DISTRIBUTION AND ABUNDANCE OF FISH EGGS AND LARVAE IN THE GULF OF CALIFORNIA

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INTRODUCTION

From time to time during its 24 year history the oceanographic cruises of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) have extended beyond the California Current system. One example is the multivessel NORPAC Expedition which encompassed much of the northeast Pacific in 1955. Another such example is the series of seven oceanographic cruises made into the Gulf of California during 1956 and 1957.

Ships and personnel from the National Marine Fisheries Service (NMFS) and Scripps Institution of Oceanography (SIO) took part in the seven cruises, employing methods described by Kramer et al. (1972). On the first of these cruises (5602) the NMFS vessel BLACK DOUGLAS occupied 93 stations from the mouth of the Gulf northward as far as Tiburón Island from February 6 to 18, 1956 (Figure 1). On the second cruise (5604) the BLACK DOUGLAS occupied 129 stations throughout the full length of the Gulf from 8 to 24 April, 1956. On the third cruise (5612) the SIO vessel HORIZON occupied an abbreviated set of 79 stations, primarily on the western side of the Gulf and as far north as Tiburón Island from December 3 to 17, 1956. On cruise 5702 the SIO vessel SPENCER F. BAIRD occupied 70 stations as far northward as Tiburón Island February 9–20, 1957 (Figure 3). The remaining cruises in 1957 (Figure 3) each occupied a pattern of stations throughout the entire Gulf. On cruise 5704 the BLACK DOUGLAS occupied 125 stations from 7 to 22 April. The SIO vessel STRANGER occupied 132 stations on cruise 5706 from June 9 to 23.

The oceanographic observations from these cruises have been published by Scripps Institution of Oceanography (1963, 1965). Except for Ahlstrom's illustration of the distribution of Pacific mackerel on cruise 5602 (Ahlstrom, 1956, Figure 21), the data on the fish eggs and larvae have never been reported, largely because their identification has been accomplished over a long period, when time has permitted diversion from the task of identifying eggs and larvae from regular CalCOFI cruises. It is the purpose of this paper to give an overview of the seasonal abundance of the fish larvae collected on six of these cruises (5602–5706) and to give the patterns of geographic distribution for the abundant species which are important as commercial or forage fishes. Eggs of the Pacific mackerel and sardine were identified for three cruises (5602, 5604, 5702) and are used to estimate the spawning biomass of these species for those years. Finally the distribution and abundance of fish larvae is discussed in relation to the special oceanographic conditions in the Gulf and in relation to zoogeographic patterns of the subtropical and tropical northeast Pacific. Before embarking on this, however, it would be useful to review briefly the environmental characteristics of the Gulf of California and to give some general background information on its ichthyofauna.

This unique body of water is bounded by arid Baja California on the west and the Mexican states of Sonora and Sinaloa on the east. It extends about 1400 km between latitudes 23 and 32 north and has an average width of about 150 km. Wegener (1922) proposed that the Gulf was formed by the separation of Baja California from the Mexican mainland, a supposition which has been strengthened by recent investigations into sea floor spreading in that region (Elders et al., 1972). The northern ⅓ of the Gulf is separated

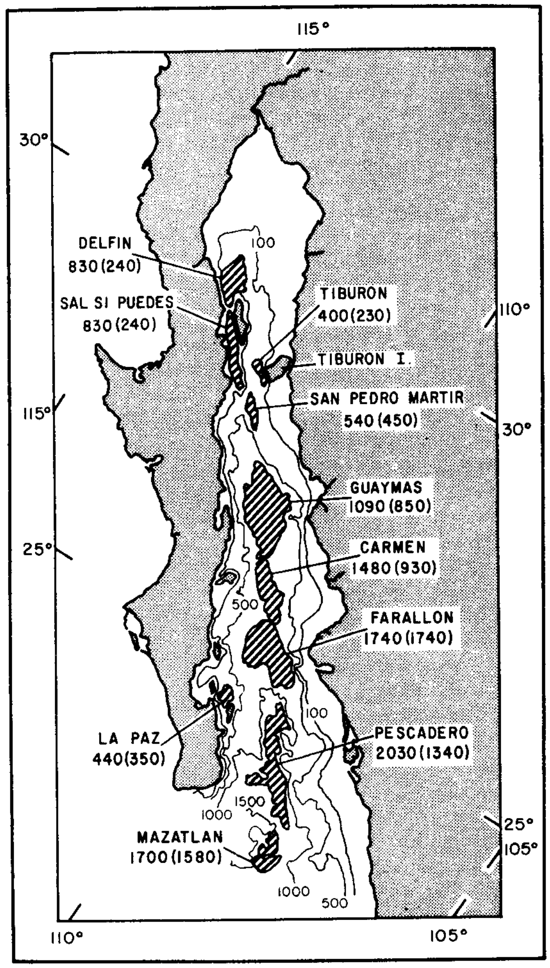

FIGURE 1. Basins of the Gulf of California with their maximum depths and sill depths (fathoms). Redrawn from van Andel (1964) and depth data from same publication.

from the lower part by two large islands, Ángel de la Guarda and Tiburón. Except for two basins, Delfín and Sal si Puedes shown in Figure 1, the head of the Gulf is shallow, with an average depth of about 200 m. Alluvial deposits, largely from the Colorado River, have filled the trough in this region to produce a smooth concave sea floor. This contrasts sharply with the bathymetry south of Tiburón and Ángel de la Guarda, which is characterized by a series of deep basins (down to 3000 m) running along the axis of the trough. These basins are separated by transverse sills of about 1500 m depth and the entire series is separated from the shallow Delfín and Sal si Puedes basins by a shallow sill of 200–250 m. The coastal features of the eastern and western sides of the Gulf are in sharp contrast. The Baja California coast south of Ángel de la Guarda is characterized by steep rocky escarpments broken occasionally by sandy beaches and by two major bays, Bahía La Paz and Bahía Concepción. Bordering the coastline is a linear series of small rocky islands. The sandy beaches become more extensive north of Bahía Concepción and are almost unbroken in the north. The eastern shoreline of the Gulf, except for a region of rocky headlands between Bahía Kino and Guaymas, is characterized by a wider shelf than is found on the western shore and by extensive beaches of sand or mud.

What is known about the oceanography of the Gulf has been reviewed in a series of papers by Roden (1958), Roden and Groves (1959), and Roden (1964). Situated between arid and mountainous Baja California on the west and the arid mainland to the east, it is an evaporation basin with highly saline and generally warm surface waters. Surface salinities show a general increase from south to north with a range of 34.8‰ to 36‰ but there is little seasonal variation for any given latitude. Surface temperatures, however, show a very large seasonal range that increases from about 9°C at the Gulf entrance to about 16°C at the head of the Gulf. Composite tidal range also increases markedly from south to north in the Gulf. From the Gulf entrance to Tiburón the increase is only slight with a spring range of about 1½ m. North of Tiburón the range increases rapidly to a maximum spring range of 10 m at the mouth of the Colorado River. This strong tidal mixing in the northern part of the Gulf is thought to be the reason for the year-round low surface temperatures in the vicinity of Ángel de la Guarda and Tiburón Islands, and for the relatively high temperatures, salinities, and oxygen concentrations at great depths in the isolated Delfín and Sal si Puedes Basins.

The water in the central and southern regions of the Gulf is in communication with the Pacific, and has the properties of Equatorial Pacific water. Below the thermocline the water is similar to that in the neighboring Equatorial Pacific with a salinity minimum of about 34.5‰ between 600 and 1000 m and a pronounced oxygen minimum of 0.1–0.2 ml/L between 400 and 800 m. Above the thermocline is a water mass referred to by Roden and Groves (1959) as "Gulf water." They view it as Equatorial Pacific water which has been transformed into water of higher salinity by evaporation.

The fish fauna indicates that the Gulf is clearly part of the Tropical American or Panamic faunal province. Walker (1960) in his review of the Gulf ichthyofauna, recorded 586 species of fish in the Gulf, of which 526 are shorefishes. Nearly ¾ of the shorefish are tropical or subtropical species with their principal ranges to the south of the Gulf. About 50 species, or 10% of the total, have their principal distributions to the north of the Gulf. The majority of these are found in the northern region of the Gulf, as disjunct species from the Southern California or San Diegan fauna. The remaining 92 species, or 17% of the total, are endemic to the Gulf.

In comparison with the Panamic fauna to the south, Walker has noted that the Gulf has an unusually high number of rocky shore species, a relatively poor representation of muddy bottom forms, and a high percentage of endemic species. The blennioid families Clinidae, Tripterygidae, and Chaenopsidae are perhaps the best examples of the profusion of rocky shore fishes in the Gulf. These groups have been reviewed extensively by a number of investigators including Hubbs (1952), Springer (1958), Rosenblatt (1959) and Steens (1963), and are among the best known of eastern Pacific shorefishes.

