Title:

Systematics, distribution, and abundance of the epiplanktonic squid (Cephalopoda, Decapoda) larvae of the California Current, April, 1954- March, 1957

Author:
Okutani, Takashi
McGowan, John A.

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Abstract:
Our knowledge of the biology of oceanic cephalopods is extremely limited. The population sizes, distribution patterns, breeding seasons, life histories, and growth rates are virtually unknown. In view of the fact that these organisms are undoubtedly abundant and ecologically important, both as predators and prey, this state of ignorance is unfortunate. Part of the reason for this lack is attributable to the great difficulty of adequately sampling the adults. The larvae and some juveniles, however, can be caught, in the types of plankton nets and trawls generally in use. Therefore the possibility exists that the times and places of spawning, and the developmental history of many species, may be determined from zooplankton surveys. Using this approach presupposes that a sufficiently extensive area is surveyed and that the sampling is intensive in both space and time. It is also necessary that enough specimens of the adults and intermediate-sized ranges be available for accurate identification of the larvae. This is best done by tracing the morphological changes through progressively smaller individuals. The Marine Life Research Group at Scripps Institution of Oceanography (SIO) has available a very large collection of zooplankton samples taken by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) in the California Current. This program has surveyed a large portion of this current system by monthly cruises for a period of ten years. It is from these samples that the data in this report are derived.

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BY
TAKASHI OKUTANI and JOHN A. McGOWAN

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CONTENTS

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BY

TAKASHI OKUTANI* and JOHN McGOWAN

INTRODUCTION

Our Knowledge of the biology of oceanic cephalopods is extremely limited. The population sizes, distribution patterns, breeding seasons, life histories, and growth rates are virtually unknown. In view of the fact that these organisms are undoubtedly abundant and ecologically important, both as predators and prey, this state of ignorance is unfortunate. Part of the reason for this lack is attributable to the great difficulty of adequately sampling the adults. The larvae and some juveniles, however, can be caught, in the types of plankton nets and trawls generally in use. Therefore the possibility exists that the times and places of spawning, and the developmental history of many species, may be determined from zooplankton surveys. Using this approach presupposes that a sufficiently extensive area is surveyed and that the sampling is intensive in both space and time. It is also necessary that enough specimens of the adults and intermediate-sized ranges be available for accurate identification of the larvae. This is best done by tracing the morphological changes through progressively smaller individuals.

The Marine Life Research Group at Scripps Institution of Oceanography (SIO) has available a very large collection of zooplankton samples taken by the California Cooperative Oceanic Fisheries Investigations in the California Current. This program has surveyed a large portion of this current system by monthly cruises for a period of ten years. It is from these samples that the data in this report are derived.

ACKNOWLEDGMENTS

We wish to acknowledge the cooperation of the Bureau of Commercial Fisheries at La Jolla for their assistance in sorting the cephalopod larvae from these samples. The Marine Life Research Program has provided material assistance. A portion of the work has been supported by the National Science Foundation under the terms of a grant (G-19417). Miss Vernie Fraundorf has rendered valuable aid in the preparation of the manuscript.

While all the work in this report was done jointly, the systematics section is primarily that of T. Okutani, and the other sections that of J. A. McGowan.

METHODS OF COLLECTION

The cephalopod larvae described in this report came from zooplankton collections made in the California Current by the California Cooperative Oceanic Fisheries

* Tokai Regional Fisheries Research Laboratory, Tokyo.

Investigations (CalCOFI) during the years 1954, 1955, 1956, and 1957. Throughout this program only one type of plankton net was used: a net with a mouth diameter of 1 meter and a length of 5 meters. It is conical in shape and made of heavyduty, grit-gauze silk, 0.65 mm between the threads. Ahlstrom (1948) has published an illustration and description of this net.

The volume of water filtered by the net was measured by a flow meter suspended in its mouth. The amount of water filtered can be derived from the flow-meter readings by the method described by Ahlstrom (1948). For the samples used in

TABLE 1

CalCOFI Cruises and Stations, April, 1954, to March, 1957

Year and month[a]	Number of stations occupied	Year and month[a]	Number of stations occupied
5404	203	5512	106
5405	206	5601	112
5406	216	5602	132
5407	123	5603	135
5408	123	5604	179
5410	108	5605	239
5501	113	5606	210
5502	119	5607	203
5503	111	5608	36
5504	127	5609	36
5505	187	5610	42
5506	180	5611	40
5507	195	5701	57
5510	109	5703	124

[a] The first two digits of each number represent the year, the second two the month of that year. The first number is April of 1954. A plankton tow was taken on each of the stations occupied.

this report the volume filtered by the nets ranged between 450 m^3 and 950 m^3 with occasional figures somewhat higher or lower.

The method of taking the tows was also the same during the entire course of this survey. Oblique tows were taken to an average depth of 140 meters with occasional tows going somewhat deeper or shallower than this. The speed of the ship and the net through the water was approximately 1.5 knots (75 cm/sec). The original data on volumes of water filtered, depth of tows, and time of tows used in this study have been published (So. Pac. Fish. Invest., 1955, 1956; Thrailkill, 1957).

The station positions and station numbers are illustrated in figure 1 which shows the complete station pattern of the CalCOFI program. None of the individual cruises used in this study covered so large an area. The extent and distribution of the station pattern used here may be seen in figures 20 to 22. The 28 cruises studied took 3,895 plankton tows, all of which were examined. Of this number, 1,240 contained squid larvae. Table 1 shows by year and month the number of stations occupied.

It is the purpose of this report to present quantitative estimates of the distribution and abundance of larval squid, and, since this sampling program was

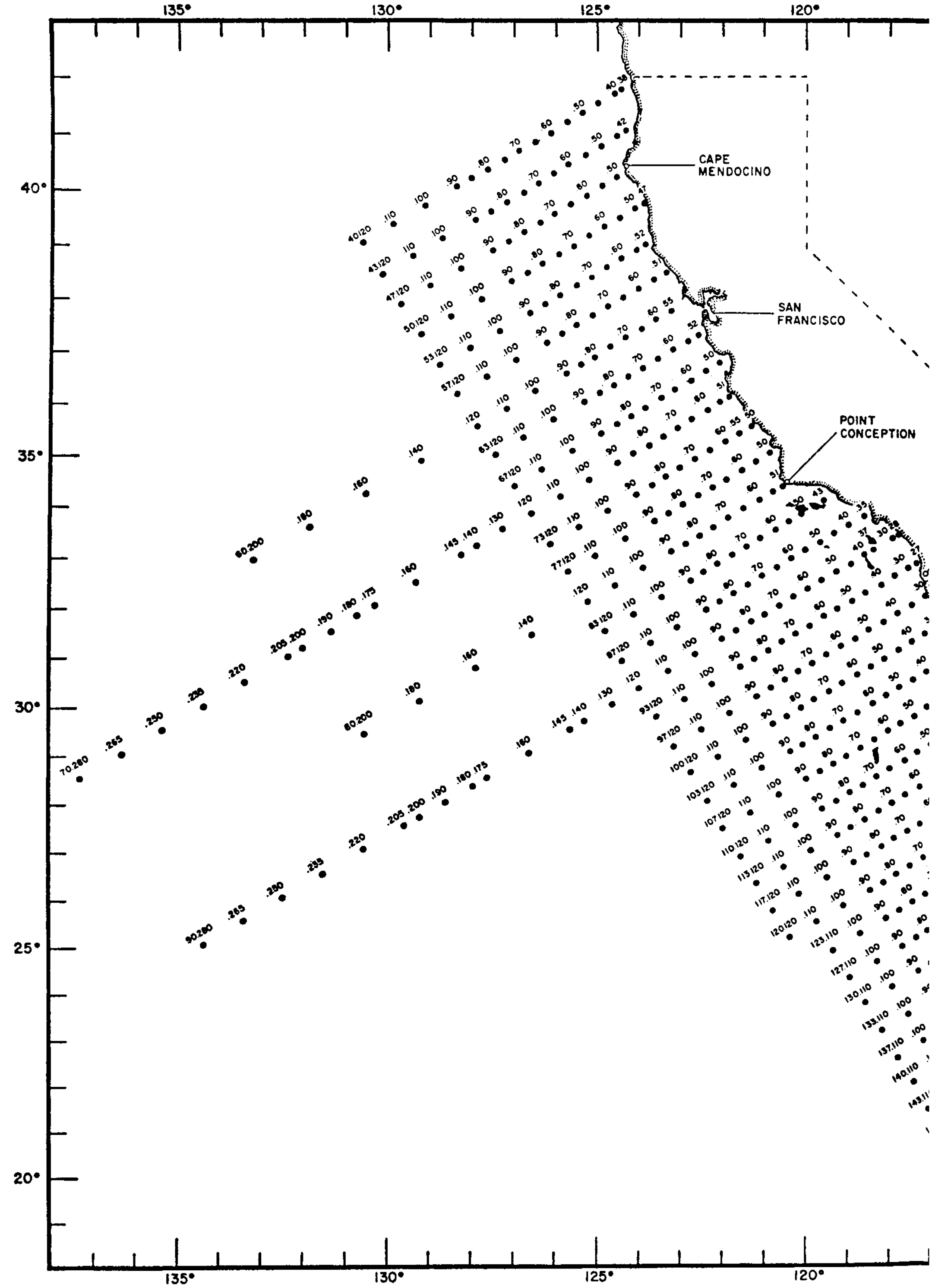
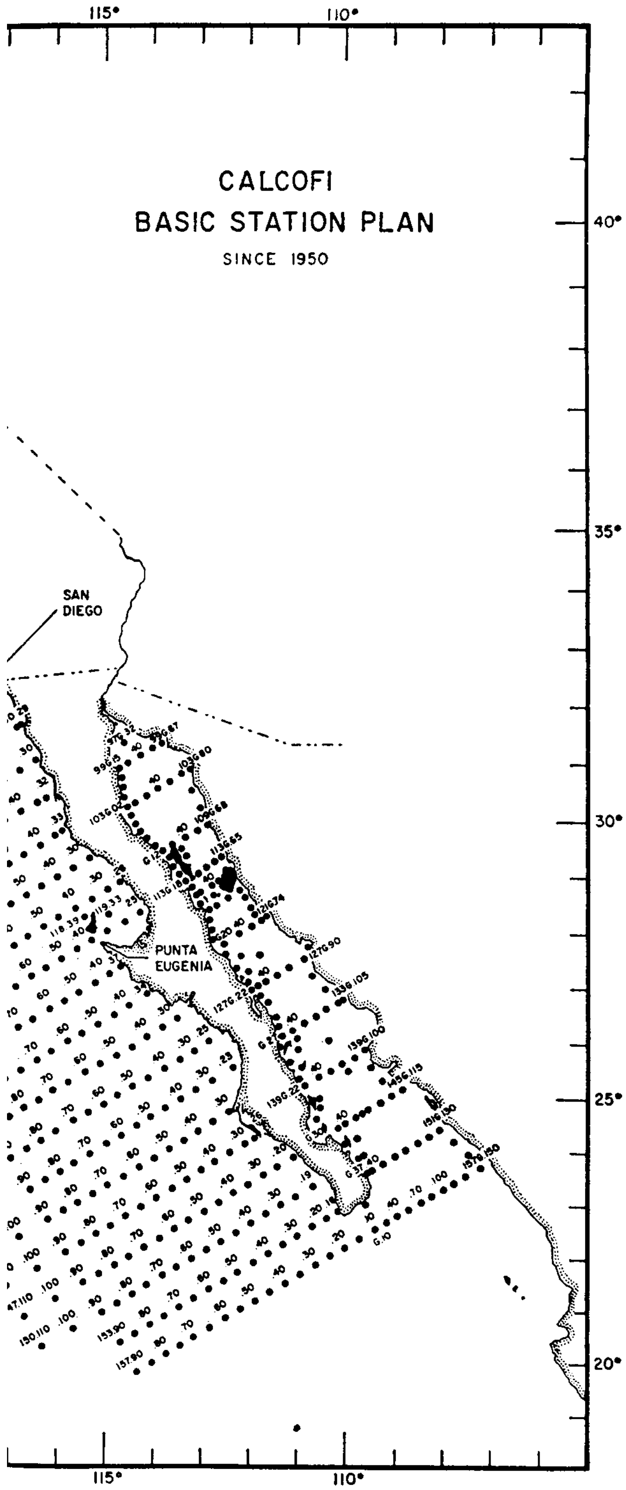


Fig. 1. Overall station plan of the California Cooperative Oceanic Fisheries Investigations. The numbers represent station numbers. These remained the same throughout the surveys.


CALCOFI
BASIC STATION PLAN
SINCE 1950
115°
110°
40°
35°
30°
25°
20°
SAN DIEGO
PUNTA EUGENIA

designed for larval fish, an examination of the efficiency of the methods is necessary (McGowan and Fraundorf, 1966). The first question that might be asked about the validity of the method is: Does the 1-meter net have a large enough mouth size to sample effectively larval squid? In order to obtain some information pertaining to this question, a study was undertaken in an area (22° 35′ N., 108° 14.6′ W., to 22° N., 108° 12′ W.) where the species diversity was known to be high, but the overall abundance was suspected to be rather law. Six nets of differing mouth diameters were used: 20, 40, 60, 80, 100, and 140 cm. Apart from the scale, the nets were identical in all other respects. The durations of the tows were such that all sampled very nearly the same volume of water. Four sets of 6 tows were taken, 2 during the night and 2 during the day. The sequence in which the different-sized nets were used was randomized.

The results of this study (tables 2, 3) indicate that a net of only 1 meter in mouth diameter and sampling less than 400 m^3 of water tends to underestimate the numbers of kinds of larval squid, as compared with a larger net sampling nearly the same volume of water. It very decidedly underestimates the species diversity as compared with a cumulative species list based on all 24 of the net tows. Of the 9 species shown to be present in the area at the time, the "best" 1-meter-net tow caught only three.

A second question may be asked about the validity of the method: Does the volume of water filtered give an adequate estimate of the species diversity and species abundance? A second sampling study was designed to provide some information on this subject. In an area (22° 50′ N., 109° 00′ W.) near the one described above, a series of 10 net tows were taken in which the mouth size of the net was held constant at 1 meter, but the volume of water filtered varied between 182 m^3 and 1,510 m^3. Table 4 shows the results of this study.

Of the five species of larval cephalopods shown to be present, the largest number of species caught on any of the tows was two. These two studies indicate that the sampling methods used during the survey may not be particularly appropriate for estimating species diversity and abundance of squid larvae. At the present time the magnitude of these errors cannot be assessed. A third study of sampling efficiency, however, gives an indication of this error for estimates of abundance.

In December, 1954, *Loligo opalescens* populations moved into La Jolla (California) Bay and spawned. This species is known to be a demersal spawner. The area of bottom on which this spawning took place, as surveyed by diving, was 1,600,000 m^2. It was estimated that 50 percent of the bottom in this area was covered with squid egg cases. Three quadrats (100 cm^2) were chosen and the number of egg cases in them was counted. This showed that there were about 10,400 egg cases per m^2. The total number of egg cases calculated to be present in the area at this time was 8.32×10^9. In 1963 a similar spawning took place. Fifty individual egg cases were collected at this time. From this collection 10 were chosen at random and the number of eggs per case was counted. This count gave a mean of 212 eggs per case. If it is assumed that in 1954 there were the same number of eggs per case, the total number of eggs spawned at La Jolla in 1954 was 1.76×10^{12}.

TABLE 2

NUMBERS OF SPECIES AND INDIVIDUALS CAUGHT BY USING NETS OF VARYING MOUTH SIZES

Species	Series I						Series II					
	Mouth size of net[a]						Mouth size of net[a]					
	20	40	60	80	100	140	20	40	60	80	100	140
Abraliopsis sp.	..	35	17	6	24	44	..	..	..	..	..	..
Abralia sp.	..	..	..	..	..	..	..	..	..	..	..	..
Cranchiidae sp.	..	9	8	6	5	..	..	..	..	..	..	..
Pterygioteuthis giardi	..	..	..	..	..	..	..	..	..	..	..	..
Onychoteuthis banksii	..	3	..	..	..	..	..	..	..	..	..	..
Rhynchoteuthion no. 1	..	..	..	..	..	..	..	..	..	..	..	5
Rhynchoteuthion no. 2	..	3	..	3	3	13	..	..	..	6	3	4
Octopodoteuthis sp.	..	3	..	..	..	..	..	..	..	..	..	..
Unidentified	..	..	..	..	..	..	..	..	..	..	..	..
Total no. species	0	5	2	3	3	2	0	0	0	1	1	2
Total no. individuals	0	53	25	15	32	57	0	0	0	6	3	9

Species	Series III						Series IV					
	Mouth size of net[a]						Mouth size of net[a]					
	20	40	60	80	100	140	20	40	60	80	100	140
Abraliopsis sp.	..	..	..	..	..	2	..	3	..	17	2	11
Abralia sp.	..	..	..	..	..	2	..	..	..	..	..	..
Cranchiidae sp.	..	..	..	..	..	..	..	3	..	..	..	11
Pterygioteuthis giardi	..	..	3	..	..	..	..	..	..	..	..	..
Onychoteuthis banksii	..	..	3	..	..	2	..	6	..	3	..	2
Rhynchoteuthion no. 1	..	..	..	..	..	..	..	..	..	..	..	..
Rhynchoteuthion no. 2	..	3	3	6	3	4	..	23	14	..	164	..
Octopodoteuthis sp.	..	..	..	3	..	..	..	..	..	..	..	..
Unidentified	..	..	..	..	..	..	..	..	..	..	2	..
Total no. species	0	1	3	2	1	4	0	4	1	2	3	3
Total no. individuals	0	3	9	9	3	10	0	35	14	20	168	24

[a] Measurement in centimeters.

TABLE 3

MEAN NUMBER OF SPECIES AND INDIVIDUALS CAUGHT IN FOUR TOWS MADE WITH EACH OF SIX NETS OF VARYING MOUTH SIZE

Mouth size of net (measurement in centimeters)	20	40	60	80	100	140
Mean number of species	0	2.50	1.50	2.00	2.00	2.75
Mean number of individuals	0	24	12	12.5	51	25

In a 1953 study (McGowan, 1954) it was shown that in *L. opalescens* there is essentially no larval mortality in the egg case before hatching. If this was also true in 1954, then a very large number of larvae were released into the water about one month after the spawning took place.

During the three months following December of 1954, the CalCOFI program sampled a number of stations in the general area where these larvae might have been present (fig. 2). Some of these samples, from cruise 5501 (January, 1955), contained no larvae of *L. opalescens*. One, nearest the site, gave the estimate of 4/1,000 m^3 (sta. 93.27, 5501), and the others ranged from 4/1,000 m^3 to 16/1,000 m^3. Recent laboratory-rearing experiments on the larvae of this species indicate

TABLE 4

NUMBERS OF SPECIES AND INDIVIDUALS CAUGHT BY A NET OF 100 CM-MOUTH DIAMETER TOWED 10 TIMES WITH EACH TOW FILTERING A DIFFERENT VOLUME OF WATER

Larvae	182 m^3	338 m^3	472 m^3	489 m^3	601 m^3	655 m^3	855 m^3	895 m^3	966 m^3	1,510 m^3
Rhynchoteuthion sp.	..	..	..	2	..	5	1	1	..	2
Cranchiidae sp. no. 1	..	..	..	..	..	..	..	1	..	..
Cranchiidae sp. no. 2	..	..	..	..	..	..	..	..	1	..
Octopus sp.	..	..	..	..	2	..	2	..	..	1
Argonauta sp.	..	..	2	..	..	..	..	..	..	..
Total no. species	0	0	1	1	1	1	2	2	1	2
Total no. individuals	0	0	2	2	2	5	3	2	1	3

that the larvae caught in these net tows were probably not more than one month post hatching. At the same time that this spawning at La Jolla took place, reports were received of other spawning sites along the coast of southern California. Although surveys of the number of eggs spawned at the other sites were not made, the spawning at Santa Catalina Island was apparently much larger than the one at La Jolla.

If it can be assumed that the larvae hatched from this spawning were dispersed within a 9.85 x 10^8 m^2 area surrounding station 93.27, near the spawning site, and that there was no post-hatching mortality, using the depth range 0–80 meters (see pp. 68, 70, below), the abundance of larvae should have been estimated at 60/1,000 m^3. If a 50 percent per month mortality is assumed, the estimate should have been 30/1,000 m^3. Since the grid-pattern method of survey implies that each point within the grid is "representative" of a certain area (in this case 9.85 x 10^8 m^2), these calculations are an index of our sampling efficiency.

