvae ranked sixth in abundance in yearly totals for both 1955 and 1956. For the same reason, jack mackerel and Pacific mackerel have a somewhat higher rank in vertical series than in yearly totals. The relative abundance of *Sebastodes* spp., *Leuroglossus stilbius*, *Lampanyctus leucopsarus*, and *Lampanyctus mexicanus* are strikingly similar in all three tabulations.

Detailed information on depth distribution is given for 46 kinds of larvae taken in vertical distribution series. The data for each of the 15 most common kinds of larvae are summarized in individual tables (tables 5–11, 14–18, 20, 21, 23); the data for the remaining 31 categories are summarized in 4 tables, as follows: 4 kinds of other flatfish (table 12), 6 kinds of other myctophids

TABLE 3.—*Comparison of relative abundance of fish larvae in vertical distribution series with their abundance in survey cruises of the California Cooperative Oceanic Fisheries Investigations in 1955 and 1956*

Species	Fish larvae taken in vertical series			Total fish larvae taken in 1955			Total fish larvae taken in 1956		
	Number taken	Percent of total	Rank	Number taken [1]	Percent of total	Rank	Number taken [1]	Percent of total	Rank
Engraulis mordax	7,991	44.28	1	140,183	39.03	1	134,931	33.06	1
Merluccius productus	2,892	16.03	2	60,090	16.73	2	94,277	23.10	2
Sardinops caerulea	1,842	10.21	3	14,121	3.93	6	15,523	3.80	6
Sebastodes spp.	1,267	7.02	4	29,344	8.17	3	29,144	7.14	3
Leuroglossus stilbius	838	4.64	5	15,111	4.21	5	18,620	4.56	5
Trachurus symmetricus	784	4.34	6	13,246	3.69	7	8,027	1.97	10
Lampanyctus leucopsarus	619	3.43	7	7,454	2.08	10	15,125	3.71	7
Lampanyctus mexicanus	273	1.51	8	13,165	3.67	8	10,802	2.65	8
Pneumatophorus diego	217	1.20	9	1,950	.54	14	1,520	.37	20
Citharichthys spp.	181	1.00	10	20,411	5.68	4	23,635	5.79	4
Lampanyctus ritteri	173	.96	11	1,988	.55	13	1,924	.47	18
Vinciguerria lucetia	159	.88	12	12,654	3.52	9	9,832	2.41	9
Diogenichthys laternatus	110	.61	13	4,771	1.33	11	3,158	.77	13
Bathylagus wesethi	84	.47	14	3,245	.90	12	2,146	.53	17
Tarletonbeania crenularis	66	.37	15	999	.28	22	3,352	.82	12
All others	549	3.04	----------	20,423	5.69	----------	36,124	8.85	----------
Total	18,045	99.99	----------	359,155	100.00	----------	408,140	100.00	----------

[1] Standard haul totals.

(table 19), 5 kinds of other deep-sea smelts (table 22), and 16 kinds of other fish larvae (table 24). Of the 46 kinds of larvae dealt with in the tables, 38 represent individual species, 7 represent genera, and 1 grouping is by family (Labridae).

Illustrations of depth distributions are of two kinds: those based on the average distribution of a category in all the series in which it occurs (figs. 2, 3, and 12), and those based on the distribution of eggs or larvae of a species (or genus) at individual stations (figs. 4–11, 13). In the latter a temperature profile is superimposed over each depth diagram.

Average vertical distributions, illustrated in figures 2, 3, and 12, are not based on a summation of the numbers taken in individual series. If this were done, undue weight would be given to a series in which a category was unusually abundant—such as series 5504–120.50 for *Engraulis mordax*, or series 5403–94.80N for *Merluccius productus*. Instead, equal weight has been given to each series in which a category was common to abundant (50 or more larvae per series) by changing numbers into percentages; thus, each of the larger series has an equal weight of 100. All series in which a category was rare to rather common (1 to 49) were combined and the composite was given a weight of 100. As an example, *Trachurus symmetricus* larvae occurred in 13 series. In 5 series more than 50 larvae were taken per series, and each of these was weighted to 100. The composite of the other 8 series (which totaled only 67 individuals) was given a group weight of 100. The 6 weighted series (5 individual and 1 composite) were then combined and used to determine the percentage occurrence at each level. Illustrations of depth distributions at individual stations also are based on percentage occurrence at each level rather than on actual number (figs. 4–11 and 13).

Depth distributions of eggs are given for 8 of the 15 common kinds of fishes. Of the other seven common categories, *Sebastodes* is ovoviviparous, the eggs of myctophids are unknown, and *Citharichthys* eggs were uncommon. Sardine and anchovy eggs were identified from all collections; the eggs of other fishes were identified from only eight series (5303–91.38N and D, 5403–94.80N and D, and the four series taken on cruise 5504).

Less complete data on the vertical distribution of eggs and larvae are available from two other sources. High-speed samplers have been towed simultaneously at four depths during special studies made with these instruments, usually at approximately 10, 20, 30, and 40 meters deep. The results are presented in a separate report (Ahlstrom et al. 1958). These samplers have been shown to be exceedingly useful instruments in studying variations in the depth distribution of eggs and larvae within the upper 40-meter level. They are of less use in studying the complete depth ranges of eggs and larvae since present models can be hauled only at shallow depths (to perhaps 50 meters), hence cannot be used for encompassing the depth distributions of most fish eggs and larvae.

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On some regular survey cruises a 1.0-meter closing net has been used to sample a depth zone below that sampled in taking the standard 1.0-meter net haul. This procedure was followed during the 1939 and 1940 cruises, for example, and the information thus obtained on the depth distribution of sardine eggs and larvae was summarized by Ahlstrom (1948). Two hauls were taken simultaneously at most stations during Norpac, the upper standard net haul sampling a depth zone from approximately 131 meters deep to the surface, the closing net sampling the level between approximately 262 and 131 meters deep. A brief comparison of the kinds and numbers of larvae taken in the two levels during Norpac is given in a latter section of this report.

The vertical distribution series were taken from five research vessels: *E. W. Scripps*, *Crest*, *Horizon*, and *Spencer F. Baird*, operated by the Scripps Institution of Oceanography, and the *Black Douglas*, operated by the U.S. Fish and Wildlife Service. Personnel of the Scripps Institution of Oceanography cooperated in the collection of material at sea. Many persons presently or formerly employed by the La Jolla Biological Laboratory aided in taking the series, including Ralph Silliman, John C. Marr, Oscar E. Sette, James R. Thrailkill, Robert C. Counts, David Kramer, Robert Livingstone, and Bruce Taft. The figures were prepared by Andrew M. Vrooman. I wish to thank David Kramer for helpful suggestions during preparation of the manuscript.

SOME GENERAL OBSERVATIONS ON DEPTH DISTRIBUTION

Before discussing the vertical distributions of individual species, some general observations will be given on depth distribution. The average weighted depth distributions of the 15 most common kinds of larvae taken in vertical distribution series are summarized in table 4. In these determinations, the depth of the zone represented by each level in the series is taken into account.

Larvae may be divided into two principal groups with respect to depth distribution: (1) Those species occurring almost entirely within the upper mixed layer and in the upper part of the thermocline; (2) those species occurring mostly within or below the thermocline.

Of the 15 kinds of larvae summarized in table 4, 12 fall into the first category and 3 into the second.

Many of the differences in the depth distribution of larvae of the same species in the various series are due to differences in the position of the thermocline. The extremes in thermocline depth were found at stations 5206–90.28N and 5504–110.60. In the former, only the two shallowest tows at average depths of 2 and 7 meters were taken in the layer above the thermocline, the hauls taken at approximately 17 and 27 meters deep were within the zone of rapid temperature decline, and the haul averaging 42 meters deep was definitely below the thermocline. At station 5504–110.60, on the other hand, there was a dif-

TABLE 4.—*Average weighted depth distributions of the 15 most common kinds of larvae taken in vertical distribution series*

Species	Percentage occurrence of larvae at—						Total
	0–23 meters	24–48 meters	49–64 meters	65–88 meters	89–122 meters	Below 122 meters	
Group I: [1]							
Pneumatophorus diego	79.4	19.9	0.7	0	0	0	100.0
Sardinops caerulea	47.1	32.3	5.8	14.8	0	0	100.0
Trachurus symmetricus	40.9	38.1	7.4	10.0	3.6	0	100.0
Engraulis mordax	38.9	46.0	11.7	3.3	.1	0	100.0
Vinciguerria lucetia	16.2	46.8	7.8	20.6	8.7	0	100.1
Sebastodes spp	14.5	41.2	24.7	16.1	3.5	0	100.0
Citharichthys spp	12.6	70.6	14.4	2.4	0	0	100.0
Lampanyctus leucopsarus	4.4	55.8	32.3	5.7	1.7	0	99.9
Lampanyctus mexicanus	5.9	45.6	29.6	15.2	2.2	1.5	100.0
Lampanyctus ritteri	3.8	43.6	27.8	20.5	4.4	0	100.1
Tarletonbeania crenularis	0	31.7	42.3	8.8	12.1	5.0	99.9
Diogenichthys laternatus	0	2.2	1.8	73.0	23.0	0	100.0
Group II: [2]							
Merluccius productus	1.5	3.5	14.0	47.5	10.6	22.9	100.0
Bathylagus wesethi	.3	.8	7.4	25.6	50.0	16.0	100.1
Leuroglossus stilbius	.4	5.1	13.2	18.0	18.9	44.4	100.0

[1] Distribution confined to upper mixed layer.
[2] Distribution mostly within or below thermocline.

ference of only 0.3° C. between the temperature at the surface and that at 83 meters deep (the average depth of the horizontal haul taken with 125 meters of towing cable payed out). The thermocline began at a depth of approximately 90 meters at this station. Since the vertical distributions of most larvae are confined to the upper mixed layer and the upper portion of the thermocline, their depth distributions are shallow in situations such as that sampled at 5206–90.28N, and deeper and more varied at stations having a deep thermocline.

Some differences in depth distribution are due to diurnal changes in level associated with phototropic response of larvae to light (usually negative). Vertical movements of larvae are apparently limited in extent, being confined for most kinds to movements within the upper mixed layer. There is no evidence that fish larvae move through the thermocline while making diurnal vertical movements.

Most kinds of fish larvae are confined in their vertical distribution to the upper mixed layer and the upper portion of the thermocline. However, within the upper mixed layer the various kinds of larvae have different but characteristic depth distributions. Several species occurred in greatest abundance in the upper 23 meters of depth at most stations. Included in this group are *Pneumatophorus diego* (fig. 3, b), *Sardinops caerulea* (fig. 2, a), and *Trachurus symmetricus* (fig. 3, c). The anchovy, *Engraulis mordax*, although it occurred mostly in the upper 23-meter level at some stations, was found on the average to be somewhat more abundant in the level between 24 and 48 meters (fig. 2, b). *Sebastodes* larvae were uncommon in the upper level (0–23 meters) at most stations (fig. 3, d), but they occurred in greatest abundance in this level in one night series. Larvae of *Vinciguerria lucetia* (fig. 2, c) and *Citharichthys* spp. (fig. 3, a) had their largest concentrations in the 24- to 48-meter level.

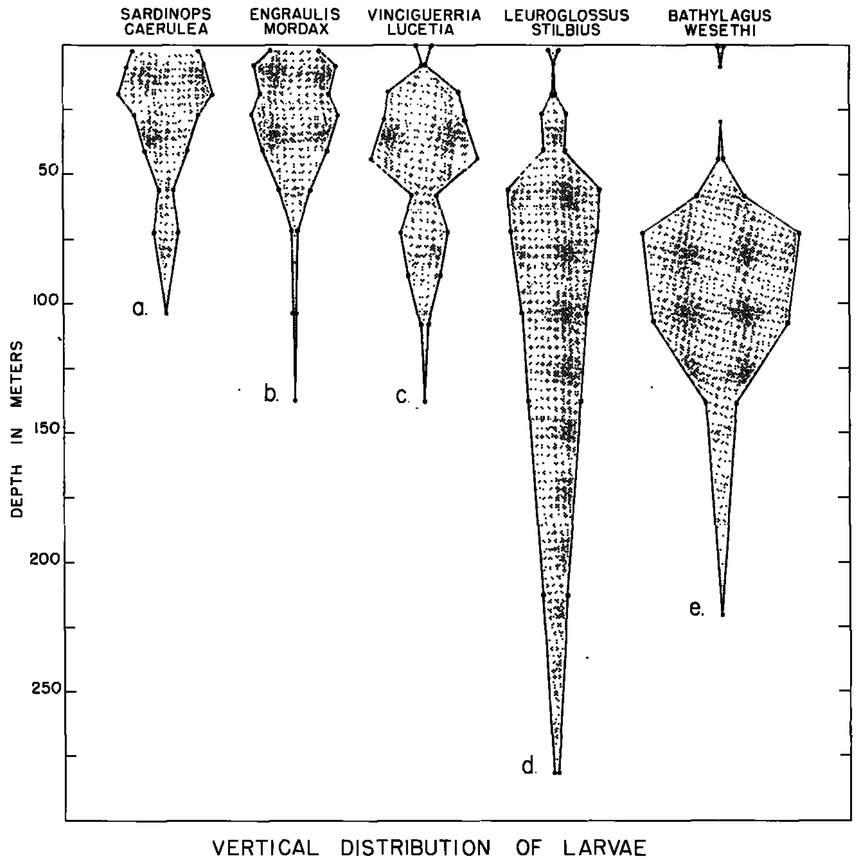

FIGURE 2.—Weighted average vertical distribution of larvae of (a) *Sardinops caerulea*, (b) *Engraulis mordax*, (c) *Vinciguerria lucetia*, (d) *Leuroglossus stilbius*, and (e) *Bathylagus wesethi*.

Myctophid larvae were not taken in any numbers in the 0–23 meter level, but usually had their centers of abundance between 24 and 64 meters (fig. 12). Larvae of *Diogenichthys laternatus* had a somewhat deeper distribution (fig. 12, e), but they still were confined to the upper mixed layer (the thermocline was deep at each station where this species was collected).

The larvae of three species occurred in greatest abundance within and below the thermocline: *Merluccius productus* (fig. 3, e), *Leuroglossus stilbius* (fig. 2, d), and *Bathylagus wesethi* (fig. 2, e). All of these species occurred at somewhat lower temperatures than larvae confined to the upper mixed layer. It is likely that temperature is a more important factor than pressure in the depth distribution of these species.

If these series are representative samplings of the depth distributions of fish larvae, it follows that the complete depth range of the larvae of most species could be completely encompassed by hauls averaging approximately 125 meters deep. In making plankton hauls on CCOFI cruises, the net is hauled obliquely from approximately 140 meters deep to the surface (depth of water permitting), hence the depth distribution of most kinds of fish larvae would be encompassed by these hauls.

DEPTH DISTRIBUTIONS OF INDIVIDUAL SPECIES

Pacific Sardine (*Sardinops caerulea*)

Larvae of the sardine were taken in 17 series, eggs in only 7 (table 5). The vertical distributions of sardine eggs and larvae have been discussed by Silliman (1943) and Ahlstrom (1948). Silliman included several series in his account that are not included here (series taken in 1939 that do not conform to spacing in subsequent series). All series taken subsequent to 1941 have not been reported upon previously.

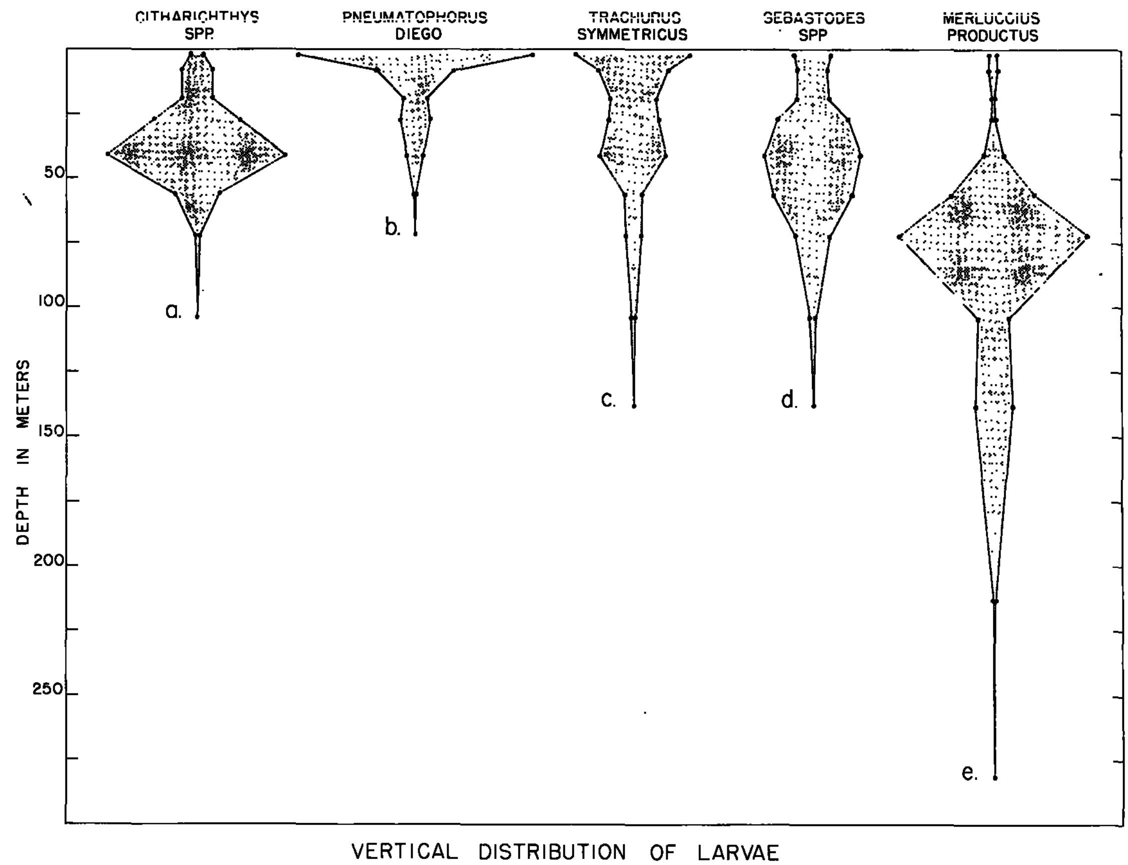

Figure 3.—Weighted average vertical distributions of larvae of (a) *Citharichthys* spp., (b) *Pneumatophorus diego*, (c) *Trachurus symmetricus*, (d) *Sebastodes* spp., and (e) *Merluccius productus*.