The high degree of speciation and endemism in these families might be accounted for by the abundance of semi-isolated rocky habitats, particularly on the peninsula coast of the Gulf. Also, the long stretch of sandy shoreline running from Guaymas to Mazatlán acts as a faunal barrier isolating the rocky shore fishes of the Gulf from those to the south. The paucity of muddy bottom species, most notably the

TABLE 1

Major constituents of three mid-water trawling expeditions to the Gulf of California

Species	Percent of Total Catch		
	Lavenberg and Fitch (1966)	Robison (1972)	Brewer (1973)
Myctophidae			
Triphoturus mexicanus	88.8	68.0	80.6
Diogenichthys laternatus	0.1	7.2	5.8
Benthosema panamense	5.0	2.8	0.9
Other myctophids	0.4	1.6	1.9
Gonostomatidae			
Vinciguerria lucetia	0.4	10.2	2.4
Cyclothone spp.	--	8.2	--
Bathylagidae			
Leuroglossus stilbius	0.5	0.6	5.4
Clupeidae			
Sardinops sagax caeruleus	1.6	--	--
Merlucciidae			
Merluccius sp.	1.3	--	--
Scombridae			
Scomber japonicus	0.6	--	--
All others	1.3	1.4	3.0

TABLE 2

Summary of occurrences and abundance (standard haul totals) of fish larvae in the Gulf of California during 6 cruises in 1956–1957

Kinds of larvae	5602		5604		5612		5702		5704		5706		Total	
	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.
Clupeidae:														
Sardinops sagax caeruleus	34	1,108	45	1,856	23	1,660	28	1,511	45	1,865	0	0	175	8,000
Etrumeus teres	11	122	40	1,090	12	335	11	172	24	757	10	278	108	2,754
Opisthonema spp.	0	0	0	0	0	0	0	0	0	0	55	23,217	55	23,217
Engraulidae	3	29	6	140	4	60	1	6	9	297	33	2,880	56	3,412
Bathylagidae:														
Bathylagus nigrigenys	8	57	6	85	2	13	3	27	8	123	13	90	40	395
Leuroglossus stilbius	50	1,139	42	1,217	14	209	32	2,168	27	357	1	6	166	5,096
Argentinidae:														
Argentina sialis	1	6	2	7	0	0	2	12	3	32	0	0	8	57
Gonostomatidae:														
Vinciguerria lucetia	35	4,718	37	4,278	32	1,800	38	18,218	34	6,818	87	19,231	263	55,063
Diplophos taenia	0	0	0	0	1	15	0	0	1	3	0	0	2	18
Sternoptychidae:														
Argyropelecus sp.	0	0	0	0	0	0	0	0	0	0	1	26	1	26
Stomiatidae:														
Stomias atriventer	1	3	2	20	0	0	1	15	1	6	6	43	11	87
Melanostomiatidae:														
Bathophilus filifer	0	0	0	0	3	22	0	0	3	19	0	0	6	41
Synodontidae:														
Synodus spp.	0	0	1	34	2	22	1	9	2	79	32	1,069	38	1,213
Aulopidae	0	0	0	0	0	0	0	0	0	0	1	4	1	4
Myctophidae:														
Benthosema panamense	12	115	0	0	36	1,438	0	0	2	148	56	5,685	106	7,386
Diaphus pacificus	0	0	0	0	4	187	0	0	1	12	2	13	7	212
Diogenichthys laternatus	45	2,142	45	2,301	32	1,342	41	2,178	29	2,326	49	2,451	241	12,740
Hygophum atratum	4	31	3	37	3	58	12	146	6	50	3	17	31	339
Lampanyctus spp.	8	103	9	103	6	45	1	10	7	62	13	140	44	463
Myctophum aurolaternatum	1	6	0	0	1	3	0	0	3	21	0	0	5	30
Triphoturus mexicanus	10	64	24	348	41	2,298	10	156	44	1,179	72	14,798	201	18,843
Myctophidae (unidentified)	2	18	0	0	5	71	2	26	3	34	18	290	30	439
Scopelarchidae:														
Scopelarchoides nicholsi	1	5	1	12	2	18	0	0	0	0	0	0	4	35
Paralepididae	0	0	0	0	2	12	0	0	0	0	2	6	4	18
Exocoetidae:														
(mostly *Oxyporhamphus*)	0	0	0	0	0	0	0	0	1	3	17	122	18	125
Gadidae:														
Merluccius sp.	5	35	19	460	0	0	4	24	9	67	0	0	37	586
Moridae:														
Physiculus spp.	5	27	3	172	2	20	6	49	1	6	0	0	17	274
Other	0	0	0	0	1	9	0	0	0	0	2	16	3	25
Macrouridae	0	0	5	47	2	21	2	19	2	11	0	0	11	98
Bregmacerotidae:														
Bregmaceros bathymaster	24	10,461	6	16,339	10	1,185	13	1,384	9	486	75	17,916	137	47,771
Fistulariidae	0	0	0	0	1	8	0	0	0	0	7	63	8	71
Syngnathidae	0	0	2	20	0	0	0	0	0	0	3	9	5	29
Melamphaidae	2	12	2	17	3	20	4	35	0	0	4	16	15	100
Leptocephali	6	29	5	42	11	102	7	66	16	115	44	263	89	617
Scombridae:														
Auxis sp.	0	0	1	13	1	3	1	2	2	27	60	1,789	65	1,834
Euthynnus	0	0	0	0	0	0	0	0	0	0	19	164	19	164
Sarda chiliensis	0	0	0	0	0	0	0	0	0	0	11	396	11	396
Scomber japonicus	34	6,469	64	2,891	7	100	29	2,969	50	4,008	4	17	188	16,454
Scomberomorus sp.	0	0	0	0	0	0	0	0	1	5	11	114	12	119
Unidentified	0	0	0	0	0	0	0	0	0	0	16	362	16	362
Apogonidae	0	0	0	0	1	5	0	0	0	0	2	7	3	12
Atherinidae	0	0	1	1	0	0	0	0	3	15	0	0	4	16
Bramidae	0	0	1	11	0	0	0	0	0	0	0	0	1	11
Branchiostegidae	0	0	0	0	0	0	0	0	2	15	2	14	4	29
Carangidae	2	17	13	90	17	281	3	21	6	36	56	1,317	97	1,762
Carapidae	1	3	1	3	1	40	1	17	1	5	7	56	12	124
Clinidae	0	0	0	0	0	0	0	0	3	38	0	0	3	38
Coryphaenidae	0	0	0	0	1	3	0	0	4	28	15	94	20	125
Gempylidae	0	0	0	0	2	5	0	0	0	0	0	0	2	5
Gerridae	0	0	0	0	0	0	0	0	0	0	27	2,064	27	2,064
Gobiidae	4	20	10	216	5	79	3	65	8	79	48	1,301	78	1,760
Kyphosidae	0	0	1	17	0	0	0	0	0	0	35	960	36	977
Labridae	1	6	0	0	0	0	1	129	1	7	16	95	19	237
Lutjanidae	0	0	0	0	0	0	0	0	0	0	2	6	2	6
Microdesmidae	0	0	0	0	0	0	0	0	0	0	3	11	3	11
Mugilidae	3	28	0	0	0	0	0	0	0	0	24	192	27	220
Nomeidae	0	0	0	0	9	149	0	0	8	93	42	415	59	657
Ophidiidae—Brotulidae	3	13	5	32	7	60	3	32	4	16	39	797	61	950
Polynemidae	0	0	0	0	0	0	0	0	0	0	6	141	6	141
Pomacentridae	9	153	0	0	0	0	0	0	1	2	15	218	25	373
Pomadasyidae	0	0	0	0	0	0	0	0	0	0	25	1,373	25	1,373
Sciaenidae	4	98	18	522	4	64	9	180	12	160	38	2,864	85	3,888

TABLE 2

Summary of occurrences and abundance (standard haul totals) of fish larvae in the Gulf of California during 6 cruises in 1956–1957 (Continued)

Kinds of Larvae	5602		5604		5612		5702		5704		5706		Total	
	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.	occ.	std. no.
Scorpaenidae:														
Sebastes spp.	8	75	15	87	5	101	6	174	1	6	0	0	35	443
Other	17	116	5	29	19	229	8	92	11	108	77	1,468	130	2,042
Serranidae	1	5	1	11	6	104	2	9	5	44	82	3,508	97	3,681
Sphyraenidae	0	0	0	0	0	0	0	0	1	4	15	136	16	140
Stromateidae	0	0	1	22	2	124	0	0	2	17	0	0	5	163
Tetragonuridae	0	0	0	0	2	20	0	0	0	0	0	0	2	20
Trichiuridae	4	37	1	13	12	232	2	32	1	5	28	4,668	48	4,987
Triglidae	2	18	4	41	4	23	2	21	12	166	38	510	62	779
Bothidae	9	76	48	620	31	536	15	145	22	138	141	2,746	264	4,261
Cynoglossidae:														
Symphurus	19	131	6	33	13	171	10	282	8	91	43	362	99	1,070
Balistidae	0	0	0	0	0	0	0	0	0	0	2	6	2	6
Tetraodontidae	0	0	0	0	0	0	0	0	0	0	4	35	4	35
Lophiidae	0	0	0	0	0	0	0	0	0	0	1	5	1	5
Gigantactinidae	0	0	0	0	0	0	0	0	1	6	0	0	1	6
Disintegrated	4	29	13	85	4	38	3	39	12	90	83	3,403	119	3,684
Unidentified	16	87	38	747	27	1,304	15	219	33	987	95	3,394	225	6,738
Total	93	27,611	129	34,109	79	14,644	70	30,659	125	21,072	132	123,657	628	251,752

croakers and catfishes, is more difficult to explain. Walker suggests that the wide expanse of open water across the mouth of the Gulf acts as a barrier isolating the Cape San Lucas region and lower peninsular coast from the mainland, but the general paucity of Panamic muddy and sandy bottom fishes in other areas of the Gulf probably relates to the lower temperatures and greater seasonal temperature ranges as compared to waters south of the Gulf. Certainly these are important limiting factors in the upper Gulf, which has only ½ the number of shore fish species found in the central and southern Gulf. Here also, the great tidal ranges probably also are a limiting factor.

The midwater fish fauna of the Gulf is reasonably well known, owing to recent studies by Lavenberg and Fitch (1966), Robison (1972), and Brewer (1973). Although their trawls differed in mouth size and in mesh size, essentially the same species were dominant in the three surveys (Table 1). As in midwater trawl surveys in other areas of the world, the family Myctophidae or lanternfishes dominated the three Gulf surveys, however, the dominance of these fishes was even more striking in the Gulf. They made up 94% of the catch in the Lavenberg and Fitch study, about 80% in Robison's samples, and 89% in Brewer's. A single myctophid species, *Triphoturus mexicanus*, was by all odds the dominant species; it represented 89%, 68% and 81% of all fish taken in the three surveys. As in the shorefishes, most of the midwater species of the Gulf have their principal distributions to the south of the Gulf, the notable exceptions being *T. mexicanus* and *Leuroglossus stilbius*, which are temperate-subtropical in distribution. To our knowledge there are no endemic midwater fishes in the Gulf, although several midwater fishes including *Hygophum atratum*, *L. stilbius* and *T. mexicanus* were described originally from the Gulf.

In general, the major midwater families are represented by a reduced number of species compared with waters at the same latitudes on the outer coast and adjacent waters south of the Gulf. For example, in the Myctophidae, about 30 species and 20 genera are found in outer coast waters and in adjacent waters to the south. Thirteen of these species and 10 of the genera, or less than half, are found in the Gulf. The same can be said for the Gonostomatidae, with about 10 species occurring on the outer coast and only 4 in the Gulf. Likewise, there are 5 species of bathylagid smelts in the outer coast waters and only 2 in the Gulf. A single species of the family Scopelarchidae has been taken in the Gulf whereas 5 species representing 4 genera are found on the outer coast. Typically, those midwater species recorded from the Gulf do not penetrate very far north and most are limited to the southernmost basins. Only *Vinciguerria lucetia*, *Diogenichthys laternatus*, *T. mexicanus*, and *L. stilbius* are widespread and abundant in the southern and central regions of the Gulf. *Benthosema panamense* and *T. mexicanus* are the only midwater species that occur in significant numbers in the upper regions of the Gulf.