It is obvious that all three studies indicate that the methods used to collect the data in this report are inadequate for measuring absolute abundance of larval squid or for indicating their actual presence at low population densities. The specimens that were collected, however, can be used for taxonomic purposes and to describe growth stages. Further, because such a large number of samples were

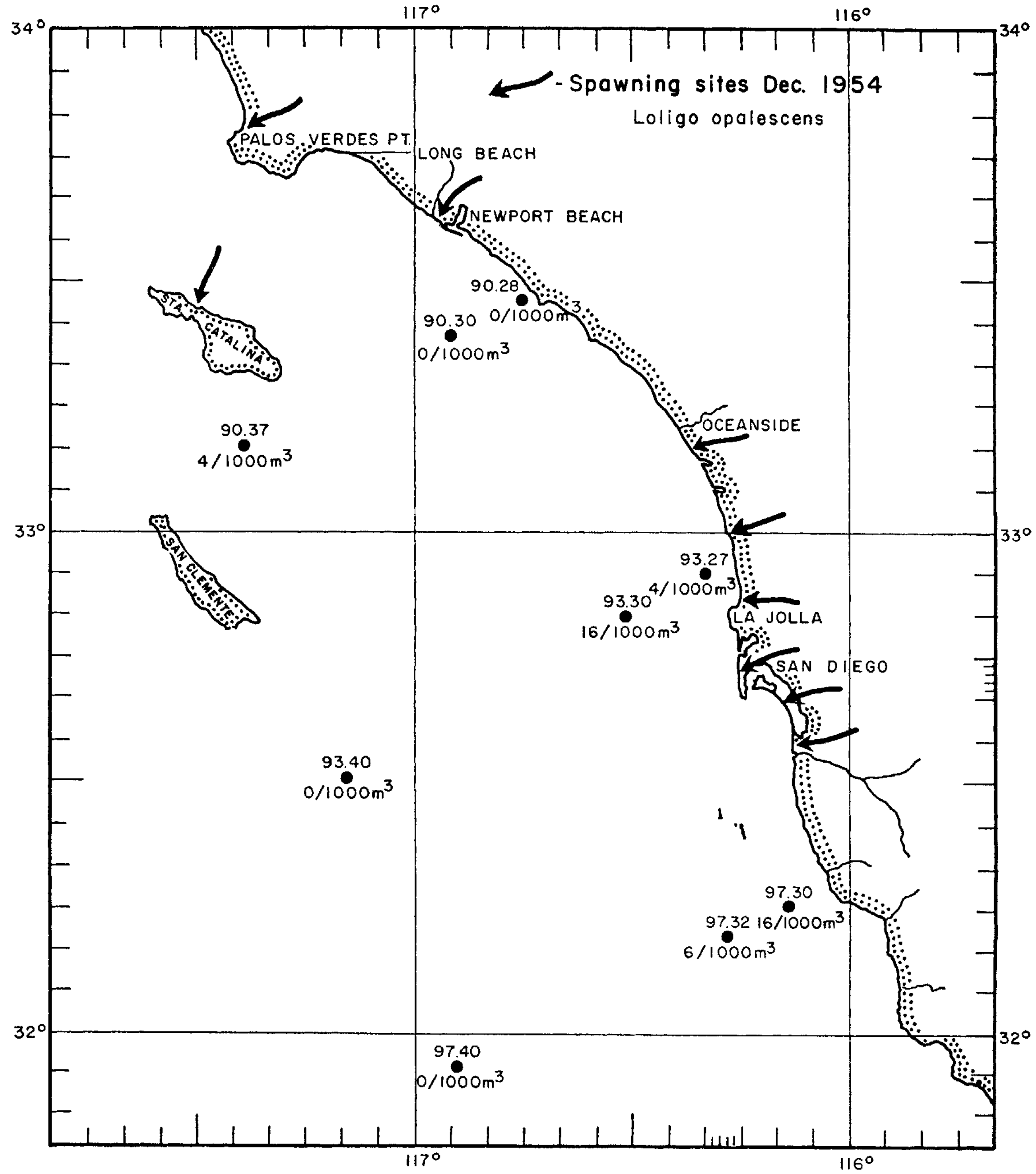


Fig. 2. The spawning sites of *Loligo opalescens* as determined in December, 1954. The black dots represent CalCOFI stations occupied in January, 1955. The numbers above the dots are station numbers, those below are numbers of larvae of *L. opalescens* per 1,000 m^3 of water filtered. The arrows indicate the position of the sites.

taken over a long period of time, and because some of the data on frequency of occurrence and relative abundance seem consistent and reproducible, the data presented in the distribution section of this report (pp. 56 ff.) may have some validity. It is emphasized, however, that the abundances should be viewed as *relative*, and that the frequency data and distributional ranges presented suffer from our inability to sample larval squid well at low population densities.

An additional problem of the sampling method is the depth of tow. The adults of many of the species studied in this report are very probably mesopelagic. This conclusion is based on the fact that in this area shallow trawls and surface dip netting have not collected these adults and that mid-water trawls occasionally have. It therefore seems possible that sizable portions of the larval populations of some of the species studies may occur deeper than 140 meters. In spite of all of these apparent deficiencies in sampling, the regularity of the peaks of seasonal occurrence indicates that we do have some estimate of the times and places of spawning.

It should also be noted that in all the net tows only 14 species of larval squid occurred. There are many more species of adults known from this area. It is probable that some of the additional species also spawn here. The fact that our nets did not capture any of their larvae may indicate that both spawning and larval development take place at depths greater than 140 meters.

RESULTS

SYSTEMATICS AND DESCRIPTIONS OF LARVAL STAGES

Almost all the previously published works on decapod cephalopods are taxonomic studies of adults with relatively little information on larval forms. The following monographs, however, contain information on larvae: Issel (1908, 1925), Chun (1910), Pfeffer (1912), Naef (1923), Degner (1926), Bouxin and Legendre (1936), and Allan (1945).

References for description.—The pelagic cephalopods in the CalCOFI material are nearly all immature specimens. Identification of this material was made by tracing the successive developmental stages to the identifiable adult. All specimens used for this comparative study are in the Invertebrata Collection of the Scripps Institution of Oceanography, La Jolla. The references cited here are those most useful for identification of the adults. Many of the original descriptions were not available to us. In these cases the most reliable subsequent description was used.

Synonyms.—Where a comprehensive and dependable synonym list has already been published, it is cited. Other synonyms that exist are added.

Methods used in describing the present material.—Although adults and adolescent individuals were occasionally caught by the nets, most of our material consists of specimens in larval and post-larval stages. Where a sufficient number of specimens were available, an attempt was made to describe the developmental stages. In many species, differentiation seems to be a continuous process, and the arbitrary division of size categories into stages served no useful purpose. Other species could be divided into stages within which there are combinations of structures or body proportions peculiar to a particular size range. Where it was possible to divide size categories into stages, the following features were considered:

a) Size (see below, relevant to measurement).

b) General shape of mantle, fins, and other parts of the body.

c) Differentiation of arms. In some species, dorsal or ventral arms are not differentiated in the early stages. The arm-length formula sometimes changes in accordance with growth. The arm-length formula in this report is that used by

Sasaki (1929) and others. The numbers 1, 2, 3, and 4 indicate the dorsal, the second lateral, the third lateral, and the ventral arms, respectively.

d) Differentiation of hectocotylus.

e) Development of buds into suckers.

f) Development of suckers into hooks.

g) Development of photophores (external and internal).

h) Number and arrangement of chromatophores.

In connection with these features, especially (*a*) and (*h*), measurements of various parts of the body were made. In published descriptions of the adults, the proportions or actual measurements of various parts of the body are generally given. With young specimens, however, these values are not so useful because, on the basis of direct observation, they usually show more shrinking or swelling when preserved. When possible the following measurements were taken:

a) Dorsal mantle length.

b) Mantle width at the broadest part of the mantle.

c) Width and length of head.

d) Width across the fins.

e) Fin length; in the case of sagittate fins, the longest part is at or near the attachment, but in the case of oval fins the longest part is approximately at the center. This measurement is unreliable when the fin is thin and delicate.

f) Total length, arm length, tentacle length, eye diameter, and other measurements were taken only when appropriate.

In the immature stages, the ratio between mantle length and mantle width is useful. If other, rather stable (persistent) proportions were found, they are given in the description. Tables of actual measurements or calculated proportions for all specimens examined are not given. The values in the descriptions represent averages for the stage described.

Remarks.—Although wide morphological differences among closely related species of cephalopods are not common in immature stages, there are certain exceptions. These differences are pointed out in a short section following the description of the species.

In the CalCOFI material, 1 species of Myopsida (Loliginacea) and 13 species of Oegopsida (Architeuthacea) were found. In the following descriptive section, Thiele's (1935) systematic arrangement of species was followed.

MYOPSIDA

Family Loliginidae

1. Loligo (s.s.) *opalescens* Berry, 1911

(Fig. 4)

References for description.—Berry, 1911*a*, p. 591 (original description: type from Puget Sound); Berry, 1912*a*, pp. 294–297, pl. 43, figs. 5–8, pl. 44, figs. 2–4, pl. 45, pl. 46, figs. 4–5.

Synonyms.—See Berry, 1912*a*, p. 294.

Distribution records.—From Puget Sound, Washington, south to Monterey Bay and San Diego, California; Guadalupe Island, Vizcaino Bay and Asuncion Bay, Mexico (SIO Collection) (see fig. 3).

DESCRIPTION

The CalCOFI material contains 276 specimens of *Loligo opalescens* ranging in size from 3.5 to 7 mm in dorsal mantle length. The smaller specimens used for comparison were newly hatched larvae kept in the laboratory tank.

Mantle.—The mantle is firm, cylindrical, elongate bell-shaped with a blunt end. The mantle length is 1.5–2 times the mantle width in specimens less than 5 mm in mantle length, and 2–3 times the width in larger specimens (more than 3 times in adolescent and about 5 times in adult). The margin of the mantle is truncated, slightly emarginated between the lateroventral projections on both sides of the funnel (fig. 4, *d*). The dorsal process of the mantle is not yet well differentiated, although the dorsal mantle margin has a broad triangular lobe in the middle.

Fins.—The fins are small, subterminal, oval in outline, and wider than long. The fins become sagittate when a mantle length of 20 mm is reached.

Head—The head is squarish in outline, flattened dorsoventrally, about $^1/_3$ the mantle length. The integumental folds observable after the adolescent stage have not yet developed. The eyes are large, myopsid in type, not protruding, and are situated more anteriorly in younger specimens than in the more mature stages. The funnel is broad and short. The funnel excavation continues anteriorly to a shallow groove that runs along the ventral side of the head (fig. 4, *d*).

Cartilages.—The socket on the funnel cartilage (fig. 4, *g*) is well developed (1.5 mm in length in 5 mm-mantle-length specimen), but the mantle cartilage is a simple, fleshy ridge.

Arms.—The arms are short, firm, and the formula is usually $3 > 2 \geqq 4 > 1$. The dorsal arm is not well differentiated in small specimens. The arms are generally four-sided with broad, membranous keels on the aboral sides of the third arms. The web that ensheathes the basal portion of the tentacles becomes more evident on the ventral arms as the animal grows. The swimming membrane and the muscular tubercles on the arms are not developed. The umbrella is not evident. Suckers of the arms are small and regularly alternating in 2 rows. The teeth of the horny rings are hardly visible in the very young stages, but they appear to be 5 in number at the 30-mm-mantle-length stage (fig. 4, *f*).

Tentacles.—The tentacles are highly contractile. The club is lanceolate with a swimming membrane along the dorsal and ventral margins (fig. 4, *c*). The suckers are arranged in 4 rows; those near the distal tip are without chitinous rings. The chitinous rings of the tentacle suckers are quite smooth; they have about 20 blunt, conical, widely spaced teeth at the 30-mm-mantle-length stage and about 35 in the adult.

Buccal membrane.—The buccal membrane is apparently septangular. Suckers are not yet developed.

Gladius.—The gladius is thin with a slender midrib; posterior $^2/_3$ of the gladius with a lanceolate expansion (fig. 4, *e*).

Chromatophores.—In specimens about 5 mm in mantle length, the dorsal surface of the mantle usually has 10–12 large chromatophores, but the shapes and sizes of these chromatophores vary with the condition of preservation. When the

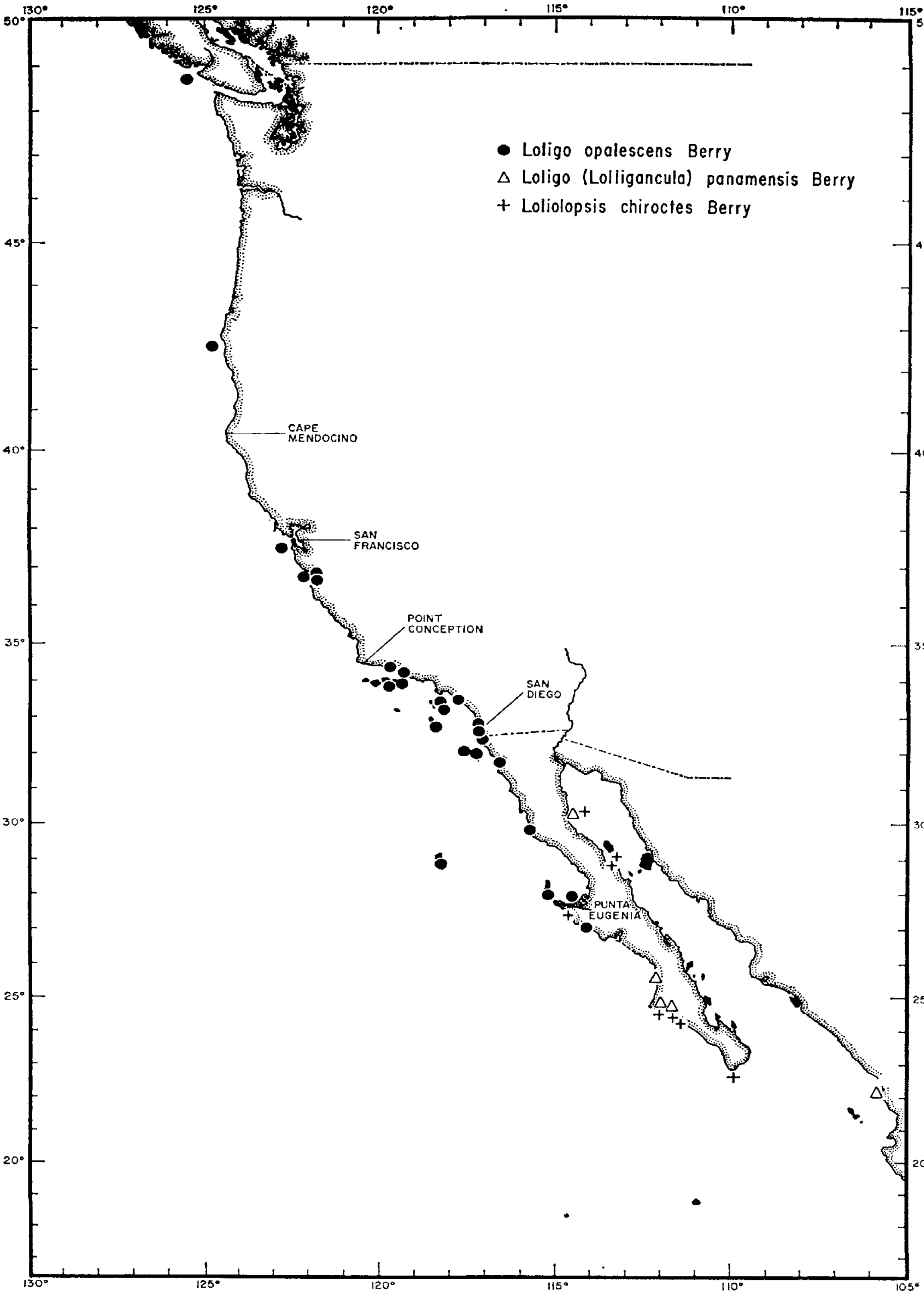


Fig. 3. Collection localities for the Loliginidae of the California Current. Based on literature records and collections at Scripps Institution of Oceanography.

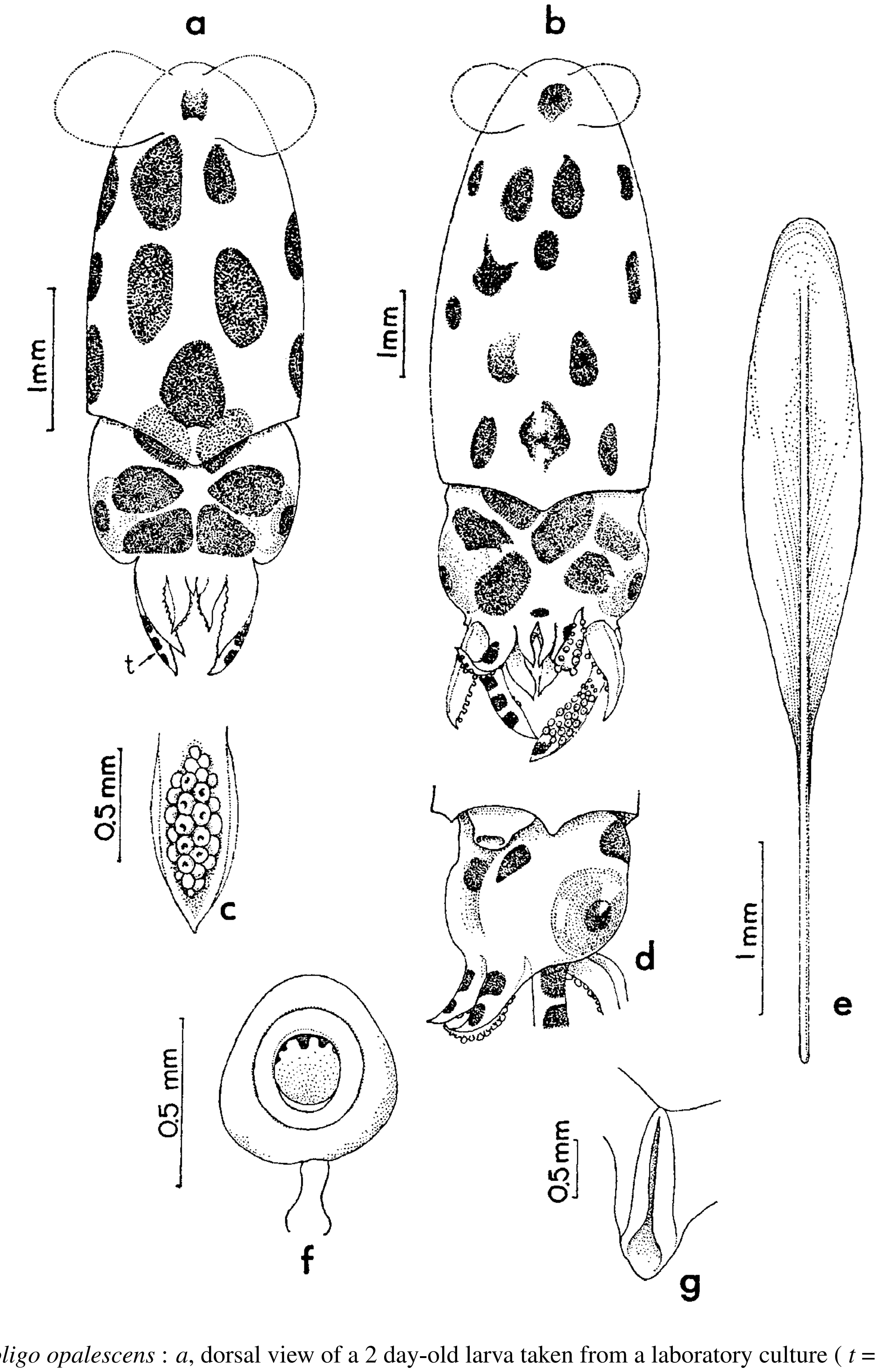


Fig. 4. *Loligo opalescens* : *a*, dorsal view of a 2 day-old larva taken from a laboratory culture (*t* = tentacle); *b*, dorsal view of a specimen from the plankton on station 82.47, cruise 5611; *c*, oral view of the tip of the right tentacle of the specimen shown in *a* ; *d*. lateroventral view of the cephalic parts of the specimen shown in *b*; *c*, gladius of the specimen shown in *b*; *f*, arm sucker of a specimen 40 mm in mantle length; *g*, funnel cartilage of a specimen 5 mm in mantle length.

larva first hatches, there are 1 small and 5 large chromatophores (fig. 4, *a*, *b*) but these become crowded as the larva grows. The head of the youngest specimens is ornamented with 3 pairs of polygonal chromatophores on the dorsal side which also increase in number and complexity of arrangement with growth.

The aboral surface of the third and ventral arms is ornamented with 1 or 2 large, squarish chromatophores. In the very early stages, no chromatophores are present on the dorsal and second arms. On the aboral side of the tentacles there are several squarish chromatophores regularly arranged in a row.

OEGOPSIDA

Family Enoploteuthidae

(Subfamily Abraliinae)

2. *Abraliopsis felis* McGowan and Okutani, 1968

(Fig. 5)

DESCRIPTION

The CalCOFI material contains 1,754 specimens of *Abraliopsis felis* ranging in size from the larval stage (1.3 mm in mantle length) to the adolescent stage (about 25 mm in mantle length). The adults used for comparison had a mantle length of 30–40 mm and were all from the California Current.

ADOLESCENT: MANTLE LENGTH LARGER THAN 20 MM

Mantle.—The mantle is conical, broadest anteriorly. It gradually tapers posteriorly and terminates in a sharply pointed extremity. The breadth of the mantle at the margin is greater than $1/3$ the dorsal mantle length. The mantle margin is slightly projected in a triangular lobe at middorsum, while the ventral part is broadly emarginated in the middle. Small, but sharply pointed, lateroventral projections are present at the locations of both funnel cartilages (fig. 5, *a*).

Fins.—The fins are subterminal; each is very broad, roughly subrhomboidal in outline, and wider than long. From the base, the length of the fins is little more than half the dorsal mantle length. The width across the fins is approximately 1.2–1.5 times the length. The fins are markedly auriculate anteriorly and their posterior margins are gently concave.

Head.—The head is subcylindrical. The eye openings are wide with a sinus at the anterior edge. The neck is moderately constricted, both sides with four obliquely longitudinal, semilunar folds. The funnel is short and conical. The funnel excavation is not sharply demarked, but the posterior part is bordered by ventral folds on the neck (fig. 5, *c*). The funnel organ consists of an inverse V-shaped dorsal pad and a pair of elliptical ventral pads. In mature specimens, both rami of the dorsal pad have a longitudinal ridge. These rami appear to be slightly twisted (fig. 5, *n*). The degree of prominence of the ridges varies among specimens. The adductor muscle of the funnel is deeply V-shaped.

Cartilages.—The funnel cartilage is lanceolate, somewhat curved and narrowed anteriorly (fig. 5, *c*). The groove of the funnel cartilage is longitudinal and of moderate depth. The mantle cartilage is slender, thin, ridgelike, and longer than the funnel cartilage. The nuchal cartilage is slender, lanceolate, bilaterally symmetrical, and about 4 times as long as wide.

Arms.—The arms are unequal and they approximate the length of mantle. The arm formula is 4 > 2 > 3 > 1. All the arms are carinated on their aboral sides. The aboral keel of the third arm, which extends the whole length of the arm, has a delicate, extensive, swimming membrane. This membrane is strengthened by slender transverse tubercles of a muscular nature occurring in alternation with the ventral row of sucker pedicles. An aboral keel also extends the entire length of the ventral arm. The keels on the dorsal and the second arms extend to the distal halves of the arms. The armature consists of biserial hooks and suckers. On the dorsal, second, and third arms, 6–8 pairs of hooks are arranged in a zigzag row with very small, crowded suckers on the distal tips. The ventral arm has very weak and sparsely arranged hooks and no distal suckers. The right ventral arm of the male is hectocotylized. The subterminal part of the swimming membrane of the hectocotylus is developed into 2 semilunar membranes of almost the same size and shape. The inner membrane is situated a little more proximally than the outer (fig. 5, *d*).