TABLE 5.—*Depth distributions of larvae and eggs of Pacific sardine,* Sardinops caerulea

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
4104-91.54	90	179	195	121	117	31	1	—	0	—	—	—	734
4105-89.38	0	0	0	32	2	0	0	—	0	—	—	—	34
4105-92.39	410	248	10	7	1	0	0	—	0	—	—	—	676
4106-94.37N	21	3	12	1	3	0	0	—	0	—	—	—	40
4106-94.37D	0	0	0	1	2	2	1	—	0	—	—	—	6
4106-94.47N	14	13	23	35	4	0	0	—	0	—	—	—	89
4106-94.47D	5	0	6	9	2	2	0	—	0	—	—	—	24
4106-97.43N	1	0	0	0	0	0	0	—	0	—	—	—	1
5206-90.28N	3	2	0	0	0	0	0	—	0	0	0	0	5
5206-90.28D	0	3	0	0	0	0	0	—	0	0	0	0	3
5208-120.35	10	65	15	17	7	0	—	—	—	—	—	—	114
5403-94.80N	0	0	1	5	2	2	0	—	0	0	0	—	10
5403-94.80D	0	0	0	0	1	1	2	—	0	0	0	—	4
5504-107.80	1	0	19	6	5	0	1	3	0	0	—	—	35
5504-110.60	0	0	0	0	23	10	24	2	0	—	—	—	59
5504-120.50	2	1	0	2	2	0	0	0	0	0	0	—	7
5504-130.60	1	0	0	0	0	0	0	0	0	0	0	—	1
Total	558	514	281	236	171	48	29	5	0	0	0	0	1,842
Eggs:													
4105-92.39	90	16	1	1	0	0	0	—	0	—	—	—	108
5206-90.28N	4	0	2	0	0	0	0	—	0	0	0	0	6
5206-90.28D	2	0	1	0	0	0	0	—	0	0	0	0	3
5208-120.35	22	17	33	35	40	5	—	—	—	—	—	—	152
5403-94.80N	37	29	46	50	65	33	11	—	0	0	0	—	271
5403-94.80D	59	51	29	20	21	11	7	—	3	0	0	—	201
5504-120.50	0	2	0	0	0	0	0	0	0	0	0	—	2
Total	214	115	112	106	126	49	18	0	3	0	0	0	743

The depth range of sardine larvae in vertical distribution series is from 0 to approximately 96 meters, and the eggs range from 0 to approximately 121 meters. I wish to clarify a usage in defining the limits of depth ranges in this and subsequent discussions of other species. When indicating the depth range of sardine larvae, I have given the deeper limits of the level, whose average depth is 88 meters. Similarly, sardine eggs were taken in a haul having an average depth of 105 meters; the deeper limit of this stratum is approximately 121 meters.

The depth distributions of sardine larvae in individual series are illustrated in figure 4. In two series, the larvae were concentrated into a rather narrow zone. Thus, at station 4105–92.39 (fig. 4, a), most larvae occurred in the upper two hauls of the series, and at station 5208–120.35 (fig. 4, b), a marked concentration occurred at the 10-meter level. At station 4104–91.54 (fig.

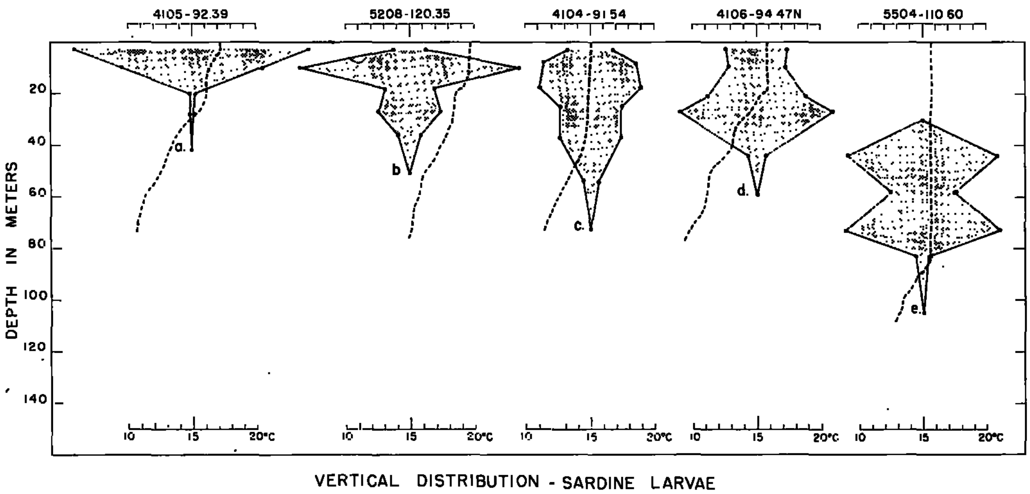

FIGURE 4.—Vertical distributions of sardine (*Sardinops caerulea*) larvae in five separate series, with superimposed temperature profiles.

4, c), however, the larvae were rather similar in numbers at four levels between 8 and 37 meters in average depth. In 4 of the 5 series illustrated in figure 4 the larvae were found almost entirely above 50 meters deep. Three of these were night series, the fourth (4104–91.54) was started in the afternoon and completed after dark. In the single day series illustrated, 5504–110.60 (fig. 4, e), the larvae occurred mostly below 50 meters, in the lower half of the upper mixed layer. The thermocline was deeper at this station than at most other stations at which depth distribution studies were made. Differences in depth distributions of sardine larvae in day and night series are discussed in a following section.

The average weighted depth distribution of sardine larvae, based on vertical distribution series, had the following percentages in different depth strata:

Strata:	Percentage of total
0–23 meters	47.1
24–48 meters	32.3
49–64 meters	5.8
65–88 meters	14.8
89 meters and below	0

A somewhat shallower distribution was indicated in studies reported by Ahlstrom (1948). Two to three closing nets were used in series at most stations in 1939; the upper net fished from approximately 42 meters to the surface, the intermediate net from 81 to 38 meters, and the bottom net from 120 to 72 meters. The exact depth fished by each net varied from haul to haul. About 93 percent of the sardine larvae were taken in the upper level, 7 percent in the intermediate level, and none in the lowest level. A closing net was used below the upper net at 133 stations occupied in 1940. It sampled the zone between approximately 130 and 57 meters. Less than 1 percent of sardine eggs and larvae were taken in the deeper stratum. Inasmuch as the 1939 and 1940 studies represent a larger number of observations than the vertical distribution series, they may reflect the average depth distribution of sardine larvae more adequately than the weighted distributions given above.

Water temperatures at the levels where sardine larvae were collected ranged from 10.9° to 19.7° C. Only 17 larvae were taken at temperatures lower than 13.0° C. The only series in which water temperatures were above 17.0° C. was at station 5208, taken during August in Sebastian Viscaino Bay, central Baja California. This series represents offseason sardine spawning, which centers in the Sebastian Viscaino Bay area. This spawning occurs at considerably higher temperatures than during the regular spawning season, and there is a possibility that the offseason spawners may belong to a separate subpopulation of sardines.

Two contrasting distributions are illustrated for sardine eggs. At station 4105–92.39 (fig. 5, a) most of the eggs were taken in the surface haul. The depth distribution of sardine eggs at this station is fairly similar to the distribution of sardine larvae (fig. 4, a). A higher percentage of sardine eggs than larvae occurred in the surface haul, but both categories have a very shallow depth distribution. Sardine eggs occurred over a fairly wide depth zone at station 5403–94.80N (fig. 5, b): from the surface to approximately 82 meters, with the largest concentration (23 percent of the total) at 42 meters. The few sardine larvae obtained in this series occurred at depths between 14 and 64 meters.

Northern Anchovy (*Engraulis mordax*)

Anchovy larvae were the most abundant kind taken in depth distribution studies: they were present in 18 of the 22 series, and were very common to very abundant (125 to 5,144 per series) in half of these (table 6). The weighted average vertical distribution of anchovy larvae is illustrated in figure 2, b.

The depth distributions of anchovy larvae in five series are illustrated in figure 6. Three of these series were made at night, two during daytime. The two daytime series have contrasting distributions. At station 4105–89.38 (fig. 6, d), most larvae were taken at one level (25 meters), while at station 5504–107.80 (fig. 6, e), the larvae were deeper and more dispersed. The thermocline was shallow at station 4105–89.38; there was a temperature drop of 3.3° C. between the 25- and 56-meter level. The thermocline was deep at station 5504–107.80; there was only 0.7° C. difference between the temperature at the surface and that at 70 meters.

Anchovy larvae were unusually abundant at station 5504–120.50; in fact the 5,144 anchovy larvae taken at this station constitute about 28 percent of all larvae taken in vertical distribution series. Anchovy larvae had a wide depth range

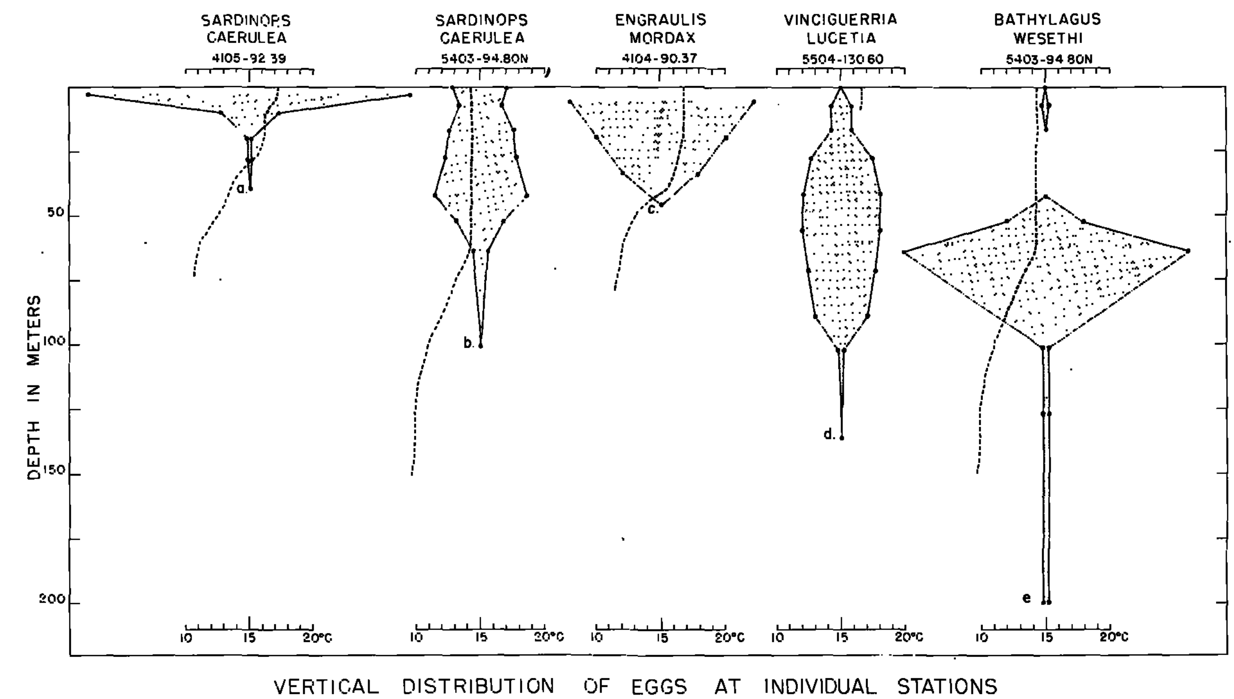

FIGURE 5.—Vertical distributions of the eggs of four species of fish at individual stations. Species and station numbers are listed above each diagram and a temperature profile is superimposed.

at this station, from 0 to approximately 125 meters. The largest concentrations were in the two shallowest hauls, but larvae were abundant to approximately 66 meters.

Additional information on depth distribution of anchovy larvae is available from the 1940 survey, when a closing net fishing from approximately 130 to 57 meters was used at most stations below the upper net. The number of anchovy larvae obtained from 133 closing-net hauls was 148, as compared to 5,940 larvae in the upper net hauls at the same stations. Thus, only about 2½ percent of the larvae were distributed as deeply as 57 meters. It is interesting to note that only

TABLE 6.—*Depth distributions of larvae and eggs of northern anchovy* (Engraulis mordax)

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
4104-91.54	3	4	4	62	248	21	0	---	---	---	---	---	342
4105-89.38	0	1	7	148	9	4	0	---	---	---	---	---	169
4105-92.39	231	247	36	53	10	0	0	---	0	---	---	---	577
4106-94.37N	4	8	6	5	4	0	0	---	0	---	---	---	27
4106-94.37D	0	0	0	1	1	2	0	---	0	0	---	---	4
4106-94.47N	7	5	61	114	a 30	0	0	---	0	0	---	---	217
4106-94.47D	1	2	0	0	4	2	1	---	0	0	---	---	10
4106-97.43N	1	1	4	6	0	0	0	---	0	0	---	---	12
5206-90.28N	196	205	114	97	0	0	0	---	0	0	0	0	612
5206-90.28D	5	136	9	0	1	0	0	---	0	0	0	0	151
5208-120.35	4	30	19	19	46	7	---	---	---	---	---	---	125
5303-91.38N	1	1	4	6	0	0	0	---	0	0	0	0	12
5305-93.50N	8	0	2	0	0	0	0	---	0	0	0	0	10
5305-93.50D	0	0	2	8	4	6	0	---	0	0	0	---	20
5504-107.80	4	0	0	19	159	271	73	16	1	0	---	---	543
5504-110.60	14	0	0	0	0	1	0	0	0	---	---	---	15
5504-120.50	1,370	1,405	837	270	697	488	72	4	1	0	0	---	5,144
5504-130.60	0	0	0	1	0	0	0	0	0	0	0	---	1
Total	1,849	2,045	1,105	809	1,213	802	146	20	2	0	0	0	7,991
Eggs:													
4105-89.38	246	30	0	9	0	2	0	---	---	---	---	---	287
5206-90.28N	0	0	1	0	0	0	1	---	0	0	0	1	3
5206-90.28D	43	4	1	0	0	1	1	---	4	2	9	4	69
Total	289	34	2	9	0	3	2	---	4	2	9	5	359

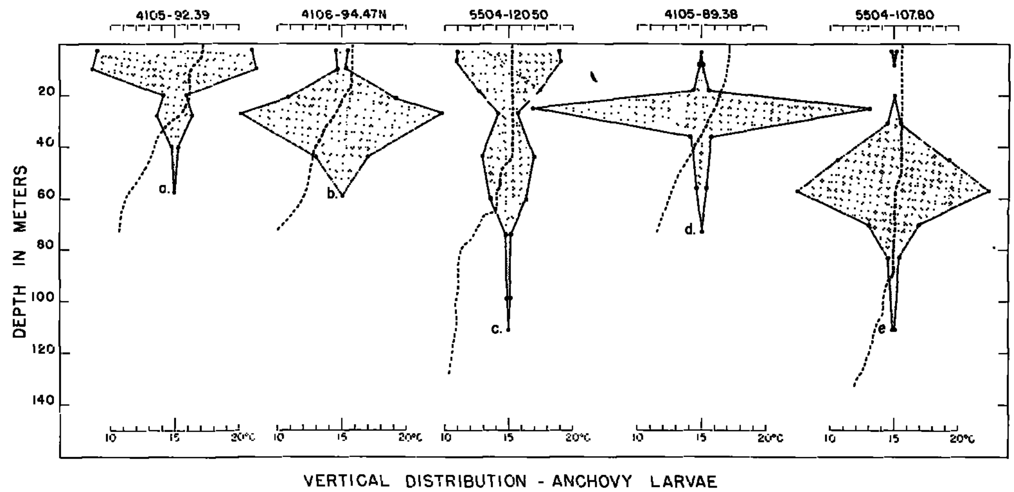

FIGURE 6.—Vertical distributions of anchovy (*Engraulis mordax*) larvae in five separate series, with superimposed temperature profiles.

11 larvae were taken in closing net hauls made at night, while 137 were taken in day hauls. A deeper distribution in day hauls was also found in replicate vertical series, discussed in a latter section.

Anchovy larvae were taken over a wide temperature range, 10.0° to 19.7° C. Most larvae occurred within a 3.5°-temperature range, 14.0° to 17.4° C., however; approximately 95 percent of the total number of anchovy larvae were obtained within this temperature range. Only nine larvae were taken at temperatures below 12.0° C., and occurrences above 17.5° C. were mostly from station 5208–120.35 in Sebastian Viscaino Bay.

Anchovy and sardine larvae had fairly similar depth distributions at most stations where they both occurred. Their depth distributions at stations 4105–92.39 and 4106–94.47N are shown in figure 4, a and d, for sardine larvae, and figure 6, a and b, for anchovy larvae. In both series the two species have similar depth ranges, but a somewhat larger portion of the sardine larvae was taken in the shallower hauls. There is a more marked contrast in the depth distributions of the two species at station 4104–91.54. In this series nearly three-fourths of the anchovy larvae were taken in the fifth haul of the series, averaging 36 meters (not illustrated), while the center of abundance of sardine larvae was much shallower (fig. 4, c).

There is limited information on the depth distribution of anchovy eggs, which were taken in only three of the regular series. In these series (table 6), 90 percent of the eggs were taken in the two shallowest hauls of each series, but some eggs were obtained throughout the depth range sampled. The presence of eggs in the deeper hauls made at station 5206–90.28 is difficult to explain, since anchovy larvae were not taken at these depths either at this station or in any other series.

Silliman (1943) made use of five vertical series (F8A, F8B, F9A, F9B taken in 1939, and 1832 taken in 1941) that are not included in the present report. Inasmuch as anchovy eggs were taken in three of these series, the information is given below:

Series F8A			Series F9A			Series 4104-90.37 (1832)		
Middepth of haul	Number of eggs	Temperature (° C.)	Middepth of haul	Number of eggs	Temperature (° C.)	Middepth of haul	Number of eggs	Temperature (° C.)
2 m	35	15.4	4 m	2,552	15.6	6 m	47	16.8
7 m	7	15.3	13 m	194	15.3	20 m	32	16.7
12 m	12	15.2	30 m	65	11.7	34 m	18	15.9
22 m	0	14.5	51 m	1	10.3	46 m	0	13.7
32 m	1	11.9	57 m	11	10.2	58 m	0	12.3
45 m	0	10.7				77 m	0	11.5
55 m	0	10.2						
111 m	2	9.5						

As in the series discussed above, the largest concentrations of eggs occurred in the upper haul of each series. The distribution in series 4104–90.37 (1832) is illustrated in figure 5c.

Information on the depth distribution of anchovy eggs within the upper 40-meter level based on material from high-speed sampler hauls is available for six sets of hauls (Ahlstrom et al. 1958). In the three sets containing the largest number of eggs, the majority were taken below 20 meters. Hence there is more variation in depth distribution of eggs than was indicated in the vertical distribution series.

It is interesting to note the differences in depth distribution of anchovy eggs and larvae at station 4105–89.38. Nearly 86 percent of the anchovy eggs were taken in the surface haul, while as large a percentage of the larvae was taken in the haul averaging 25 meters deep (fig. 6, d). Most of the larvae were under 4 millimeters in length, hence too small to participate in any marked vertical movement. The only fins developed on 4-millimeter anchovy larvae are larval pectorals.

Jack Mackerel (*Trachurus symmetricus*)

The majority of vertical distribution series were not taken in areas where jack mackerel larvae commonly occur. The center of abundance of jack mackerel larvae is usually between 80 and 240 miles offshore (Ahlstrom and Ball, 1954: 227), while most vertical series were taken within 80 miles of the coast. Jack mackerel larvae were taken in 13 series (table 7), but occurred in small numbers (1 to 7 larvae per series) in nearly half of the series, and commonly (50 or more per series) in only five series.

The larvae were taken between the surface and approximately 122 meters, although approximately four-fifths of the larvae occurred within the upper 50 meters (fig. 3, c). Considerable variation was found from series to series, as is shown in figure 7. Jack mackerel larvae decreased in abundance with depth at station 5504–120.50 (fig. 7, b), were mostly concentrated within the upper 10 meters at station 5403–94.80D (fig. 7, a), had a marked center of abundance at 44 meters at station 5504–110.60 (fig. 7, c), and had a wide depth range at station 5504–107.80 (fig. 7, d).