Midwater trawls are highly selective sampling devices as shown by comparing their catches with relative abundances of species taken as larvae in plankton nets. The results of the CalCOFI cruises in the Gulf as shown below form an interesting comparison with those of the midwater trawl surveys.

RESULTS

Over a quarter of a million fish larvae (standard haul totals) were obtained on the six cruises. As shown in Table 2 the total numbers of larvae varied considerably from cruise to cruise. Cruise 5612 had the lowest total number of larvae, although on the basis of numbers of larvae per station, 5704 was the lowest with about 172 larvae per station. Cruise 5706 ranked highest in total numbers and in numbers per station with 937. Nearly as many larvae were collected on this single cruise as on the other five cruises combined.

In contrast to the fluctuation in numbers of larvae from cruise to cruise there was a general consistency in the kinds of larvae that were most abundant during the six cruises.

The larvae of two commercial species, the Pacific mackerel, *Scomber japonicus*, and the Pacific sardine, *Sardinops sagax caeruleus*, were highly prominent. Pacific mackerel larvae ranked second in total abundance on three of the six cruises (5602, 5702, 5704) and third on 5604 (Table 2). Overall they ranked fifth with 6.5% of the total larvae obtained on all six cruises (Table 3). They were widespread, as well as abundant, and on 5604 and 5704 had the highest number of occurrences of any species collected (Table 2). Spawning of *S. japonicus* (a species of northern affinity) was found to be curtailed sharply during the

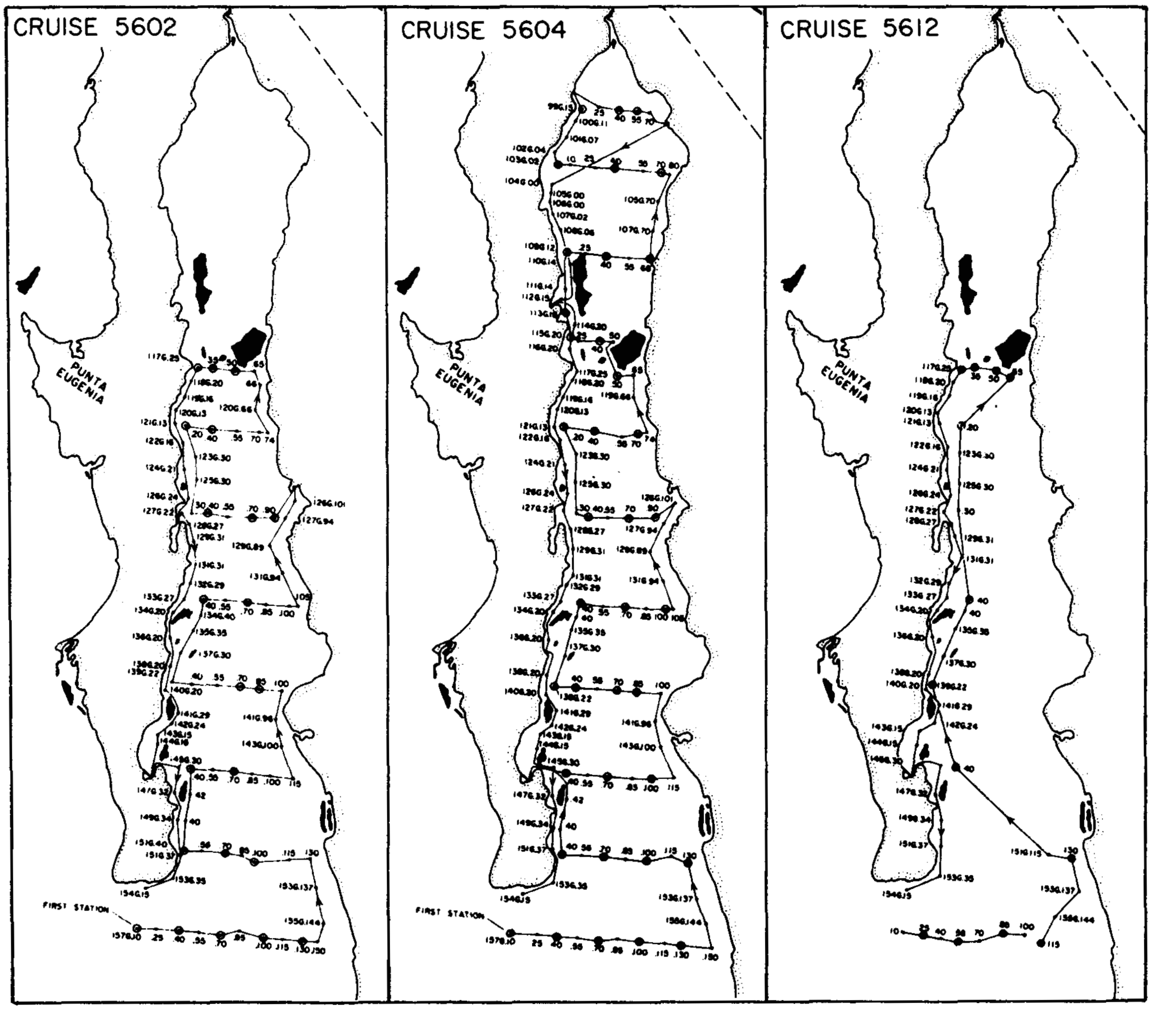

FIGURE 2. Station pattern for CalCOFI cruises into the Gulf of California in February, April, and December, 1956. From Oceanographic Observations of the Pacific: 1956 (SIO, 1963).

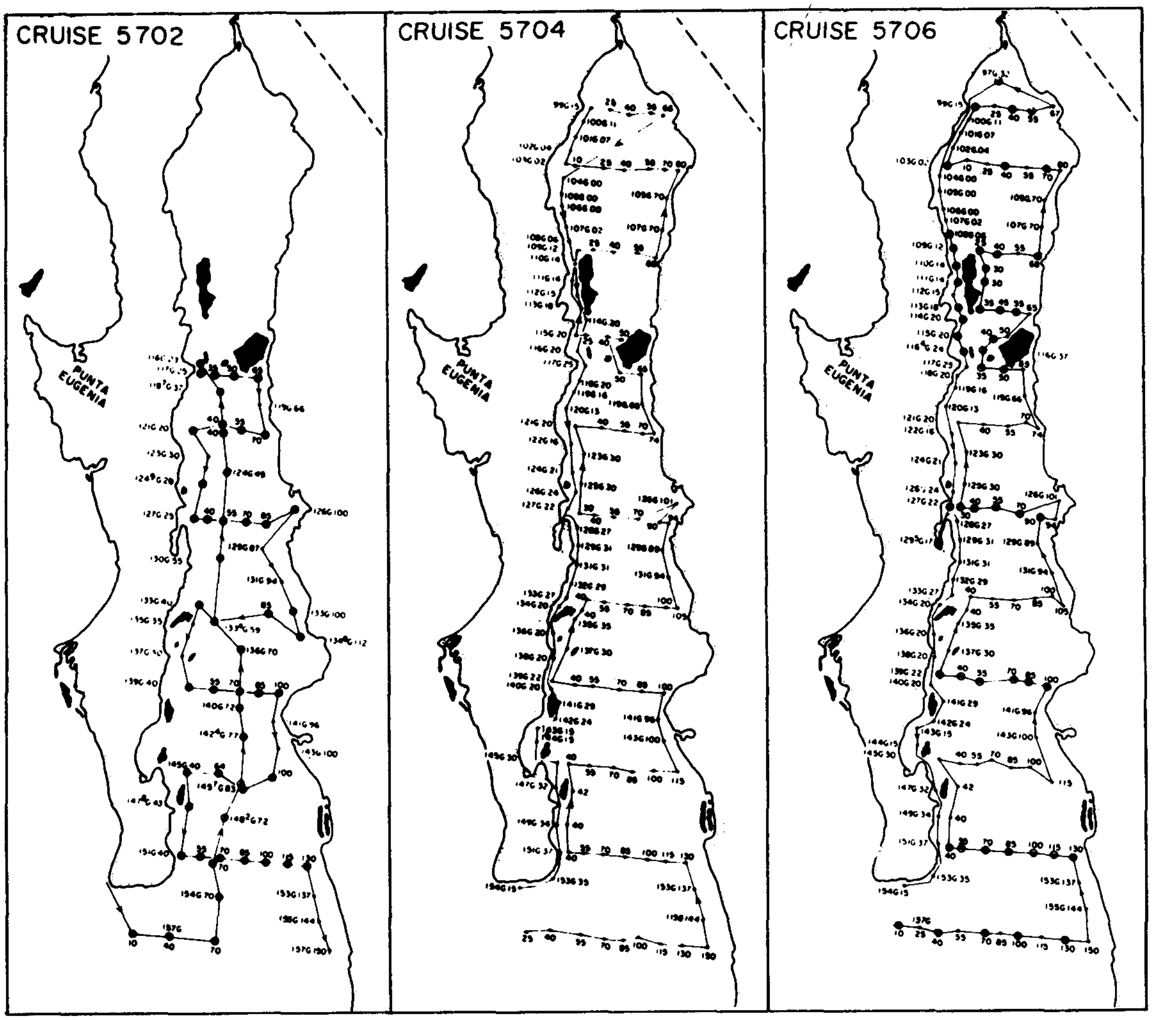

FIGURE 3. Station pattern for CalCOFI cruises into the Gulf of California in February, April, and June, 1957. From Oceanographic Observations of the Pacific: 1957 (SIO, 1965).

warm water cruise of 5706, and the larvae of tropical scombrids (*Auxis, Sarda, Euthynnus, Scomberomorus*) appeared in the collections.

Pacific sardine larvae were more consistent in relative abundance than those of Pacific mackerel, although they ranked as high as third on only one cruise (5612). They ranked sixth on 5602, fifth on 5604 and 5702, and fourth on 5704. It too is a species of cold water affinity and was not taken on 5706, but was replaced by larvae of the tropical clupeid genus *Opisthonema,* which ranked first in total abundance on that cruise.