Tentacles.—The tentacles are slightly longer than the length of the mantle; the stems are squarish in cross section and taper distally. The club is somewhat expanded, occupying 1/7 of the entire length of the tentacle. The armature consists of a double row of hooks and a group of suckers. The proximal part of the club is equipped with 4 large suckers (which grow into a fixing apparatus in the adult); the middle part of the club has a ventral row of 3–4 large, solid, sharply pointed hooks and a dorsal row of 3–4 small hooks that alternate with small sucker pedicles. The distalmost part of the club has about 65 suckers, primarily arranged in a quadriserial pattern (fig. 5, *b*). The horny rings of these suckers have a few very small teeth on the distal margin.

Buccal membrane.—The buccal membrane is a deep-violet color throughout (in preserved specimens) and is supported by 8 ribs that protrude as pointed processes at the margin. The inner surface of the buccal membrane is heavily papillate (fig. 5, *k*).

Gladius.—The gladius is penniform. The keel of the rachis appears externally as a distinct, dark streak on the middorsum. The widest part of the vanes is about 1/7 the entire length. The gladius terminates in a blunt end posteriorly with a hollow concavity ventrally.

Photophores.—The ventral surface of the head, the mantle, the funnel, the third and the ventral arms are ornamented with many minute, round, pearly photophores (fig. 5, *a*, *m*). These are all apparently the same kind, but tend to differ in size. The mantle has about 200 photophores (about 500 in mature specimens). They are arranged irregularly on the ventral and lateral sides, except for a narrow, longitudinal space on the midline of the ventrum where there are none. The funnel has about 30 irregularly spaced photophores, the head about 70, and the eyelid about 20. There are about 30 photophores arranged in a double row on each of the ventral arms, and several on the third arm. The numbers of photophores are markedly smaller in less mature specimens.

On the dorsal side of the distal tip of the ventral arm there are 3 large photophores

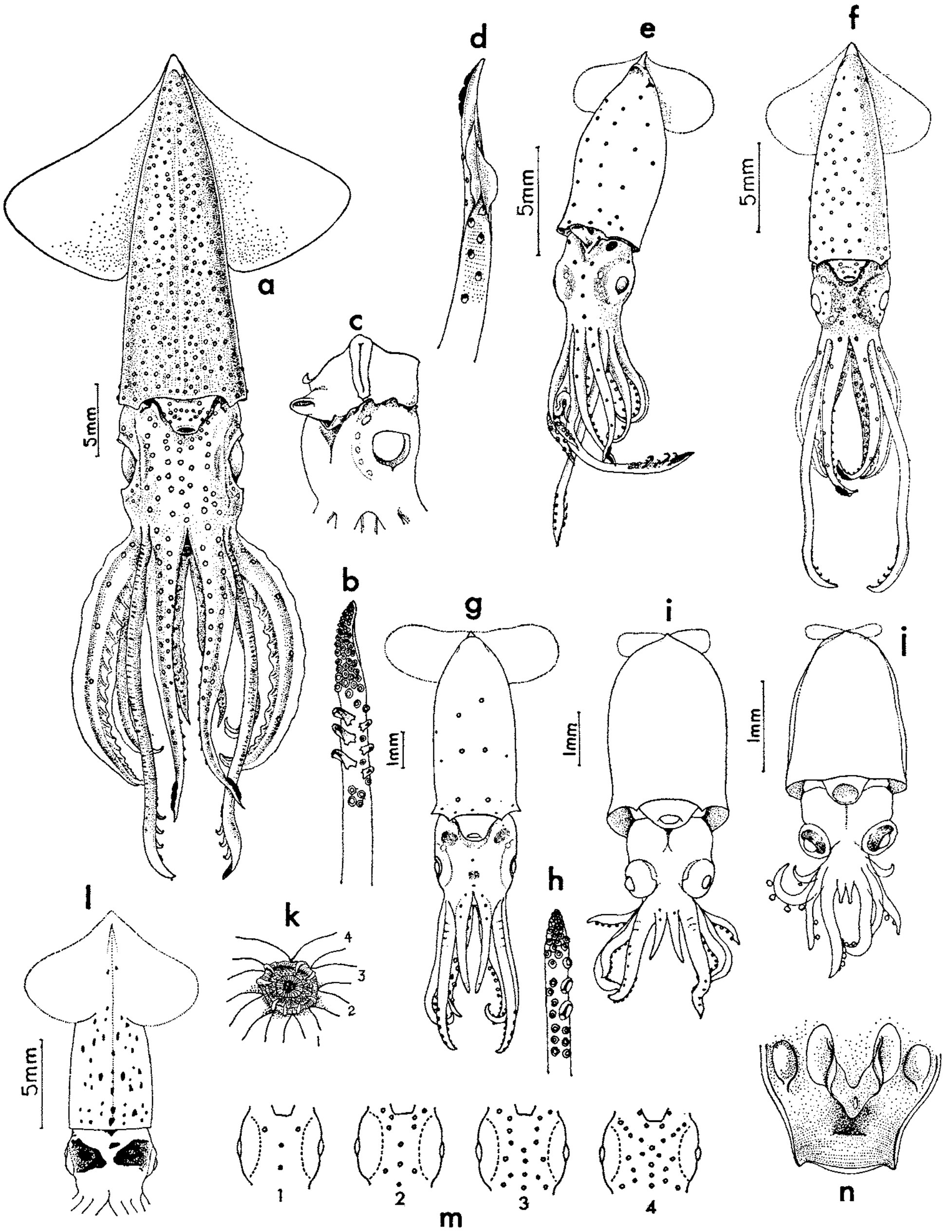


Fig. 5. *Abraliopsis felis*: *a*, ventral of an adolescent taken at station 117.50, cruise 5502; *b*, left tentacle club of the above specimen; *c*, lateroventral view of the cephalic parts of the specimen in *a*, showing funnel cartilage and ocular photophores: *d*, the hectocotylus of an adult; *e*, lateroventral view of a specimen in the 2-photophore stage, from station 103.85, cruise 5505; *f*, ventral view of a specimen in the early 3-photophore stage, from station 97.40, cruise 5406; *g*, ventral view of an early first-photophore-stage specimen from station 67.55, cruise 5507; *h*, right tentacle club of the specimen shown in *g*; *i*, ventral view of a prephotophore specimen from station 67.55, cruise 5507; *j*, ventral view of a very young specimen from station 93.60, cruise 5703, showing detail of eye; *k*, the buccal membrane of the specimen shown in *a*; the tentacles have been removed and the arms are numbered; *l*, dorsal view of the early 3-photophore-stage specimen of *f*, showing the dorsal chromatophore pattern: *m*, diagram of the photophore development of the ventral side of the head: *1*, mantle length, 7.4 mm; 2, mantle length, 12.0 mm; 3, mantle length, 16.0 mm; 4, mantle length, 26.0 mm; *n*, funnel organ of adult male.

of which the middle is the largest. They are ellipsoid in shape and show a dark-purplish color. The eye has five reddish photophores arranged along the periphery and embedded beneath the skin. The most posterior one is the largest.

Chromatophores.—The body is generally brownish yellow in preserved specimens. Many chromatophores are distributed all over the body. No persistent patterns were visible.

PHOTOPHORE STAGE: MANTLE LENGTH 1.3–20 MM

The development and differentiation of each part of the body varies to some extent among individuals. The 0- to 3-photophore stages (i.e., 0 to 3 photophores on the tip of the ventral arms) may, however, roughly indicate the major morphological changes between larval and post-larval stages as tabulated in table 5.

COMPARISON WITH ALLIED SPECIES (ADULT FORMS)

An allied species, *A. morisii* Verany, 1837 (in Chun, 1910, p. 78, plates 5–10), is distinguished from *A. felis* in having a *left* hectocotylized arm of a different type, as well as having a proportionately larger fin (*ibid.*, p. 82. plate 6, fig. 1, plate 10, fig. 1). *A. affinis* Pfeffer, 1912, is another similar species whose larvae were described by Hoyle (1904, p. 36, pl. 1, fig. 3, pl. 8) from "Tropical America" and by Allan (1945, p. 323, pl. 24, figs. 11–17) from the east coast of Australia. This species differs from *A. felis* in having a different type of hectocotylus and 4 large hooks with 4 smaller ones on the club of the adult. *Abraliopsis (Watasenia) scintillans* (Berry, 1911a: 1911*c*, p. 93; 1912*b*, p. 424, pls. 7, 8, 9, figs. 1–6; Ishikawa, 1913, p. 162), which is the commonest Enoploteuthid of Japan, differs from *A. felis* in having a different type of tentacular armature. See McGowan and Okutani (1968) for references, synonyms (none), and distribution records of the adult.

(Subfamily Pyroteuthinae)

3. *Pterygioteuthis giardi* Fischer, 1895

(Figs. 6, 7)

References for description.—Fischer, 1895, pp. 205–211, pl. 9 (14) (see Fischer and Joubin, 1906, p. 334); Fischer and Joubin, 1906, pp. 334–341, fig. 6; Chun, 1910, pp. 108–131, plates 12–16.

Synonyms.—See Fischer and Joubin, 1906, p. 334; Massy, 1916a, p. 164.

Distribution records.—Nearly cosmopolitan, mostly cool and warm temperate to tropical zones.

DESCRIPTION

The CalCOFI material contains 196 specimens ranging in size from the earliest larval stages to adults.

ADOLESCENT: MANTLE LENGTH LARGER THAN 20 MM

Mantle.—The mantle is conical, broadest anteriorly, tapering posteriorly to a sharply pointed extremity that contains the solid posterior end of the gladius. The breadth of the mantle is about $^1/_3$ the dorsal mantle length. The mantle margin slightly projects at middorsum forming a triangular lobe, and is broadly emarginated in the middle of the ventral side, leaving small, but sharp, lateroventral projections on both sides of the funnel (fig. 6, *f*, *g*, *h*).

TABLE 5

MORPHOLOGICAL CHANGES OF DIFFERENT PHOTOPHORE STAGES OF *Abraliopsis felis*

Feature	Three-photophore stage (Fig. 5, *f*, *l*)	Two-photophore stage (Fig. 5, *e*)	One-photophore stage (Fig. 5, *g*, *h*)	No-photophore stage (Fig. 5, *i*, *j*)
Approximate range of mantle length	About 10–20 mm	7.4–10.5 mm	4.8–7.4 mm	1.3–5.3 mm
Mantle	Conical; length 2 to 3 times width	Bell-shaped; length about 2 times width	Bell-shaped; length less than 2 times width	Bell-shaped; length less than 1.5 times width
Fins	Subrhomboidal; length slightly longer than ½ mantle length	Cordate; length slightly shorter than ½ mantle length	Elliptical to squarish; length ½ to ⅓ mantle length	Very small, delicate and squarish
Eyes	Same as adult	....	....	Slightly protruding
Third arm	Swimming membrane present but poorly developed	Swimming membrane not developed	Swimming membrane not developed; always longest of all arms	....
Ventral arm	....	....	Always the shortest of all arms	Last to be differentiated; without suckers
Arm formula	Mostly $3 > 4 = 2 > 1$	Variable	$3 > 2 > 1 > 4$, $3 > 2 = 1 > 4$, $1 = 2 = 3 > 4$	$3 > 2 = 1 > 4$ or $2 > 3 > 1 > 4$
Tentacle hooks				
Large	3, rarely 4	3	2 to 3	0 to 2
Small	2 to 3	1 to 2	0 to 2	0
Buccal membrane	Pigmented in specimens greater than 16 mm in mantle length	Nonpigmented	Nonpigmented	Nonpigmented
Gladius	From the first to the third photophore stages the posterior part of the gladius (anteroventral rim of the hollow concavity of the gladius) makes a rimlike swelling at the subterminal part of the mantle (fig. 5, *e–g*).			

	Number of photophores present at different stages			
Ventral arm	3	2	1	0
Mantle	40 to 100 irregularly arranged	Usually 18; bisymmetrically arranged	4 to 18; bisymmetrially arranged	0–4; may differentiate at about 5-mm stage
Head (excluding eyelid)	11 to 19	4 to 6	0 to 6	0
Funnel	4 to 6	Usually 4	0 to 4	0
Eye (beneath skin)	5	5	0 to 5	0

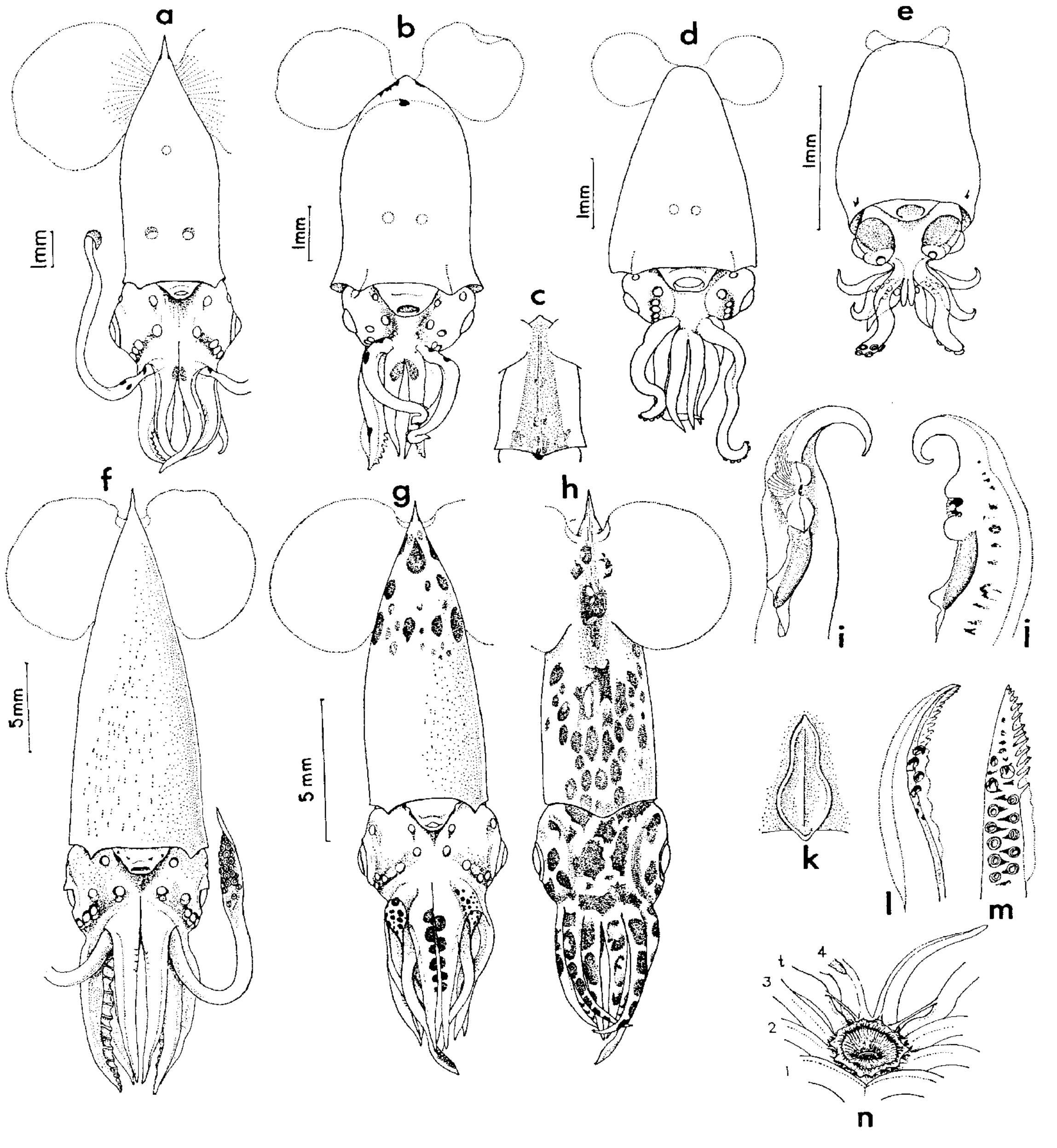


Fig. 6. *Pterygioteuthis giardi: a*, ventral view of a specimen in the ventral-photophore stage from station 130.30, cruise 5602; *b*, specimen in the anal-photophore stage from station 139.70, cruise 5602; *c*, dorsal view of above specimen; *d*, slightly less developed and smaller specimen than in *c*, anal-photophore stage, from station 139.70, cruise 5602; *e*, ventral view of a specimen in the no-photophore stage from station 81.05, cruise 5508; *f*, ventral view of a specimen from station 127.40, cruise 5410, branchial-photophore stage; *g*, ventral view of a slightly younger specimen than in *f*; this individual was taken in the Gulf of California, station G147.43, cruise 5702; *h*, dorsal view of the specimen in *g; i*, the hectocotylus of an adult male; *j*, a lateral view of the hectocotylus in *i; k*, nuchal cartilage of the specimen in *f; l*, the left second arm of a branchial-photophore-stage specimen; *m*, the right third arm of a branchial-photophore-stage specimen; *n*, a buccal view of the specimen in *a* (numbers indicate the bases of the first, second, third, and fourth arms (*t* = tentacles); note the accessory muscle running from below the buccal membrane to the tentacles.

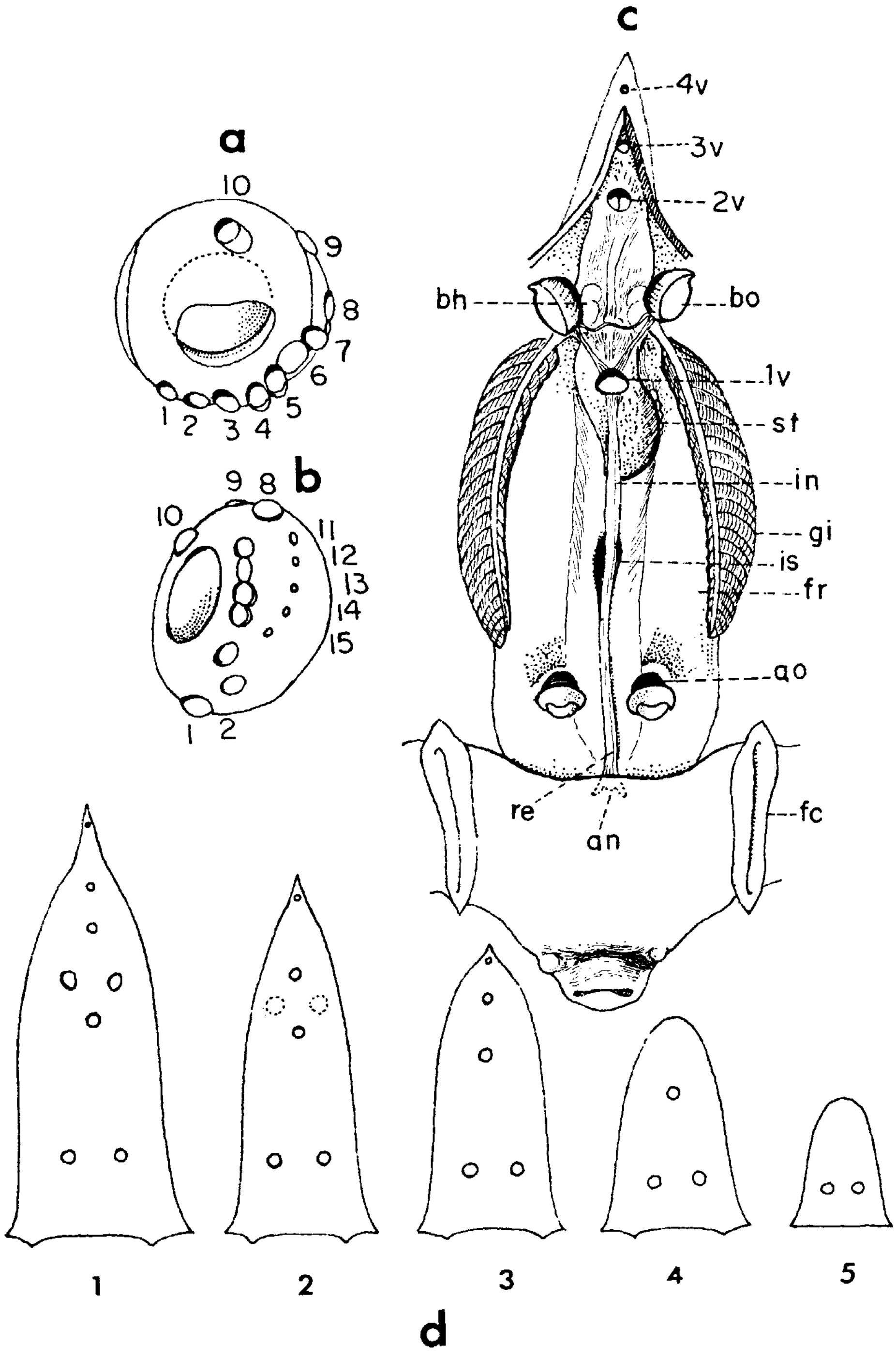


Fig. 7. *Pterygioteuthis giardi: a*, lateral view of the right eye of specimen in figure 6, *a*, showing the photophores; (numbering system of photophores is that of Chun [1910]); *b*, ventral view of the right eye of *a; c*, arrangement of the visceral photophores of the specimen in figure 6, *a, (an* = anus, *fc* = funnel cartilage, *rc* = rectum, *ao* = anal organ, *fr* = funnel retractor, *gi* = gill, *in* = intestine, *is* = ink sac, *st* = stomach, *bo* = branchial organ, *bh* = brachial heart, *lv* = first ventral organ, 2*v* = second ventral organ, 3*v* = third ventral organ, 4*v* = fourth ventral organ); *d*, development of the visceral photophores; size of specimens: 1, 21 mm ML (dorsal mantle length); 2, 9 mm ML; 3, 8 mm ML; 4, 7 mm ML; 5, < 5 mm ML.

Fins.—The fins are terminal, but are not joined together at the posterior extremity of their attachment to the mantle. They are oval in outline. There is a thin edge at the posterior basal part of the fin at the attachment.

Head.—The head is slightly wider than the mantle opening. The eyes are large and have a semilunar opening. The nuchal part is smooth, except for a pair of small muscular projections at the posterior edge of the funnel excavation. The funnel is short and conical. The funnel excavation is deep, but not well demarked from the surrounding area. The funnel organ consists of a pair of ovoid pads.

Cartilages.—The funnel cartilage is very slender and lanceolate with pointed ends (fig. 7, *c, fc*). The nuchal cartilage is subovoid with a slight constriction at the middle and is narrowed posteriorly (fig. 6, *k*).