The depth distributions of jack mackerel eggs are illustrated in figure 8. The same series are shown for eggs as for larvae, with the addition of station 5403–94.80N. The secondary concentration of eggs, which occurred at a depth of 42 meters at the latter station (fig. 8, c) resulted from eggs spawned during the night of collection. Of the 346 jack mackerel eggs taken in this haul, 338 were recently spawned. Most of the newly spawned eggs (321) had not yet initiated cleavage, hence spawning may have occurred within the hour. This haul was taken at about 11 p.m.

TABLE 7.—*Depth distributions of larvae and eggs of jack mackerel* (Trachurus symmetricus)

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
4104–91.54	2	0	1	1	0	0	0						4
4105–92.39	10	9	1	1	0	0	0		0				21
4106–94.37D	0	0	0	0	1	0	0		0	0			1
4106–94.47N	0	0	4	3	0	0	0		0	0			7
5206–90.28N	12	13	0	0	1	0	0		0	0	0	0	26
5206–90.28D	0	2	0	0	0	0	0		0	0	0	0	2
5305–93.50N	0	4	0	0	0	0	0		0	0	0	0	4
5305–93.50D	0	0	0	0	2	0	0		0	0	0		2
5403–94.80N	26	0	5	7	6	8	0		0	0	0		52
5403–94.80D	92	86	24	2	2	2	2		0	0	0		210
5504–107.80	4	0	14	24	6	4	8	8	4	0			72
5504–110.60	6	0	3	25	209	13	34	6	1				297
5504–120.50	34	24	15	9	3	1	0	0	0	0	0		86
Total	186	138	67	72	230	28	44	14	5	0	0	0	784
Eggs:													
5403–94.80N	602	51	32	54	346	25	6		0	1	0		1,117
5403–94.80D	1,017	822	265	38	30	11	6		7	0	0		2,196
5504–107.80	36	19	11	30	10	4	11	0	0	0			121
5504–110.60	54	11	27	4	7	6	21	3	1				134
5504–120.50	29	38	24	1	0	0	0	0	0	0	0		92
Total	1,738	941	359	127	393	46	44	3	8	1	0		3,660

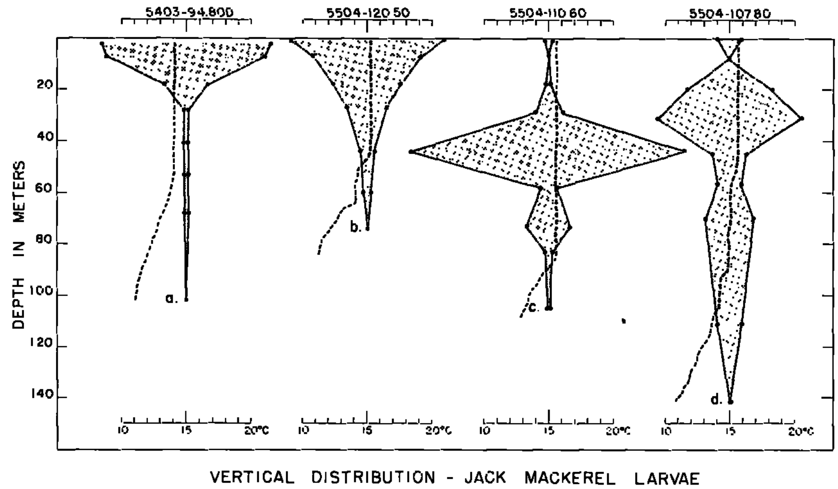

FIGURE 7.—Vertical distributions of jack mackerel (*Trachurus symmetricus*) larvae in four separate series, with superimposed temperature profiles.

The distribution of recently spawned eggs at this station is shown in the following tabulation:

Average depth of haul	Number of jack mackerel eggs		
	Recently spawned	Middle and late stage	Total
2 meters	0	602	602
7 meters	2	49	51
17 meters	3	29	32
27 meters	36	18	54
42 meters	338	8	346
52 meters	6	19	25
64 meters	1	5	6
101 meters	0	0	0

Some newly spawned eggs were taken at other depths, especially in the haul averaging 27 meters in depth. If the depth of occurrence of newly spawned eggs can be assumed to reflect the depth at which spawning took place, then in this instance, at least, spawning occurred below the level of abundance of the older eggs. Two possible explanations of this difference in distribution are that the older eggs had changed their depth distribution since spawning by floating upward, or that spawning had occurred at shallower depths on the preceding several nights. I consider the latter explanation to be the more likely.

There are interesting similarities and differences in the depth distributions of eggs and larvae. The distributions of eggs and larvae in series 5403–94.80D are quite similar; their distributions in series 5504–110.60 are markedly different. In the latter series, only about 3 percent

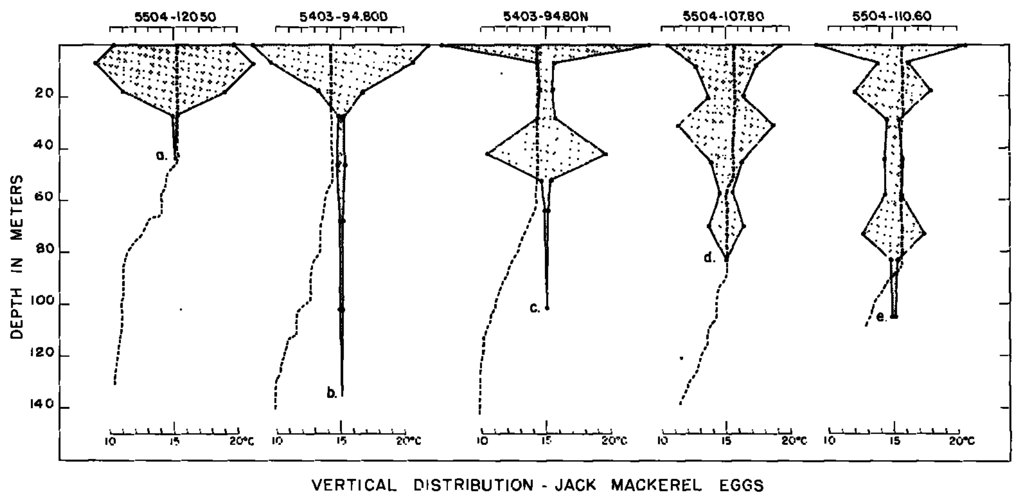

FIGURE 8.—Vertical distributions of jack mackerel (*Trachurus symmetricus*) eggs in five separate series, with superimposed temperature profiles.

of the larvae were taken in the upper three hauls, while nearly 69 percent of the eggs were taken in these hauls. In the two other series that are illustrated, the eggs also have a somewhat shallower distribution than the larvae. At station 5504–107.80, about 45 percent of the eggs were taken in the two shallowest hauls and only 6 percent of the larvae.

Jack mackerel larvae were taken within a 4°-temperature range, 13.0°–16.9° C., except for one occurrence at 10.1° C. The great majority of larvae occurred within a 2° range, 14.0°–15.9° C. The eggs had an even more restricted range: 99.6 percent of the eggs occurred at temperatures between 14.0° and 15.7° C. These observations agree well with those given in table 10 of Ahlstrom and Ball (1954), who found that over 70 percent of the larger collections of larvae (50 or more per standard haul) occurred within the 2°-temperature range noted above (14°–16° C.). The authors were dealing with a much larger mass of data—780 collections of larvae made in 1950 to 1952—hence it is not surprising that they found a wider temperature range, 10.0°–19.5° C., for the larvae in these collections.

Pacific Mackerel (*Pneumatophorus diego*)

Pacific mackerel larvae were obtained in only three series (table 8). None of the larvae occurred below approximately 66 meters deep, and nearly 80 percent of them occurred in the 0- to 23-meter level. This is the shallowest depth distribution found for any of the more common kinds of larvae. The temperature range at which larvae occurred was between 14.1° and 17.1° C. The weighted average depth distribution of larvae is shown in figure 3, b, the distributions at individual stations are shown in figure 9, a and b.

Inasmuch as Pacific mackerel larvae were not taken in any vertical series where the upper mixed layer was deep, it is probable that a somewhat deeper distribution would be found in these situations. Pacific mackerel larvae are taken in such situations on regular survey cruises.

Pacific mackerel eggs, which occurred in abundance at station 5504–120.50, had a less restricted depth distribution than the larvae (fig. 9, c).

Hake (*Merluccius productus*)

Hake larvae rank second in abundance to anchovy, both in yearly summaries of larvae in the CCOFI survey area and in the vertical distribution series. Hake larvae were taken in 13 series, commonly in 4; hake eggs in 6 series, commonly in 2 (table 9). Some of the data on vertical distribution of hake larvae have already been given in Ahlstrom and Counts (1955: 315).

Hake larvae were taken mostly within or below the thermocline. Only 5 percent of the larvae were obtained between the surface and 48 meters (table 4). In three of the four series in which hake larvae were common, the center of abundance occurred in the haul at an average of 72 meters deep (fig. 10, a, b, and d), and very few larvae were taken below 122 meters.

A deeper distribution of larvae was obtained at station 5504–107.80. Unfortunately, this is an incomplete series, with the deepest haul averaging 142 meters in depth. Hake larvae were taken in the six hauls made between 45 and 142 meters, with an increase in abundance with depth. Nearly 38 percent of the larvae were taken in the bottom haul of this series. Depth distribution at this station is so different from the others, that it points up the incompleteness of our depth distribution data for this species and the need for additional series.

TABLE 8.—*Depth distributions of larvae and eggs of Pacific mackerel* (Pneumatophorus diego)

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	128	215	285	
Larvae:													
4105–92.39	52	5	1	4	0	0	0	------	0	------	------	------	62
4106–94.47N	1	0	6	1	0	0	0	------	0	0	------	------	8
5504–120.50	56	48	15	13	14	1	0	0	0	0	0	------	147
Total	109	53	22	18	14	1	0	0	0	0	0	------	217
Eggs: 5504–120.50	544	721	450	221	164	51	35	13	13	9	0	------	2,221
Total	544	721	450	221	164	51	35	13	13	9	0	------	2,221

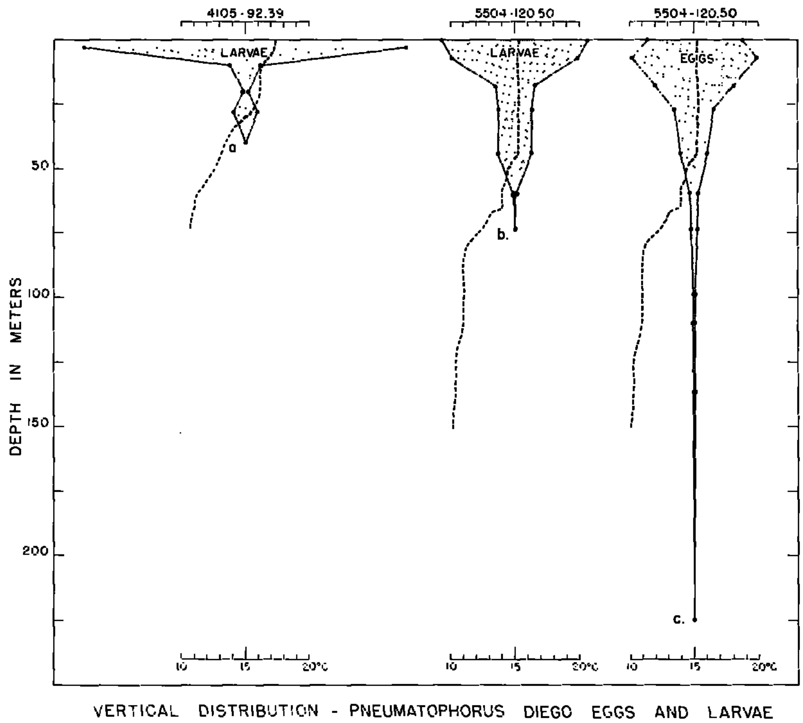

FIGURE 9.—Vertical distributions of Pacific mackerel (*Pneumatophorus diego*) larvae and eggs in separate series, with superimposed temperature profiles.

In vertical series, hake larvae were taken at temperatures between 8.7° and 15.7° C., with most occurring between 10.6° and 15.0° C. Interestingly, Ahlstrom and Counts (1955: 328) found that larger concentrations of hake larvae (1,001 or more per standard haul) taken on survey cruises occurred within this identical 4½° temperature range.

Hake eggs were common only in the two series (N and D) taken at station 5403-94.80. The distribution of hake eggs in the series taken at night (fig. 10, c) is strikingly similar to the dis-

TABLE 9.—*Depth distributions of larvae and eggs of hake* (Merluccius productus)

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
4104-91.54	0	0	0	0	3	20	13	----	----	----	----	----	36
4105-89.38	0	0	0	0	0	14	7	----	0	----	----	----	21
4105-92.39	0	0	0	3	5	9	4	----	1	----	----	----	22
4106-94.37N	0	0	0	0	2	0	1	----	0	----	----	----	3
4106-94.47N	0	0	0	1	3	4	0	----	0	0	----	----	8
4106-97.43N	0	0	0	0	0	0	0	----	0	1	----	----	1
5303-91.38N	0	0	0	0	0	8	12	----	0	----	0	0	20
5303-91.38D	0	0	0	0	3	2	0	----	0	0	0	----	5
5403-94.80N	15	6	5	1	2	93	1,622	----	8	0	1	----	1,753
5403-94.80D	69	86	24	14	49	156	287	----	22	0	0	----	707
5504-107.80	0	0	0	0	1	4	31	38	59	81	----	----	214
5504-110.60	0	0	0	0	0	0	0	0	2	----	----	----	2
5504-120.50	0	0	0	0	4	23	48	22	0	2	1	----	100
Total	84	92	29	19	72	333	2,025	60	92	84	2	0	2,892
Eggs:													
5303-91.38N	2	0	0	2	1	0	0	----	0	0	0	0	5
5303-91.38D	0	0	0	1	0	0	0	----	0	0	0	0	1
5403-94.80N	1	2	3	0	0	5	87	----	3	1	0	----	102
5403-94.80D	2	0	0	2	7	22	66	----	0	0	2	----	101
5504-107.80	0	0	0	0	8	2	1	4	0	0	----	----	15
5504-120.50	0	0	0	0	0	0	0	0	1	2	0	----	3
Total	5	2	3	5	16	29	154	4	4	3	2	----	227

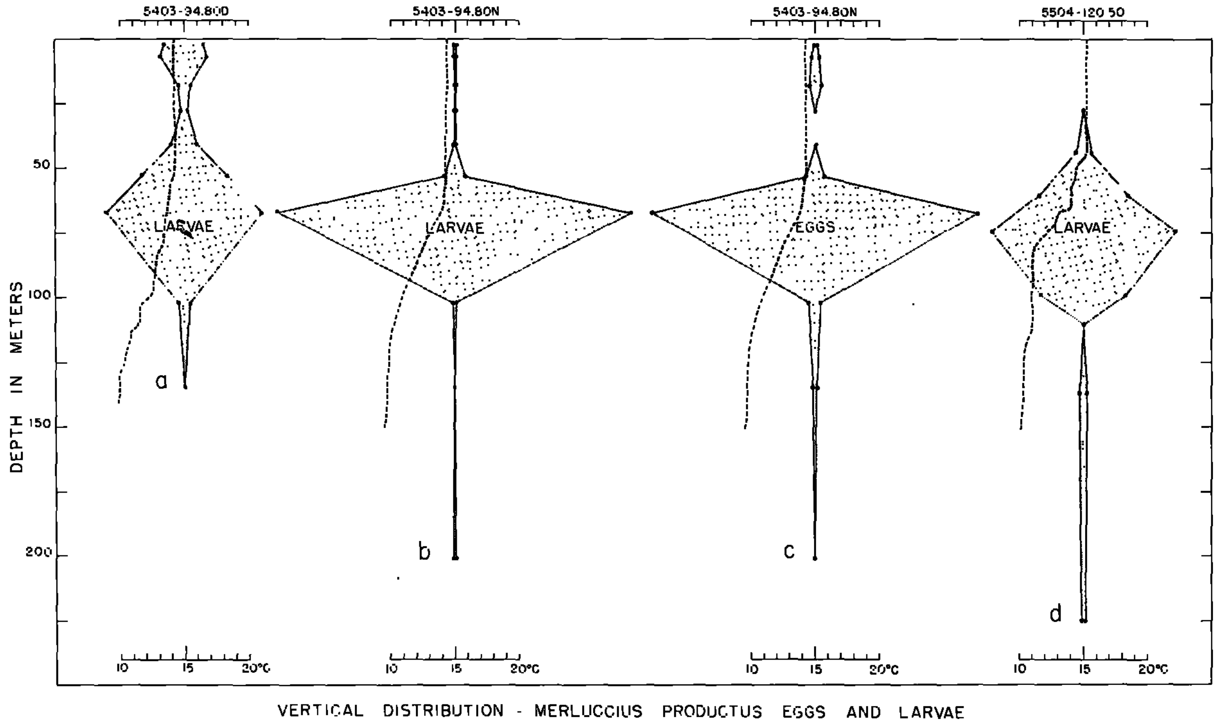

FIGURE 10.—Vertical distributions of Hake (*Merluccius productus*) larvae and eggs in separate series, with superimposed temperature profiles.

tribution of larvae in the same series (fig. 10, b). Almost identical numbers of eggs were taken in these day and night series, although there was not as marked a concentration of the eggs at one depth in the day series as in the night. A few (15) hake eggs were taken at station 5504–107.80; they were taken in the four contiguous hauls made between 41 and 88 meters, but no eggs were taken in the two lower hauls of this series; hence, the depth distribution of eggs at this station was shallower than the distribution of larvae.

Rockfish Larvae (*Sebastodes* spp.)

The category of rockfish larvae is restricted to a single genus, *Sebastodes*, containing a number of species. Larvae of *Sebastodes* can be identified to genus without difficulty, but no attempt has been made to extend identification to the specific level. According to Phillips (1957), 49 species of *Sebastodes* occur off California, and 34 of them are definitely known to occur off Baja California, as well.

Rockfish larvae usually are taken in a larger number of plankton hauls on CCOFI cruises than any other kind of larva. This wide distribution is also reflected in their frequency of occurrence in vertical distribution series. Rockfish larvae were taken in 17 series, and in all but 1 of these, 15 or more larvae were taken per series (table 10).

Rockfish larvae were seldom common in the upper 23 meters (figs. 3, d, and 11, a to d). Usually the largest numbers were taken in hauls averaging 28, 41, and 56 meters deep. However, at station 5305–93.50N (fig. 11, a) the largest number was taken in the surface haul, and at station 5504–120.50 (fig. 11, d) there were two levels of concentration, one near the surface, the other at 72 meters deep. Only nine rockfish larvae were taken below 100 meters, all of these occurring in hauls averaging 105 meters deep. Thus, rockfish larvae belong to the large group of fish larvae that occurs in the upper mixed layer or within the thermocline, but not below it.