Another species of potential commercial importance, the round herring, *Etrumeus teres,* was consistently represented on all but cruise 5706, it ranked no lower than eleventh and on two cruises, 5604 and 5704, ranked seventh.

The most consistently abundant species was the eastern Pacific lightfish, *Vinciguerria lucetia.* It ranked no lower than third in total abundance (5602), and on two cruises (5702, 5704), it ranked first. On 5702 it accounted for almost 60% of the total fish larvae collected. On 5706, it ranked second but occurred on 87 stations, the highest number of occurrences for any species during the six cruises. Its overall rank for all cruises was first, contributing 21.9% of all fish larvae obtained.

Another consistently abundant species was the small gadoid fish, *Bregmaceros bathymaster.* It was the most abundant species on the first two cruises, decreased in

TABLE 3

Rank and percentage contribution by cruise of categories of fish larvae that ranked among the top 25 for all cruises combined in Gulf of California during 1956–1957

Kinds of Larvae	5602		5604		5612		5702		5704		5706		Total	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Clupeidae:														
Sardinops sagax caeruleus	6	4.0	5	5.4	3	11.3	5	4.9	4	8.8	0	0	7	3.2
Etrumeus teres	10	0.4	7	3.2	9	2.3	11	0.6	7	3.6	--	0.2	17	1.1
Opisthonema spp.	0	0	0	0	0	0	0	0	0	0	1	18.8	3	9.2
Engraulidae	22	0.1	15	0.4	24	0.4	--	<0.1	10	1.4	10	2.3	16	1.4
Bathylagidae:														
Leuroglossus stilbius	5	4.1	6	3.6	13	1.4	4	7.1	9	1.7	--	<0.1	10	2.0
Gonostomatidae:														
Vinciguerria lucetia	3	17.1	2	12.5	2	12.3	1	59.4	1	32.4	2	15.5	1	21.9
Synodontidae:														
Synodus spp.	0	0	25	0.1	--	0.2	--	<0.1	21	0.4	20	0.9	24	0.5
Myctophidae:														
Benthosema panamense	11	0.4	0	0	4	9.8	0	0	13	0.7	5	4.6	8	2.9
Diogenichthys laternatus	4	7.8	4	6.8	5	9.2	3	7.1	3	11.0	13	2.0	6	5.1
Triphoturus mexicanus	16	0.2	12	1.0	1	15.7	12	0.5	5	5.6	4	12.0	4	7.5
Bregmacerotidae:														
Bregmaceros bathymaster	1	37.9	1	47.9	7	8.1	6	4.5	8	2.3	3	14.5	2	19.0
Scombridae:														
Auxis rochei	0	0	--	<0.1	--	<0.1	--	<0.1	--	<0.1	15	1.4	20	0.7
Scomber japonicus	2	23.4	3	8.5	21	0.7	2	9.7	2	19.0	--	<0.1	5	6.5
Carangidae	--	0.1	17	0.3	11	1.9	--	0.1	--	0.2	18	1.1	21	0.7
Gerridae	0	0	0	0	0	0	0	0	0	0	14	1.7	19	0.8
Gobiidae	--	0.1	13	0.6	22	0.5	18	0.2	22	0.4	19	1.0	22	0.7
Pomadasyidae	0	0	0	0	0	0	0	0	0	0	17	1.1	23	0.5
Sciaenidae	13	0.4	10	1.5	23	0.5	10	0.6	12	0.8	11	2.3	13	1.5
Scorpaenidae:														
(incl. *Sebastes*)	7	0.7	16	0.3	10	2.3	8	0.9	16	0.5	16	1.2	18	1.0
Serranidae	--	<0.1	--	<0.1	18	0.7	--	<0.1	--	0.2	7	2.8	14	1.5
Trichiuridae	18	0.1	--	<0.1	12	1.6	23	0.1	--	<0.1	6	3.8	11	2.0
Bothidae	15	0.3	9	1.8	8	3.7	13	0.5	14	0.7	12	2.2	12	1.7
Cynoglossidae:														
Symphurus spp.	9	0.5	--	0.1	15	1.2	7	0.9	19	0.4	--	0.3	25	0.4
Disintegrated specimens	23	0.1	19	0.2	--	0.3	20	0.1	20	0.4	8	2.8	15	1.5
Unidentified	14	0.3	8	2.2	6	8.9	9	0.7	6	4.7	9	2.7	9	2.7
All others	--	2.0	--	3.6	--	7.0	--	2.1	--	4.8	--	4.8	--	4.0

rank to seventh, sixth, and eighth during the next three cruises, and increased again to third on 5706. Its composite rank for all six cruises was second. Except for cruise 5706, this species was characterized by a relatively low number of occurrences. For example, on cruise 5604 it occurred on only six stations but accounted for nearly half the fish larvae taken on the entire cruise. Similarly clumped occurrences of this species were found on EASTROPAC cruises (Ahlstrom 1972).

Three species of lanternfishes of the family Myctophidae were abundant. The most consistent of these was *Diogenichthys laternatus* which ranked among the top five kinds of larvae in total abundance on all cruises except 5706, and ranked as high as third on two cruises (5702, 5704). It also had a consistently high number of occurrences, ranging from 29 in 5704 to 49 in 5706. For all cruises *D. laternatus* ranked sixth with 5.1% of the total larvae. Another lanternfish, *Triphoturus mexicanus,* ranked among the top ten on only three cruises, but on these it ranked first in abundance on 5612, fifth on 5704, and fourth on 5706. For all cruises *T. mexicanus* larvae ranked fourth with 7.5% of total fish larvae. *Benthosema panamense* ranked among the upper ten most abundant only on 5612 and 5706, but on these cruises ranked fourth and third, respectively. Its overall ranking was eighth.

Another midwater species, the deepsea smelt, *Leuroglossus stilbius,* was consistently abundant on five of the six cruises. It ranked fifth on 5602, sixth on 5604, thirteenth on 5612, fourth on 5702, and ninth on 5704. It also was characterized by a high number of occurrences, and on 5602 had the most occurrences (50) of any species collected. Being a species of northern affinity it occurred on only a single station on the warm water cruise of 5706. Its overall rank was tenth, with 2.0% of the total larvae.

It is interesting to compare the relative abundance of species of these cruises with the rankings for waters of the same latitudes on the outer coast. In 1956 (Table 4) the northern anchovy, *Engraulus mordax,* was by far the most abundant species, at about 38% of the total, followed by the hake, *Merluccius producuts,* with about 28%. These were followed by the sardine, *Sardinops sagax caeruleus,* and the genera *Sebastes* and *Citharichthys,* each of which made up about 4% of the catch. The lanternfish, *Triphoturus mexicanus,* and the tropical gonostomatid, *Vinciguerria lucetia,* ranked sixth and seventh at about 3% of the catch. In 1957, a warmer year, *E. mordax* remained the most abundant, but was followed closely by *V. lucetia*

TABLE 4

Relative abundance of fish larvae obtained on all CalCOFI cruises off the western coast of Baja California in 1956

Species	Rank	Standard No. of larvae	Percent of total	No. of occurrences
Engraulis mordax	1	116,464	37.6	363
Merluccius productus	2	87,708	28.3	281
Sardinops sagax caeruleus	3	13,975	4.5	149
Sebastes spp.	4	12,489	4.0	284
Citharichthys spp.	5	12,102	3.9	218
Triphoturus mexicanus	6	10,526	3.4	296
Vinciguerria lucetia	7	9,781	3.1	220
Leuroglossus stilbius	8	6,934	2.2	253
Trachurus symmetricus	9	5,907	1.9	156
Diogenichthys laternatus	10	3,123	1.1	115
Stenobrachius leucopsarus	11	2,009	0.6	98

TABLE 5

Relative abundance of fish larvae obtained on all CalCOFI cruises off the western coast of Baja California in 1957

Species	Rank	Standard No. of larvae	Percent of total	No. of occurrences
Engraulis mordax	1	66,502	26.0	376
Vinciguerria lucetia	2	54,369	21.2	546
Merluccius productus	3	46,298	18.1	227
Triphoturus mexicanus	4	15,308	5.9	578
Citharichthys spp.	5	14,224	5.5	326
Diogenichthys laternatus	6	11,581	4.5	398
Trachurus symmetricus	7	10,093	3.9	178
Sardinops sagax caeruleus	8	7,711	3.0	148
Leuroglossus stilbius	9	3,742	1.4	155
Stenobrachius leucopsarus	10	1,244	0.4	51
Sebastes spp.	11	1,014	0.3	227

(Table 5). The hake remained abundant, in third place, followed by *T. mexicanus, Citharichtys* spp., and the warm-water lanternfish, *Diogenichthys laternatus.*

It is also useful to compare the relative abundance of species of the Gulf cruises of 1956 and 1957, with those of a recent cruise in a restricted area of the northern Gulf (Table 6). In March 1972 the Mexico/FAO/UNDP Fisheries Research and Development Program research vessel, ALEJANDRO DE HUMBOLDT, occupied 28 stations, largely in the cold water region around Ángel de la Guarda and Tiburón Islands. The hake, *Merluccius* sp., made up over half of the the total followed by *Leuroglossus stilbius* and *Citharichthys* spp. at about 9% of the total. The gadoid genus, *Physiculus,* ranked 4th at about 4%, followed by *Etrumeus teres, Diogenichthys laternatus,* and *Sardinops sagax caeruleus* each at about 3%. It is apparent that the rankings from this cruise in a restricted area of cold water in the northern Gulf correlate more closely with the rankings for the outer coast waters during 1956 and 1957 than with those within the Gulf for those years.

The seasonal fluctuations in areal distribution of fish larvae within the Gulf are shown in Figures 4–24.