Arms.—The arms are unequal, 1/2 to 1/3 the mantle length, with membranous keels on their aboral sides and biserial suckers or hooks on the oral surfaces. Along the margin of the sucker-bearing sides of the arms are numerous muscular filaments that are joined together by very thin membranes. The swimming membranes on the ventral sides of the arms are better developed than those on the dorsal sides. The arm formula is usually $3 > 2 > 4 > 1$ or $3 > 4 > 2 > 1$. The armature consists primarily of about 40 suckers placed in a double row on each arm. Some of the suckers (generally between the fifth and eleventh rows, counting from the base of the arm) on the dorsal, second, and third arms are, however, occasionally replaced by hooks, but the occurrence of hooks here is apparently without any consistent pattern. The horny ridges of the suckers have 5–6 squarish teeth that are arranged with large interspaces on the distal margins.

The left ventral arm of the male is hectocotylized; the right ventral arm has very vestigial suckers or none at all. The hectocotylus is thick proximally, without suckers and hooks. The ventral side of this arm has an elongated glandular pad (*Drüsenpolster* of Chun, 1910) which consists of proximal and distal halves. The proximal portion is cylindrical and pigmented. The distal half consists of two white, solid, semilunar pads arranged longitudinally, which have a chitinous plate with two curved, sharp points between them. This chitinous plate is situated in a hollow surrounded by the pads mentioned above and lamellar glandular folds (*Zahnplatte und lamellares Drüsenfeld* of Chun, 1910) (fig. 6, *i, j*).

Tentacles.—The tentacles are highly contractile, with fine accessory muscles attached to the oral surface of the bases (fig. 6, *n*). The club is lanceolate, with 4 series of suckers; more than 15 suckers in each row.

Buccal membrane.—The buccal membrane is pale violet throughout (in preserved specimens) and is supported by 14 very fine muscles connected to the base of the arms. It has an octagonal free margin and the inner surface is heavily lamellated (fig. 6, *n*).

Gladius.—The gladius is lanceolate, of Enoploteuthidae type. The rachis is thick, and has a solid tip that protrudes posteriorly.

Photophores.—The optic vesicle is ornamented with 15 photophores of various sizes; only 10 are visible through the skin (fig. 7, *a*, nos. 1–10). Two are on the ventral surface, 7 on the anterior periphery, and 1 on the posterior periphery. The other 5 small photophores are arranged in a row on the proximal portion of the eye (fig. 7, *b*, nos. 11–15).

There are 2 paired and 4 unpaired light organs on the ventral side of the viscera. The first pair consists of 1 on each side of the rectum, and the second pair occurs near each of the 2 branchial hearts (anal organ and branchial organ [fig. 7, *c, ao* and *bo*]). The 4 unpaired organs are spaced in a median ventral row; the first is anterior to the base of the gills and the second through fourth are posterior to the branchial light organs (first to fourth ventral organs [fig. 7, *c, 1v* to *4v*]). An example of measurements of these photophores on a 21-mm specimen is: diameter of anal organ, 0.75 mm; branchial organ, 1.35 mm; first ventral organ, 0.65 mm; second ventral organ, 0.30 mm; third ventral organ, 0.15 mm; fourth ventral organ, 0.08 mm.

Chromatophores.—The chromatophores are distributed more densely on the dorsal side of the body than on the ventrum. They are somewhat reddish with a golden tint.

PHOTOPHORE STAGES: MANTLE LENGTH SMALLER THAN 20 MM

As in *Abraliopsis felis*, the development and differentiation of each part of the body varies to some extent among individuals. Development of some of the photophores on the viscera, however, indicate roughly the morphological changes from larval to post-larval stages (table 6).

Family Octopodoteuthidae

4. *Octopodoteuthopsis* sp.

(Fig. 8)

DESCRIPTION

Our collections contain 41 specimens ranging in size from 4 mm to 15 mm in dorsal mantle length. The known species of this genus are *Octopodoteuthopsis megaptera* (Verrill) (Verrill, 1885, p. 399, pl. 42, fig. 1; Pfeffer, 1912, p. 223) from New England waters, and *Octopodoteuthopsis* sp. Robson (1924, p. 606, pl. 1, fig. 2) from African waters. Our specimens, however, seem different from either of the known species. It is not known whether this is because of the immaturity of our specimens or of specific differences. No species designation can therefore be given.

Mantle.—The mantle is soft, somewhat depressed dorsoventrally, bell-shaped with a round end, and has loose integument covering firm flesh underneath. In specimens with a 4–5-mm mantle length, the length is equal to the mantle width. In larger specimens, however, the dorsal mantle length is slightly longer than twice the mantle width. The margin of the mantle is thin, smooth, and feebly emarginated on the ventral side (fig. 8, *a, b*).

Fins.—The fins of larger specimens are very broad and oval in outline. They are muscular throughout and about 2/3 as long as the mantle. The posterior margin is somewhat thickened and emarginated in the middle. The anterior margin is not articulated at the attachment. In younger specimens, the fins are squarish, thin, and membranous.

Head.—The head is as wide as the mantle opening. The eyes are large, and protrude in the early stages. The eye opening is oval. The funnel is short and conical. The funnel excavation is not well demarked.

TABLE 6

MORPHOLOGICAL CHANGES OF DIFFERENT PHOTOPHORE STAGES OF *Pterygioteuthis giardi*

Feature	Branchial-photophore stage (Fig. 6, *f*, *g*, *h*)	Ventral-photophore stage (Fig. 6, *a*)	Anal-photophore stage (Fig. 5, *b*, *c*, *d*)	No-photophore stage (Fig. 6, *e*)
Approximate range of mantle length	About 10.0–20 mm	5.0–10.0 mm	2.5–5.0 mm	< 2.5 mm
Mantle	Conicocylindrical; length about 3 times width	Conical; length 2–2.5 times width	Bell-shaped; length less than 2 times width	Bell-shaped; length less than 1.5 times width
Fins	Oval	Oval	Oval	Oval, but somewhat squarish
Arms	Similar to adult	Never with hooks	Never with hooks	Ventral arm last to be differentiated; 3 > 2 > 1 > 4 2 > 3 > 1 > 4
Photophores on viscera				
	Fig. 7, *d*, 1	Fig. 7, *d*, 2, 3, 4	Fig. 7, *d*, 5	....
Branchial	Present	Present, but immature (nonpigmented)	Absent	Absent
Anal	Present	Present	Present	Usually absent
Ventral	3–4	1–3	0	0
Chromatophores	Tend to be poorly developed on the mantle, but are present on the dorsal sides of basal portions of tentacles			None

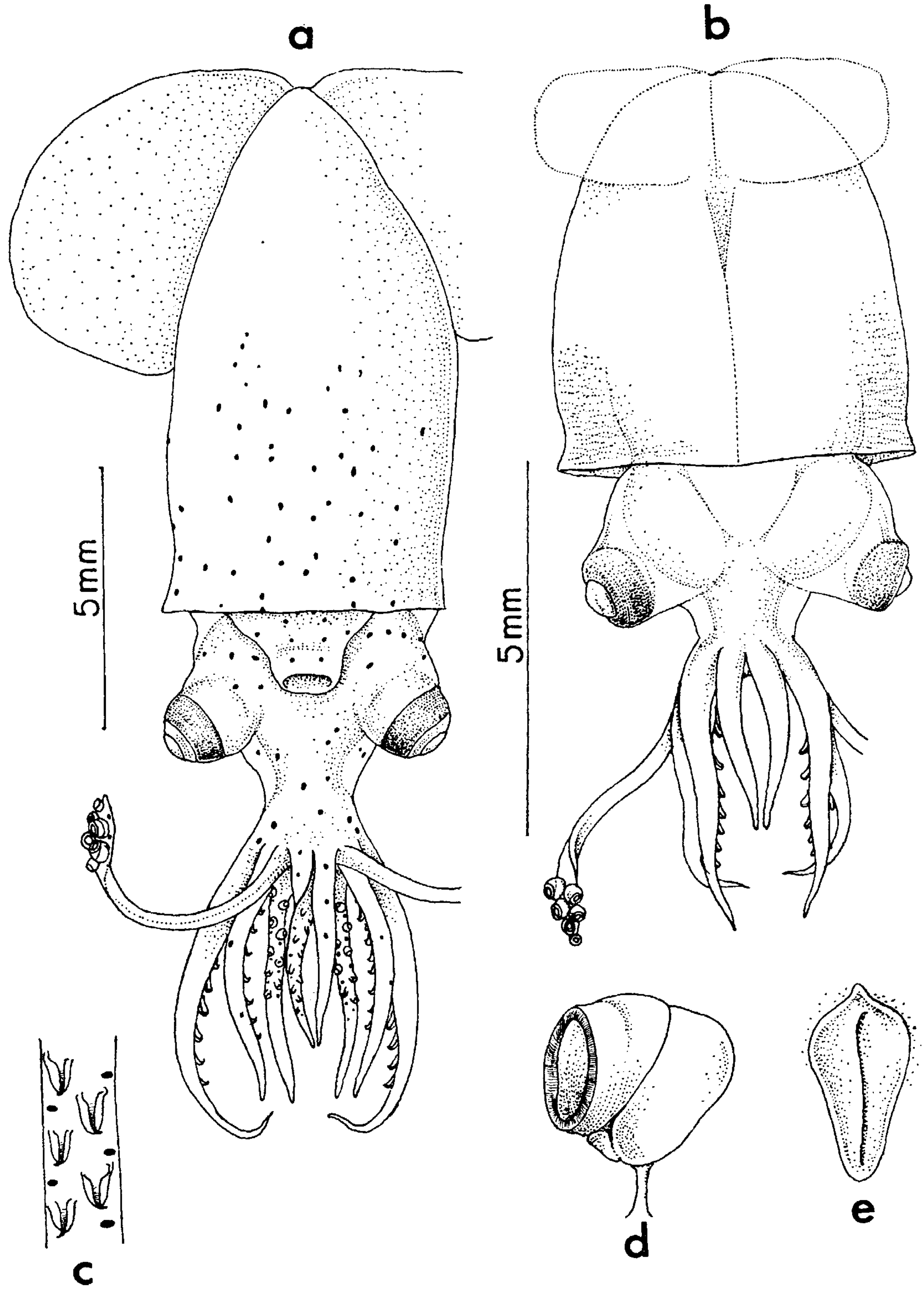


Fig. 8. *Octopodoteuthopsis* sp.: *a*, ventral view of a specimen taken at station 80.90, cruise 5407; *b*, dorsal view of a small specimen taken at station 47.55, cruise 5605; *c*, armature on the third arm of the individual in *a; d*, a tentacular sucker from the individual in *a; e*, the funnel cartilage of the individual in *a*.

Cartilage.—The funnel cartilage is pear-shaped in outline (fig. 8, *e*).

Arms.—The arms are slender and tapering, without terminal swellings. The arms formula is 2 > 3 > 1 > 4, or 2 = 3 > 1 > 4, or 2 > 3 > 1=4. The armature consists of hooks arranged in a zigzag row (fig. 8, *c*). Hooks are usually present only on the proximal 1/2 or 2/3 of the arm. The proximal 2 or 3 pairs of hooks on the dorsal arms are replaced by suckers.

Tentacles.—The tentacles are short, delicate, and cylindrical (fig. 8, *d*). The club has only 6 suckers in the early stages (fig. 8, *a, b*), but 10 in larger specimens.

Buccal membrane.—Not examined.

Gladius.—Not examined.

Chromatophores.—The chromatophores are small, numerous, and irregularly scattered all over the body.

Remarks.—Octopodoteuthopsis megaptera (Verrill) (44 mm in mantle length, from 707 fathoms in New England waters) differs from our specimens in the following points: (*a*) The fins of *Octopodoteuthopsis megaptera* are rhomboidal in outline and are as long as the mantle; (*b*) the posterior end of the mantle projects beyond the posterior margin of the fins; (*c*) the dorsal and lateroventral projections of the mantle are well defined; and (*d*) the funnel cartilage is *Ommastrephes*-like. *Octopodoteuthopsis* sp. Robson (13.5 mm in mantle length, from 900 fathoms near Cape Town) also differs from our specimens in having fins that are as long as the mantle. Robson's species, however, shows a strong resemblance to ours in the manner of attachment of the fin and the thickened and emarginated posterior margin of the fin. Larvae of *Octopodoteuthis sicula* Rüppel are also similar to our specimens in general appearance, but they have terminal swellings at the distal tips of the second arms even at the 5-mm stage (e.g., Chun, 1910, plate 17, figs. 1, 2; Pfeffer, 1912, plate 19, figs. 5–8).

Family Onychoteuthidae

5. *Onychoteuthis banksii* (Leach), 1817

(Fig. 9)

References for description.—Leach, 1817, p. 141 (original description as *Loligo* [see Sasaki, 1929, p. 228]); Pfeffer, 1912, pp. 70–88, plate 3, figs. 13–25, plates 4–6; Naef, 1923, p. 311; Degner, 1926, pp. 10–14; Sasaki, 1929, pp. 228–230, pl. 20, fig. 12, pl. 30, figs. 1, 2.

Synonyms.—See Pfeffer, 1912, pp. 70–71; Berry, 1914, p. 322; Sasaki, 1929, p. 228.

Distribution records.—Cosmopolitan, except in the polar regions.

DESCRIPTION

The 132 specimens in the CaLCOFI material range in size from 2 mm to 47 mm in mantle length.

Mantle.—The mantle is firm, fusiform, and usually 2–3 times longer than wide (more than 4 times in the adult). The anterior part of the mantle is almost cylindrical, and it is slightly swollen near the middle. The margin of the mantle is truncated, slightly projected at the middorsum, and emarginated ventrally, leaving lateroventral projections on both sides of the funnel (fig. 9, *a, b*).

Fins.—The fins are subterminal, ovate, wider than long, and have a somewhat lobed anterior margin. In the adolescent stage, the fins become rhomboidal in outline and equal to half the mantle length (e.g., 18 x 26 mm in a 35-mm-mantle-length individual).

Head.—The head is squarish, sometimes withdrawn into the mantle cavity (fig. 9, *a, h, i*). The eyes are large, slightly protruding in the very early stages. The funnel is rather small. The first olfactory crest on the ventral side is differentiated in specimens about 11 mm in mantle length; the second one, at 35 mm (fig. 9 *k*, 1, 2).

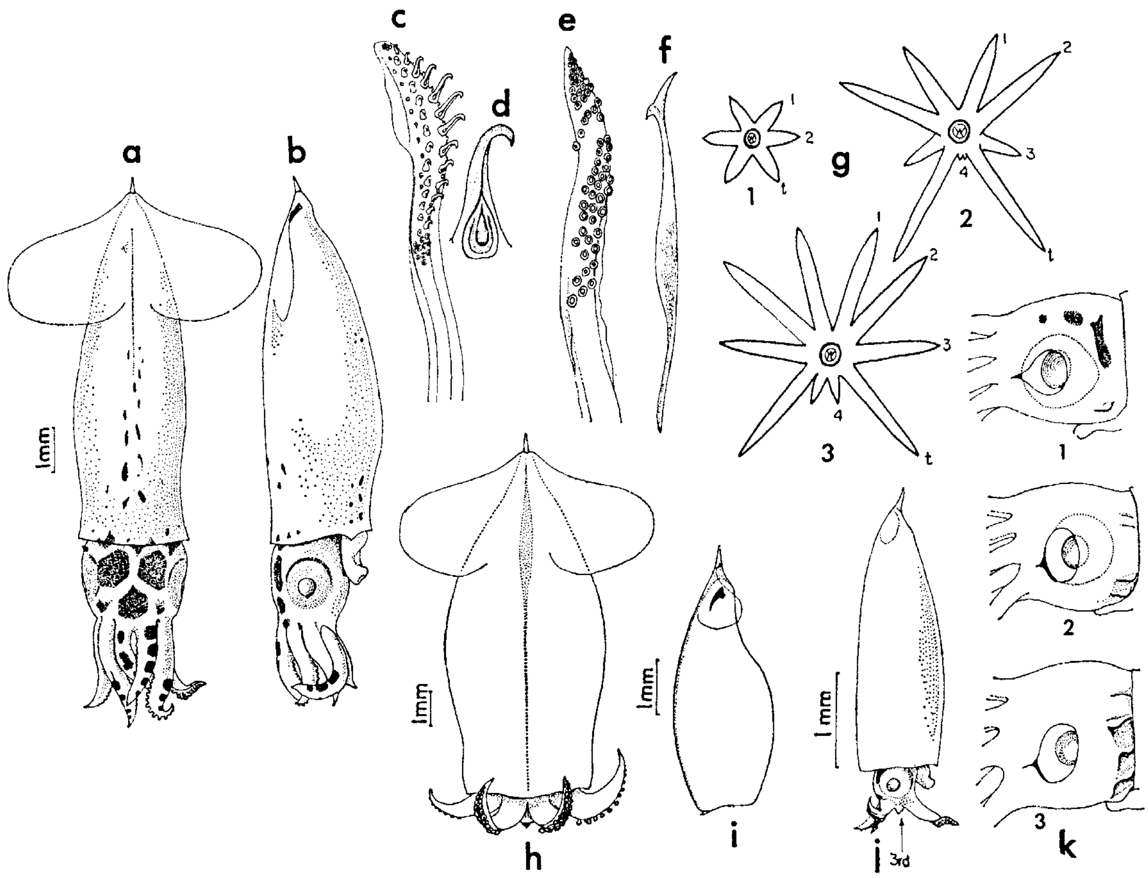


Fig. 9. *Onychoteuthis banksii: a*, dorsal view of a specimen taken at station 153.30, cruise 5601; *b*, lateral view of *a; c*, tentacle of a juvenile taken at station 87.70, cruise 5607; *d*, tentacular hook from *c; e*, tentacle of a larva < 20 mm ML (dorsal mantle length) taken at station 73.60, cruise 5607; *f*, gladius of a specimen 3 mm in mantle length, taken at station 170.20, cruise 5612; *g*, diagram of the development of the arms and tentacles (numbers 1, 2, 3, and 4 = first, second, third, and fourth arms; *t* = tentacles): 1, 3.1 mm ML; 2, 5.5 mm ML; 3, 8.0 mm ML; *h*, dorsal view of an individual with its head withdrawn into the mantle cavity; *i*, lateral view of an individual younger than *h*; the head is withdrawn and the tips of the arms are just visible; *j*, lateral view of a young individual showing the relative size of the third arms; *k*, the development of the olfactory crests. The ventral-most crest develops first (1) followed by a second ventral and the beginnings of two dorsal crests (2). Following these a medial crest develops (3).

Cartilages.—The funnel cartilages are somewhat curved and lanceolate. The mantle cartilage is ridgelike and about twice as long as the funnel cartilages.

Arms.—Two pairs of arms, the dorsal and second, are already differentiated at the earliest stage (fig. 9, *g*, 1); the third arm is developed between the second arm and tentacle at the stage of 5.5-mm mantle length (fig. 9, *g*, 2); the ventral arm is slightly delayed in differentiation (fig. 9, *g*, 3). Thus the formula changes: 1=2 (= tentacle ?), 2 > 1 > 3 > 4, then 2 > 3 > 1 > 4 during growth (adult 4 > 2 > 3 > 1). The suckers are arranged in a double row.

Tentacles.—Tentacles are present from the earliest stage and are situated between the third and ventral arms (fig. 9, *g*, 3). The tentacular clubs are oblong with suckers loosely arranged in 4 rows (fig. 9, *e*). Hooks differentiate after the 30-mm-mantle-length stage or thereabouts, and the development of the fixing apparatus follows later (fig. 9, *c, d*).

Buccal membranes.—The buccal membrane has 7 ribs. They are connected with the dorsal sides of the second arms and the ventral sides of the third and fourth arms.

Gladius.—The gladius has a peculiar carina near its end, which projects out the posterior end of the mantle so that the fins are apparently situated subterminally (fig. 9, *a*). The dark streak running through the dorsum of the mantle from its pointed tip to the middle of the anterior margin is the impression of the gladius (fig. 9, *h*).

Chromatophores.—The mantle usually has several chromatophores on the ventral side near the margin and a pair of triangular chromatophores (which persist through the larval stage) on both sides near the posterior extremity (fig. 9, *b, i*). There are several small chromatophores on the sucker-bearing surfaces of the arms.

Family Gonatidae

6. *Gonatus* (s.s.) *fabricii* (Lichtenstein), 1818

(Figs. 10, 11)

References for description.—Lichtenstein, 1818 (as *Onychoteuthis* [see Pfeffer, 1912]); Pfeffer, 1912, p. 230, pl. 15; Degner, 1926, p. 7; Sasaki, 1929, p. 666, pl. 22, figs. 7–18.

Synonyms.—See Hoyle, 1886, p. 174; Berry, 1912*a*, p. 308; Pfeffer, 1912, p. 230; Sasaki, 1929, p. 266.

Distribution records.—Arctic Ocean; boreal to cool temperate Atlantic and Pacific; Antarctic Ocean.

DESCRIPTION

The CalCOFI material contains 636 specimens ranging from about 4 mm to 27 mm in mantle length. The stages larger than 20 mm in mantle length have many adult characteristics. A comparison of successive stages of growth shows the present material to be a single species. Figure 11 is a diagram of the developmental succession of morphological changes of various parts of the body. It is based on 7 specimens selected from our collections.

ADOLESCENT: MANTLE LENGTH LARGER THAN 20 MM

Mantle.—The mantle is thin, elongated, and slightly longer than three times the width. The sides of the mantle are parallel in the anterior 2/3 of the length, but they taper posteriorly and terminate in a point. This point does not protrude beyond the posterior margin of the fins. The margin of the mantle is very thin, and nearly truncated, except for a somewhat triangularly lobed middorsal edge (figs. 10, *b, e*, 11).

Fins.—The fins are terminal, and connected together at their posterior extremities; the posterior margin of each fin is nearly straight or very slightly concave. The anterior margin of the fin is roundly convex and deeply indented at a point of attachment. The width across the fins is about half the mantle length (figs. 10, *b, e*, 11).

Head.—The head, which is depressed dorsoventrally, is narrower than the mantle opening, and sometimes withdrawn into the mantle cavity (figs. 10, *b, e*, 11). The eyes are prominent. The eye opening is elongate and oval and has a deep sinus anteriorly. The funnel is short and is attached to the funnel excavation with a pair of adductor muscles (fig. 10, *c*).