Sebastodes larvae were taken at temperatures between 9.0° and 17.2° C., with the larger concentrations occurring at temperatures between 10.2° and 16.1° C. At individual stations, the temperature ranges over which larvae were taken was as great as 5.7° C. (series 4105–89.38 and 4105–92.39). In about half of the series the largest

TABLE 10.—*Depth distributions of larvae of rockfishes* (Sebastodes *spp.*)

Station series	Number of larvae per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
4104-91.54	3	13	5	26	41	9	0	------	------	------	------	------	97
4105-89.38	2	0	0	25	1	10	1	------	0	------	------	------	39
4105-92.39	3	9	0	16	21	18	0	------	0	------	------	------	67
4106-94.37N	0	0	0	0	5	6	8	------	1	------	------	------	20
4106-94.37D	0	0	0	0	6	25	15	------	0	0	------	------	46
4106-94.47N	0	0	0	2	28	10	1	------	0	0	------	------	41
4106-94.47D	0	0	0	0	15	27	16	------	7	0	------	------	65
4106-97.43D	0	0	0	0	0	1	0	------	0	0	------	------	1
5206-90.28N	0	0	23	22	3	0	0	------	0	0	0	0	48
5206-90.28D	0	0	1	30	2	0	0	------	0	0	0	0	33
5303-91.38N	1	0	9	71	62	76	5	------	1	0	0	0	225
5303-91.38D	0	9	7	16	7	7	0	------	0	0	0	0	46
5305-93.50N	60	24	12	22	6	0	0	------	0	0	0	0	124
5305-93.50D	0	2	48	24	52	18	0	------	0	0	0	------	144
5504-107.80	0	0	5	5	4	1	0	0	0	0	------	------	15
5504-110.60	2	0	2	1	32	3	0	0	0	------	------	------	40
5504-120.50	33	21	9	2	12	41	70	28	0	0	0	------	216
Total	104	78	121	262	297	252	116	28	9	0	0	0	1,267

numbers of larvae were taken within the zone of rapid temperature change (i.e., within the thermocline). In some series, however, the larvae occurred within a zone of uniform or nearly uniform temperature (series 5504–110.60 and 5303–91.38N). In series 5504–120.50, there were two levels of concentration of larvae, the upper occurring at 15.3° C., the lower at 12.2° C. There may have been two (or more) species of rockfish with different temperature requirements present in this series.

Rockfish are ovoviviparous; the eggs are carried by the female until embryonic development is completed. Hence, only the larvae are taken in plankton collections.

Sand Dabs (*Citharichthys* spp.)

Four species of *Citharichthys* occur off California and Baja California: *C. sordidus*, *C. stigmaeus*, *C. xanthostigma*, and *C. fragilis*. Larvae of all four species were taken in vertical distribution series. *C. sordidus* was taken in the series made off California, *C. xanthostigma* and *C. fragilis* in two series made off central Baja California, and *C. stigmaeus* in both areas. The larvae of these species will be described in a subsequent publication.

Citharichthys larvae were common in only 1 series, although they were taken in 14 (table 11). They occurred between the surface and approximately 88 meters (fig. 3, a). In Sebastian

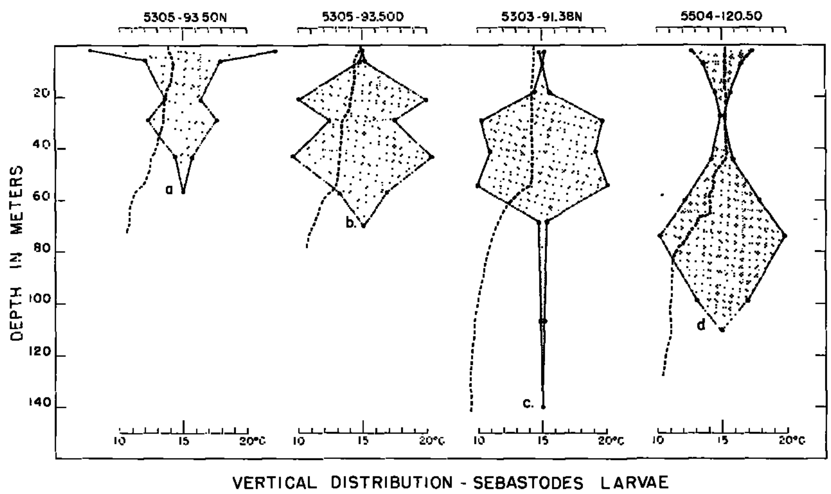

FIGURE 11.—Vertical distributions of *Sebastodes* larvae in four separate series, with superimposed temperature profiles.

TABLE 11.—*Depth distributions of the larvae of sand dabs* (Citharichthys *spp.*)

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
4104-91.54	1	0	0	2	4	0	0	--------	--------	--------	--------	--------	7
4105-89.38	1	0	0	0	0	1	0	--------	--------	--------	--------	--------	2
4105-92.39	0	1	4	2	1	0	0	--------	0	--------	--------	--------	8
4106-94.37D	0	0	0	0	1	1	0	--------	0	0	--------	--------	2
4106-94.47N	0	0	0	0	1	2	0	--------	0	0	--------	--------	3
4106-94.47D	0	0	0	0	2	1	0	--------	0	0	--------	--------	3
4106-97.43N	0	0	0	0	0	1	0	--------	0	0	--------	--------	1
5206-90.28N	1	0	0	0	0	0	0	--------	0	0	0	0	1
5208-120.35	0	2	1	2	31	66	--------	--------	--------	--------	--------	--------	102
5303-91.38N	0	3	4	3	3	4	0	--------	0	0	0	0	17
5303-91.38D	0	1	1	1	2	1	0	--------	0	0	0	0	6
5305-93.50N	0	4	0	0	0	0	0	--------	0	0	0	0	4
5305-93.50D	0	0	0	2	2	0	0	--------	0	0	0	0	4
5504-120.50	0	3	2	1	6	7	2	0	0	0	0	--------	21
Total	3	14	12	13	53	84	2	0	0	0	0	0	181

Viscaino Bay (5208–120.35), where the depth of the series was limited by the shallowness of the bay, most of the larvae were taken in the two deeper hauls.

Other Flatfish Larvae

Limited information on depth distributions of the larvae of four other species of flatfish is given in table 12. The distribution of *Symphurus atricauda* larvae at station 5208–120.35 is in contrast to the distribution of *Citharichthys* larvae at the same station. Most of the *Symphurus* larvae were taken in the upper haul of the series, and none was taken at the levels where most of the *Citharichthys* larvae occurred.

Lyopsetta exilis is close to the southern limit of its distribution in the series made off Point San Eugenio, Baja California (5504–120.50), hence it is not surprising that the larvae occurred only in the deeper hauls between 72 and 138 meters. In contrast to the relation noted between *Symphurus* larvae and *Citharichthys* larvae in Sebastian Viscaino Bay, *Lyopsetta* larvae occurred almost completely below the level of occurrence of *Citharichthys* larvae at station 5504–120.50.

Lanternfish (Myctophid) Larvae

There is some information on the vertical distribution of 11 kinds of lanternfish (myctophid) larvae, although 3 species occurred in but a single series each. Four kinds were taken only in series made off southern California, three in series made off central Baja California, and four occurred in both areas. These distributions are consonant with the more detailed distributions obtained from the CCOFI cruises.

Larvae of *Diogenichthys laternatus* and *Loweina rara* have seldom been taken north of central Baja California; larvae of *Lampanyctus leucopsarus* and *Tarletonbeania crenularis* are uncommon south of California. *Lampanyctus mexicanus* and *L. ritteri* are taken both off southern

TABLE 12.—*Depth distributions of the larvae of other flatfish*

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Lyopsetta exilis: 5504-120.50	0	0	0	0	0	0	3	3	2	2	0	--------	10
Paralichthys californicus:													
4106-94.47D	0	0	0	0	1	0	0	--------	0	0	--------	--------	1
5208-120.35	0	0	0	0	1	0	--------	--------	--------	--------	--------	--------	1
Total	0	0	0	0	2	0	0	--------	0	0	--------	--------	2
Pleuronichthys decurrens:													
5303-91.38N	0	1	2	0	1	0	0	--------	0	0	0	0	4
5303-91.38D	0	3	0	1	0	0	0	--------	0	0	0	0	4
Total	0	4	2	1	1	0	0	--------	0	0	0	0	8
Symphurus atricauda: 5208-120.35	30	6	1	2	0	0	--------	--------	--------	--------	--------	--------	39

TABLE 13.—*Summary of depth distributions of lanternfish larvae, and their relation to temperature*

	Number of series in which species occurred	Total number of individuals taken	Depth range [1] (m.)	Depth of greatest abundance (m.)	Temperature range (° C.)	Weighted mean temperature (° C.)
Lampanyctus leucopsarus	15	619	8–105	28	9.7–16.1	13.2
Lampanyctus mexicanus	15	273	2–138	41	13.3–16.1	15.2
Lampanyctus ritteri	19	173	2–105	41	11.2–16.1	14.5
Lampanyctus regalis	1	1	56	56	----------	----------
Diogenichthys atlanticus	2	5	8–72	72	14.1–16.5	14.6
Diogenichthys laternatus	3	110	28–105	72	13.2–16.5	----------
Electrona spp	9	20	8–138	105	9.1–15.3	11.0
Loweina rara	1	3	41–56	56	16.5	16.5
Myctophum californiense	7	18	28–105	88	9.7–15.4	14.0
Myctophum margaritatum	1	2	88	88	14.3	14.3
Tarletonbeania crenularis	6	66	28–138	56	9.0–13.4	10.7

[1] Based on average depth (in meters) of the shallowest and deepest haul in which specimens occurred.

California and off central Baja California. However, *L. mexicanus* is near the northern limit of its distribution off southern California, while *L. ritteri* is near the southern limit of its distribution off central Baja California.

A summary tabulation of the depth distributions of lanternfish larvae is given in table 13. The temperature range over which each species was taken also is included, along with the weighted mean temperature of occurrence for each species. The occurrences in separate hauls are given for the larvae of *Lampanyctus leucopsarus* in table 14, of *L. mexicanus* in table 15, of *L. ritteri* in table 16, of *Tarletonbeania crenularis* in table 17, of *Diogenichthys laternatus* in table 18, and of the remaining kinds of lanternfish in table 19. The weighted average depth distributions of the five most common kinds of lanternfish larvae are illustrated in figure 12.

Only three species, all belonging to the genus *Lampanyctus*, were common in the vertical series. *Lampanyctus ritteri* had the most widespread distribution of any kind of fish larvae, being taken in 19 of the 22 series. *L. leucopsarus* and *L. mexicanus* each occurred in 15 series.

A notable feature of the depth distributions of lanternfish larvae is their paucity above 23 meters. Six of the species were not taken in this stratum; *Electrona* spp. and *Diogenichthys atlanticus* each had one occurrence, and only about 5 percent (4–6 percent) of the larvae of *Lampanyctus leucopsarus*, *L. mexicanus*, and *L. ritteri* were taken in this layer.

Lanternfish larvae occurred mostly in the upper mixed layer above the thermocline or in the upper part of the thermocline. The three common species of *Lampanyctus* appear to have the shallowest distributions: *L. leucopsarus* occurred in greatest abundance in the hauls averaging 28 meters deep, *L. mexicanus* and *L. ritteri* in the hauls averaging 41 meters deep. Less than 2 percent of the larvae of *L. leucopsarus* were found to occur

TABLE 14.—*Depth distributions of the larvae of* Lampanyctus leucopsarus

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
4104–91.54	0	0	0	0	19	16	0	--------	--------	--------	--------	--------	35
4105–89.38	0	0	0	2	2	11	3	--------	--------	--------	--------	--------	18
4105–92.39	0	0	5	8	10	2	0	--------	0	--------	--------	--------	25
4106–94.37D	0	0	0	3	0	0	1	--------	0	0	--------	--------	4
4106–94.47N	0	0	0	0	3	3	0	--------	0	0	--------	--------	6
4106–94.47D	0	0	0	5	0	2	0	--------	0	0	--------	--------	7
4106–97.43N	0	0	0	0	0	0	1	--------	0	0	--------	--------	1
5206–90.28N	0	0	4	148	5	1	0	--------	0	0	0	0	158
5206–90.28D	0	0	0	2	1	1	0	--------	0	0	0	0	4
5303–91.38N	0	0	0	65	18	32	3	--------	1	0	0	0	119
5303–91.38D	0	3	5	8	4	38	0	--------	2	0	0	0	60
5305–93.50N	0	0	2	26	12	11	0	--------	0	0	0	0	51
5305–93.50D	0	0	14	30	48	20	0	--------	0	0	0	--------	112
5403. 94.80N	0	0	0	0	0	1	9	--------	0	0	0	--------	10
5403–94.80D	0	0	0	0	0	3	6	--------	0	0	0	--------	9
Total	0	3	30	297	122	141	23	--------	3	0	0	0	619

TABLE 15.—*Depth distributions of the larvae of* Lampanyctus mexicanus

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
4105-89.38	0	0	0	0	1	0	0	------	0	------	------	------	1
4105-92.39	0	0	1	14	0	0	0	------	0	------	------	------	15
4106-94.37N	0	0	1	3	1	0	0	------	0	------	------	------	5
4106-94.37D	0	0	0	0	1	0	0	------	0	0	------	------	1
4106-94.47N	0	0	8	11	0	0	0	------	0	0	------	------	19
4106-94.47D	0	0	0	0	2	0	0	------	0	0	------	------	2
4106-97.43N	0	0	3	20	3	1	0	------	0	0	------	------	27
4106-97.43D	0	0	0	5	7	2	0	------	0	0	------	------	14
5206-90.28N	0	0	3	0	0	0	0	------	0	0	0	0	3
5305-93.50N	0	0	0	2	0	0	0	------	0	0	0	0	2
5403-94.80N	0	0	0	0	0	5	0	------	0	0	0	------	5
5504-107.80	0	0	0	0	21	36	21	9	0	1	------	------	88
5504-110.60	3	0	0	0	22	4	6	1	0	------	------	------	36
5504-120.50	2	3	2	3	5	7	0	0	0	0	0	------	22
5504-130.60	0	0	0	1	15	14	3	0	0	0	0	------	33
Total	5	3	18	59	78	69	30	10	0	1	0	0	273

TABLE 16.—*Depth distributions of the larvae of* Lampanyctus ritteri

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
4104-91.54	0	0	0	0	5	0	0	------	0	------	------	------	5
4105-89.38	0	0	0	2	0	0	0	------	0	------	------	------	2
4105-92.39	0	0	2	15	2	0	0	------	0	------	------	------	19
4106-94.37N	0	0	0	0	1	0	0	------	0	------	------	------	1
4106-94.37D	0	0	0	0	2	0	0	------	0	0	------	------	2
4106-94.47N	0	0	0	0	1	0	0	------	0	0	------	------	1
4106-97.43N	0	0	0	1	1	2	0	------	0	0	------	------	4
4106-97.43D	0	0	0	0	5	1	0	------	0	0	------	------	6
5206-90.28N	0	0	1	0	0	0	0	------	0	0	0	0	1
5206-90.28D	0	0	1	1	0	0	0	------	0	0	0	0	2
5303-91.38N	0	0	0	5	0	4	0	------	0	0	0	0	9
5303-91.38D	0	0	1	0	2	2	0	------	0	0	0	0	5
5305-93.50N	0	0	0	10	0	0	0	------	0	0	0	0	10
5305-93.50D	0	0	0	0	4	0	0	------	0	0	0	------	4
5403-94.80N	0	1	0	0	0	9	9	------	0	0	0	------	19
5403-94.80D	0	0	2	3	5	10	1	------	0	0	0	------	21
5504-107.80	0	0	0	3	9	9	8	8	1	0	------	------	38
5504-110.60	0	0	0	0	6	0	3	2	0	------	------	------	11
5504-120.50	1	1	0	0	1	5	5	0	0	0	0	------	13
Total	1	2	7	40	44	42	26	10	1	0	0	0	173

TABLE 17.—*Depth distributions of the larvae of* Tarletonbeania crenularis

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
5206-90.28N	0	0	0	10	3	0	0	------	0	0	0	0	13
5206-90.28D	0	0	0	1	8	23	2	------	0	0	0	0	34
5303-91.38N	0	0	0	0	0	0	1	------	0	0	0	0	1
5303-91.38D	0	0	0	0	0	1	0	------	0	0	0	0	1
5305-93.50N	0	0	0	4	2	3	0	------	1	1	0	0	11
5305-93.50D	0	0	0	0	0	2	1	------	3	0	0	------	6
Total	0	0	0	15	13	29	4	------	4	1	0	0	66

TABLE 18.—*Depth distributions of the larvae of* Diogenichthys laternatus

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
5504-107.80	0	0	0	0	0	0	0	0	1	0	------	------	1
5504-110.60	0	0	0	0	0	0	0	0	1	------	------	------	1
5504-130.60	0	0	0	1	2	2	64	36	3	0	0	------	108
Total	0	0	0	1	2	2	64	36	5	0	0	------	110

TABLE 19.—*Depth distributions of the larvae of other myctophids*

Station series	Number per haul at an average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Diogenichthys atlanticus:													
4106-94.37N	0	1	0	0	0	0	0	-	0	0	-	-	1
5403-94.80N	0	0	0	0	0	1	3	-	0	0	0	-	4
Total	0	1	0	0	0	1	3	-	0	0	0	-	5
***Electrona* spp.:**													
4104-91.54	0	0	0	0	0	0	0	-	1	-	-	-	1
4106-94.37N	0	0	0	0	0	0	1	-	1	-	-	-	2
4106-94.47N	0	0	0	0	0	1	2	-	2	0	-	-	5
5206-90.28N	0	0	0	0	0	1	0	-	0	0	0	0	1
5303-91.38N	0	0	0	0	0	0	1	-	0	0	0	0	1
5403-94.80N	0	0	0	0	0	0	0	-	3	1	0	-	4
5403-94.80D	0	0	0	0	0	0	0	-	1	0	0	-	1
5504-107.80	0	0	0	0	0	0	0	0	0	3	-	-	3
5504-120.50	0	1	0	0	0	0	0	1	0	0	0	-	2
Total	0	1	0	0	0	2	4	1	8	4	0	0	20
Lampanyctus regalis: 4106-97.43N	0	0	0	0	0	1	0	-	0	0	-	-	1
Loweina rara: 5504-130.60	0	0	0	0	1	2	0	0	0	0	0	-	3
Myctophum californiense:													
4105-92.39	0	0	0	2	0	0	0	-	0	-	-	-	2
4106-94.37D	0	0	0	0	0	0	0	-	1	0	-	-	1
4106-94.47N	0	0	0	0	2	0	0	-	0	0	-	-	2
4106-97.43N	0	0	0	0	0	2	0	-	0	0	-	-	2
5403-94.80N	0	0	0	0	0	1	0	-	0	0	0	-	1
5504-107.80	0	0	0	0	0	0	2	5	2	0	-	-	9
5504-120.50	0	0	0	0	0	1	0	0	0	0	0	-	1
Total	0	0	0	2	2	4	2	5	3	0	0	-	18
Myctophum margaritatum: 5504-107.80	0	0	0	0	0	0	0	2	0	0	-	-	2

below 88 meters. About 4 percent of the larvae of *L. mexicanus* and *L. ritteri* occurred below 88 meters.