Larvae of the Pacific mackerel, *Scomber japonicus,* were widespread in the southern region of the Gulf during the February cruises of both years (Figures

TABLE 6

Relative abundance of fish larvae obtained on cruise 7203 of the Mexican research vessel ALEJANDRO DE HUMBOLDT in the Gulf of California

Kinds of Larvae	Rank	Standard No. of larvae	Percent of total	No. of occurrences
Merluccius spp.	1	4,301	56.6	17
Leuroglossus stilbius	2	716	9.4	9
Citharichthys spp.	3	709	9.3	14
Physiculus spp.	4	314	4.1	13
Etrumeus teres	5	253	3.3	12
Sardinops sagax caeruleus	6	205	2.7	10
Diogenichthys laternatus	7	205	2.7	5
Sebastes spp.	8	194	2.6	16
Unidentified	9	123	1.6	13
Scomber japonicus	10	76	1.0	5
Argentina sialis	11	74	1.0	5
Triglidae	12	74	1.0	8
Vinciguerria lucetia	13	54	0.7	4
Carangidae	14	42	0.6	2
Bregmaceros bathymaster	15	41	0.5	1
Stromateidae	16	37	0.5	2
Stomias atriventer	17	35	0.5	5
Scorpaenidae	18	32	0.4	4
Benthosema panamense	19	25	0.3	1
Symphurus spp.	20	25	0.3	1
Macrouridae	21	21	0.3	3
Disintegrated	22	19	0.2	4
Heterostomata	23	12	0.2	3
Sciaenidae	24	6	0.1	1
Triphoturus mexicanus	25	5	0.1	1
Leptocephali	26	3	<0.1	1

4, 5). Abundance tended to diminish towards the north and their distribution terminated well south of Tiburon Island. In the April cruises, *S. japonicus* larvae were widespread and abundant throughout all regions of the Gulf with some regions of coastal concentration and with a marked absence at the cold water region around the large islands of the upper Gulf. The lower abundance toward the north on the February

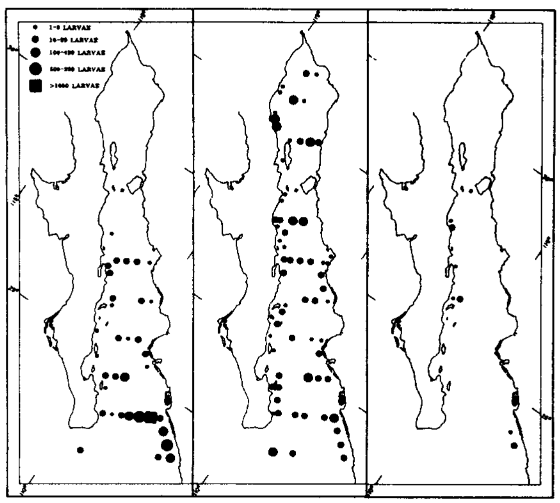

FIGURE 4. Distribution and abundance of *Scomber japonicus* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

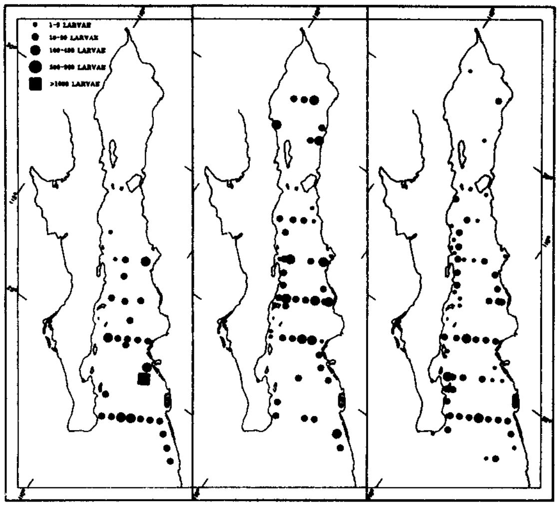

FIGURE 5. Distribution and abundance of *Scomber japonicus* larvae on CalCOFI cruises 5702 (left) and 5704 (center) and *Auxis rochei* larvae on cruise 5706 (right) in the Gulf of California.

cruises suggests a progression of spawning related to rising surface temperatures.

Larvae of *S. japonicus* were strikingly more abundant and widespread in the Gulf than on the outer coast, where they averaged about three larvae per station during the spawning seasons of 1956 and 1957. In the Gulf the average for the February and April cruises was about 39 larvae per station.

The abundance of *S. japonicus* in the Gulf is even more apparent from egg abundance, which was over 3,000 per station in some areas of the Gulf (Figure 6).

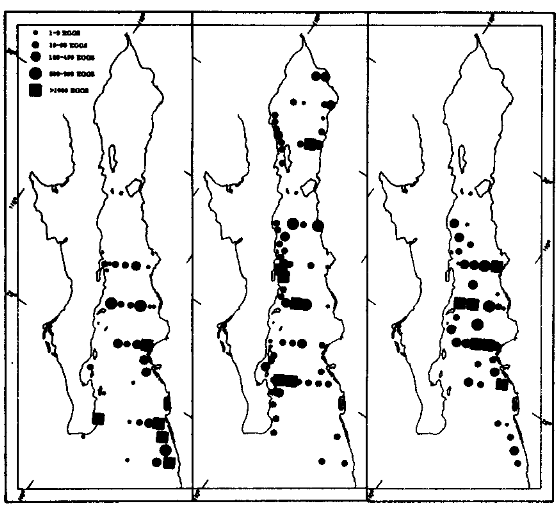

FIGURE 6. Distribution and abundance of *Scomber japonicus* eggs in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5702 (right).

The widespread nature of spawning in 5604 is shown in the chart, as is the avoidance of the cold water region around the large islands. Approximate calculation of spawning stock size from egg abundance, using the method of Ahlstrom (1968), gives a conservative estimate of about 500,000 metric tons for 5602 and about 300,000 tons for 5604 and 5702. This is at least five times the estimate for the spawning stock on the outer coast during the same years.

Concomitant with the marked scarcity of *S. japonicus* larvae on cruise 5706, the larvae of other scombrids made their appearance. Larvae of the bullet mackerel, *Auxis rochei,* were abundant and widely distributed in the central and southern Gulf and occurred on a few stations in the upper region (Figure 5). Larvae of the black skipjack, *Euthynnus lineatus,* occurred in the southern region but were fewer in the central region and did not occur in the north (Figure 7). The larvae of the bonito, *Sarda chiliensis,* and the

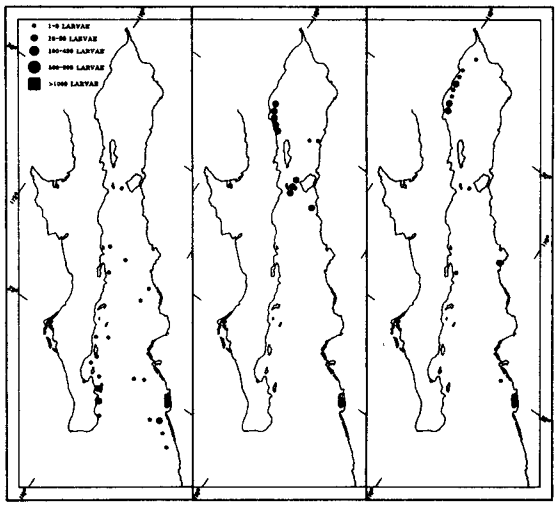

FIGURE 7. Distribution and abundance of larvae of *Euthynnus lineatus* (left), *Sarda chiliensis* (center) and *Scomberomorus* spp. (right) on CalCOFI cruise 5706 in the Gulf of California.

sierra, *Scomberomorus* spp., showed a nearly opposite distribution with a small area of high concentration along the western coast of the upper Gulf and only a few occurrences to the south (Figure 7).

The sardine, *Sardinops sagax caeruleus,* is a species of northern affinity, occurring from British Columbia to the Cape San Lucas region. On the February cruises (Figures 8, 9) its larvae were widespread and abundant in the central region and diminished to the north and south. In the April cruises larvae occurred widely in the upper Gulf but remained most abundant in the central region of the Gulf. The eggs showed a patchy and more restricted distribution, with high numbers in the central portion of the Gulf and isolated patches in the northern and southern regions (Figure 10). Calculation of spawning stock size from egg abundance gives an estimate of about 48,000, 505,000 and

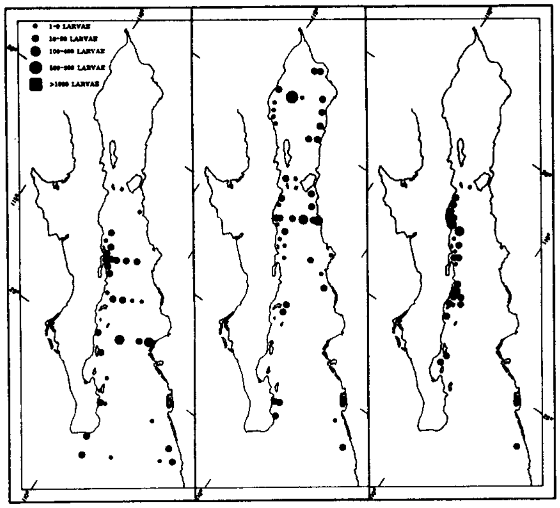

FIGURE 8. Distribution and abundance of *Sardinops sagax caeruleus* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

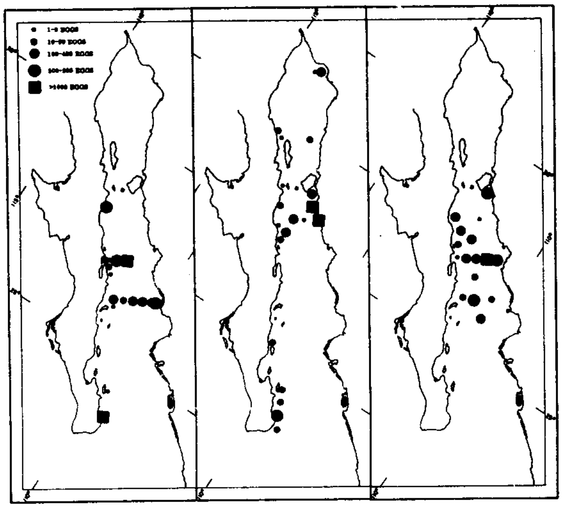

FIGURE 10. Distribution and abundance of *Sardinops sagax caeruleus* eggs in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5702 (right).