Cartilages.—The funnel cartilage is lanceolate, narrowing a little anteriorly, and is slightly concave on the outer margin (fig. 10, *d*). The longitudinal groove is distinct and is slightly shorter than the corresponding mantle cartilage which is slender and ridgelike. The nuchal cartilage is elongated, slightly widened on both ends.

Arms.—The arms are unequal in length but similar in shape. The arm formula is 3 > 2 > 4 > 1, or 3 > 2 > 4 = 1, or 3 = 2 > 4 = 1. The armature is composed of 4 series of suckers, about 20 in number on each row. The marginal suckers are slightly larger than the central ones. No hooks are present (fig. 11). They may develop after the animal grows to a size larger than 27 mm (fig. 10, *l*).

Tentacles.—The tentacles are long, and ensheathed basally by a web between the third and ventral arms (fig. 10, *h*). The tentacular stem is robust and four-sided. The club is lanceolate, with a short membranous keel on the aboral side. On the oral side, the distal portion of the club has 4 series of suckers arranged quite regularly; the centrodistal portion with 8 series of suckers; the centroproximal portion also with 8 series of suckers. These suckers are divided into 4 series on each side leaving a broad space in between occupied by a single large sucker that sometimes is developed into a strong hook (fig. 10, *a*). The proximal portion of the club has multiserial small suckers that are irregularly arranged. Groups of small suckers are present on the carpus, and on the ventral face of the stem rows of minute suckers arranged in alternation with minute pads appear on both sides of the margins.

Buccal membrane.—The buccal membrane is fleshy, with 8 supporting muscles connected to the dorsal sides of the first and second arms and to the ventral sides of the third and fourth arms. A pair of accessory muscles are connected to the bases of the tentacles (fig. 10, *h*).

Gladius.—The gladius is flimsy and the end cone is barely visible.

Chromatophores.—The chromatophores are sparse but distinct. The large chromatophores on the dorsum of the mantle (fig. 11) are arranged as follows: a pair at the attachment of the fin; a pair (which is sometimes fused into one) at about a point on the midline 2/3 distal from the mantle edge; and 2 pairs on the lateral sides of the mantle at about 1/3 and 2/3 distal from the edge (another pair is occasionally found between the 2 pairs). In addition to these, a number of small chromatophores are sometimes scattered on the dorsal surface of the mantle (fig. 10, *e*). The ventral side of the mantle is without chromatophores. Five large, polygonal chromatophores are present on the dorsal side of the head (fig. 11). One is

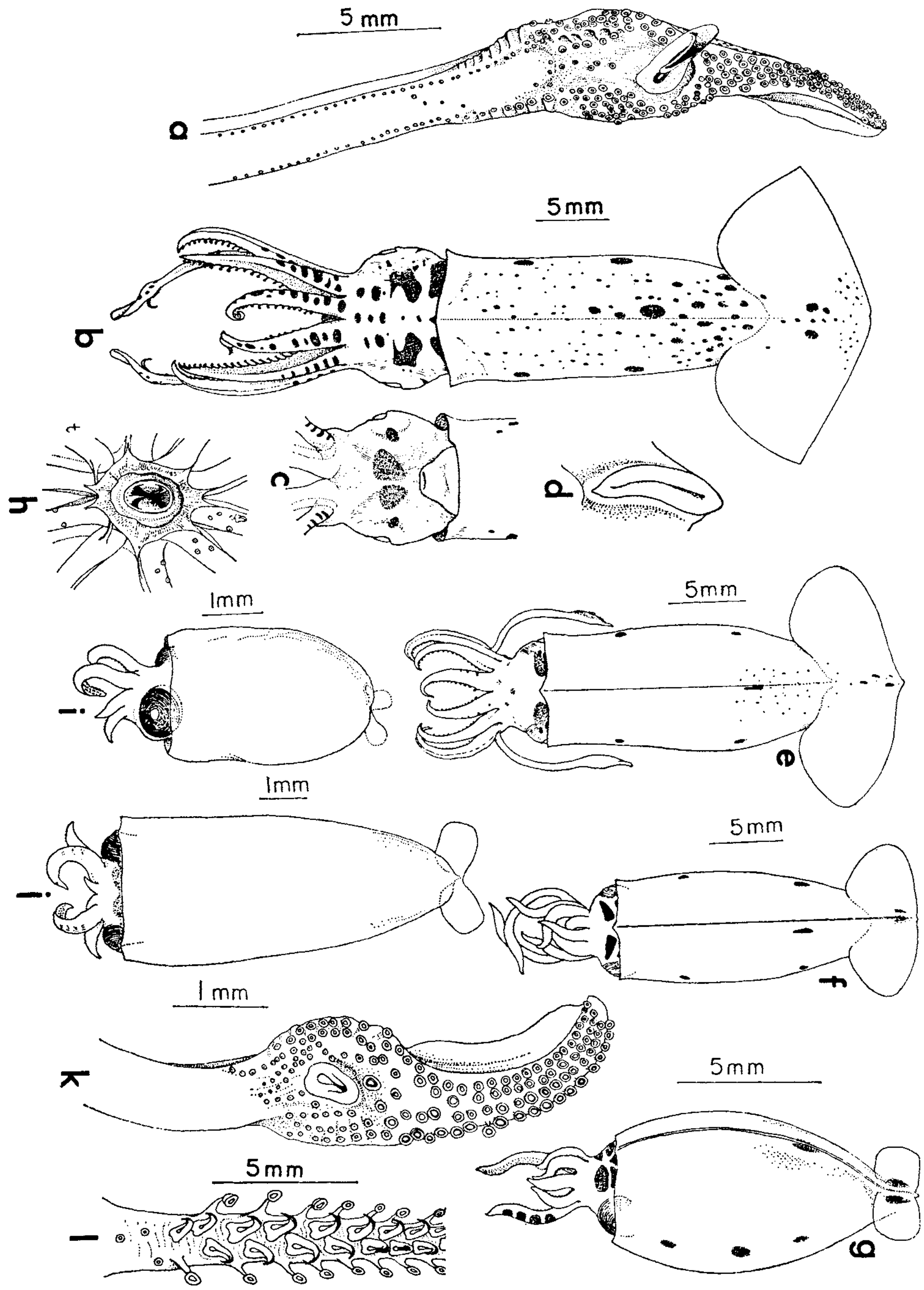


Fig. 10. *Gonatus fabricii: a*, tentacle club of the specimen shown in *b; b*, dorsal view of an adolescent taken in Monterey Bay, California, station 426B, "Tage" cruise; *c*, ventral view of the head of the specimen in *b; d*, funnel cartilage of the specimen in *c; e*, dorsal view of a young adolescent showing its head partially retracted into the mantle cavity; specimen taken at station 70.55, cruise 5604; *f*, dorsal view of a post-larval-stage individual taken at station 70.55, cruise 5604; *g*, dorsolateral view of a young post-larval-stage individual; note the swollen appearance of the mantle; this condition is typical of many, but not all, larval and post-larval individuals collected; *h*, buccal region of the specimen in *e; i*, dorsolateral view of a larval individual from station 67.50, cruise 5406; *j*, a slightly older larva than in *i; k*, tenacle club of the young adolescent specimen in *c; l*, right dorsal arm of the individual in *b*.

situated on the median line near the neck and 2 lateral pairs are near the eye. Small chromatophores lie between these two pairs of lateral chromatophores. Other small ones appear on the nuchal part of some specimens, but they are obscure and seem not to be persistent.

POST-LARVAL STAGE: MANTLE LENGTH 7–20 MM

Mantle.—The mantle is soft, thin, membranous, translucent, and usually considerably swollen as in cranchiid larvae (figs. 10, *f, g*, 11). The margin of the mantle is very thin and truncated.

Fins.—The fins are very small, thin, delicate, membranous, and transversely elongate, oval, or somewhat squarish in outline. The posterior margin is concave near the point of the attachment (figs. 10, *g*, 11).

Head.—The head, which is somewhat depressed dorsoventrally, is narrower than the mantle opening, and is usually entirely or partially withdrawn into the mantle cavity (fig. 10, *g, j*). The eyes are prominent, and the eye opening is the same as that of the adolescent stage. The funnel cartilage, mantle cartilage, and nuchal cartilage are like those of the adolescent stage.

Arms.—The arms are short and thick (fig. 11). The arm formula is usually 2 > 3 > 1 > 4. The armature is composed of 4 series of suckers rather densely arranged; those near the tips are not yet well developed.

Tentacles.—The tentacles are cylindrical and taper distally. The club is not well differentiated in small specimens (fig. 11). The sucker arrangement on the tentacles of larger specimens proceeds from proximal to distal as follows: 2 rows, 4 rows, 8 rows, and 4 rows. There is a large prominent bud (immature sucker) in a naked space on the midpoint of the club. The armature of the tentacles in small specimens is composed of 4 series of suckers distally and 2 series of suckers proximally. The suckers situated near the marginal areas of either portions are usually not yet developed and appear as buds.

Buccal membrane.—The buccal membrane is very fragile, apparently the same as that of the adolescent.

Gladius.—Not examined.

Chromatophores.—The primary chromatophores on the mantle are composed of a pair at the attachment of the fin, a pair at the posterior 1/3 on the midline (these are sometimes fused into a single chromatophore) and 3 pairs on the sides (fig. 11). Five large cephalic chromatophores similar to those in the adolescent stage are present, but the smaller ones that occur on the older stages have not yet appeared.

LARVAL STAGE: MANTLE LENGTH LESS THAN 7 MM

Mantle.—The mantle is thin, membranous, translucent, bell-shaped, with a truncated margin (fig. 10, *i, j*).

Fins.—The fins are very small, thin, delicate, membranous, and attached to the posterior extremity of the mantle.

Head.—The head is narrower than the mantle opening, usually withdrawn into the mantle cavity. The eyes are prominent and slightly protruding.

Arms.—The arms are very short; the formula is 2 > 1 = 3. The armature is

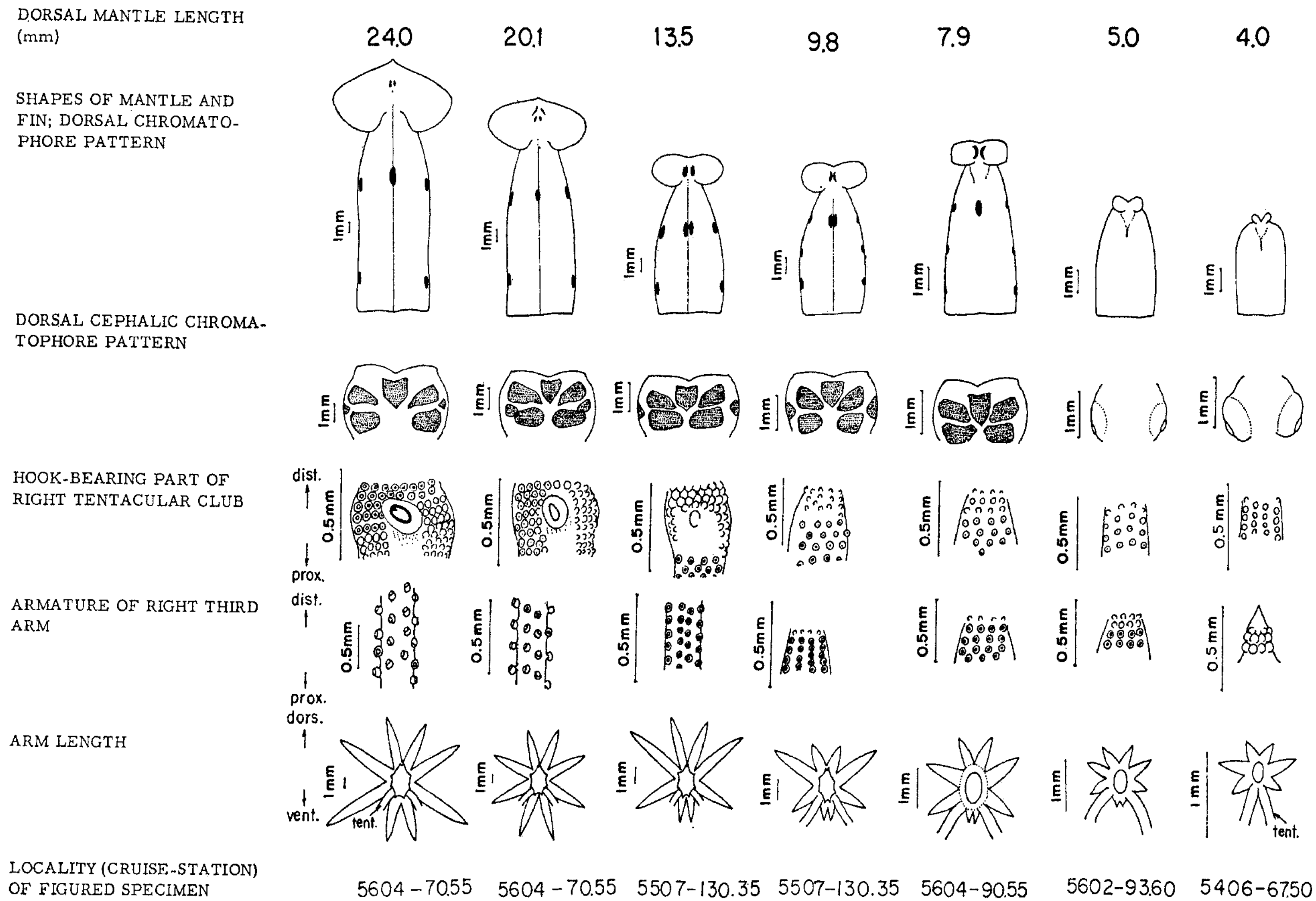


Fig. 11. *Gonatus fabricii*: diagram of the morphological changes during growth from the larval stage to the adolescent stage.

composed of four series of buds on the distal portion and small suckers arranged sparsely and irregularly on the proximal portion (fig. 11).

Buccal membrane.—Not examined.

Gladius.—Not examined.

Chromatophores.—Chromatophores are not present. The body is milky white throughout in preserved specimens.

Remarks.—Of the *Gonatus* specimens from the CalCOFI material under study, about 10 larvae showed slightly different characteristics from the rest. They are identical with *G. fabricii* in many respects, but have somewhat more slender and opaque (thicker?) mantles. It is not known at present whether they are a different species. Only one other species of the same genus, *G. (Berryteuthis) magister* Berry, 1913 (p. 76), is known from the California coast. Furthermore, observations on the larvae of Gonatidae from elsewhere in the North Pacific reveal that there are more unidentified species in the area (McGowan, unpublished). Therefore, if the morphological differences are not attributable to preservation, there is a good possibility that this type of larvae is of another species.

Family Histioteuthidae

7. *Meleagroteuthis heteropsis* Berry, 1913

(Fig. 12)

References for description.—Berry, 1912*a*, p. 305, pl. 50, figs. 1–3, pl. 52, figs. 5–7 (as *Meleagroteuthis hoylei*, not of Pfeffer, 1900); Berry, 1913, p. 75 (as *Calliteuthis (Meleagroteuthis) heteropsis* [amendment of the preceding (1912*a*) identification]).

Distribution records.—From Monterey Bay south to Santa Barbara Island, California.

DESCRIPTION

The size of the 9 specimens examined ranges from 5.5 mm to 18.5 mm in mantle length.

Mantle.—The mantle is soft, semigelatinous, short, bell-shaped, with a rounded blunt end (fig. 12, *a, b, c*). The length is less than twice the width. The ventral surface of the integument is beset with numerous photophores. The margin is thick, with a triangularly lobed, middorsal projection and inconspicuous lateroventral angles at the positions of the funnel cartilages (fig. 12, *a, b*).

Fins.—The fins are small, delicate, and oval in outline. They are attached to the mantle by their anterior half, with a shallow indentation at the middle of the posterior margin.

Head.—The head is slightly narrower than the mantle opening. It becomes very large and asymmetrical in the adult. An olfactory lobe is situated posterior to the eyes and toward the neck. The eyes are moderately large, but their swelling gives the head a globular appearance in smaller specimens. The eyes are almost equal in size and prominence at this stage (fig. 12, *c*). The funnel is short and thick. The funnel excavation is moderate.

Cartilages.—The funnel cartilage is pyriform and somewhat acuminated in front, deeply hollowed in the middle. The nuchal cartilage is an elongate oval shape.

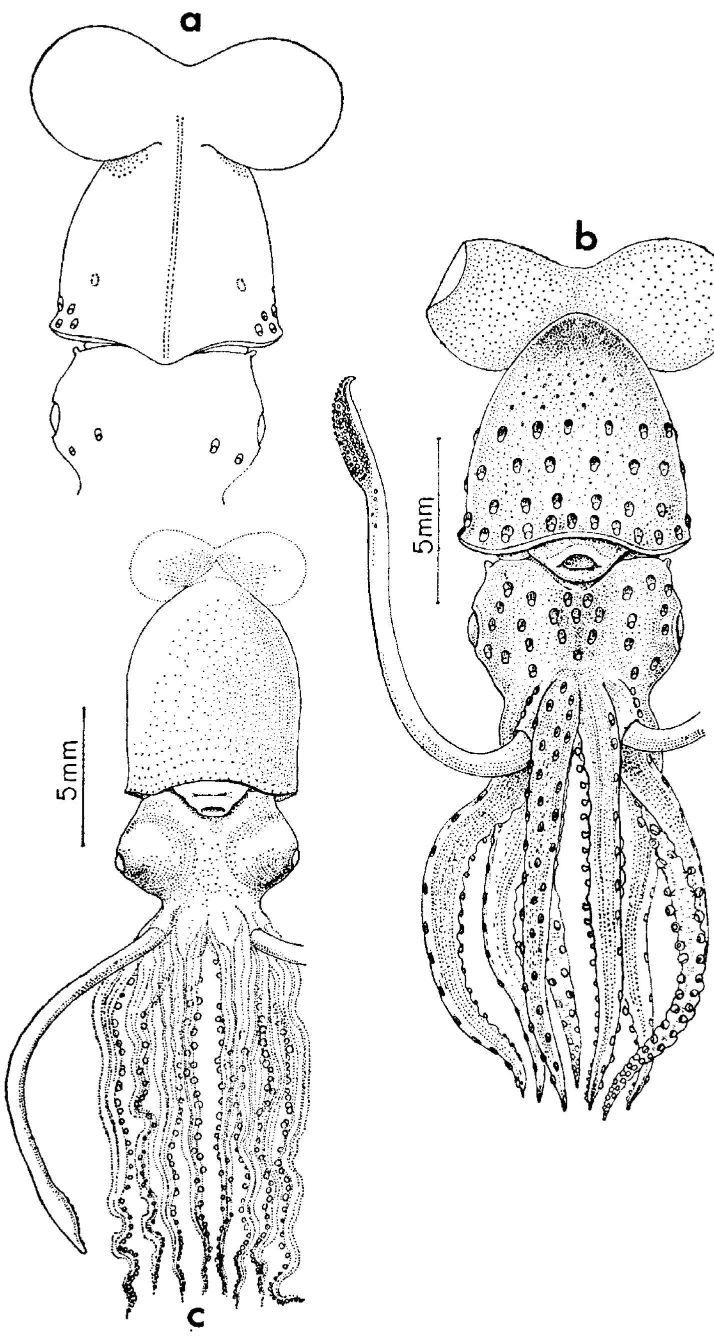


Fig. 12. *Meleagroteuthis heteropsis: a*, dorsal view of the specimen shown in *b; b*, ventral view of a young individual taken at station 107.50, cruise 5703; *c*, ventral view of a somewhat younger specimen than shown in *b*.

Arms.—The arms are nearly equal in length, semigelatinous and tapered. The arms in large specimens are more muscular than those in younger individuals. The suckers are globose and arranged in a double row. They are attached on the marginal portions of the arms, leaving a wide space in between (fig. 12, *b*). The sucker-bearing faces of the arms have membranous, rippled fringes that are fused with the sucker pedicles. In smaller specimens with arms that are gelatinous, translucent, and rippled, the arrangement of the suckers is less regular.

Tentacles.—The tentacles are firm with cylindrical stalks and lanceolate clubs. The clubs have small suckers of about equal size, arranged in 8 rows. Several small suckers are present on the oral surface of the stalk very near the club (fig. 12, *b*).

Buccal membrane.—The buccal membrane of the larger specimen is very extensive and seven-angled.

Gladius.—The gladius is very thick and fragile, apparently with a broad lateral area.

Photophores.—Younger individuals have no photophores as such, but do have numerous, regularly arranged dots that later develop into photophores (fig. 12, *c*). The largest specimen taken in the plankton (20-mm mantle length) has fully developed photophores arranged in the same way as the adult. In the specimen shown in figure 12, *b*, there are 4 transverse rows of photophores which cover the ventral and lateral sides of the mantle (there are about 15 rows in the largest specimen). The numbers of photophores in each row are: 12 in the most anterior row along the free margin of the mantle, 14 in the second row, and 8 in the third and posterior rows (for the photophores of the adult, see Berry 1912*a*, pp. 306–307). The largest specimen has multiserial photophores arranged in oblique rows on the aboral sides of the arm. The aboral surfaces of the dorsal, second, and third arms of the specimen shown in figure 12, *b*, are ornamented with a row of from 8–12 large photophores. The ventral arm has 2–3 series of photophores obliquely arranged. The younger specimens are without photophores on the arms (fig. 12, *c*).

Chromatophores.—There are no large chromatophores on the body. The coloration is brownish violet in the large preserved specimens and paler in smaller specimens.

Remarks.—In all adults of *M. heteropsis*, the right eye is very much larger than the left. Such an asymmetry was not as marked in the stages discussed here.

It is evident that there is not a wide difference in mantle length among the individuals shown in figure 12, *b, c*. There are, however, wide differences among the states of development of body and arm musculature, fins, and ventral photophores. These features, apparently, develop with no marked accompanying increase in body length.

Family Bathyteuthidae

8. *Ctenopteryx sicula* (Verany), 1851

(Fig. 13)

References for description.—Verany, 1851 (as *Sepioteuthis* [see Pfeffer, 1912]); Pfeffer, 1912, p. 332, plate 27, figs. 16–23; Degner, 1926, pp. 5–7.

Synonyms.—See Pfeffer, 1912, p. 332; Degner, 1926, p. 5.

Distribution records.—Mediterranean Sea, North and South Atlantic, and eastern waters of Australia.

DESCRIPTION

The single specimen in the CalCOFI material, 8.0 mm in dorsal mantle length, came from a southern station (sta. 120.50, cruise 5607, 27° 33′ N., 115° 52′ W.).