Information on depth distributions of the eight other kinds of lanternfish larvae is suggestive, although fragmentary. Larvae of *Diogenichthys laternatus* were mostly taken in one series (108 larvae at 5504–130.60), hence our information on the depth distribution of this species is almost wholly confined to the distribution at a given place at a given time. In this situation, *D. laternatus* occurred at the bottom of the upper mixed layer. Although larvae of *Tarletonbeania crenularis*, *Myctophum californiense*, and *Electrona* spp. occurred in 6 or more series, the largest number of individuals of each that were taken in any one series was 34, 9, and 5, respectively. Despite the limited material, it is evident that the larvae of all three species have somewhat deeper vertical distributions than the larvae of *Lampanyctus*. *Electrona* spp. have the deepest distribution of any of the lanternfish larvae: about 60 percent of the larvae were taken at depths of 105 meters or below.

The temperatures at which the three common species of myctophid larvae were taken in the vertical distribution studies reflect their geographical distribution. Larvae of the more northerly distributed *Lampanyctus leucopsarus* occurred at a mean temperature of 13.2° C., larvae of the intermediately distributed *L. ritteri* at a mean temperature of 14.5° C., and larvae of the more southerly *L. mexicanus* at a mean temperature of 15.2° C.

The mean temperatures of occurrence of larvae of *Tarletonbeania* and *Electrona* spp. were several degrees below that for the other lanternfish larvae; *Tarletonbeania* larvae occurred at a mean temperature of 10.7° C., *Electrona* larvae at 11.0° C. These temperatures are quite similar, yet the larvae of *Electrona* are taken considerably farther south than those of *Tarletonbeania*. This is made possible by the greater depth at which *Electrona* larvae occur.

There are not many stations at which it is possible to compare the depth distributions of different kinds of myctophid larvae. At most stations where species of *Lampanyctus* occurred together, their depth distributions were fairly similar. The distributions of *L. leucopsarus* and *Tarletonbeania crenularis* were similar in 5206–90.28N but *Tarletonbeania* larvae had a wider

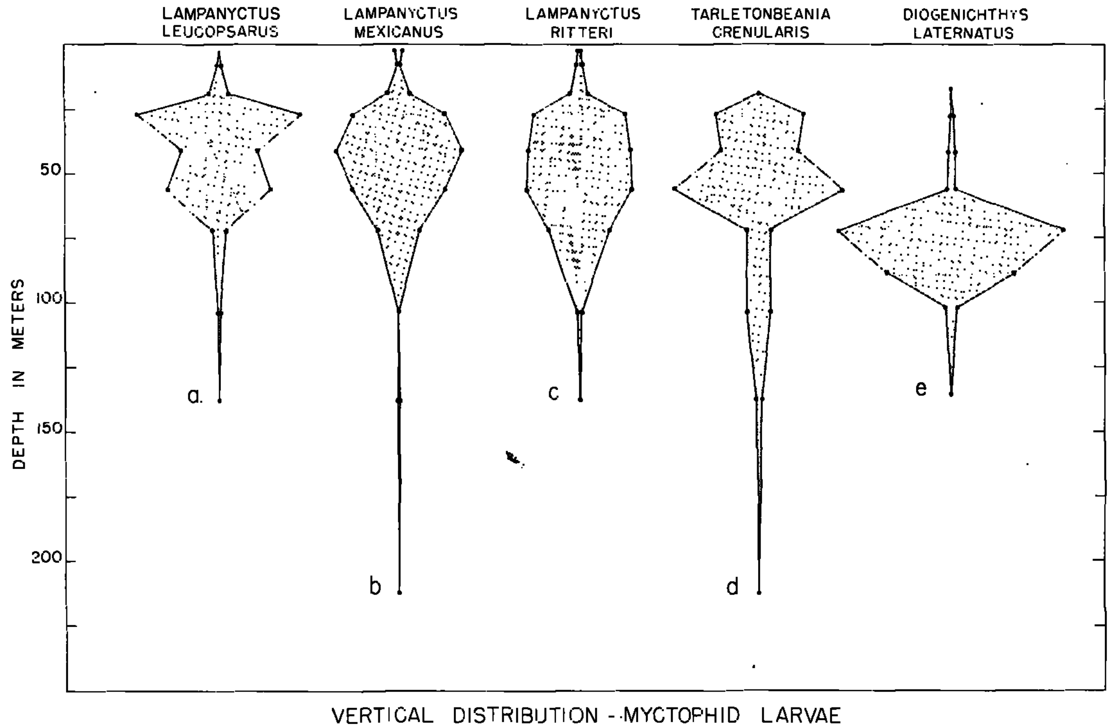

FIGURE 12.—Weighted average vertical distributions of the larvae of five species of myctophids.

depth range at station 5305–93.50N. There was a more marked contrast in the distributions of the larvae of *L. mexicanus* and *Diogenichthys laternatus* at station 5504–130.60: 29 of the 33 larvae of the former species occurred in the hauls averaging 41 and 56 meters deep, while 100 of the 108 larvae of *D. laternatus* were taken in the hauls averaging 72 and 88 meters. Hence, at this locality the larvae of these two species were fairly well separated in their depth distributions.

Leuroglossus stilbius

Larvae of *Leuroglossus stilbius* have the deepest distribution of any of the species studied. They have been taken in the bottom haul of a number of series, hence must occur at still deeper levels than those sampled in taking vertical distribution series. This is the only common species taken in vertical series for which it was found that the larger proportion of the larvae occurred below a depth of 100 meters.

Leuroglossus larvae were taken in 16 series, eggs in 5 (table 20). The weighted average vertical distribution of larvae is shown in figure 2, d. The depth of occurrence of larvae appears to be influenced by the depth of the thermocline. The shallowest thermocline encountered while taking vertical series was at station 5206–90.28 N, and here the larvae occurred nearer to the surface than in other series. At several stations where both day and night series were taken, the larvae had a somewhat shallower distribution in the night series.

The vertical distributions of eggs and larvae of *Leuroglossus* are illustrated in figure 13. The depth range of eggs and larvae is fairly similar at station 5504–120.50 (fig. 13, b and e). Except for a few larvae at the surface, no eggs or larvae were taken in the upper six hauls, and both eggs and larvae were taken in the five lower hauls. Abundance within the zone of occurrence differed for the two categories: the largest number of eggs occurred in the haul averaging 110 meters deep; the largest number of larvae was obtained in the haul averaging 137 meters deep.

Both eggs and larvae were exceedingly abundant at station 5303–91.38. Over three times as many eggs were taken in the night series as in the day, possibly indicating a difference in the water mass being sampled during the two periods. In the night series most eggs were taken between the surface and 88 meters (fig. 13, c), with a marked

TABLE 20.—*Depth distributions of the larvae and eggs of* Leuroglossus stilbius

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
4104-91.54	0	0	0	0	0	9	9						18
4105-92.39	0	0	0	0	3	59	5	----	3	----	----	----	70
4106-94.37N	0	0	0	0	1	0	0	----	1	----	----	----	2
4106-94.37D	0	0	0	0	0	0	1	----	0	0	----	----	1
4106-94.47N	0	0	0	1	4	9	5	----	1	2	----	----	22
4106-94.47D	0	0	0	0	0	0	1	----	0	0	----	----	1
4106-97.43N	0	0	0	0	0	0	1	----	0	0	----	----	1
5206-90.28N	3	0	0	22	10	4	4	----	5	5	6	1	60
5206-90.28D	0	0	0	0	1	8	14	----	4	1	0	2	30
5303-91.38N	0	0	1	0	0	104	260	----	11	6	57	21	460
5303-91.38D	0	0	0	0	6	0	10	----	32	23	3	----	74
5305-93.50N	0	0	0	2	0	11	2	----	10	0	0	----	25
5305-93.50D	0	0	0	0	0	0	3	----	4	0	0	0	7
5403-94.80D	0	0	0	0	0	0	0	----	0	1	0	----	1
5504-110.60	3	0	0	0	0	0	0	0	2	----	----	----	5
5504-120.50	4	0	0	0	0	0	9	11	12	19	6	----	61
Total	10	0	1	25	25	204	324	11	85	57	72	24	838
Eggs:													
5303-91.38N	102	91	270	1,160	981	7,428	2,873	----	46	0	38	39	13,028
5303-91.38D	305	311	271	516	640	696	232	----	1,175	8	4	----	4,158
5403-94.80D	0	0	0	0	0	1	5	----	0	1	0	----	7
5504-120.50	6	0	0	0	0	0	26	115	160	54	1	----	362
Total	413	402	541	1,676	1,621	8,125	3,136	115	1,381	63	43	39	17,555

concentration at approximately 54 meters (7,428 eggs in this one haul). The eggs in the day series were mostly taken between the surface and 122 meters (fig. 13, d), with the largest concentration at 92 meters. Larvae were about six times as abundant in the night series as in the day. In the night series most larvae occurred in the hauls made between 54 and 291 meters, with the largest concentration at approximately 68 meters (fig. 13, a). Most larvae in the day series occurred in contiguous hauls with average depths of 92 and 139 meters.

The lower limit of the temperature of occurrence of *Leuroglossus* larvae in vertical series is not known, since temperature observations were not available for some of the deeper hauls. Larvae were taken at temperatures at least as low as 8.6° C. Nearly half of the occurrences were at temperatures below 10° C., and barely a fourth of the occurrences were at temperatures above 12° C. The overall temperature range for larvae was 8.6° to 16.6° C. The temperature range for eggs was from 8.6° to 15.3° C., with more occurrences at temperatures above 12° C. than below.

Bathylagus wesethi

Originally described from off Monterey, the type locality has since proved to be near the northern limit of the range of this species. The larvae are widely distributed off southern California and Baja California. The larvae of this species were taken in six series, the eggs in six (table 21).

TABLE 21.—*Depth distributions of the larvae and eggs of* Bathylagus wesethi

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
5305-93.50D	0	0	0	0	0	0	0	----	1	0	0	----	1
5403-94.80N	0	0	0	0	0	0	2	----	0	0	0	----	2
5403-94.80D	0	0	0	0	0	5	0	----	0	0	0	----	5
5504-107.80	1	0	0	0	0	0	2	38	20	5	----	----	66
5504-110.60	0	0	0	0	0	2	0	1	1	----	----	----	4
5504-120.50	0	0	0	0	1	1	4	0	0	0	0	----	6
Total	1	0	0	0	1	8	8	39	22	5	0	----	84
Eggs:													
5403-94.80N	0	1	0	0	0	12	45	----	1	1	1	----	61
5403-94.80D	0	0	0	0	4	8	8	----	0	0	0	----	20
5504-107.80	1	1	0	0	0	1	2	8	12	1	----	----	26
5504-110.60	1	0	1	0	1	5	12	31	41	----	----	----	92
5504-120.50	1	2	2	0	0	0	2	1	0	0	0	----	8
5504-130.60	0	0	0	0	0	1	2	0	0	0	0	----	3
Total	3	4	3	0	5	27	71	40	54	2	1	----	210

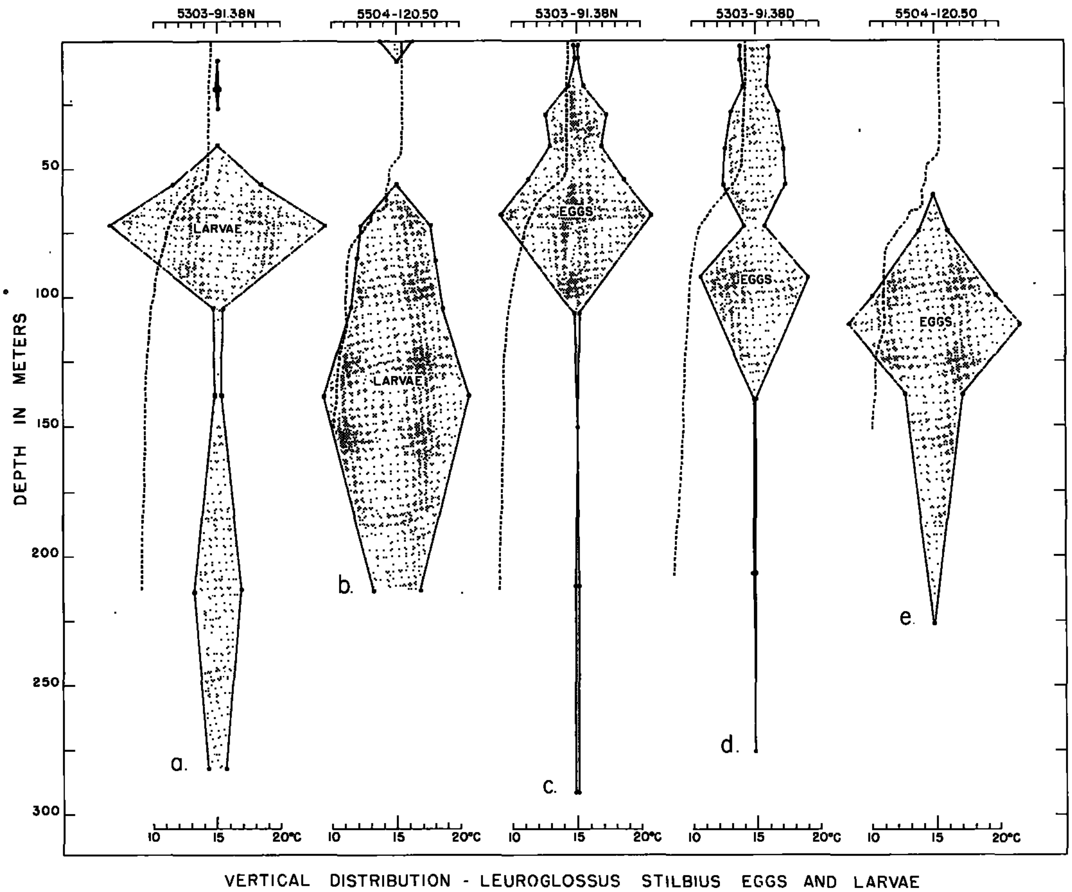

Figure 13.—Vertical distributions of *Leuroglossus stilbius* larvae and eggs in separate series, with superimposed temperature profiles.

The only series in which larvae were at all common was 5504–107.80. Except for one larva in the surface haul, all larvae occurred in the four lower hauls, having average depths of 70, 88, 111, and 142 meters, and the greatest numbers of larvae were taken in the two middle hauls of this group.

Of the 84 larvae collected in all series, only 2 were taken in the upper 50 meters (table 4). A smaller proportion of the larvae of *Bathylagus wesethi* than of *Leuroglossus stilbius* were taken in the deeper hauls, and there is no clear-cut evidence that larvae of *B. wesethi* occurred below the levels sampled.

Eggs of *B. wesethi* were rather common in two series (5403–94.80N and 5504–110.60). In the former series, most eggs occurred between 50 and 100 meters deep (fig. 5, e), in the latter series, which extended only to approximately 105 meters the largest numbers were taken in the bottom haul.

Other Deep-Sea Smelts

Larvae of five additional species of deep-sea smelts were taken in the vertical series (table 22), but only one species occurred in even moderate abundance. Most occurrences were within or below the thermocline.

An undescribed species of *Bathylagus* was taken in 13 series, mostly less than 5 individuals per series. Most of these larvae were obtained between 50 and 100 meters deep. This species is more northerly in its distribution than *Bathylagus wesethi*, and the occurrences off central Baja California are near the southern limit of its distribution.

The *Nansenia* sp. is also probably undescribed. There are two or three species of this genus in the eastern North Pacific, none of which has been previously reported.

TABLE 22.—*Depth distributions of the larvae of other deep-sea smelts*

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Argentina sialis:													
5206-90.28N	0	0	0	1	0	0	0	--------	0	0	0	0	1
5504-120.50	0	0	0	0	0	0	0	0	1	2	0	0	3
Total	0	0	0	1	0	0	0	0	1	2	0	0	4
Bathylagus alascanus: 5403-94.80N	0	0	0	0	0	1	0	--------	0	0	0	--------	1
Bathylagus sp.:													
4104-91.54	0	0	0	0	0	3	2	--------	--------	--------	--------	--------	5
4105-92.39	0	0	0	0	0	14	0	--------	0	--------	--------	--------	14
4106-94.37N	0	0	0	0	0	0	1	--------	1	--------	--------	--------	2
4106-94.37D	0	0	0	0	0	0	0	--------	1	0	--------	--------	1
4106-94.47N	0	0	2	1	0	2	1	--------	0	0	--------	--------	6
4106-94.47D	0	0	0	0	0	0	2	--------	0	0	--------	--------	2
4106-97.43N	0	0	0	0	0	1	0	--------	0	0	--------	--------	1
5206-90.28N	1	0	0	1	0	0	0	--------	0	0	0	1	3
5303-91.38N	0	0	0	2	0	0	6	--------	0	0	0	0	8
5303-91.38D	0	0	0	0	1	0	0	--------	0	0	0	0	1
5305-93.50N	0	0	0	0	0	2	0	--------	0	0	0	--------	2
5504-107.80	0	0	0	0	0	0	0	0	0	1	--------	--------	1
5504-120.50	0	0	0	0	0	0	1	0	0	0	0	--------	1
Total	1	0	2	4	1	22	13	0	2	1	0	1	47
Microstoma sp.:													
5206-90.28N	0	0	0	0	0	1	0	--------	0	0	0	0	1
5206-90.28D	0	0	0	0	0	0	1	--------	0	0	0	0	1
5403-94.80N	0	0	0	0	0	0	0	--------	3	0	0	--------	3
Total	0	0	0	0	0	1	1	--------	3	0	0	0	5
Nansenia sp.: 5504-107.80	0	0	0	0	0	0	0	0	0	2	--------	--------	2

Vinciguerria lucetia

The eggs and larvae of this species are not as well represented in vertical series as would be anticipated from their abundance in the CCOFI area (table 23). The weighted average vertical distribution of larvae is shown in figure 2, c. The only series in which the larvae were common was 5504–130.60. The thermocline was deep at this station, as was evident from bathythermograms made at the station. These records were subsequently lost. The larvae were distributed in the upper mixed layer (0–80 meters). *Vinciguerria* eggs had a wider depth distribution at this station than the larvae (5 to 121 meters; fig. 5, d). Eggs occurred in all hauls of the shallow series, 5504–110.60, the deepest haul of which averaged 105 meters.

Other Larvae

Limited information on the vertical distribution of 16 kinds of larvae is given in table 24. Larvae of *Chromis punctipinnis* (blacksmith) and of *Sphyraena argentea* (barracuda), each taken in three series, occurred only in the two shallowest hauls. The larvae of another commercially important species, *Palometa simillima* (pompano), occurred between the surface and 48 meters deep.