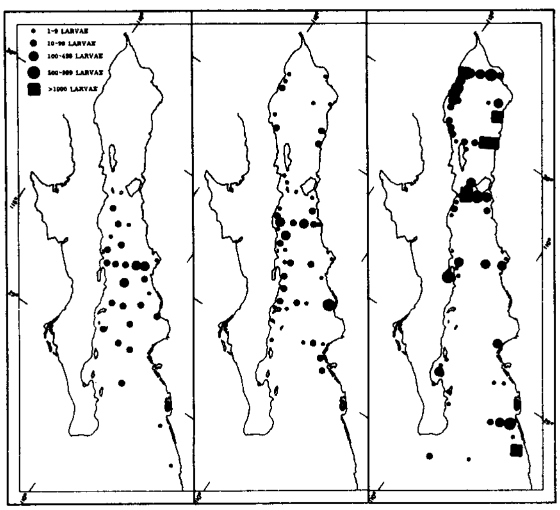

FIGURE 9. Distribution and abundance of *Sardinops sagax caeruleus* larvae on CalCOFI cruises 5702 (left) and 5704 (center) and larvae of *Opisthonema* spp. on cruise 5706 (right) in the Gulf of California.

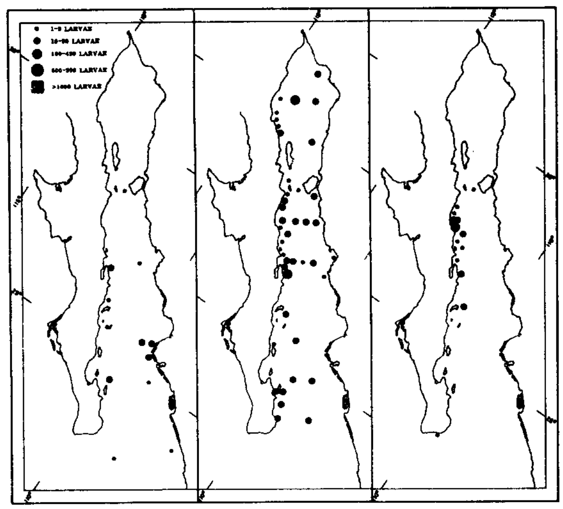

FIGURE 11. Distribution and abundance of *Etrumeus teres* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

74,000 metric tons for 5602, 5604, and 5702 respectively.

As with other species of northern affinity, the larvae of the sardine were not present during the June cruise. This void was filled by the larvae of the tropical clupeid genus, *Opisthonema* (Figure 9). The larvae were patchily distributed throughout the Gulf with pockets of high concentration in coastal areas, and even in Bahía Concepción.

Larvae of the round herring, *Etrumeus teres,* had a seasonal fluctuation in abundance (Figures 11, 12). They occurred scantily in the southern and central regions during February. In April of 1956 they were widespread and abundant throughout the entire Gulf but in 5704 they were only abundant in the upper and central regions and were almost absent in the southern region. In 5706 they occurred only in the upper Gulf and on two stations in the vicinity of La Paz.

Vinciguerria lucetia has the typical distributional pattern for tropical midwater species in the Gulf—decreasing abundance from south to north (Figures

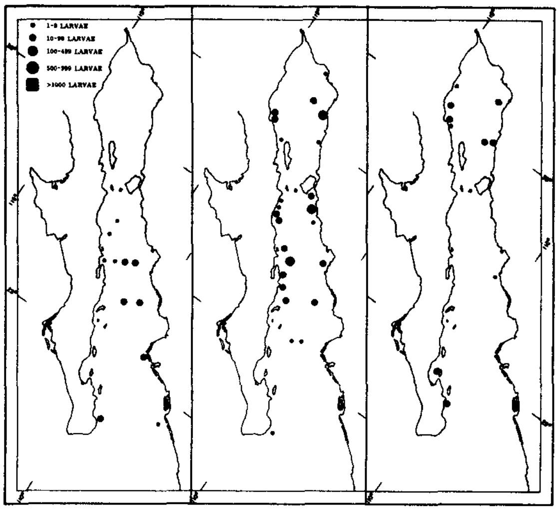

FIGURE 12. Distribution and abundance of *Etrumeus teres* larvae in the Gulf of California on CalCOFI cruises 5702 (left), 5704 (center) and 5706 (right).

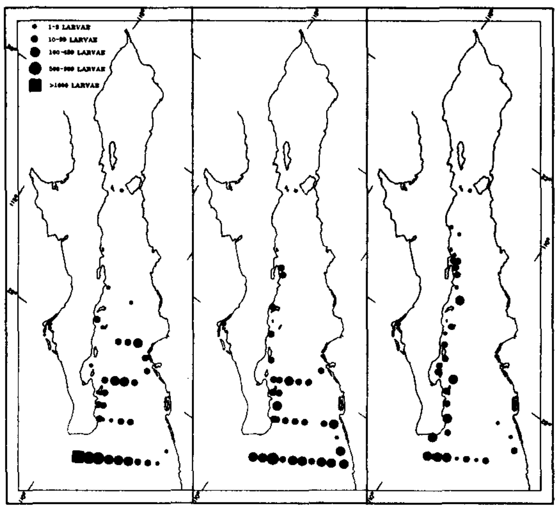

FIGURE 13. Distribution and abundance of *Vinciguerria lucetia* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

13, 14). In five of the six cruises shown, this species was widespread and abundant in the southern Gulf, scattered and much less abundant in the central Gulf, and absent from the upper portion. Only in 5706 did the larvae appear in abundance as far north as Tiburón Island. Here also there was a single record in the upper Gulf. Within its latitudinal range in the Gulf, *V. lucetia,* like other abundant midwater species, tends to be more concentrated over the deep waters of the central and western side of the Gulf, compared with the shallower waters of the eastern side.

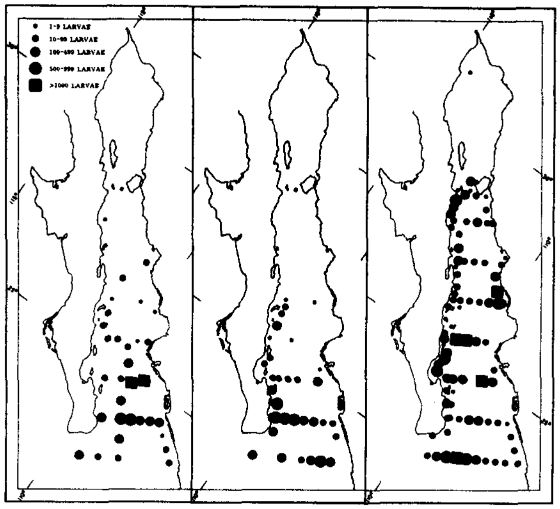

FIGURE 14. Distribution and abundance of *Vinciguerria lucetia* larvae in the Gulf of California on CalCOFI cruises 5702 (left), 5704 (center) and 5706 (right).

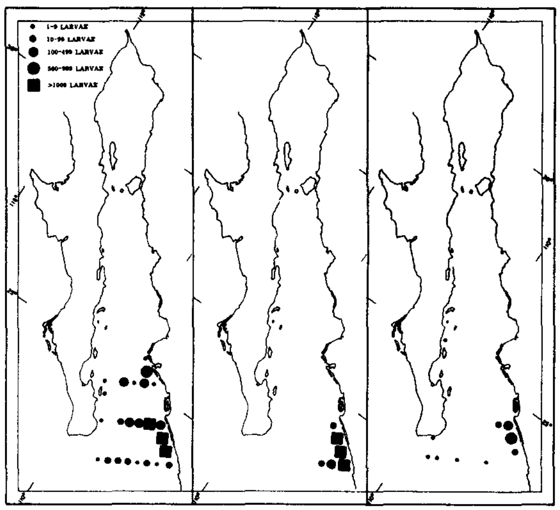

FIGURE 15. Distribution and abundance of *Bregmaceros bathymaster* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

Larvae of *Bregmaceros bathymaster* had a highly concentrated and restricted distribution at the southern end of the Gulf on five of the six cruises (Figures 15, 16). On 5706 the larvae were widespread and abundant as far north as Tiburón Island. On all these cruises it is evident that the species is concentrated near shore and shows a general diminution over open water areas of the Gulf. This is consistent with Ahlstrom's (1971, 1972) findings that *B. bathymaster* is a coastal species in the eastern tropical Pacific.

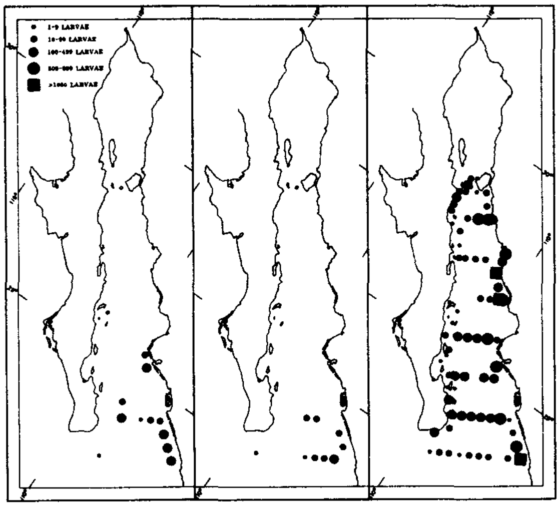

FIGURE 16. Distribution and abundance of *Bregmaceros bathymaster* larvae in the Gulf of California on CalCOFI cruises 5702 (left), 5704 (center) and 5706 (right).

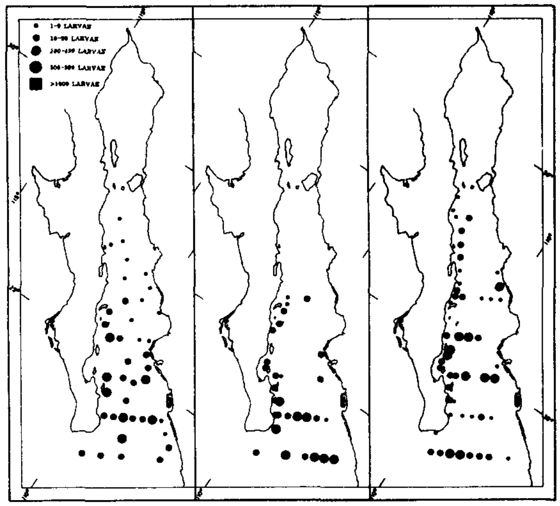

FIGURE 18. Distribution and abundance of *Diogenichthys laternatus* larvae in the Gulf of California on CalCOFI cruises 5702 (left), 5704 (center) and 5706 (right).