Mantle.—The animal is firm, cylindrical, but somewhat compressed dorsoventrally and its general shape is reminiscent of Sepia (fig. 13). The mantle is oblong, 1.65 times as long as the width, and has an obtuse end. The margin is feebly angulated at the middorsum and considerably emarginated on the ventral side leaving small lateroventral projections on both sides of the funnel.

Fins.—The fins consist of 24 long, tapered, fleshy filaments on each side. The longest are the ninth and eleventh filaments (counted from the posterior), and

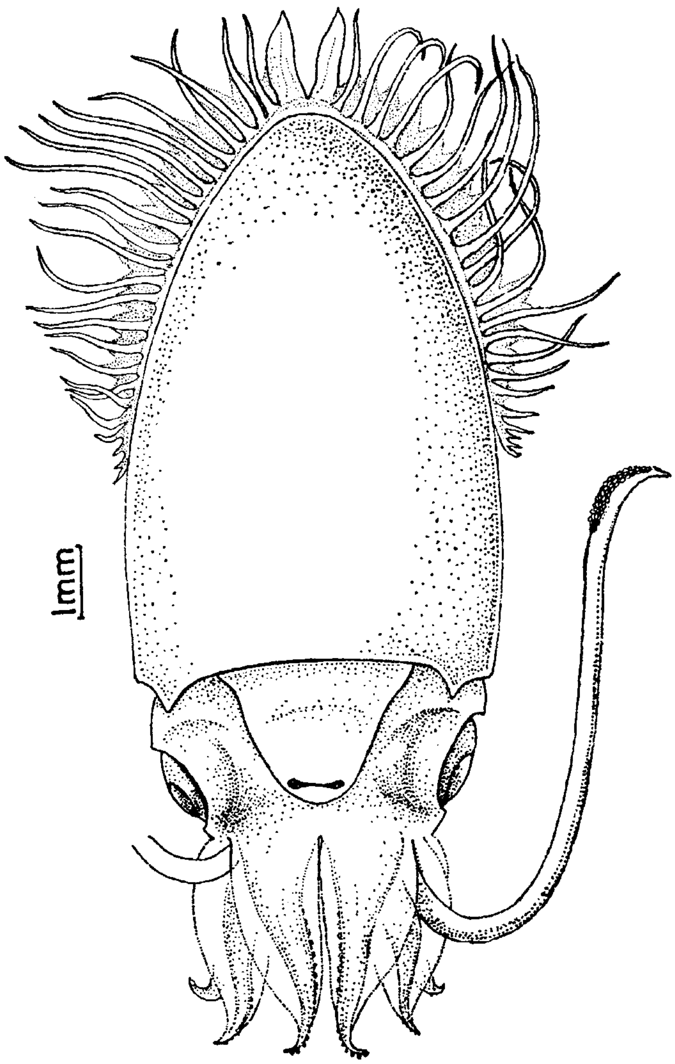


Fig. 13. *Ctenopteryx sicula*: ventral view of a young individual taken at station 120.50, cruise 5607.

they become as long as 2/3 the mantle length. The first (posteriormost) filament is short but widest and a V-shaped space exists between the two first filaments. The filaments are connected to one another by very thin, fragile membranes occurring on the proximal half of the filaments.

Head.—The head is narrower than the mantle opening. The eyes are large. The funnel nearly reaches the base of the arms.

Arms.—The arms are rather short, tapered toward the tips, and have swimming membranes on their lateral sides. The quadriserial, small suckers of the arms become biserial near the distal ends; the arm formula is 1 > 2 > 3 > 4.

Tentacles.—The tentacles are long, slender, and sheathed at the base by the ventral arm. On the distal 1/6 the club is narrow, with multiserial rows of small suckers.

Buccal membrane.—Not examined.

Gladius.—Not examined.

Chromatophores.—No chromatophores are present.

Remarks.—As pointed out by Allan (1945, p. 329), the illustrations by Pfeffer (1912) show the interfilamentary membranes reaching the distal tips of all filaments. This might be an oversight of the artist. Allan was the first to describe this species from the Pacific. Ours is the second record of the species from this ocean.

Family Ommastrephidae

9. Rhynchoteuthion Larvae

(Fig. 14)

References for description.—There are 25 earlier works referring to this type of larvae. Few of them have identified the larvae by tracing successive stages of the species to the identifiable adults. None of these references are quoted here, because no specimen in the present material was large enough to be regarded as a link between Rhynchoteuthion and any advanced stages having distinct species characters.

DESCRIPTION

The size range of our 23 specimens is from 1.4 mm to 7.3 mm.

Mantle.—The mantle is rather firm, bell-shaped, has a round posterior extremity, and is shorter than twice the width. The mantle margin is plain, but occasionally has very feebly developed lateroventral projections on both sides of the funnel (fig. 14, *a-d, j*).

Fins.—The fins are very small, delicate, membranous, and somewhat oval in outline.

Head.—The head is rather squarish. The eyes are very large and protruding up to the 3-mm-mantle-length stage, but gradually become more typical (fig. 14, *c, d, j*). The eye opening is transversely oval with a sinus on the anterior edge. The funnel is normal, but sometimes has a constriction in the middle owing to shrinkage by preservation.

Cartilages.—The funnel cartilage is elongate-triangular, narrowed anteriorly and widened posteriorly (the typical shape for the family). The socket groove is very deep and widened posteriorly (fig. 14, *g*). The mantle cartilage is button-shaped, corresponding to the peculiar shape of the groove of the funnel cartilage. The nuchal cartilage is spatulate.

Arms.—The arms are unequal in length. The dorsal arms may be differentiated after the mantle is longer than 1.7 mm. The ventral arms are not differentiated until the mantle length is 2.5 mm. The arm formula until then is 3 = 2 > 1. Only 1 sucker is present on each arm in the earliest stage (fig. 14, *a, b*), but the numbers of suckers gradually increase, and finally in the more advanced stages, form a double row.

Tentacles.—In the earliest stages, the tentacles are fused and form a proboscislike rod (fig. 14, *a-e*). The tip has 6 suckers (fig. 14, *f*) but it gradually bifurcates a little in older stages and grows more suckers (fig. 14, *h, i*). The tentacles begin

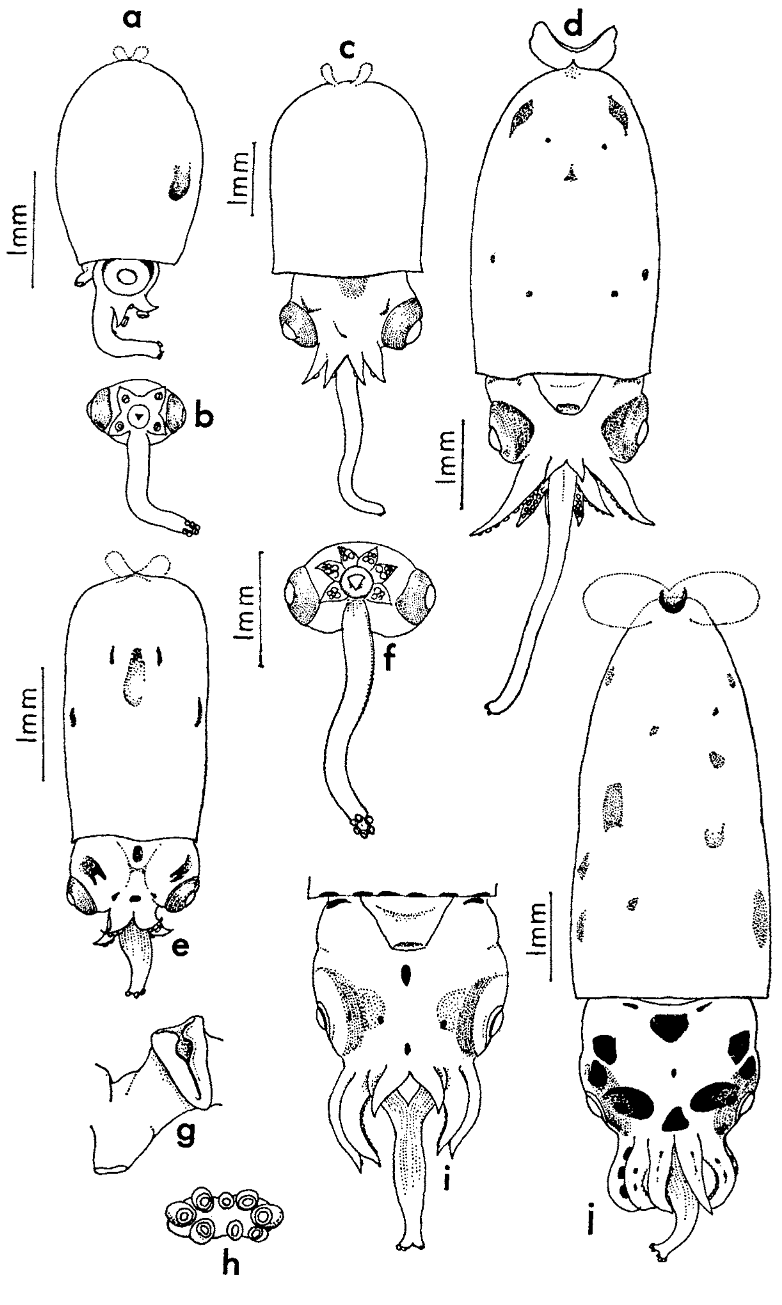


Fig. 14. *Rhynchoteuthion larvae: a*, lateral view of the right side of our smallest specimen taken at station 131.15, cruise 5508; *b*, oral view of *a; c*, dorsal view of a slightly larger individual than in *a* and *b*; taken at station 103.38, cruise 5701; *d*, ventral view of a "medium" sized specimen taken at station 157.15, cruise 5602; *e*, dorsal view of a "medium" sized specimen taken at station 157.100, cruise 5602; *f*, oral view of a "small" specimen; note that the arm-bud suckers and tentacle stalk are more developed than in the specimen in *b*; specimen taken at station 163.60, cruise 5612; *g*, funnel cartilage of the individual in *d; h*, tip of the tentacle stalk ("Rüssel") of a "small" specimen; *i*, ventral view of the cephalic area of *j; j*, dorsal view of a "large" larval individual taken at station 163.60, cruise 5612.

to separate at the base at about the 4.5-mm stage (fig. 14, *i*) when the ventral arms are already differentiated. They bear crowded biserial sucker buds.

Buccal membrane.—Not examined.

Gladius.—The gladius is very fragile, but shows the typical form for the family.

Chromatophores.—The chromatophores on the mantle appear at the earliest stage. There are 5 dorsal chromatophores in the 2-mm stage (fig. 14, *e*) and 9 at the 3-mm stage. The cephalic chromatophores are generally darker than those on the mantle. On the dorsal side of the head, a pair of chromatophores are present on the eye and two on the median line (fig. 14, *e*). When a mantle length of 4.5 mm is attained, 4 paired and 3 unpaired chromatophores are present on the dorsal side of the head (fig. 14, *j*), and 2 paired and 2 unpaired ones are present on the ventral side (fig. 14, *i*). The second and third arms usually have squarish chromatophores at this stage.

Remarks.—Chun (1903, p. 716) was the first to point out that Rhynchoteuthion is a larval form of an ommastrephid. Although he and many other authors called this *Rhynchoteuthis*, according to Pfeffer (1908, p. 88), the name *Rhynchoteuthis* was preoccupied by a fossil cephalopod. Chun (1910, pp. 202, 204) found that there are two forms of this larva in the Atlantic and Indian oceans. One is relatively slender in shape with medium-sized, but not protruding, eyes. The other form is characterized by a plump body. Massy (1916*a*, *b*) sustained Chun's two types as the result of an examination of her "Terra Nova" and "Helga" expedition specimens. Pfeffer (1912, p. 383) felt, however, that these two types were not specifically different. He suggested that they were probably affected by environmental conditions and might belong to *Ommastrephes bartrami (Stenoteuthis* of Verrill and many authors; see Adam, 1960*a*, for nomenclature), which is the commonest ommastrephid in the tropical Atlantic and Indian oceans.

Berry (1914, p. 341) also found two types of Rhynchoteuthion larvae in Hawaiian waters and he identified one as "*Ommastrephes" hawaiiensis*. He also regarded these larvae as being identical with *Rhynchoteuthis chuni* Hoyle, 1904.

Naef (1923) made a comparison of Rynchoteuthion larvae which he called "Rynchoteuthisstadium" of *Todarodes sagittatus* (Lamarck) and *Ommastrephes bartrami*. Although the specimens he examined were of a rather advanced stage (after the proboscis-like tentacle had begun to separate), the latter species is distinguished from the former by delay of tentacle development, denser distribution of the chromatophores, more slender mantle, wider tips of arms and tentacles, and so on.

Allan (1945, p. 332) studied some Rhynchoteuthion larvae from the eastern Australian waters and concluded that they were all larvae of *Nototodarus gouldi* (McCoy) which is the only ommastrephid known from that locality.

Rhynchoteuthion larvae of the Japanese common squid, *Todarodes pacificus* Steenstrup (= *Ommastrephes sloani pacificus* of Pfeffer, 1912, and many later authors; see Adam, 1960*a*, for nomenclature), were studied by Yamamoto (1946), Hayashi and Iizuka (1953*a*, *b*), Hamabe (1960*a*, *b*), and Okutani (1965) from material collected from various localities in the Tsushima Warm Current. The smallest specimen reported by Yamamoto was only 4.5 mm. Hayashi and Iizuka found that larvae smaller than 3.2-mm mantle length had their mantle openings nearly closed, and therefore the degree of tentacle and arm development was not observed. Hamabe showed, however, that larvae 1–2 days after hatching had the first to third arms and proboscis-like fused tentacles present.

Robson, 1948, reported that 102 specimens collected by the "Arcturus" expedition might belong to two species of *Stenoteuthis* (now *Ommastrephes*). His illustrations show a type of larva with a rather short mantle and an extraordinary long proboscis-like tentacle.

According to Berry (1912*a*), ommastrephid species previously recorded from California waters are: *Todarodes sagittatus* (Lamarck), *Ommastrephes bartrami* (Lesueur), *Dosidicus gigas* (d'Orbigny), and *Symplectoteuthis oualaniensis* (Lesson). The occurrence of *T. sagittatus* is doubtful, because the main habitats of the species are known to be the Atlantic Ocean and the Mediterranean Sea. Another species of the family, *Symplectoteuthis (Eucleoteuthis) luminosa* Sasaki, can be added to California cephalopod fauna (in the SIO invertebrate collection). All Rhynchoteuthion specimens in our material seem, however, to be a single form, not necessarily a single species. It is inconclusive as to which species they belong.

Our specimens definitely differ from *Todarodes pacificus* in having an undifferentiated dorsal arm at the 1.4-mm stage. Hamabe reported the dorsal arm of this Japanese species in already differentiated at the stage of less than 1 mm (Okutani, 1965). Further, Pfeffer's illustrations of successive stages of *Ommastrephes pteropus* show a somewhat more slender mantle shape, especially in the advanced stage. No comparisons to Naef's data were made owing to our lack of larger specimens. The most similar types previously recorded may be a plump type reported by Chun and some specimens of "(?) *Stenoteuthis* sp. (Rhynchoteuthion stage)" reported by Robson. It is interesting to note that the commonest ommastrephid adult from the southern sector of the California Current area is probably *Symplectoteuthis oualaniensis*.

To define more clearly the species of Rhynchoteuthion larvae from the area under survey, more intensive collections are required to obtain the intermediate stages linking the larval and adult forms.

Family Chiroteuthidae

10. *Chiroteuthis veranyi* (Ferrusac), 1835

(Fig. 15)

References for description.—Pfeffer, 1912, p. 55, pl. 46; Berry, 1963.

Synonyms.—See Berry, 1963.

Distribution records.—Atlantic Ocean, Mediterranean Sea, and California Current.

DESCRIPTION

Our 103 specimens of this species ranged in size from 7 mm in mantle length to about 25 mm. The morphological changes of this species during development are more gradual than most of the other species examined.

Mantle.—The mantle is translucent, subfusiform, and tapers posteriorly to a prolongation of the gladius which protrudes far beyond the posterior end of the body (fig. 15, *a, b*). The width of the mantle is 1/3 to 1/4 the length. The anterior margin of the mantle has a triangularly lobed middorsal projection.

Fins.—The fins are subterminal, and heart-shaped to subcircular in outline.

Head.—The neck is very long, transparent, cylindrical, narrowed toward the head, and is as long as the mantle (excluding the posterior prolongation) (fig. 15, *a, b*). The head is small, and clearly demarked from the transparent nuchal portion by its opaqueness. The eyes are circular and small. The olfactory tubercles are situated just behind the eyes, but are not found in very small specimens. The funnel is short, contracted, and abruptly narrowed distally.

Cartilage.—The funnel cartilage is thin, and ovate in outline.

Arms.—The arms are unequal in length and the formula is 4 > 3 > 2 > 1 in larger specimens (fig. 15, *b*), and 3 > 4 > 2 > 1 in smaller ones (fig. 15, *a*). In smaller specimens, all the arms are similar in thickness and shape. In larger specimens, the ventral arm is enormously developed and of a gelatinous nature. It has a wide swimming membrane on the outer margin and a narrow rim on the inner margin. It also bears small suckers arranged sparsely in a zigzag row (fig. 15, *c*).

Tentacles.—The tentacles are very long, flattened orally, round aborally. The club is somewhat expanded with 4 series of small suckers, about 50–60 in number. The carpus has numerous minute suckers in 4 series on the distal 1/3 to 1/4 of its length.

Buccal membrane.—Not examined.

Gladius.—The gladius is very fragile with a prolonged extension posteriorly.

Chromatophores.—The body is translucent and not many chromatophores are present.

Family Cranchiidae

(Subfamily Cranchiinae)

11. *Pyrgopsis pacificus* (Issel), 1908

(Fig. 16)

References for description.—Issel, 1908, p. 223, pl. 10, figs. 33–44 (as *Zygaenopsis*); Chun, 1910, p. 354, pl. 52, figs. 1–3; Sasaki, 1929, p. 338, pl. 27, figs. 7–17.

Synonyms.—See Sasaki, 1929, p. 338.

Distribution records.—Warm temperate to tropical areas of the Pacific, Atlantic, and Indian oceans.

DESCRIPTION

The 143 specimens collected ranged in size from 2.5 to 42 mm in mantle length. The morphological changes that take place during the growth of this species are so gradual that it is difficult to classify them into distinct growth stages. It is convenient to divide them for the purposes of description into larval, post-larval, and adolescent. It is important to note that characters described for the “stages” may be variable or overlap.

ADOLESCENT: MANTLE LENGTH LONGER THAN 12.0 MM

Mantle.—The mantle is subfusiform, with a sharply pointed posterior end stiffened by the gladius. The length of the mantle is less than 6 times the width. The mantle margin has a middorsal projection also stiffened by the anterior end of the gladius (fig. 16, *a*).

Fins.—The fins are oval, muscular rather than membranous.

Head.—The head is small. The eyes are protruding and ovoid. The funnel

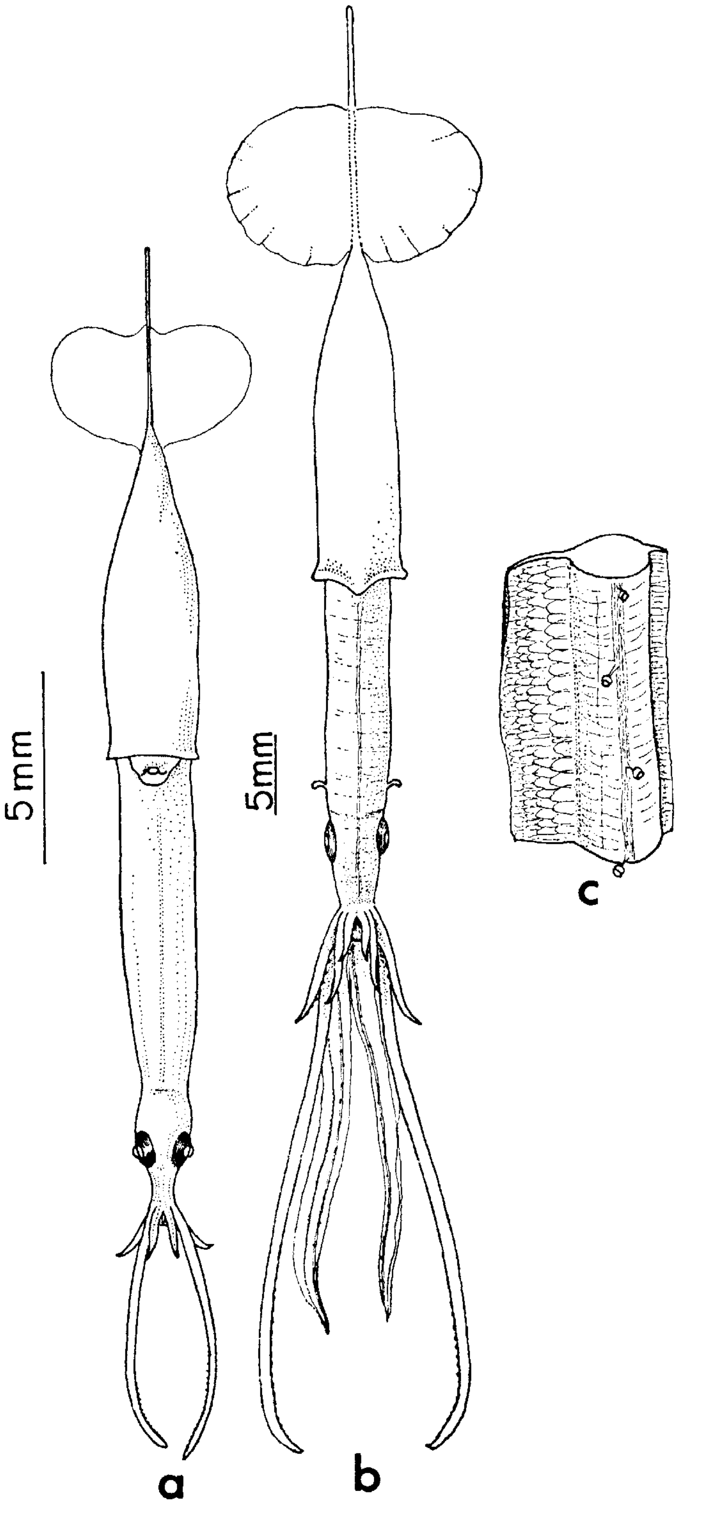


Fig. 15. *Chiroteuthis veranyi: a*, ventral view of a small individual taken at station 47.55, cruise 5605; *b*, dorsal view of a somewhat larger individual than in *a*; note the enlarged ventral arms; taken at station 70.80, cruise 5407; *c*, a section of the right ventral arm of the specimen in *b*.

reaches to the base of the eyestalk. The cephalic pillar (*Kopfpfeiler* of German authors) is cylindrical and slightly narrowed anteriorly (fig. 16, *b*).