TABLE 23.—*Depth distributions of the larvae and eggs of* Vinciguerria lucetia

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Larvae:													
4106-97.43N	1	0	0	0	0	0	0	--------	0	0	--------	--------	1
5504-107.80	0	0	0	0	2	2	8	4	0	0	--------	--------	16
5504-110.60	0	0	0	0	0	2	11	9	3	--------	--------	--------	25
5504-120.50	4	1	0	0	0	0	0	0	0	0	0	--------	5
5504-130.60	2	0	29	33	41	6	1	0	0	0	0	--------	112
Total	7	1	29	33	43	10	20	13	3	0	0	--------	159
Eggs:													
5504-107.80	0	0	0	0	0	0	0	0	4	2	--------	--------	6
5504-110.60	3	9	12	1	13	8	4	11	14	--------	--------	--------	75
5504-130.60	0	4	4	12	15	15	13	10	1	0	0	--------	74
Total	3	13	16	13	28	23	17	21	19	2	0	--------	155

TABLE 24.—*Depth distributions of other larvae taken in vertical distribution series*

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Argyropelecus spp.:													
4106-94.47N	0	0	0	0	0	0	1	--------	0	0	--------	--------	1
5303-91.38N	0	0	0	0	0	0	0	--------	0	0	1	0	1
5504-107.80	0	0	0	0	0	0	0	0	0	1	--------	--------	1
5504-120.50	0	0	0	0	0	0	0	0	0	0	1	--------	1
5504-130.60	0	0	0	0	0	0	0	0	0	2	0	--------	2
Total	0	0	0	0	0	0	1	0	0	3	2	0	6
Aristostomias scintillans: 5504-107.80	0	0	0	0	0	0	1	0	0	0	--------	--------	1
Chauliodus macouni:													
5305-93.50D	0	0	0	0	0	0	0	--------	1	0	0	--------	1
5403-94.80N	0	0	0	0	0	0	0	--------	1	0	0	--------	1
Total	0	0	0	0	0	0	0	--------	2	0	0	--------	2
Cyclothone spp.:													
4106-94.47N	0	0	0	0	1	0	0	--------	0	0	--------	--------	1
4106-97.43D	0	0	0	1	0	0	0	--------	0	0	--------	--------	1
5504-107.80	0	0	0	0	1	1	2	3	0	0	--------	--------	7
5504-110.60	0	0	0	0	1	2	1	3	0	--------	--------	--------	7
5504-120.50	1	0	0	1	0	0	1	0	0	0	0	--------	3
5504-130.60	0	0	0	0	2	6	3	0	0	0	0	--------	11
Total	1	0	0	2	5	9	7	6	0	0	0	--------	30
Ichthyococcus sp.: 5504-130.60	0	0	0	0	0	0	2	1	0	0	0	--------	3
Idiacanthus antrostomus: 5403-94.80N	0	0	0	0	0	0	0	--------	1	1	0	--------	2
Stomias atriventer:													
5504-120.50	0	0	0	0	1	0	0	0	0	0	0	--------	1
5504-130.60	0	0	0	0	0	0	1	0	0	0	0	--------	1
Total	0	0	0	0	1	0	1	0	0	0	0	--------	2
Brosmophycis marginata:													
5206-90.28N	0	0	2	0	0	0	0	--------	0	0	0	0	2
5305-93.50D	0	0	1	0	0	0	0	--------	0	0	0	--------	1
Total	0	0	3	0	0	0	0	--------	0	0	0	0	3
Chromis punctipinnis:													
4106-94.47D	3	2	0	0	0	0	0	--------	0	0	--------	--------	5
4106-97.43D	1	0	0	0	0	0	0	--------	0	0	--------	--------	1
5206-90.28N	5	0	0	0	0	0	0	--------	0	0	0	0	5
Total	9	2	0	0	0	0	0	--------	0	0	0	0	11
Cololabis saira:													
5504-107.80	1	0	0	0	0	0	0	0	0	0	--------	--------	1
5504-130.60	2	0	0	0	0	0	0	0	0	0	--------	--------	2
Total	3	0	0	0	0	0	0	0	0	0	--------	--------	3
Icichthys lockingtoni:													
5206-90.28N	0	0	1	0	0	0	0	--------	0	0	0	0	1
5206-90.28D	0	0	0	0	1	0	0	--------	0	0	0	0	1
5305-93.50N	0	0	0	0	1	0	0	--------	0	0	0	0	1
5305-93.50D	0	0	0	0	0	1	0	--------	0	0	0	--------	1
5403-94.80D	1	0	0	0	0	0	0	--------	0	0	0	--------	1
Total	1	0	1	0	2	1	0	--------	0	0	0	0	5
Melamphaes spp.:													
4104-91.54	0	0	0	0	0	0	1	--------	--------	--------	--------	--------	1
4105-92.39	0	0	0	0	0	1	0	--------	0	--------	--------	--------	1
4106-94.37D	0	0	0	0	0	0	1	--------	0	0	--------	--------	1
5403-94.80N	0	0	0	0	0	0	2	--------	1	0	0	--------	3
5403-94.80D	0	0	0	0	0	1	2	--------	3	0	0	--------	6
5504-107.80	0	0	0	0	0	0	0	0	1	1	--------	--------	2
Total	0	0	0	0	0	2	6	0	5	1	0	--------	14
Palometa simillima:													
4105-89.38	0	3	0	0	0	0	0	--------	--------	--------	--------	--------	3
5208-120.35	1	0	0	2	2	0	--------	--------	--------	--------	--------	--------	5
5504-120.50	0	4	0	0	1	0	0	0	0	0	0	--------	5
Total	1	7	0	2	3	0	0	0	0	0	0	--------	13
Sphyraena argentea:													
4105-89.38	0	3	0	0	0	0	0	--------	--------	--------	--------	--------	3
5206-90.28N	1	3	0	0	0	0	0	--------	0	0	0	0	4
5206-90.28D	0	10	0	0	0	0	0	--------	0	0	0	0	10
Total	1	16	0	0	0	0	0	--------	0	0	0	0	17

TABLE 24.—*Depth distributions of other larvae taken in vertical distribution series*—Continued

Station series	Number per haul at average depth (m.) of—												Total
	2	8	19	28	41	56	72	88	105	138	215	285	
Trachypterus rexsalmonorum:													
5403-94.80N	0	0	0	0	0	1	0	--------	0	0	0	--------	1
5403-94.80D	1	0	0	0	0	0	0	--------	0	0	0	--------	1
Total	1	0	0	0	0	1	0	--------	0	0	0	--------	2
Labrids:													
4105-89.38	0	2	0	2	0	0	0	--------	0	--------	--------	--------	4
4105-92.39	6	2	0	0	0	0	0	--------	0	--------	--------	--------	8
4106-94.47N	0	1	0	1	0	0	0	--------	0	0	--------	--------	2
4106-94.47D	7	3	1	0	0	0	0	--------	0	0	--------	--------	11
5206-90.28N	26	25	6	0	0	0	0	--------	0	0	0	0	57
5206-90.28D	1	0	0	0	0	0	0	--------	0	0	0	0	1
5303-91.38N	0	0	1	0	0	0	0	--------	0	0	0	0	1
5305-93.50D	0	0	2	0	2	0	0	--------	0	0	0	--------	4
5504-120.50	0	0	0	0	0	1	0	0	0	0	0	--------	1
Total	40	33	10	3	2	1	0	0	0	0	0	0	89

Two species have been included under labrids: *Halichoeres semicinctus* and *Oxyjulis californica.* There is such a marked difference in the abundance of labrid larvae in the replicate series taken at station 5206–90.28 (57 in night series, 1 in day series) that this must reflect rather marked horizontal clumping of the larvae associated with a change in the water mass between the night and day series. More than 90 percent of the labrid larvae occurred above 23 meters.

The few larvae of *Chauliodus macouni* and *Idiacanthus antrostomus* were taken in hauls below 100 meters. A comparison based on closing and upper net hauls on Norpac confirms the deep distribution of the larvae of these two species. The few larvae of *Argyropelecus* spp. taken in these vertical series confirm the deep distribution of this category that is so strikingly shown in Norpac material (discussed in a following section).

Larvae of *Cyclothone* spp. appear to have a distribution similar to that of *Vinciguerria lucetia.* Larvae of *Melamphaes* spp. (mostly *M. lugubris* and *M. bispinosus*) appear to occur mostly within or below the thermocline.

Discussion

The two most striking facts brought out by the present studies on vertical distribution of fish eggs and larvae are the following:

1. Most fish eggs and larvae occur within the upper mixed layer or in the upper portion of the thermocline—between the surface and approximately 125 meters. Of the 15 most common kinds of larvae taken in vertical distribution studies, 12 were so distributed.

2. Within this zone of occurrence, all of the more common kinds of fish eggs and larvae showed marked differences in vertical distribution from series to series.

In the light of these findings on vertical distribution of fish eggs and larvae, it appears to me that the best method for quantitatively sampling this parameter is by oblique net hauls taken between the surface and at least 125 meters. It is impossible to obtain a representative sampling of fish eggs and larvae by sampling at any one level, such as a horizontal surface tow. In the four series where sardine eggs were common, from 15 to 85 percent of the total number were taken in surface hauls. Similarly, from 0 to 60 percent of sardine larvae were taken in surface hauls, 0 to 35 percent of anchovy larvae, 2 to 50 percent of jack mackerel larvae, 0 to 50 percent of rockfish larvae, and so on.

VERTICAL DISTRIBUTION DATA FROM NORPAC SAMPLES

Norpac is the name given to the most extensive simultaneous coverage of an oceanic area that has yet been made. In July to September 1955, a systematic coverage of the North Pacific Ocean, north of 20° N. latitude, was carried out cooperatively by research groups in the United States, Canada, and Japan. The section of Norpac that was occupied by agencies participating in the California Cooperative Oceanic Fisheries Investigations extended from Cape San Lucas, Baja California, to the Straits of Juan de Fuca, and offshore to 150° W. longitude. The following discussion is based solely on material collected in the CCOFI section of Norpac.

Two net hauls were taken simultaneously at the majority of stations occupied on Norpac (139 stations). A closing net was fastened to the towing cable 200 meters below a standard open plankton net. The closing net was opened immediately before attachment of the upper net and closed immediately after retrieving the upper net at the completion of a tow. The upper net was lowered on 200 additional meters of cable and then hauled obliquely upward. The actual stratum fished by the upper net differed from station to station, depending on variations in vessel speed, state of the sea, et cetera, but averaged 131 meters to the surface. The range in depths fished by the upper net at different stations was from 88 to 146 meters. The closing net fished from depths of approximately 262 meters to 131 meters on the average, but on occasion was as shallow as 88 meters.

A comparison of the larvae taken in the two hauls on stations where both nets were used is given in table 25. Only those categories are included which are discussed in the preceding sections. About one-ninth as many larvae were taken in the closing net hauls as in the upper net hauls.

TABLE 25.—*Comparison of number of larvae taken in upper net and closing net hauls at stations occupied on Norpac, August–September, 1955*

	Upper net hauls [1]	Closing net hauls [2]	Total both levels	Percentage of total taken in closing-net hauls
Total (139 hauls)	6,358	705	7,063	10
Sardinops caerulea	8	0	8	0
Engraulis mordax	99	1	100	1
Trachurus symmetricus	22	0	22	0
Sebastodes spp	35	1	36	3
Citharichthys spp	68	0	68	0
Lampanyctus leucopsarus	78	1	79	1
Lampanyctus mexicanus	483	1	484	1
Lampanyctus ritteri	72	6	78	8
Lampanyctus regalis	18	0	18	0
Tarletonbeania crenularis	42	11	53	21
Diogenichthys altanticus	140	24	164	15
Diogenichthys laternatus	203	6	209	3
Loweina rara	10	7	17	41
Myctophum californiense	76	8	84	10
Myctophum margaritatum	25	2	27	7
Electrona spp	51	47	98	48
Argentinids [3]	53	32	85	39
Vinciguerria spp	1,605	30	1,635	2
Cyclothone spp	615	3	618	1
Argyropelecus spp	21	352	373	94
Idiacanthus antrostomus	58	25	83	32
Chauliodus macouni	5	13	18	72
Melamphaes spp	91	15	106	14
Icichthys lockingtoni	5	2	7	29
Trachypterus spp	8	1	9	11
Chromis punctipinnis	10	0	10	0
All others	2,457	117	2,574	5

[1] Depth of upper-net hauls approximately 131–0 meters.
[2] Depth of closing-net hauls approximately 262–131 meters.
[3] Includes *Leuroglossus stilbius*, *Bathylagus wesethi* and all other deep-sea smelts taken on Norpac.

The information from these closing-net hauls is an interesting supplement to that given in the earlier portion of the paper. Actually both strata sampled on Norpac, 0 to 131 meters and 131 to 262 meters, were also covered in taking many of the vertical distribution series. The data from Norpac were much more extensive, however; hauls were taken at 139 stations on Norpac, as compared to the 22 vertical distribution series. The number of larvae per station was markedly fewer on Norpac: only 7,063 larvae were obtained in the combined haul data on Norpac, while 18,045 larvae were taken in vertical distribution series. Numbers are greater in the vertical distribution series, both because larval-rich areas were selected and considerably larger volumes of water were strained at each station. In fact, as much water was strained in taking each haul in a vertical series as was strained in a single net haul on Norpac.

Many of the categories discussed in the earlier sections of the paper are poorly represented in Norpac material. This is especially true of the categories that are routinely reported in the series, Sardine Eggs and Larvae and Other Fish Larvae, Pacific Coast (Ahlstrom and Kramer, 1957, Ahlstrom, 1958). Larvae of hake and Pacific mackerel were not taken at all, larvae of sardine, jack mackerel, and *Sebastodes* spp. were rare, and only anchovy larvae occurred in even moderate abundance (100 individuals). The vertical distributions of these larvae in Norpac material, however, were similar to their distributions in the vertical series—only 0 to 3 percent were taken in the deeper closing-net hauls.

The most abundant category in the Norpac material was *Vinciguerria* spp. Three species are grouped in this category: *V. lucetia*, *V. nimbaria*, and *V. poweriae*, listed in order of their abundance. The presence of only 2 percent of the specimens in the deeper net supports the depth distribution of *Vinciguerria* larvae as determined from the less extensive material obtained in vertical distribution series.

Half of the larvae taken in closing-net hauls on Norpac belonged to a single genus, *Argyropelecus*. Larvae of this genus are seldom taken in regular survey net tows, and the reason for this is apparent from Norpac results. Only 21 larvae were taken in upper-net hauls, while 352 occurred in hauls taken with the deeper-fishing closing net.

Seven other categories of larvae had 20 percent or more of their numbers in the closing-net hauls: argentinids, *Idiacanthus antrostomus*, *Chauliodus macouni*, *Icichthys lockingtoni*, *Tarletonbeania crenularis*, *Loweina rara*, and *Electrona* spp. So few specimens of *Leuroglossus stilbius* and *Bathylagus wesethi* were taken on Norpac that all larvae of deep-sea smelts are grouped together as argentinids; about 40 percent of the specimens of argentinids were taken in the deep closing-net hauls. Information on depth distribution of *Idiacanthus antrostomus* is more complete from Norpac samples than from the vertical distribution series; about one-third of the specimens were taken in the deeper net on Norpac. Information on depth distribution of *Icichthys lockingtoni* is meager in both sets of data; the presence of two specimens out of seven in the closing-net hauls on Norpac indicates a somewhat deeper distribution than was noted from vertical distribution series. Larvae of *Chauliodus* were more common in the closing-net hauls on Norpac than in the upper net hauls: 13 of the 18 larvae were from the deeper samples.

All 11 categories of myctophid larvae that were taken in vertical distribution series were also obtained in Norpac material. It is interesting to compare the depth distributions of the more common kinds, as determined from the two sets of data (table 26).

Larvae of *Lampanyctus leucopsarus* and *L. mexicanus* were almost entirely confined to upper net hauls on Norpac. These two species had the shallowest depth distributions of any lanternfish larvae taken in vertical distribution series. Somewhat more larvae of *L. ritteri* were taken in closing net hauls on Norpac (8 percent of the total) than was indicated for these levels in vertical series. It will be recalled that the distribution of *Diogenichthys laternatus* in vertical series was based mostly on a single series. Larvae of this species were taken at a number of stations on Norpac. Only about 3 percent of the total occurred in the level fished by the closing net. Larvae of *Electrona* spp., which had the deepest distribution of any lanternfish in vertical series, also had the highest percentage occurrence in closing-net hauls on Norpac. A larger percentage of larvae of *Tarletonbeania crenularis* was taken in closing-net hauls on Norpac than in deeper levels in vertical distribution series.

UNDERSAMPLING OF FISH LARVAE DURING DAYTIME

Silliman (1943) called attention to undersampling of sardine larvae during daylight hours, based on data from the replicate vertical series taken at station 4106–94.37 and 4106–94.47. Ahlstrom (1954) gave data on the extent of undersampling of sardine larvae of different sizes in daylight hauls, based on 626 collections of sardine larvae. The statistics of a linear regression line fitted to the data show an increase in the ratio of larvae in night hauls to day hauls of 0.7 for each millimeter increase in size above 4.75 millimeters ($s_{yx}=0.96$). Thus, the number of 9.75-millimeter larvae in night hauls was five times as many as in day hauls, and the number of 15.75-millimeter larvae was nearly nine times as many.

A similar analysis has been made for catches of anchovy larvae. The night/day (N/D) ratio was found to increase 0.64 for each millimeter increase

TABLE 26.—*Comparison of depth distributions of lanternfish larvae in Norpac material and vertical distribution series*

	Norpac				Vertical distribution series		
	Number of larvae taken by—			Percentage in deeper haul (262-131 m.)	Total larvae obtained	Number of larvae taken below 100 m.	Percentage of total taken below 100 m.
	Upper net (131-0 m.)	Closing net (262-131 m.)	Both nets				
Lampanyctus leucopsarus	78	1	79	1	619	3	1
Lampanyctus mexicanus	483	1	484	0.2	273	1	1
Lampanyctus ritteri	72	6	78	8	173	1	1
Diogenichthys laternatus	203	6	209	3	110	5	5
Tarletonbeania crenularis	42	11	53	21	66	5	8
Myctophum californiense	76	8	84	10	18	3	17
Electrona spp	51	47	98	48	20	12	60

TABLE 27.—*Diurnal differences in number of larvae taken in 63 replicate hauls at station 70.130, October 1950*

	Total all hauls	Day hauls[1]		Night hauls		Ratio N/D
		Occurrences	Average per haul	Occurrences	Average per haul	
Total larvae	7,223		49.6		177.6	3.6
Vinciguerria lucetia	660	14	2.35	31	18.30	7.8
Cyclothone spp.	850	14	2.10	32	24.52	11.7
Bathylagus wesethi	2,139	31	23.10	32	44.58	1.9
Ceratoscopelus townsendi	955	16	2.60	32	27.30	10.5
Diaphus theta	338	7	.90	31	9.75	10.8
Diogenichthys atlanticus	183	7	.72	22	4.95	6.9
Electrona spp.	252	10	1.28	28	6.68	5.2
Lampanyctus ritteri	173	3	.35	25	5.05	14.4
Myctophum californiense	379	13	2.18	28	9.70	4.4
Idiacanthus antrostomus	605	16	3.32	31	15.62	4.7
Melamphaes spp.	146	11	1.68	19	2.90	1.7
Brama brama	136	12	1.20	19	3.05	2.5

[1] Based on 31 samples. One sample taken during daylight hours spoiled because preservative was not added.

in size above 3.5 millimeters. Thus, undersampling of larger larvae of anchovies during daytime is in the same order of magnitude as undersampling of sardine larvae.

Surprisingly enough, no consistent difference was found between the numbers of jack mackerel larvae in night and day hauls. The night/day ratio is close to 1. The analysis was based on nearly 1,000 samples containing jack mackerel larvae.