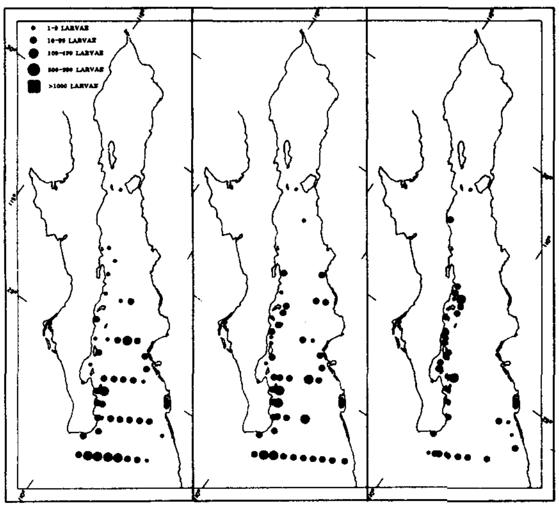

FIGURE 17. Distribution and abundance of *Diogenichthys laternatus* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

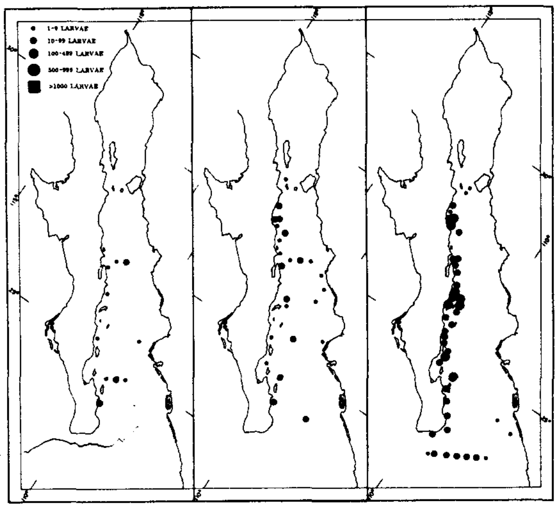

FIGURE 19. Distribution and abundance of *Triphoturus mexicanus* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

The lanternfish, *Diogenichthys laternatus*, has a distribution similar to that of *Vinciguerria* (Figures 17, 18). It is widespread and abundant in the southern region, diminishes markedly in abundance in the central region, and is totally absent from the upper Gulf. Like *Vinciguerria* it tends to be more abundant in the center and along the western side of the Gulf, generally avoiding the shallow areas of the eastern side.

The lanternfish, *Triphoturus mexicanus*, showed a marked seasonal abundance (Figures 19, 20). On the two February cruises, larvae were scarce and were restricted to the central and southern regions of the Gulf. Larvae were abundant and widespread on the two April cruises but remained restricted to the central and southern regions. The tendency for larvae to be concentrated along the western side of the Gulf and to diminish in density towards the east and near the mouth of the Gulf is beginning to be evident on these cruises. This tendency is strikingly illustrated on 5706, where abundance has increased markedly and some larvae occurred in the upper Gulf. It is obvious that the center of distribution of *T. mexicanus* in the

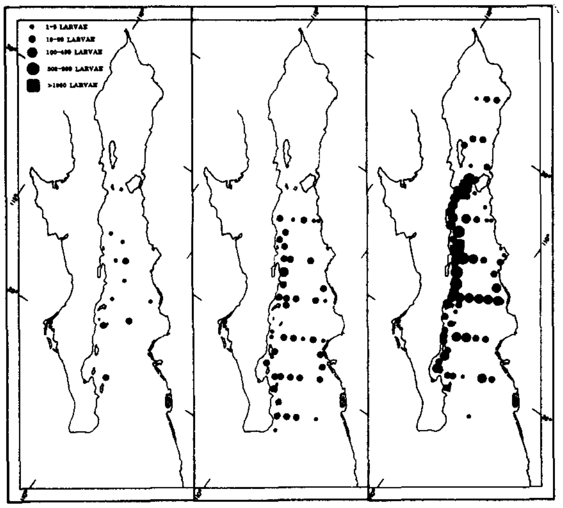

FIGURE 20. Distribution and abundance of *Triphoturus mexicanus* larvae in the Gulf of California on CalCOFI cruises 5702 (left), 5704 (center) and 5706 (right).

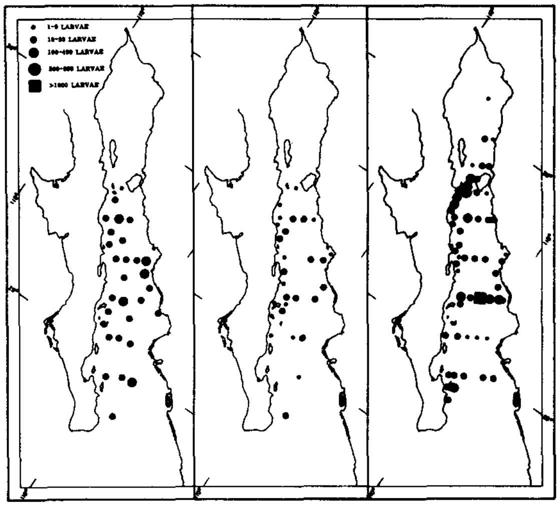

FIGURE 22. Distribution and abundance of *Leuroglossus stilbius* larvae on CalCOFI cruises 5702 (left) and 5704 (center) and *Benthosema panamense* larvae on cruise 5706 (right) in the Gulf of California.

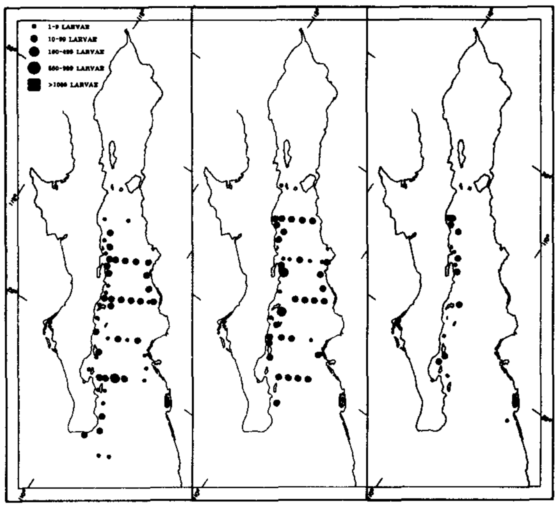

FIGURE 21. Distribution and abundance of *Leuroglossus stilbius* larvae in the Gulf of California on CalCOFI cruises 5602 (left), 5604 (center) and 5612 (right).

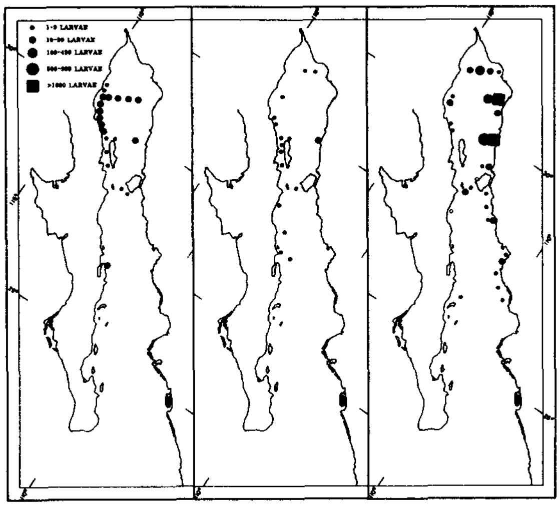

FIGURE 23. Distribution and abundance of larvae of *Merluccius* sp. on CalCOFI cruise 5604 (left), larvae of *Sebastes* spp. on cruise 5604 (center) and *Trichiurus nitens* larvae on cruise 5706 (right) in the Gulf of California.

Gulf is in the central region along the islands of the western coast. A very similar pattern of distribution is shown for the myctophid, *Benthosema panamense* (Figure 22).

The deep sea smelt, *Leuroglossus stilbius,* is essentially a cold water species that ranges from Cape San Lucas to the Gulf of Alaska. It has a distributional pattern that is somewhat similar to that of *T. mexicanus* although spawning occurs more evenly throughout the cold months of the year (Figures 21, 22). Larvae were abundant and widely distributed throughout the central region of the Gulf during February and April but their northward distribution terminated abruptly at Tiburón Island and more gradually southward towards the mouth. Within its latitudinal range in the Gulf, *L. stilbius* is evenly distributed and does not appear to concentrate along the western side like *T. mexicanus.*

Larvae of the genus *Sebastes* are definitely cold water fishes, and the restriction of their larvae to the cold water region around the large islands in the