Arms.—The arms are very short and the formula is 3 > 2 = 4 > 1. The arms have a double row of suckers and narrow swimming membranes when fully developed.

Tentacles.—The tentacles are long. The stems are flattened on the oral side, with a row of 7–10 tiny suckers on the median line. The clubs are lanceolate with 4 series of suckers. The centroproximal ones eventually become much larger than the others.

Buccal membrane.—The buccal membrane is protruding and lamellate.

Gladius.—The gladius is visible on the dorsal surface of the mantle. It is slightly widened anteriorly and forms a lanceola posteriorly.

Photophores.—Six photophores are present on the ventral periphery of the eye (fig. 16, *b*).

Chromatophores.—The chromatophores are not numerous. There are 4–5 pairs on the dorsal sides of the mantle, 1 on each side of the cephalic pillar near the base of the arms, 4–5 on the aboral surface of the tentacular stem, and several on the fins.

Crystalline streaks.—The crystalline streaks are present on both lateroventral sides of the mantle. The length of these streaks is as much as $^1/_5$ the mantle length and they bear several clusters of large tubercles interspersed with small ones (fig. 16, *b*).

4.1.11.3. POST-LARVAL: MANTLE LENGTH 2.5–12 MM

Mantle.—The mantle is semitransparent and subfusiform (fig. 16, *c, d*). The sharply pointed end is stiffened by the posterior end of the gladius. The length of the mantle is about 3 times the width. The mantle margin is smooth, or slightly projected at the middorsum on larger specimens.

Fins.—The fins are small, squarish to suboval, delicate, and membranous.

Head.—The head is small. The eyes are protruding and elliptical in outline. The funnel is conicocylindrical. The cephalic pillar is delicate, cylindrical, and elongated (fig. 16, *c, d*).

Arms.—The arms are poorly developed with a single to a few suckers on each. All arms are equal in length and size in the smaller specimens (fig. 16, *f, g*).

Tentacles.—The stems are flattened orally and bear a few sucker buds on the median line. The clubs are slightly expanded, bearing 4 rows of buds.

Buccal membrane.—The buccal membrane is not well developed; it is represented by a muscular ring encircling the mouth.

Gladius.—The gladius is very fragile, but visible on the dorsal surface of the mantle (fig. 16, *d*).

Photophores.—The photophores are immature or undeveloped.

Chromatophores.—The body is translucent and has no chromatophores.

Crystalline streaks.—The crystalline streaks are not developed, and on specimens of about 7 mm, only the precursors of a few tubercles are present (fig. 16, *e*).

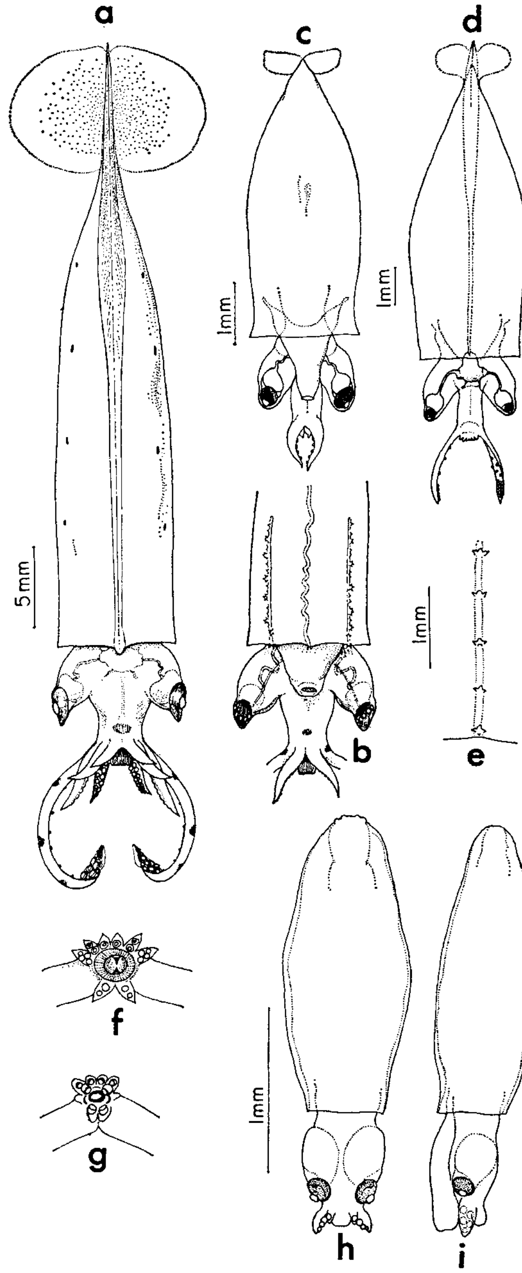


Fig. 16. *Pyrgopsis pacificus: a*, dorsal view of an adolescent taken at station 120.70, cruise 5701; *b*, ventral view of the cephalic region of *a; c*, ventral view of a post-larval individual taken at station 117.30, cruise 5507; *d*, dorsal view of a larger post-larval individual than *c*; taken at station 163.60, cruise 5612; *e*, a ventral hyaline streak of a post-larval specimen of 12-mm dorsal mantle length; taken at station 110.70, cruise 5604; *f*, buccal region of *e; g*, buccal region of the post-larval individual in *d*; note the developing arm buds; *h*, a larval individual taken at station 117.30, cruise 5507; note that the arms have not yet developed and that the tentacles are very small; *i*, a lateral view of the right side of *h*; note the relatively huge funnel and that the fins have not yet developed.

LARVAL: MANTLE LENGTH SMALLER THAN 2.5 MM

Mantle.—The mantle is translucent, delicate, elongate, cylindrical, with a blunt end. The mantle length is 3 times the width. The mantle margin is very thin and regular and has no indentations (fig. 16, *h, i*).

Fins.—The fins are undifferentiated (fig. 16, *h, i*).

Head.—The head is thick. The eyes do not protrude, and large optic thalami are visible through the cutis. The funnel is as long as the entire head part (fig. 16, *i*). The cephalic pillar is not elongated.

Arms.—The arms are undifferentiated, but their precursor is present as a short, thick, fleshy column (fig. 16, *h, i*).

Tentacles.—The tentacles are differentiated, but very short, with several sucker buds in a double row (fig. 16, *h, i*).

The gladius, buccal membrane, crystalline streaks, tubercles, photophores, and chromatophores are all undifferentiated.

(Subfamily Toaniinae)

12. *Teuthowenia megalops* (Prosch), 1849

(Fig. 17)

References for descriptions.—Pfeffer, 1912, p. 742, plate 48, figs. 5–11, 17, 18.

Synonyms.—See Pfeffer, 1912.

Distribution records.—Atlantic and North Pacific oceans.

DESCRIPTION

The 42 specimens examined range in size from 4 mm to 10 mm in mantle length. A single individual of 26 mm was found. The large specimen and the small ones are described separately.

ADOLESCENT: MANTLE LENGTH 26 MM

Mantle.—The mantle is semitranslucent, and drop-shaped (fig. 17, *b*). The broadest part is at about the anterior one-third. The conical posterior portion of the mantle ends in a sharply pointed extremity stiffened by the gladius. The margin is smooth and has a dorsal projection that is stiffened by the anterior end of the gladius.

Fins.—The fins are small, semicircular, and inserted near the posterior half of the lanceola. Both fins are feebly emarginated at the point of attachment (fig. 17, *c*).

Head.—The head is small, with stalked eyes and a very short cephalic pillar. The eyes are rather small and oval (fig. 17, *d*). The funnel is conical, reaching to the base of the arms (fig. 17, *b*).

Arms.—The arms are approximately equal in length. The arm formula is $3 > 2 = 1 > 4$. The longest arm is equal to 1/10 the mantle length. A double row of small, globular suckers is arranged alternately on the arms.

Tentacles.—The tentacles are thin, slender, as long as half the mantle length, and have weakly developed swimming membranes. The club has 4 series of suckers (fig. 17, *e*). The central suckers are slightly larger than the marginal ones. The stem has about 30 pairs of very thinly stalked small suckers sparsely arranged along the median line on the oral side.

Buccal membrane.—Not examined.

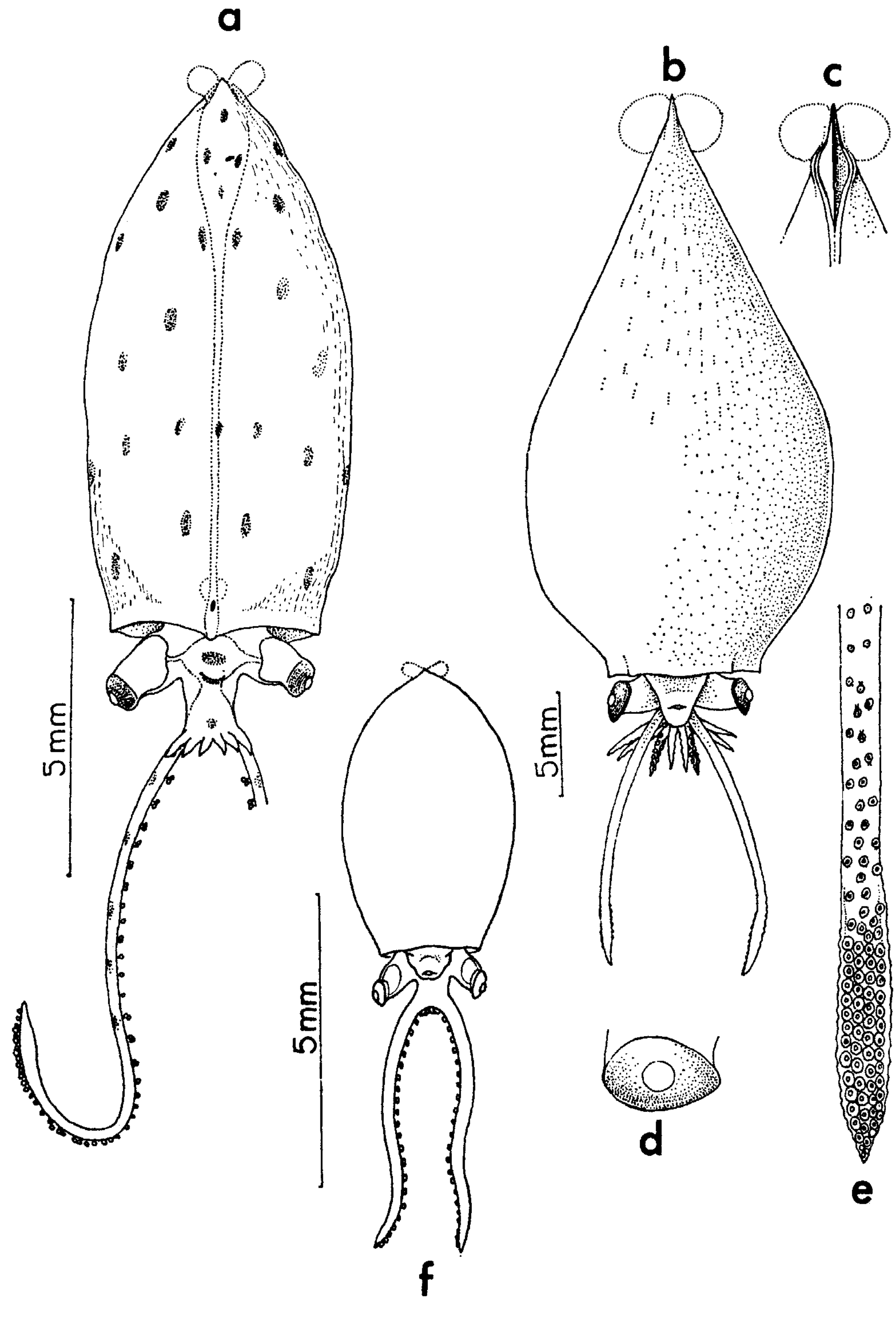


Fig. 17. *Teuthowenia megalops: a*, dorsal view of a larva taken at station 73.60, cruise 5607; *b*, ventral view of an adolescent taken at station 123.35, cruise 5408; *c*, dorsal view of the fin region of *b; d*, left eye of the specimen in *b; e*, a tentacle club and portion of the tentacle of the specimen in *b; f*, a very young larva taken at station 67.50, cruise 5607.

Gladius.—The gladius is visible on the middorsal line. The lanceola is transparent and rhomboidal in outline, and its posterior portion is solid and protrudes beyond the mantle (fig. 17, *c*).

Photophores.—Photophores on the optic vesicle were not visible.

Chromatophores.—There are traces of numerous chromatophores on the mantle surface.

Crystalline tubercles.—Neither crystalline tubercles nor streaks are present.

LARVAL: MANTLE LENGTH 4–10 MM

Mantle.—The mantle is barrel-shaped, transparent and membranous, broadest at the middle, with a blunt posterior. The margin has a dorsal projection at the anterior end of the gladius and very weak lateroventral projections (fig. 17, *a, f*).

Fins.—The fins are very small, ovoid, membranous, and delicate, inserted in the posterior half of the lanceola (fig. 17, *a, f*).

Head.—The head is small, with stalked eyes and a short, cylindrical, transparent cephalic pillar. The eyes are moderately large, oval, and have large optic thalami that are visible through the cutis (fig. 17, *a*). The funnel is contracted in the middle, and reaches to the middle of the cephalic pillar.

Arms.—In the earliest stages, only the dorsal and second arms are differentiated (they bear only two to four suckers); the third arm is differentiated at about the 8-mm stage; the ventral arm is differentiated at about the 10-mm stage.

Tentacles.—The lengths of the tentacles are about equal to the mantle length. The club is barely expanded, with four series of equal-sized suckers. The stem has twenty to thirty pairs of very small, long-stalked suckers on the oral side.

Buccal membrane.—Not examined.

Gladius.—The gladius is visible on the middorsal line (fig. 17, *a*). The lanceola is transparent and subrhomboidal in outline. It is indistinct, in small specimens.

Photophores.—None present.

Chromatophores.—The elliptical chromatophores are arranged sparsely and regularly on the mantle. No chromatophores are present in specimens smaller than about 6 mm in mantle length. Several chromatophores are present on the aboral face of the tentacular stems.

13. *Helicocranchia pfefferi* Massy, 1907

(Fig. 18)

References for descriptions.—Massy, 1907, p. 382; Massy, 1909, pp. 34–46, pl. 3; Pfeffer, 1912, p. 750.

Distribution records.—Northern Atlantic.

DESCRIPTION

Since this species has been previously known only from a limited area in the North Atlantic (type locality: “Helga,” 51° 54′ N., 11° W., 378–411 fathoms, Massy, 1907; Gulf of Gascogne and its neighborhood, Bouxin and Legendre, 1936), it was with some hesitation that our specimens were assigned to it. But the results of the examination of a series of specimens of different growth stages indicate that they are identical with those described by Massy. A comparison of her description with our 71 specimens is shown in table 7. The order of descriptive items was taken from Massy's description.

Remarks.—In addition to this species, only two other species of *Helicocranchia* are known from the Pacific. One is Berry's (*Helicocranchia* sp.) from Hawaii and the other is Robson's *H. beebei* from the eastern tropical Pacific (Berry, 1914; Robson, 1948).

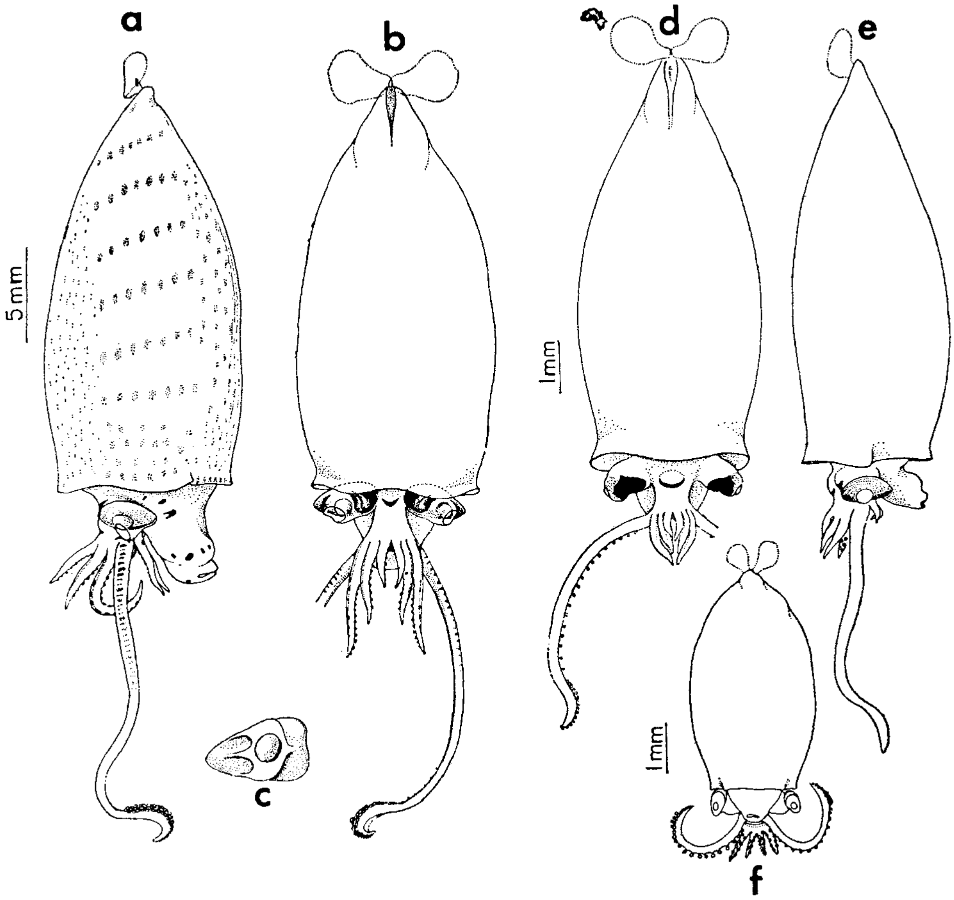


Fig. 18. *Helicocranchia pfefferi: a*, lateral view of our largest specimen taken at station 127.50, cruise 5701; note the extremely large funnel; *b*, dorsal view of *a; c*, anterior view of the right eye of *a; d*, dorsal view of a small specimen taken at station 150.25, cruise 5601; *e*, lateral view of *d; f*, ventral view of our smallest specimen; taken at station 127.40, cruise 5607.

14. *Liguriella* sp. (aff. *L. podophthalma*) Issel, 1908

(Fig. 19)

References for L. podophthalma.—Issel, 1908, p. 228, pl. 10, fig. 45, pl. 11, figs. 46–49; Pfeffer, 1912, pp. 693–694.

DESCRIPTION

Two chanchiids from station 100.80, cruise 5404, and station 113.35, cruise 5609, are a species of *Liguriella*. The only species known is *L. podophthalma* Issel from

TABLE 7

COMPARISON OF THE ORIGINAL DESCRIPTION OF *Helicocranchia pfefferi* AND OUR MATERIAL

Feature	Original descriptions (Massy, 1907, 1909)	CalCOFI material
Size	39 mm (dorsal mantle length of the type).	4.5 mm–22 mm (dorsal-mantle-length range).
Mantle	Broadest in the middle, tapering gradually and rounded posteriorly; breadth of the body less than half the mantle length.	Almost the same shape as the type specimen. Breadth about half the mantle length, but varies somewhat; posterior end of the body less tapered in small specimens than in larger ones (fig. 18, *a–f*).
Surface	Creamy white; dorsal surface closely freckled with dull-red, oblong chromatophores arranged irregularly; ventral surface and sides with 8 transverse rows of chromatophores, as well as a number of spots arranged in no particular order.	Opaque in large specimens, but translucent, pale yellow in small ones; chromatophore pattern coincides with that of the type specimen; on the sides of the mantle the regular arrangement of the chromatophores into rows is most obvious (fig. 18, *a*).
Fins	Narrowly pendunculate, broadly pyriform in outline, and somewhat fleshy; rather more than ⅕ the length of mantle; attached to the dorsal surface close to the posterior end of the body.	Pyriform in outline, large for the subfamily, separated; both fins attached to the posterior tip of the mantle where the posterior end of the lanceola is barely visible; both fins apparently connected to each other at their very narrow bases; this basal area is the only point of attachment of the fins to the mantle; width across the fins ⅙–¼ the mantle length (fig. 18, *b*, *d*).
Mantle margin	Depressed in midline dorsally, and there joined to siphon.	Same as the type specimen (fig. 18, *b*).
Eyes	Large, cone-shaped, attached in center of cone to a very short, broad stalk; lens placed in the center of cone and set obliquely, half on top and half on outer lateral surface; ventral surface on the cone occupied by a large, bluntly conical process; a luminous organ; on the dorsal face is a slight swelling strongly pigmented, possibly owing to the retinal pigment showing through the transparent tissues.	Large, stalked, conical, and slipper-shaped; large, semitranslucent process (luminous organ of Hoyle) covering the cone more conspicuous in large specimens (fig. 18, *c*); retinal pigment visible through the translucent integument.
Olfactory papilla	Toward the ventral end of each eye on the outer surface is an oblong, soft, white papilla, possibly the olfactory papilla.	Not visible; in other species such papillae undifferentiated until later stages.
Head	No description.	Cephalic pillar narrow, depressed dorsoventrally, with a small swelling on the dorsal surface; semilunar chromatophore present around the swelling in addition to a pair of circular ones in the area between the pillar and eyestalks on both sides.