When data of larvae of other fishes are analyzed for night and day differences, most kinds are found to occur in markedly lower numbers in daytime hauls than in night hauls. The problem may be illustrated from data obtained on a special cruise made during October 1950. Three vessels participated in this cruise (cruise 5010), each holding a fixed geographical position on line 70 (off Monterey) while taking observations at 3-hour intervals over an 8-day period. The data from station 70.130 (33°33′ N. lat., 127°16.5′ W. long.) have been summarized in table 27.

The total number of larvae taken in 32 night hauls at station 70.130 was 5,684, or an average of 177.6 larvae per haul; the number taken in 31 day hauls was 1,539, or an average of 49.6 larvae per haul. The night/day ratio for all larvae was 3.6. Twenty-eight kinds of larvae were taken in the hauls, 12 kinds in some abundance. The night/day ratios for the latter were all larger than one. The lowest ratio was 1.7 for *Melamphaes* spp., the highest 14.4 for *Lampanyctus ritteri*.

REPLICATE VERTICAL DISTRIBUTION SERIES

In order to obtain information on differences in vertical distribution of larvae during day and night, and also on daytime undersampling of larvae, replicate vertical series were taken at seven localities. The data are summarized in table 28.

TABLE 28.—*Night vs. daytime sampling of larvae in 7 replicate vertical distribution series*
[N=night series: D=day series]

Species	Number of larvae taken at station—																Ratio N/D
	4106-94.37		4106-94.47		4106-97.43		5206-90.28		5303-91.38		5305-93.50		5403-94.80		Total		
	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	
Sardinops caerulea	40	6	89	24	1	0	5	3	0	0	0	0	10	4	145	37	3.9
Engraulis mordax	27	4	217	10	12	0	612	151	12	0	10	20	0	0	890	185	4.8
Trachurus symmetricus	0	1	7	0	0	0	26	2	0	0	4	2	52	210	89	215	0.4
Sebastodes spp.	20	46	41	65	0	1	48	33	225	46	124	144	0	0	458	335	1.4
Merluccius productus	3	0	8	0	1	0	0	0	20	5	0	0	1,753	707	1,785	712	2.5
Leuroglossus stilbius	2	1	22	1	1	0	60	30	460	74	25	7	0	1	570	114	5.0
Lampanyctus leucopsarus	0	4	6	7	1	0	158	4	119	60	51	112	10	9	345	196	1.8
Lampanyctus mexicanus	5	1	19	2	27	14	3	0	0	0	2	0	5	0	61	17	3.6
Lampanyctus ritteri	1	2	1	0	4	6	1	2	9	5	10	4	19	21	45	40	1.1
All others	5	5	34	23	6	2	110	56	83	18	19	34	26	14	283	152	1.9
Total	103	70	444	132	53	23	1,023	281	928	206	245	323	1,875	966	4,671	2,003	2.3

In all but one replicate series, more larvae were taken in night hauls than in daytime hauls. The night/day ratios for total larvae in the seven stations were as follows:

Station	Total larvae take in—		N/D ratio
	Night series	Day series	
4106-94.37	103	70	1.5
4106-94.47	444	132	3.4
4106-97.43	53	23	2.3
5206-90.28	1,023	281	3.5
5303-91.38	928	208	4.5
5305-93.50	245	323	0.8
5403-94.80	1,875	966	1.9
Total	4,671	2,003	2.3

Replicate series have several limitations that should be kept in mind. For one thing, it is almost impossible to sample the same water mass for a 24-hour period. If a geographical position is maintained, the water mass will change, slowly in some localities, rather rapidly in others, depending on the currents. Furthermore, water masses will move past the geographical position at different rates of speed at different levels. If an attempt is made to stay with a water mass, the investigator is still faced with the problem of water moving at different rates of speed at different levels. Furthermore, if larvae are sharply stratified in depth, the center of abundance may be missed on one, or both, of the series taken at a station. Any horizontal clumping of larvae will also affect the numbers taken in the two series.

There are some marked changes in abundance in the replicate series that must be due either to changes in water mass or to marked stratification or clumping of larvae. Two examples of marked stratification or clumping are the catch of 148 *Lampanyctus leucopsarus* larvae in the 27-meter haul at 5206-90.28N, and the catch of 1,622 hake larvae in the haul averaging 64 meters deep at 5403-94.80N. Two differences which appear to be due to a change in water mass are the marked change in abundance of anchovy larvae at station 4106-94.47, decreasing from 217 larvae in the night series to only 10 in the day, and the daytime increase in abundance of jack mackerel larvae at station 5403-94.80 (210 larvae in day series, 52 in night).

It is interesting to note that only one kind of larva, jack mackerel, occurred in greater abundance in day hauls than in night. As pointed out earlier, this species has shown no consistent difference in abundance of larvae between day and night hauls on regular survey cruises. There is an inconsistency in the N/D ratio of *Lampanyctus ritteri* as obtained from replicate vertical series and from repeated sampling at station 5010-70.130. In the replicate series the ratio was only 1.1, but at station 70.130 the difference in abundance between night and day hauls was more marked than for any other species (N/D ratio 14.4). Individual species are treated in more detail in following sections.

Fish eggs should be taken in comparable abundance in both night and day hauls. Eggs can neither migrate vertically nor avoid the net. Hence any differences found in abundance of eggs in day and night hauls must be due to vertical stratification or horizontal clumping. The abundance of eggs in three replicate series is summarized in table 29. In two instances considerably more eggs were taken in the day series, in three instances more eggs were taken in the night series, and in one comparison the numbers were about equal in the two series. Some of the differences are quite large. Only 3 anchovy eggs were taken in the night series at station 5206-90.28, but 69 were taken in the day series. At station 5303-91.38, *Leuroglossus* eggs were more than three times as abundant in night hauls as in day hauls. A part of this difference is probably due to vertical stratification of the eggs, since 57 percent of the eggs in the night series were taken at one

TABLE 29.—*Fish eggs taken in replicate vertical distribution series, by station and species*

	Station 5206-90.28		Station 5305-91.38	Station 5403-94.80			
	Sardinops caerulea	*Engraulis mordax*	*Leuroglossus stilbius*	*Sardinops caerulea*	*Trachurus symmetricus*	*Merluccius productus*	*Bathylagus wesethi*
Night series	6	3	13,028	271	1,117	102	61
Day series	3	69	4,158	201	2,196	101	20
Total	9	72	17,186	472	3,313	203	81

depth. A comparison of sardine eggs at station 5403–94.80 is given in the following section.

Sardine Larvae

Sardine larvae were not particularly abundant in the replicate hauls. The two best series were 4106–94.37 and 4106–94.47 (table 5): in the former, 40 larvae were taken in the night series, 6 in the day; in the latter, 89 in the night series, 24 in the day. Silliman (1943) has discussed these particular replicate series as they apply to the sardine larvae.

In night series, no sardine larvae were taken below 48 meters, while in day series five larvae occurred below this level. Sardine larvae taken in replicate series are grouped by size in table 30. A summary follows:

Size category (mm.)	Night series	Day series	N/D ratio
2.76–6.25	31	21	1.5
6.26–11.25	51	4	12.8
11.26–16.25	61	7	8.7
16.26 and larger	2	5	.4
Total	145	37	3.9

Although more of the larger sizes of sardine larvae were taken in night hauls than day, there is a discrepancy in the largest size category. More larvae of the largest category (16.26 mm. and larger) were taken in day hauls than night. Since this finding does not agree with the much larger mass of data available from routine hauls, it must be regarded as an artifact. It points up the variability that is encountered in individual situations, and the need for caution in interpreting data based on a limited number of observations. Interestingly enough, the five larvae taken below 48 meters in day hauls were all larger than 16.26 millimeters. These larvae occurred in hauls averaging 58, 60, and 73 meters deep. Since no larvae were taken below 48 meters in night hauls, it is assumed that there was a movement of larger larvae to deeper levels in the daytime.

Sardine Eggs

A comparison of sardine eggs in the replicate series at station 5403–94.80 is given in table 31. The day series was taken before the night series at this station. Each series contained eggs of three to four different ages. Sardine eggs can be aged without difficulty and are routinely reported by age (Ahlstrom and Kramer, 1957). Sardine spawning is confined to a limited portion of a day, usually between 8 p.m. and midnight (Ahlstrom 1943). Because of this periodicity, eggs from successive days' spawning are sharply separated in stage of development. In comparing the series taken at station 5403–94.80, eggs spawned on the night of March 23–24 are designated "A" eggs; eggs spawned on the night of March 22–23, "B" eggs; eggs spawned on the night of March 21–22, "C" eggs; and eggs spawned on the night of March 20–21, "D" eggs.

B eggs were most abundant in the day series, C eggs in the night. Since there was a fivefold increase in numbers of C eggs in the night series, which is reflected at all depths between 2 to 64 meters, there must have been a change in the water mass between the times the two series were taken. There are differences in the depth distribution of eggs of different ages. In both series the largest concentrations of B eggs were taken in the surface

TABLE 30.—*Comparison of numbers of sardine and anchovy larvae taken in night and day series, grouped by size*

Station	Number taken in night series in size group—				Total taken in night series	Number taken in day series in size group—				Total taken in day series
	2.76–6.25 mm.	6.26–11.25 mm.	11.26–16.25 mm.	16.26 mm. and larger		2.76–6.25 mm.	6.26–11.25 mm.	11.26–16.25 mm.	16.26 mm. and larger	
Sardine (*Sardinops caerulea*):										
4106–94.37	0	7	32	1	40	0	0	3	3	6
4106–94.47	17	44	27	1	89	14	4	4	2	24
4106–97.43	0	0	1	0	1	0	0	0	0	0
5206–90.28	4	0	1	0	5	3	0	0	0	3
5403–94.80	10	0	0	0	10	4	0	0	0	4
Total	31	51	61	2	145	21	4	7	5	37
Anchovy (*Engraulis mordax*):										
4106–94.37	0	12	12	3	27	0	3	1	0	4
4106–94.47	8	195	12	2	217	0	8	2	0	10
4106–97.43	1	4	6	1	12	0	0	0	0	0
5206–90.28	164	351	72	25	612	135	15	1	0	151
5303–91.38	0	7	5	0	12	0	0	0	0	0
5305–93.50	0	0	10	0	10	0	2	12	6	20
Total	173	569	117	31	890	135	28	16	6	185

TABLE 31.—*Sardine eggs taken in replicate vertical distribution series at station 5403–94.80, by age*

Day series (III: 24)						Night series (III: 24–25)					
Average depth	Number of eggs by age				Total eggs	Average depth	Number of eggs by age				Total eggs
	A	B	C	D			A	B	C	D	
2 m	0	58	1	0	59	2 m	0	35	2	0	37
7 m	0	49	2	0	51	7 m	0	17	12	0	29
18 m	0	21	8	0	29	17 m	2	17	27	0	46
28 m	1	13	6	0	20	27 m	5	12	33	0	50
41 m	4	9	8	0	21	42 m	3	9	53	0	65
53 m	2	5	4	0	11	52 m	3	7	23	0	33
68 m	2	2	2	1	7	64 m	1	2	8	0	11
102 m	0	1	1	1	3	101 m	0	0	0	0	0
135 m	0	0	0	0	0	127 m	0	0	0	0	0
201 m	0	0	0	0	0	200 m	0	0	0	0	0
Total	9	158	32	2	201	Total	14	99	158	0	271

NOTE.—A eggs—spawned on night of III: 23–24; B eggs—spawned on night of III: 22–23; C eggs—spawned on night of III: 21–22; D eggs—spawned on night of III: 20–21.

haul, and there was a fairly regular decrease in numbers with depth. C eggs had their largest concentration at 42 meters in the night series, and decreased in abundance fairly uniformly both above and below this level. The depth distribution of C eggs in day hauls corresponded fairly well to this pattern. The depth distribution of A eggs in both series was similar; the distribution of A eggs paralleled the distribution of C eggs and thus differed from that of B eggs. Hence, the differences in depth distributions of eggs of different ages were not a result of systematic changes in level with time, but must reflect differences in actual depth of spawning.

Anchovy Larvae

Nearly five times as many anchovy larvae were taken in the night series as in the day (table 6). In the night series all larvae were taken between 0 and 48 meters, corresponding to the depth distribution found for sardine larvae. In the day series, 11 larvae were obtained below 48 meters. The deeper distribution in day hauls must result from a limited vertical movement of the larvae, probably due to a negative phototropism. No larvae were taken below 88 meters in any day series. Abundance by size in day and night series is given in table 30.

The night/day ratio of anchovy larvae of different sizes is summarized below:

Size category (mm.)	Night series	Day series	N/D ratio
2.76–6.25	173	135	1.3
6.26–11.25	569	28	20.3
11.26–16.25	117	16	7.3
16.26 and larger	31	6	5.2
Total	890	185	4.8

There was no consistent increase in night/day ratio with size, but unlike the finding for sardine larvae, all larger sizes of larvae were considerably more abundant in night hauls than in day.

Jack Mackerel Larvae

Although jack mackerel larvae occurred in five replicate series, they were common in only one (table 7). At this station (5403–94.80) over four times as many larvae were taken in the day series as in the night. This probably resulted from a change in abundance associated with a change in water mass between the times at which the day and night series were taken. There is no close correspondence between any of the replicate series. At station 5206–90.28, 26 larvae were taken in the night series, 2 in the day series. At station 4106–94.47, seven larvae were taken in the night series, none in the day. These series suggest a high degree of contagion in the distribution of jack mackerel larvae. This species has shown no consistent difference in abundance of larvae between day and night collections taken on regular survey cruises.

Leuroglossus Larvae

Larvae of *Leuroglossus stilbius* were taken in all seven replicate series, commonly in two (table 20). At station 5206–90.28, twice as many larvae were taken in the night series, while at station 5303–91.38 where *Leuroglossus* larvae were most abundant, over six times as many larvae were taken in the night series. The night/day ratio of 5.0 for the total of all series is the highest for any species in the replicate series. The average depth distribution of *Leuroglossus* larvae in day and night series was as follows:

Average depth	Day series		Night series	
	Number	Percent	Number	Percent
2 m	0	0	3	0.5
8 m	0	0	0	0
19 m	0	0	1	.2
28 m	0	0	25	4.4
41 m	7	6.2	15	2.6
56 m	8	7.1	128	22.5
72 m	29	25.7	272	47.7
105 m	40	35.4	28	4.9
138 m	24	21.2	13	2.3
215 m	3	2.7	63	11.1
285 m	2	1.8	22	3.9
Total	113	100.1	570	100.1

In night hauls, the larvae occurred at somewhat shallower depths: 29 larvae were taken above 34 meters at night, none in day hauls. The center of abundance was between 48 and 88 meters in night hauls, while in day hauls it was between 64 and 175 meters. However, more larvae were taken below 88 meters in night hauls than in day: 126 in night hauls, 69 in day hauls. Some migration to deeper levels is indicated for day hauls, but the migration appears to be of moderate extent and within the zones being sampled in taking the vertical distribution series.

Hake Larvae

Hake larvae were common in only one replicate series (5403–94.80), although they occurred in five (table 9). At three stations, larvae were taken only in the night series (one to eight larvae). In the series at station 5403–94.80, most of the larvae taken in the night series occurred at one level (68 meters); in all other hauls taken between the surface and approximately 105 meters, there were more larvae in the day series than in the night at this station (fig. 10, a and b). The night/day ratio of 2.5 for hake larvae is so markedly influenced by one haul that little reliance can be placed on this ratio. Hake larvae had similar depth ranges in both the day and night series.

Sebastodes Larvae

There is no clear-cut evidence that *Sebastodes* larvae are taken in greater numbers in night hauls than in day hauls. Of the five replicate series in which rockfish larvae were common (table 10), the largest numbers were taken in day series at three stations. In fact, were it not for the large difference found at station 5303–91.38 (225 larvae in night series, 46 in day) the night/day ratio would be less than 1. In most series there is no consistent difference in depth distribution between the day and night series. At station 5303–91.38 the larvae occurred somewhat deeper in the night series than in the day, while at station 5305–93.50 most rockfish larvae occurred at notably shallower depths in the night series than in the day.

Lanternfish Larvae

Larvae of *Lampanyctus leucopsarus* occurred in all seven replicate series, commonly in three (table 14). At station 93.50 the larvae had identical depth ranges in the day and night series, but larger numbers of larvae were taken in the day hauls. At stations 5206–90.28 and 5303–91.38, larger numbers were taken in the night series. Because of the unusual concentration of larvae at one level in series 5206–90.28 (94 percent of total taken in haul averaging 27 meters deep), this series has been strongly influenced by localized clumping of larvae. The clumping may have resulted from a vertical concentration of larvae that was missed in daytime sampling, or a horizontal concentration that was missed in daytime due to a change in the water mass. The night/day ratio of 1.8 was strongly influenced by this haul; without the day and night hauls from this level at station 5206–90.28 the night/day ratio for replicate series would approximate 1.

Larvae of *Lampanyctus mexicanus* occurred in six replicate series, usually in small numbers (table 15). In each instance, more larvae were taken in night series than in day, and the larvae had a somewhat shallower depth distribution in night series. Larvae of *L. mexicanus* in the replicate series were limited to four levels with average depths of 19, 28, 41, and 56 meters. Approximately 83 percent of the larvae taken in night series occurred at the 19- and 28-meter levels, while 70 percent of the larvae taken in day series occurred at the 41- and 56-meter levels.

Larvae of *Lampanyctus ritteri* occurred in small numbers in all seven replicate series (table 16). The night/day ratio is only slightly greater than 1. It is difficult to reconcile this finding with the night/day ratio of 14.4 based on repeated hauls taken at station 5010–70.130. There is no consistent difference in depth of occurrence between day and night series.

Discussion

In summary, there are marked differences in abundance of sardine, anchovy, and *Leuroglossus* larvae in night collections as compared with day collections. For all three species, there is evidence of a limited vertical migration, but no evidence that the larvae migrate below the levels sampled.

Most other species (*Sebastodes*, lanternfish, hake) were taken in somewhat larger numbers, on the average, in night collections, but not necessarily so at any given station. The larvae of most of these were taken at approximately the same levels in day and night series, but larvae of *Lampanyctus mexicanus* occurred somewhat deeper in day hauls than in night. Abundance of jack mackerel larvae does not appear to be affected by time of collection.

There are a number of papers which have called attention to the disparity between day and night catches of larvae, particularly clupeid larvae. Bridger (1956), for example, reported that seven times as many herring larvae were taken in night collections as in day collections during five cruises made in 1952 and 1953. Bridger has summarized much of the previous work on day and night variation in catches of fish larvae. F. S. Russell (1926, 1928, and others) has done the most extensive research in this field. A rather typical finding reported by Russell (1926) was the difference in pilchard catches between night and day series taken on July 15–16, 1924: pilchard larvae 5 to 10 mm. in length were 6.0 times as abundant in night collections, larvae between 11 and 20 mm. in length were 13.9 times as abundant.

Both Silliman (1943) and Ahlstrom (1954) have suggested that the lower catches of larvae during daylight hours must result from avoidance of the net by the larger larvae. Bridger (1956: 55) came to the same conclusion. He stated that "On the evidence presented it seems almost certain that the lower catches by day are due to the ability of the larger larvae to avoid the nets in daytime. This would explain the increasing night/day ratio obtained as the larvae develop and become more agile."

SUMMARY

Information is given on the vertical distribution of 46 kinds of fish larvae and 8 kinds of fish eggs, based on 22 vertical distribution series made off southern California and central Baja California in 1941 and 1952 through 1955. Each series consisted of 6 to 11 hauls taken with closing gear at successively deeper levels.