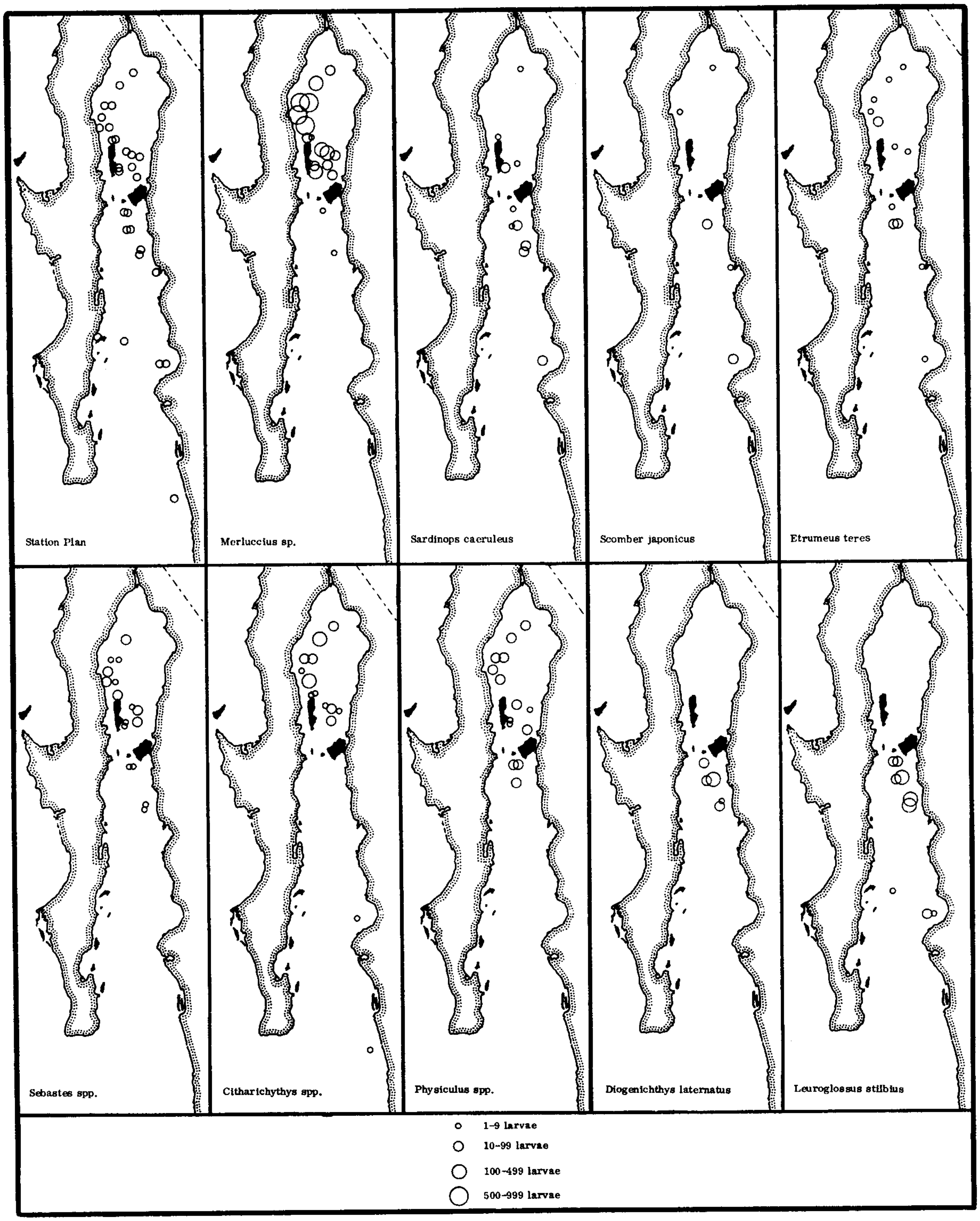

FIGURE 24. Distribution and abundance of the nine most abundant larvae obtained on cruise 7203 (March, 1972) of the Mexico/FAO/UNDP Fisheries Research and Development Program in the Gulf of California.

upper Gulf is shown in Figure 23. The larvae of the hake, *Merluccius* sp., have a similar distribution in the vicinity of these islands (Figure 23). According to Dr. Mathews (see this symposium) these larvae are of an endemic species which occurs southward as far as Bahía Concepción. The larvae of the cutlassfish, *Trichiurus nitens,* has an interesting distribution (Figure 23). It is abundant along the eastern coast of the upper Gulf and is scantily distributed along the eastern coast in the central region of the Gulf.

Areal distributions and abundances of larvae from the cruise of the ALEJANDRO HUMBOLDT in March of 1972 are shown in Figure 24. Although the pattern of stations was largely concentrated in the vicinity of the large islands in the upper Gulf, the larval distributions correlate closely with those shown by the more extensive CalCOFI cruises. The hake, *Merluccius* sp., was extremely abundant near and to the north of the island. The three epipelagic species, *Sardinops sagax caeruleus, Scomber japonicus,* and *Etrumeus teres,* were move evenly distributed throughout the station pattern. The rockfishes, *Sebastes* spp., had a distribution similar to *Merluccius*, as did the larvae of the gadoid genus *Physiculus*. The two midwater species, *Leuroglossus stilbius* and *Diogenichthys laternatus,* were restricted to south of Tiburón Island.

DISCUSSION

The Gulf of California offers a paradoxical environment for those organisms that would invade its waters and flourish. On one hand it has some of the greatest environmental extremes of any of the world's seas. With a seasonal surface temperature flux that increases from 9° C at the mouth to as high as 22° C at the head, it offers the most extreme annual temperature range of any region in the eastern Pacific. An evaporation basin, its surface salinities are typically 1–2‰ higher than waters of the outer coast and increase 1–2‰ from the mouth to the head of the Gulf. The extreme tidal ranges of the upper Gulf, as great as 10 m, are well known. Equally well known is the pronounced oxygen minimum of 0.1–0.2 ml/L at 400–800 m depth in the central and southern Gulf.

Counterposed against these conditions is the great productivity of the Gulf. Prevailing northerly winds during the winter months induce upwelling in the lee of islands and capes along the eastern coast, while during summer months, the prevailing southerly winds cause upwelling along the peninsular coast. Tidal currents around the large islands of the upper Gulf insure a continual vertical mixing of water in that region. The result of this widespread upwelling of nutrient-rich water is an enormous productivity. The year-round plankton blooms are a notable feature of the Gulf and provoked the early explorer, Ulloa, to name it the "Vermillion Sea" (van Andel, 1964). Such productivity, with its attendant abundance of life at higher levels of the food web would seem to assure a propitious environment for those fish species capable of meeting the environmental demands outlined above. That the harsh environmental factors reduce the attractiveness of this environment is obvious from an examination of the ichthyofauna.

The depauperate nature of the shorefish fauna has been described by Hubbs (1960), Hubbs and Roden (1964) and Walker (1960). Isolated from the effects of the cold California Current, except in the area of Cabo San Lucas, the elevated water temperatures have allowed Panamic shorefishes to dominate the Gulf and extend considerably northward of their limits on the outer coast. The paucity of certain Panamic groups (croakers, catfishes, and anchovies) indicates their inability to adapt to the environmental extremes of the Gulf. In contrast, these extremes, along with the abundance and isolated nature of rocky shore habitats have allowed an impressive evolution of blennioid fishes.

The midwater fish fauna, also dominated by warm water species, is even more depauperate than the shorefish fauna (Lavenberg and Fitch, 1966; Robison, 1972, Brewer, 1973). These investigators have established that only a few midwater species are abundant and that most of midwater species recorded for the Gulf are restricted to the southern portion. This is even more graphically shown by the data on larvae presented herein. The larvae of only six mesopelagic species were abundant. The gonostomatid, *Vinciguerria lucetia,* ranked first among all species recorded and represented 22% of all the fish larvae obtained in the six cruises. Striking in their total absence were the larvae of the gonostomatid genus, *Cyclothone,* which are extremely abundant in waters adjacent to the Gulf. Less abundant than *V. lucetia* but prominent on certain cruises were the myctophids, *Benthosema panamense, Diogenichthys laternatus,* and *Triphoturus mexicanus* and the bathylagid smelt, *Leuroglossus stilbius.* The gadoid, *Bregmaceros bathymaster,* was abundant on all cruises and ranked second in overall abundance with 19% of all larvae obtained on the six cruises. Only a few adults of *B. bathymaster* were recorded from the three midwater trawling expeditions, indicating that plankton hauls obtain a much more representative sampling of a fauna than do midwater trawls.

Except for *T. mexicanus* and *B. panamense,* which occurred sparsely in the upper Gulf on cruise 5706, the larvae of the abundant midwater species were restricted to the central and southern Gulf. The proclivity of these species for waters of the western side of the Gulf is strikingly illustrated by the distribution of *T. mexicanus* larvae on cruise 5706. Larval abundance of the warm water species, *V. lucetia, B. panamense, D. laternatus, T. mexicanus,* and *B. bathymaster,* increased with rising water temperatures and were most abundant on cruise 5706. Also, the areal extent of spawning increased northward with rising water temperatures. This is best illustrated by *B. bathymaster* larvae which were restricted to the extreme southern Gulf from December to April but were abundant and widespread northward to Tiburon Island in June of 1957. Larvae of the bathylagid smelt, *L. stilbius,* of northern affinity, showed an opposite pattern of seasonal abundance. They were abundant and widespread during the cold months and all but absent on the June cruise.

The larval distributions clearly show that the abundant midwater species of the Gulf are restricted areally and in season of reproduction. Why these few species should be able to flourish in the Gulf, while the members of the rich midwater fauna of adjacent waters are excluded is of great interest. All of the abundant Gulf species have wide latitudinal ranges outside the Gulf and are equipped to tolerate the seasonal temperature range of the Gulf. Probably more important than this is their ability to tolerate the low oxygen concentrations at 400–800 m depth. The effect of this oxygen-poor zone is certainly obvious where it impinges on the coast, as Parker (1964) has shown that these areas are all but devoid of animal life. Also suggestive of the importance of the oxygen minimum zone is the fact that *Scopelarchoides nicholsi*, the sole scopelarchid recorded from the Gulf, has the greatest development of gill filaments of any member of that family (Johnson, 1971). The vertical distributions of most of the abundant midwater species of the Gulf are shoaler than 400 m (Robison, 1972) thus they have adapted to the oxygen minimum zone by simply avoiding it. The exception, *T. mexicanus,* whose daytime depths overlap broadly with the oxygen minimum zone, may adapt behaviorly by becoming lethargic as suggested by Barham (1970).

The epipelagic species of commercial importance are largely unaffected by the oxygen minimum layer. The larval data shows that two species of northern affinity, *Scomber japonicus* and *Sardinops sagax caeruleus,* are strikingly abundant throughout the Gulf. These species have broad latitudinal ranges outside of the Gulf and are well suited to tolerate the Gulf's annual temperature extremes. Spawning of these species is restricted to the cold water months as illustrated by the near absence of their larvae in the June cruise. During warm water months *Sardinops* larvae are replaced by those of the warm water Clupeid genus, *Opisthonema,* which appears to be heavily concentrated in the upper Gulf. The data suggests that these thread herring may be the most abundant pelagic fishes in the Gulf since their larvae represented 9 percent of the total fish larvae even though a fraction of their probable spawning season was sampled. The larvae of *Scomber* are replaced by those of the more tropical scombrids *Auxis, Euthynnus, Sarda* and *Scomberomorus.* Of these, *Auxis* larvae are the most widespread and abundant, although the restricted distributions of the others may simply reflect the partial sampling of their spawning seasons.

The data from the recent plankton tows of the ALEJANDRO DE HUMBOLDT in March 1972 indicate that the demersal hake, *Merluccius* sp., is an extremely abundant fish in the upper Gulf, particularly in the areas just east and north of Angel de la Guarda Island. This abundance was not apparent from the data of the CalCOFI cruises, since only on cruise 5604 were significant numbers of larvae taken. A possible explanation for this is that the reproductive season of the species is very short. It may reach its peak in March, as suggested by the data from cruise 7203, and may last only a month. This could explain the poor representation of *Merluccius* larvae in the CalCOFI samples of February and April. Such an abbreviated reproductive season, limited to the coldest time of the year, is also typical of *Sebastes* and other pleistocene relicts of the upper Gulf.

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