Most fish larvae were found to occur in the upper mixed layer and in the upper part of the thermocline between the surface and approximately 125 meters. Of the 15 most common kinds of larvae taken in vertical distribution series, 12 occurred within this depth range.

All of the more common kinds of larvae showed marked differences in their vertical distribution from series to series.

Larvae of the four pelagic fishes of considerable commercial importance in California—Pacific mackerel, Pacific sardine, jack mackerel, and northern anchovy—had the shallowest depth distributions of any of the more common kinds sampled. Between 79 and 99 percent of the larvae of these species occurred above 50 meters.

Rockfish larvae were as commonly taken within the thermocline as above, but they were not taken below the thermocline. Larvae of *Citharichthys* spp. were taken between the surface and 88 meters.

Larvae of lanternfish (myctophids) were seldom taken in the upper 23 meters. Larvae of the three most common species of *Lampanyctus* in the CCOFI survey area (*L. leucopsarus*, *L. mexicanus*, and *L. ritteri*) occurred mostly between 24 and 64 meters. Larvae of *Electrona* spp. were found to have the deepest distribution of the lanternfish studied. The gonostomatid, *Vinciguerria lucetia*, occurred between the surface and 122 meters, with the largest concentrations occurring between 24 and 48 meters.

Three common kinds or larvae occurred in greatest abundance within or below the thermocline: *Merluccius productus* (hake), *Leuroglossus stilbius*, and *Bathylagus wesethi*. The depth distribution of *Leuroglossus* larvae was not completely covered by hauls extending to approximately 285 meters.

Temperature data are given for the more common fish larvae taken in vertical distribution series.

Replicate vertical distribution series were taken at seven stations, one in daylight hours, the other during darkness. More larvae were taken in the night series at six stations; the night/day ratio for the seven series combined was 2.3. Larvae of *Leuroglossus*, anchovy, and sardine showed the most marked differences between day and night series (4 to 5 times as many as in night series, on the average). Most other species (*Sebastodes*, lanternfish, hake) were taken in somewhat larger numbers, on the average, in night collections, but not necessarily so at any given station. Abundance of jack mackerel larvae did not appear to be affected by time of collection.

Diurnal differences in abundance of larvae have been observed also in regular survey collections, and in studies involving repeated occupancies of a station. An example of the latter is discussed—repeated occupancies of station 70.130 at 3-hour intervals for an 8-day period in October 1950. The night/day ratio for all larvae collected in 63 hauls at this station was 3.6; the variation in night/day ratios for individual species was from 1.7 to 14.4.

A comparison of the catches at two levels on Norpac (upper, 0–131 meters; lower, 131–262 meters) supplemented data obtained from vertical distribution series; 26 kinds of larvae occurred in both Norpac material and vertical series. About one-ninth as many larvae were taken in the 131 to 262-meter level as in the 0 to 131-level on Norpac. Half of the larvae taken in the deeper level belonged to a single genus, *Argyropelecus*; in addition, seven other kinds of larvae had 20 percent or more of their numbers in this level on Norpac.

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APPENDIX

Haul data for the 22 series of closing net hauls are given in the following table. It is included in an appendix rather than in the text because of its length. For each series the following information is given.

Station position is the position at the beginning of a series. At intervals during a series the vessel was brought back to the starting position, but some hauls were taken several miles away from the position listed.

Station number, as for example, 4105–92.39. The first group of figures identifies the year and month of collection. Thus, 4105 refers to collections made in 1941 during the fifth month. The second group identifies geographic position in an arbitrary but consistent numbering system of a grid pattern, oriented roughly parallel to the general trend of the coastline along California and Baja California. The figures before the decimal in the second group refer to the station line, those following to position on the line. The pivotal station in the grid is station 80.60 (34°09′ N., 121°09′ W.) located about 40 miles offshore from Point Conception. The coastwise base line through this point has a true bearing of 330°. Station lines are oriented at right angles to the base line on a mercator projection. Numerical value assigned to a station line increases to the south of the pivotal station (or decreases to the north) at the rate of 12 miles for each unit. The numerical value assigned to a station on the line increases (or decreases) by one unit for each 4-mile interval from the base line (drawn through station 80.60).

Date, midtime of haul, and duration of haul in minutes are self-explanatory.

Wire out. When two values are given for wire out, such as 140–160 meters, the net was opened with the longer length of cable payed out (160 meters, in the example), raised in steps during the haul to the lesser value (140 meters) and closed at this depth before being brought to the surface.

Range in depth is the shallowest and deepest depth reached by the net during a haul, determined from the cosine of the angle of stray of the towing wire from the vertical, multiplied by the length of the towing cable. Determinations of the angle of stray of the towing wire were made at minute intervals in 1941, at half-minute intervals in 1952 through 1955.

Middepth of haul is the average of the depth determinations (usually 15 to 20) made for each haul.

Temperature determinations are based on bathythermograms. Usually three bathythermograph casts were made for each series—one immediately before, one during, and one immediately after completing a series.

APPENDIX TABLE 1.—*Data on 22 series of closing net hauls for determining the vertical distribution of fish eggs and larvae*

Station and haul	Date	Midtime of haul	Duration of haul (min.)	Wire out (m.)	Middepth of haul (m.)	Range in depth (m.)	Temperature at middepth (° C.)
Position, 32°29′ N., 119°26′ W.:							
4104-91.54-1	IV-30-41	1718	16	4	3	0–3	15.0
-2	do	1746	16	10–15	8	6–12	15.0
-3	do	1816	16.5	25–30	18	15–25	14.8
-4	do	1846	16.5	35–40	24	14–29	14.8
-5	do	1943	16.5	55–60	37	28–42	14.6
-6	do	2011	15.5	75–85	54	44–62	13.0
-7	do	2040	15.5	100–110	72	65–92	11.4
Position, 33°20′ N., 118°33′ W.:							
4105-89.38-1	V-2-41	0815	15	4	3	0–3	17.2
-2	do	0845	16	10–15	8	5–14	17.1
-3	do	0909	16	25–30	18	15–21	16.6
-4	do	1001	16	35–40	25	19–31	16.1
-5	do	1026	16	55–60	36	30–43	15.0
-6	do	1318	16	75–85	56	48–70	12.8
-7	do	1348	15.5	100–110	73	65–87	11.5
Position, 32°50′ N., 118°18′ W.:							
4105-92.39-1	do	2005	15	4	3	0–4	17.1
-2	do	2038	16	10–15	10	7–13	16.3
-3	do	2106	16	25–30	20	17–26	16.1
-4	do	2132	16	35–40	28	25–33	15.4
-5	do	2200	17	55–60	40	30–53	13.5
-6	do	2230	15	75–85	58	52–73	11.4
-7	do	2300	15.5	100–110	76	68–98	10.7
-8	do	2348	15.5	140–160	112	97–142	9.8
Position, 32°23′ N., 117°52′ W.:							
4106-94.37N-1	VI-17-41	2215	16.5	4	3	0–3	16.8
-2	do	2318	17	10–15	9	7–12	16.5
-3	do	2353	17.5	25–30	20	15–24	16.0
-4	VI-18-41	0037	17	35–40	27	22–35	15.4
-5	do	0111	17	55–60	41	36–52	14.1
-6	do	0144	16	75–85	58	48–84	11.9
-7	do	0222	17.5	100–110	69	57–101	10.9
-8	do	0312	17.5	140–160	100	90–146	9.8
Position, 32°17′ N., 117°52′ W.:							
4106-94.37D-1	do	0906	16	4	3	0–3	17.2
-2	do	0944	17	10–15	9	6–12	17.0
-3	do	1014	17	25–30	19	14–21	16.3
-4	do	1044	17.5	35–40	30	25–36	15.2
-5	do	1114	18	55–60	41	38–43	13.8
-6	do	1147	18	75–85	58	52–67	12.2
-7	do	1223	17.5	100–110	73	68–81	11.2
-8	do	1310	17	140–160	105	96–152	9.7
-9	do	1352	17	190–210	139	125–156	9.2

APPENDIX TABLE 1.—*Data on 22 series of closing net hauls for determining the vertical distribution of fish eggs and larvae*—Con.

Station and haul	Date	Midtime of haul	Duration of haul (min.)	Wire out (m.)	Middepth of haul (m.)	Range in depth (m.)	Temperature at middepth (° C.)
Position, 32°12′ N., 118°38′ W.:							
4106-94.47N-1	do	2116	15	4	3	0-4	15.8
-2	do	2145	17	10-15	10	7-13	15.8
-3	do	2216	17	25-30	21	18-25	15.2
-4	do	2248	17.5	35-40	27	24-32	14.5
-5	do	2321	18	55-60	44	38-52	12.8
-6	do	2352	16	75-85	59	52-69	11.1
-7	VI-19-41	0028	16.5	100-110	76	66-108	9.9
-8	do	0107	17	140-160	107	90-149	9.1
-9	do	0148	17	190-210	141	122-208	8.7
Position, 32°10′N., 118°39′ W.:							
4106-94.47D-1	do	0834	15	4	3	0-3	15.7
-2	do	0858	16.5	10-15	9	7-14	15.6
-3	do	0925	18	25-30	21	17-25	14.9
-4	do	0952	17	35-40	28	23-36	14.5
-5	do	1018	17	55-60	42	36-47	13.3
-6	do	1045	16	75-85	60	52-69	10.9
-7	do	1118	17	100-110	76	70-85	10.2
-8	do	1153	18	140-160	110	99-121	9.0
-9	do	1236	17.5	190-210	141	120-198	<8.8
Position, 31°55′ N., 118°03′ W.:							
4106-97.43N-1	do	2145	15	4	3	0-3	(*)
-2	do	2209	17	10-15	10	7-14	(*)
-3	do	2235	17	25-30	21	17-25	(*)
-4	do	2305	17	35-40	27	24-32	(*)
-5	do	2332	17	55-60	43	39-50	(*)
-6	VI-20-41	0002	16	75-85	57	50-62	(*)
-7	do	0036	16.5	100-110	79	67-100	(*)
-8	do	0105	16.5	140-160	106	90-133	(*)
-9	do	0202	17	190-210	142	127-168	(*)
Position, 31°55′ N., 118°03′ W.:							
4106-97.43D-1	do	0828	15	4	3	0-3	(*)
-2	do	0854	17	10-15	10	7-13	(*)
-3	do	0920	17	25-30	20	18-22	(*)
-4	do	0946	17	35-40	28	24-32	(*)
-5	do	1040	17	55-60	42	36-47	(*)
-6	do	1138	17	75-85	60	57-64	(*)
-7	do	1209	16	100-110	77	70-85	(*)
-8	do	1244	16.5	140-160	104	92-119	(*)
-9	do	1406	17	190-210	133	120-172	(*)
Position, 33°28.5′ N., 117°46.7′ W.:							
5206-90.28N-1	VI-12-52	2224	10	3	2	0-3	16.6
-2	do	2157	10	10	7	7-8	16.6
-3	do	2258	10	25	17	15-19	14.7
-4	VI-13-52	0005	10	40	27	21-35	12.1
-5	do	0034	10	60	42	39-44	10.1
-6	do	0108	10	80	57	54-59	9.7
-7	do	0140	10	100	73	68-80	9.2
-8	do	0210	10	150	107	104-111	9.2
-9	do	0248	10	200	142	136-146	8.9(131 m.)
-10	do	0330	10	300	206	189-216	(*)
-11	do	0415	10	400	286	268-302	(*)
Position, 33°28.5′ N., 117°46.7′ W.:							
5206-90.28D-1	do	0918	10	3	2	0-3	18.2
-2	do	0940	10	10	7	5-8	16.4
-3	do	1000	10	25	18	16-19	15.1
-4	do	1025	10	40	29	26-32	11.2
-5	do	1112	10	60	44	41-47	10.0
-6	do	1135	10	80	56	54-58	9.9
-7	do	1200	10	100	71	64-76	9.7
-8	do	1228	10	150	105	100-111	9.4
-9	do	1305	10	200	134	112-141	9.4
-10	do	1425	10	300	216	208-223	(*)
-11	do	1500	10	400	286	278-292	(*)
Position, 28°05.5′ N., 114°57.5′ W.:							
5208-120.35-1	VIII-17-52	0302	5	5	3	2-4	19.7
-2	do	0323	5	15	10	10-11	19.6
-3	do	0339	5	25	18	14-22	18.9
-4	do	0401	5	40	27	22-30	18.4
-5	do	0426	5	55	36	30-40	17.8
-6	do	0452	5	70	51	49-53	16.1
Position, 33°02′ N., 118°23′ W.:							
5303-91.38N-1	III-4-53	2005	10	3	2	0-3	14.4
-2	do	2031	10	10	7	6-9	14.4
-3	do	2115	10	25	18	16-20	14.3
-4	do	2137	10	40	29	25-33	14.3
-5	do	2247	10	60	41	37-46	14.2
-6	do	2316	10	80	54	51-58	14.0
-7	III-5-53	0022	10	100	68	60-77	11.6
-8	do	0100	10	150	106	96-118	9.8
-9	do	0128	10	200	150	131-168	9.4
-10	do	0218	10	300	211	197-230	9.0
-11	do	0329	10	400	291	262-311	
Position, 33°02′ N., 118°23′ W.:							
5303-91.38D-1	do	0620	10	3	2	0-3	14.2
-2	do	0642	10	10	7	6-8	14.2
-3	do	0702	10	25	18	15-20	14.1
-4	do	0724	10	40	28	24-32	14.0
-5	do	0753	10	60	42	27-47	13.9
-6	do	0817	10	80	56	51-61	13.2
-7	do	0843	10	100	72	64-83	10.7
-8	do	0910	10	150	92	82-102	9.9
-9	do	0945	10	200	139	131-141	9.3
-10	do	1018	10	300	206	197-212	8.6

*No temperature data available.

APPENDIX TABLE 1.—*Data on 22 series of closing net hauls for determining the vertical distribution of fish eggs and larvae*—Con.

Station and haul	Date	Midtime of haul	Duration of haul (min.)	Wire out (m.	Middepth of haul (m.	Range in depth (m.)	Temperature at middepth (° C.)
Position, 32°10.5′ N., 118°57′ W.:							
5305-93.50N-1	V-25-53	2045	10	3	2	0-3	13.9
-2	do	2132	5	10	6	6-7	14.2
-3	do	2145	5	25	21	20-22	13.4
-4	do	2157	5	40	29	27-33	13.4
-5	do	2212	5	60	43	29-48	12.5
-6	do	2225	10	80	57	55-62	11.2
-7	do	2247	10	100	70	62-78	10.6
-8	do	2310	10	150	106	96-110	9.3
-9	do	2357	10	200	138	123-146	9.0
-10	V-26-53	0033	10	300	222	189-243	8.4
-11	do	0109	10	400	276	252-302	7.8
Position, 32°10.5′ N., 118°57′ W.:							
5305-93.50D-1	do	0715	5	3	2	0-3	14.9
-2	do	0722	5	10	7	6-7	14.4
-3	do	0735	5	25	16	14-16	14.1
-4	do	0748	5	40	25	24-27	13.5
-5	do	0759	5	60	33	25-38	13.2
-6	do	0845	5	80	46	40-54	12.5
-7	do	0924	10	100	63	42-73	11.0
-8	do	0945	10	150	103	82-120	9.9
-9	do	1029	10	200	138	131-149	9.4
-10	do	1159	10	300	239	230-252	(*)
Position, 30°58.5′ N., 120°45′ W.:							
5403-94.80N-1	III-24-54	2030	10	3	2	0-3	14.3
-2	do	2102	10	10	7	6-7	14.3
-3	do	2125	10	25	17	16-18	14.3
-4	do	2143	10	40	27	24-29	14.3
-5	do	2308	10	60	42	39-48	14.3
-6	do	2331	10	80	52	44-57	14.3
-7	III-25-54	0000	10	100	64	53-72	14.1
-8	do	0025	10	150	101	96-106	10.8
-9	do	0135	10	200	127	118-141	9.9
-10	do	0215	10	300	200	176-208	8.7
Position, 30°58.5′ N., 120°45′ W.:							
5403-94.80D-1	III-24-54	0908	10	3	2	0-3	14.1
-2	do	0940	10.5	10	7	6-7	14.1
-3	do	1005	10	25	18	17-19	14.1
-4	do	1025	10.5	40	28	26-29	14.0
-5	do	1105	10	60	41	39-42	14.0
-6	do	1140	10.5	80	53	50-60	14.0
-7	do	1232	10.5	100	68	59-72	13.2
-8	do	1305	10.5	150	102	96-110	11.1
-9	do	1350	10	200	135	126-141	9.7
-10	do	1425	10.5	300	201	193-219	8.6
Position, 28°51.5′ N., 119°22.5′ W.:							
5504-107 80-1	IV-16-55	1355	10	3	2	0-3	15.7
-2	do	1430	10	10	8	6-10	15.7
-3	do	1455	10	25	20	18-22	15.7
-4	do	1515	10	40	31	27-36	15.7
-5	do	1535	10.5	60	45	40-50	15.7
-6	do	1600	10	80	57	54-63	15.3
-7	do	1620	10	100	70	63-81	15.0
-7A	do	1640	10.5	125	83	79-88	14.3
-8	do	1720	10	150	111	104-124	13.8
-9	do	1745	10.5	200	142	129-149	12.5
Position, 28°56.5′ N., 117°39′ W.:							
5504-110. 60-1	IV-23-55	1155	10	3	2	0-3	15.6
-2	do	1220	10	10	7	6-8	15.6
-3	do	1235	10	25	18	16-20	15.6
-4	do	1255	10	40	29	26-32	15.6
-5	do	1315	10	60	44	39-50	15.6
-6	do	1330	10	80	58	54-63	15.6
-7	do	1400	10.5	100	73	64-86	15.4
-7A	do	1420	9.5	125	83	77-100	15.3
-8	do	1440	9.5	150	105	100-110	13.2
Position, 27°33′ N., 115°52.5′ W.:							
5504-120.50 1	IV-18-55	2015	10	3	2	0-3	15.3
-2	do	2045	10	10	7	6-8	15.3
-3	do	2100	10	25	18	16-22	15.3
-4	do	2120	10	40	27	25-33	15.3
-5	do	2135	10	60	44	39-49	15.3
-6	do	2155	10	80	60	52-66	14.1
-7	do	2215	10	100	74	66-86	12.2
-7A	do	2235	10	125	99	85-107	10.8
-8	do	2300	10	150	110	100-123	10.8
-9	do	2355	11.5	200	137	123-164	10.8
-10	IV-19-55	0025	11	300	225	208-270	
Position, 25°29′ N., 115°24′ W.:							
5504-130.60-1	IV-21-55	2325	10	3	2	0-3	16.6
-2	IV-22-55	0005	10	10	8	7-8	16.55
-3	do	0020	10.5	25	17	14-21	
-4	do	0035	10	40	28	24-32	
-5	do	0050	10	60	42	36-46	
-6	do	0110	10	80	56	54-61	
-7	do	0125	10	100	72	66-76	
-7A	do	0145	10.5	125	89	84-100	
-8	do	0205	10.5	150	102	98-106	
-9	do	0230	10.5	200	136	129-141	
-10	do	0330	10.5	300	215	205-230	

*No temperature data available.

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