TABLE 7—*Continued*

Feature	Original descriptions (Massy, 1907, 1909)	CalCOFI material
Buccal membrane	Apparently seven-angled.	Rather circular; supporting muscles obscure.
Siphon	Extremely large, extending about ⅔ the length of the ventral arms.	Extremely large, as long as 1/5–1/7 the mantle length (fig. 18, *a*).
Funnel organ	Consisting of two quadrangular folds on sides and a median dorsal organ; latter composed of a thin, trifoliate plate occupied by an anterior acicular tubercle, and two lateral tubercles in the form of thin, curved, roughly triangular processes.	Same as the type specimen, but undeveloped in small specimens.
Arms	Arms about ⅓ as long as the mantle; they are unequal, the apparent order of length 3, 2, 1, 4 (tips of ventral arms absent), slender and tapering, with transparent keel moderately developed on distal ⅔ of all, but least developed on dorsal arms; lateral membrane moderate, extending entire length of arms; margin usually straight; arms appear to be free.	Arms unequal in length; formula $3 > 2 > 1 > 4$ or $3 > 2 > 4 > 1$; ventral arm not well differentiated until the mantle length is more than 8 mm; arms have a depressed keel on the aboral faces: swimming membrane (lateral membrane of Massy) moderately developed; margin of the sucker-bearing faces truncated; arms very short and delicate in immature specimens (fig. 18, *f*).
Arm suckers	Stalked and arranged in two rows until the distal ⅓ of arm is reached, when they suddenly become very minute, crowded, and arranged irregularly. These minute suckers are stalked, and have a circular aperture. Toward the extreme tip they appear to be imperfectly formed. The large suckers have a circular, horny ring and about four rows of papillae. The latter when they cross the edge look like teeth. The suckers on all the arms are placed furthest apart on the proximal portion, gradually becoming placed closer together, and reaching their maximum size just before the commencement of the distal ⅓, where they are abruptly succeeded by the tiny suckers.	In small specimens, suckers immature; in large specimens, arrangement of suckers exactly the same as those of the type specimen.
Tentacles	Long, slender, and round. When bent back they extend rather more than ¾ the length of the mantle. The stem is thickest at its base, whence it narrows gradually but considerably, again expanding into a club furnished with a moderate swimming crest and lateral membrane.	Long, slender, and round; club lanceolate with a short, narrow aboral keel.
Tentacular suckers	In four rows, of which the 2 median are perhaps slightly the largest; about	Arrangement of suckers on the clubs same as in the type specimen; large

TABLE 7—*Continued*

Feature	Original descriptions (Massy, 1907, 1909)	CalCOFI material
	60 suckers present on each club with circular, horny rings with about four rows of papillae; about 15 pairs of minute suckers occur on the inner surface of the stem, placed close together near the club, become gradually more distant; apparently none are modified into fixing pads. There are none on the proximal portion of the stem, which is quite smooth in the type for the last 10 mm.	sucker rings have several horny teeth; stem of large specimens is suckerless (or with several pairs of small suckers on the distal portion), but the stem of smaller specimens bears more than 10 pairs of thin-stalked suckers; in suckerless specimens, oral surface (sucker-bearing face) of the stem has a longitudinal line.

the South Atlantic (28° 38
Mantle. S., 47° 32
Mantle. W.). Our specimens have some affinities with Issel's species. The comparison of the main characteristics of our species with *L. podophthalma* is given in table 8.

Remarks.—The measurements given in table 8 show that one of our specimens is much larger than Issel's specimen. Ours, however, has a very inconspicuous hyaline tubercle pattern. It is probably not merely a growth difference, but most likely a specific one. The other characters in both specimens are very similar. Hence, the present material is regarded as being congeneric with Issel's *Liguriella*, but probably not conspecific with *L. podophthalma*.

DISTRIBUTION AND ABUNDANCE

Although certain publications mentioned earlier in this report contain collection records of larval squid, none of them can be considered quantitative distributional studies. Some of these earlier works do give a considerable number of distribution records for larvae: Issel (1908), Degner (1926), Bouxin and Legendre (1936), and Allan (1945).

Because the collections used in the present study were intensive, in that they were repeated over a considerable period of time, a quantitative approach to the problems of spatial and temporal distributions was possible.

Definitions of terms used in this report:

Number of individual/station: the actual number of individuals per tow (multiplied by the appropriate factor if aliquots were used) was standardized to numbers per 1,000 m^3. In practice, the volume of water filtered by the nets was frequently greater than half of 1,000 m^3, and in very few cases were the samples split into aliquots.

Abundance: the standardized number of individuals collected/number of stations occupied on the cruise. This term is used in the same sense in both areal and temporal presentations.

Frequency: The number of positive stations/number of stations occupied on the cruise. This term is used in the same sense in both areal and temporal presentations.

In some cases both abundance and frequency data from several cruises were combined into seasonal groups. Also in some cases both frequency and abundance figures were combined by area.

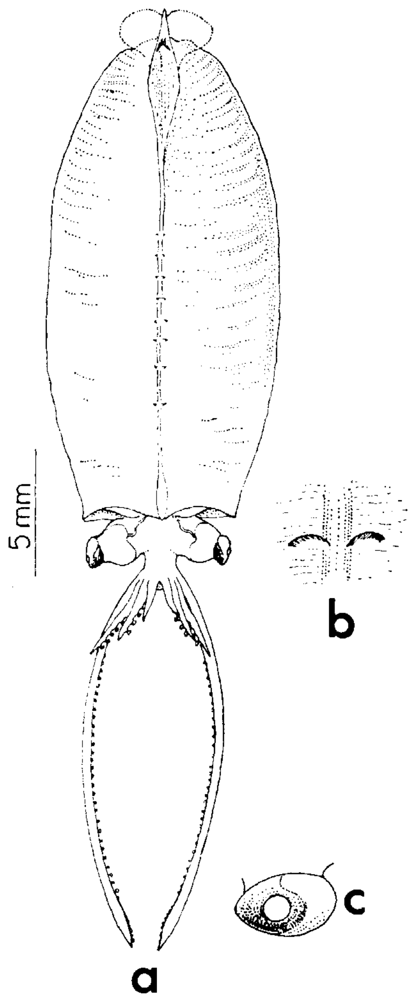


Fig. 19. *Liguriclla* sp. *a*, dorsal view of a specimen 20 mm in mantle length; taken at station 113.35, cruise 5609; *b*, anterior hyaline tubercle of *a*; *c*, left eye of *a*.

GENERAL COMPOSITION

COMPARISON WITH PREVIOUS STUDIES

Our material consists of 1 species of Myopsida and 13 species of Oegopsida. Table 9 shows family composition of the catches by past surveys and by our material. The results referred to are all plankton-net catches; material taken by other means is not included unless specified (table 9).

The adults of some of the larvae found in our collections have been known from the California Current prior to this survey, but there are very few records of larval cephalopods from this area. The decapods (mostly adults) previously reported from the area are as follows (Gabb, 1862*a*, *b*; Dall, 1872; Hoyle, 1886, 1904; Berry, 1911*a*, *b*, 1912*a*, 1913):

TABLE 8

COMPARISON OF *Liguriella podophthalma* WITH *Liguriella* sp.

Feature	*Liguriella podophthalma* Issel	*Liguriella* sp.
Size	Mantle length: 9 mm; width: 4 mm (L/W = 2.25).	(1) Mantle length: 20 mm; width: 8 mm (L/W = 2.50). (2) (Shrunken specimen) mantle length: 10.7 mm; width: 6 mm (L/W = .78).
Mantle	Entirely transparent (alive), membranous, and cylindrical. Narrowed toward the mantle margin, and posteriorly ending in a blunt point.	Translucent (preserved), membranous, barrel-shaped in general, ending in a sharp point (fig. 19, *a*).
Mantle margin	With a slight middorsal projection and ventral projections leaving a broad indentation.	With a middorsal projection, and inconspicuous ventral projections.
Gladius	Visible on the back; length of the lanceola ⅛ the gladius length; width of lanceola ⅔ its length.	Visible on the back; relationship of lanceola to other dimensions similar to Issel's species.
Fins	Very small, inserted in the posterior half of lanceola; most posterior point of the lanceola protrudes beyond mantle.	Very small, cordate in outline; attached to the posterior half of lanceola; posterior part of lanceola protrudes beyond posterior margin of fin (fig. 19, *a*).
Head and eyes	With stalked eyes that reach to arm base; cephalic pillar long and slender.	With stalked ovoid eyes (fig. 19, *ι*); stalk somewhat inflated toward base; cephalic pillar slender, tapering, medium in size and length (fig. 19, *a*).
Funnel	Protrudes slightly from the mantle edge; anterior tip oblique and posterior part constricted.	Conicocylindrical; frontal face constricted.
Arms	Rudimentary, length 1/7–1/8 of gladius; dorsal arm very short; second, third, and ventral arms nearly equal.	Well developed; arm formula $4 > 3 > 2 > 1$ in larger specimen (fig. 19, *c*).
Arm suckers	Globular, with nail-like teeth on chitinous ring.	Globular.
Tentacles	Strong, tapered, nearly equal to mantle length; club with swimming membrane along entire length. Stem naked on proximal ⅓ with biserial suckers on middle ⅓, and with four series of suckers on distal ⅓; club has 4 series of suckers of which central ones are larger than marginal ones.	Cylindrical, slender; club slightly expanded, with 4 series of suckers; central suckers slightly larger than marginal ones. Stem with 2 series of suckers, except the proximal ¼, which is naked.
Crystalline tubercles	Crystalline streak runs along the middorsal line from the end of the gladius expansion (lanceola?) to the anterior end of the gladius; 18 hyaline tubercles present on streak; tubercles serrated, with a longer slope anteriorly, and a shorter slope posteriorly.	No crystalline streak present, but half-embedded in the mantle integument are 8 tiny, inconspicuous, crescent-shaped, paired hyaline tubercles on the middorsal line in its central position (fig. 19, *a*, *b*).

Rossia pacifica Berry, *R. p. diegensis* Berry (primarily benthic).
Loligo opalescens Berry.*
Abraliopsis felis McGowan and Okutani.*
Pterygioteuthis giardi Fischer (reported from farther south).*
Onychoteuthis banksii (Leach).*
O. lobipennis Dall (never rediscovered since the original description was given).

TABLE 9

NUMBER OF SPECIES OF LARVAL OEGOPSIDS (BY FAMILY) IN COLLECTIONS OF DIFFERENT SURVEYS

Name of survey or ship	"Liguria"	"Mario Bianco"	Danish Oceanographic Expedition	....	"Warreen"	CalCOFI
Author	Issel	Issel	Degner	Bouxin and Legendre	Allan	Present survey
Year	1908	1925	1925	1936[a]	1945	1954–1957
Area covered	Worldwide tropical	Mediterranean	Mediterranean and North Atlantic	North Atlantic	East Australia	California Current
Family	Number in collection					
Enoploteuthidae	2	3	6	..	3	2
Octopodoteuthidae	1	..	1	1	..	1
Onychoteuthidae	1	1	1	1	2	1
Gonatidae	..	..	1	1	..	1
Histioteuthidae	..	..	2	2	1	1
Bathyteuthidae	..	1	1	1	1	1
Brachiteuthidae	..	1	1	1	1	..
Ommastrephidae[b]	2	2	3	4	1	1
Thysanoteuthidae	..	..	1	..	..	..
Chiroteuthidae	..	..	3	2	1	1
Cranchiidae	4	1	5	7	3	4
Total	10	9	25	20	13	13

[a] Includes findings from stomachs of Germons (*Germo alalunga*).
[b] Rhynchoteuthion larvae and other identifiable ommastrephids.

O. fusiformis Gabb (probably identical with *O. banksii*).
Moroteuthis robustus (Verrill).
Gonatus fabricii (Lichtenstein).*
G. (*Berryiteuthis*) *magister* Berry.
Meleagroteuthis heteropsis Berry.*
Todarodes sagittatus (Lamarck) (Berry, 1912*a*, quoted Whiteaves, 1887, with some doubt).
Ommastrephes bartrami (Leseur) (Although there were no records of this species from the area, Berry (1912*a*) suggested that it might occur here. His presumption is proved correct by the SIO collections).
Dosidicus gigas (d'Orbigny).

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*Larvae of this species occurred in our plankton collection.

Symplectoteuthis oualaniensis (Lesson).
S. (Eucleoteuthis) luminosa (Sasaki).
Cranchia scabra Linnaeus.
Galliteuthis phyllura Berry.
Chiroteuthis veranyi.*

The species listed tend to have different distributional ranges. Based on the collection records available (mostly of adult forms), they may be classified into three groups: (*a*) those known from the California Current only (endemic forms); (*b*) those distributed widely (cosmopolitan forms, temperate forms, tropical forms, and so on); (*c*) those presently little known (including those new to the Pacific, new species, and so on).

The ranges of the adults of the larvae that occurred in our plankton collections are given below (and on pp. 8–50, above). These ranges are based on the existing, published records and on our own (nonplankton) collections.

1. *Loligo opalescens* Berry. Local endemic form. According to Berry (1912*a*), this species is distributed from Puget Sound, Washington (about 48° N.), south to Monterey Bay and San Diego, California (32° 46' N.). The SIO collections (adult and adolescent) show that the southern extremity can be extended to Guadalupe Island and Turtle Bay, Mexico (27° 30' N.) (fig. 3).
2. *Pterygioteuthis giardi* Fischer. Nearly cosmopolitan, warm to cool temperate and tropical. This species has been collected from: Mediterranean Sea (Fischer and Joubin, 1906); Gulf of California; Galapagos Islands; Cape San Francisco, Ecuador (Hoyle, 1904; Robson, 1948); Indian and Atlantic oceans (Chun, 1910, 1913; Joubin, 1920); Gulf of Mexico (Voss, 1958); New Zealand (Massy, 1916*a*); Australia (Allan, 1945); Banda Sea (Adam, 1954) and the southern part of the California Current.
3. *Onychoteuthis banksii* (Leach). Nearly cosmopolitan; tropical to cool temperate, boreal and antiboreal in part, completely avoiding arctic and antarctic regions. Pfeffer (1912) cited more than 40 localities covering the area from the North Atlantic to the South Atlantic, and from the Central Pacific to the South Pacific and Indian Ocean. In the Atlantic Ocean there are no records from farther north than Hammerfest, Norway (71° N.), or farther south than Cape Horn (56° S.) (Massy, 1916). The northernmost record from the Pacific Ocean is the Bering Sea (Middendorf, 1849 [see Berry, 1913, and SIO collection]), and the southernmost, from New Zealand (Dell, 1952).
4. *Gonatus fabricii* (Lichtenstein). High arctic, boreal and antiboreal; rarely cool to warm temperate. This species has been known from such northern regions as: Greenland, Iceland, various places in Scandinavia (Sars, 1878; Friele and Grieg, 1901; Pfeffer, 1912; Hjort and Ruud, 1929; Grimpe, 1933; Frost and Thompson, 1934, and elsewhere), the North Atlantic (Degner, 1926; Bouxin and Legendre, 1936), and more southern locations such as, New England, Nova Scotia (Verrill, 1880), Kamchatka, Bering Sea, northern Japan (Dall, 1886; Sasaki, 1920, 1929), and the western coast of North America (Berry, 1912). The southern most records in the northern hemisphere are 36° 12' N. in the Atlantic (Degner, 1926)

and about 54° 30′ N. in the Pacific (Sasaki, 1920).* This species has also been found in or near the Antarctic Ocean (two records only), south of the Cape of Good Hope (Steenstrup, 1881) and south of South America (Lönnberg, 1898, as *Gonatus antarcticus*). The latter specimens have been treated as a "southern form" of the species by Pfeffer (1912).

5. *Meleagroteuthis heteropsis* Berry. Endemic? Since Berry (1912*a*, as *M. hoylei*; 1913, emended) originally described this species from the California coast, no other records have been published. This may be a deep endemic form, as the three known species of this genus show somewhat restricted distributions. They are: *M. asteroessa* Chun (western Indian Ocean); *M. hoylei* Pfeffer (tropical Pacific); and *M. separata* Sasaki (Japan). The distributional ranges of these species are not clear.
6. *Ctenopteryx sicula* (Verany). This species has been found in the Mediterranean Sea and in the Atlantic Ocean (Chun, 1910; Pfeffer, 1912; Issel, 1925; Degner, 1926; Naef, 1923). It has also been reported from the eastern coast of Australia (Allan, 1945). The northernmost record in the Atlantic is from 41° 44′ N. (Degner, 1926) and the southernmost record is from 32° 08′ S. (Thiele, 1920). No records from the Indian Ocean are available.
7. *Chiroteuthis veranyi* (Ferrusac). Previously known only from the Atlantic Ocean and the Mediterranean Sea (Joubin, 1900; Pfeffer, 1912).
8. *Pyrgopsis pacificus* (Issel). Indo-Pacific tropical to warm temperate. This species has been collected from the tropical Pacific (Issel, 1908), Japan (Chun, 1910; Sasaki, 1929), Australia (Allan, 1945), Banda Sea (Adam, 1954) and the African coast (Robson, 1924).
9. *Teuthowenia megalops* (Prosch). Previously known only from the Atlantic Ocean, in the Gulf Stream, Sargasso Sea, South Equatorial Current, Bay of Biscay, and Faroe Islands (Pfeffer, 1912; Joubin, 1920; Voss, 1960).
10. *Helicocranchia pfefferi* Massy. Previously recorded only from Irish waters (Massy, 1907, 1909) and the North Atlantic (Bouxin and Legendre, 1936).
11. *Abraliopsis felis* McGowan and Okutani. This species is probably endemic to the California Current. All our records of the occurrence of both adults and larvae are from this area only. It has not occurred in our many collections from the area south of here (the eastern tropical Pacific), or from the central or subarctic Pacific Ocean.
    If it is truly endemic, it is similar in this regard to a closely related species, *A.* (*Watasenia*) *scintillans* Berry, which is known to occur only in the waters around Japan.
12. Undetermined species.
    - *a*) *Octopodoteuthopsis* sp. The difference between this species and the two known *Octopodoteuthopis* species was mentioned above (p. 21). There is not enough information to discuss the relationship between our material and the known forms.
    - *b*) Rhynchoteuthion larvae. Since it is not known to which species of ommastrephid these larvae belong, no discussion of adult ranges can be given. The adult

* According to Sasaki (1929), Steenstrup gave the vague locality as "Japan." The exact position is not known.

TABLE 10

GENERAL SUMMARY OF DISTRIBUTIONAL RANGES[a]

Region	Subregion[c] (approximate positions)	Species: *Loligo opalescens*	*Abraliopsis felis*	*Pterygioteuthis giardi*	*Octopodoteuthopsis* sp.	*Onychoteuthis banksii*	*Gonatus fabricii*	*Meleagroteuthis heteropsis*	*Ctenopteryx sicula*	Rhynchoteuthion larvae[b]	*Chiroteuthis veranyi*	*Pyrgopsis pacificus*	*Liguriella* sp.	*Teuthowenia megalops*	*Helicocranchia pfefferi*
Arctic							+								
West Pacific	Boreal (Kamchatka; northern Japan).........					+	+								
	North temperate (Japan)..					+				+		+			
	Tropical (East Indies; northern Australia).....			+		+				+					
	South temperate (southern Australia)			+		+			+	+		+			
	Antiboreal (New Zealand).			+		+						+			
Mid-Pacific	Mostly tropical...........					+				+					
East Pacific	Boreal (Bering Sea; Alaska)					+	+								
	North temperate (*area under study*).............	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Tropical (Central and northern South America)			+		+				+					
	South temperate (mid-South America).........	(No information)													
	Antiboreal (Southern South America).........	(No information)													
Atlantic	Boreal (Scandinavia; England; Davis Strait)..			+		+	+							+	+
	North temperate (Bay of Biscay; Azores; Mediterranean; New England)..			+		+	+		+	+	+			+	+
	Tropical (East Africa: Caribbean Sea).........			+		+				+	+				
	South temperate (South Africa; Mid-South America)					+			+						
	Antiboreal (Southern South America).........					+									
Indian Ocean	Mostly tropical to South temperate.............					+				+		+			
Antarctic							+								

[a] SOURCES: Adam, 1954, 1960*b*; Allan, 1945; Berry, 1912*a*, 1912*b*, 1913, 1914, 1916, 1918, 1920; Bouxin and Legendre, 1936; Chun, 1910, 1914; Dall, 1884, 1886; Degner, 1926; Dell, 1952; Fischer and Joubin, 1906; Friele and Grieg, 1901; Frost and Thompson, 1934; Goodrich, 1896; Grimpe, 1933; Hjort and Ruud, 1929; Hoyle, 1886, 1904; Issel, 1908, 1925; Joubin, 1895, 1900, 1920; Lönnberg, 1898; Massy, 1907, 1916*a*, 1916*b*; Naef, 1923; Pfeffer, 1908, 1912; Powell, 1957; Rees and Maul, 1956; Robson, 1924, 1948; Sars, 1878; Sasaki, 1920, 1929; Thiele, 1920, 1935; Verrill, 1880, 1885; Voss, 1956, 1958, 1960.

[b] Rhynchoteuthion larvae are not monospecific.

[c] Areal subdivisions are based on Ekman, 1953, and Steuer, 1933, cited by Hedgpeth, 1957.

members of this genus known to be present in the area are species that range widely in the warm temperate and tropical Pacific.

c) *Liguriella* sp. As our material consists of only two specimens, no discussion of this species can be given.

Based on the above information, species distribution ranges are summarized in table 10. As mentioned earlier, they are mostly collection records for adults, and contain few larval data.

TABLE 11

NUMERICAL COMPOSITION OF THE CALCOFI COLLECTION

Species	Actual number of specimens examined	Number of positive stations	Percent of all positive stations	Percent of total stations occupied
Loligo opalescens	276	101	8.1	2.6
Abraliopsis felis	1,754	615	49.6	15.8
Pterygioteuthis giardi	196	90	7.3	2.3
Octopodoteuthopsis sp.	41	43	3.5	1.1
Onychoteuthis banksii	132	85	6.8	2.2
Gonatus fabricii	636	359	28.9	9.2
Meleagroteuthis heteropsis	9	9	0.7	0.2
Ctenopteryx sicula	1	1	0.08	0.03
Rhynchoteuthion larvae	23	16	1.3	0.4
Chiroteuthis veranyi	103	87	7.0	2.2
Pyrgopsis pacificus	143	77	6.2	2.0
Liguriella sp.	2	2	0.2	0.05
Teuthowenia megalops	42	33	2.7	0.8
Helicocranchia pfefferi	71	64	5.2	1.6
Total	3,429	...	....	....

RELATIVE ABUNDANCE AND FREQUENCY

Of 3,895 stations occupied during the period from April, 1954, through March, 1957, the positive stations are 1,240. The total number of specimens examined was 3,429. The numerical composition is shown in table 11.

As evident from table 11, the most abundant species in our collections was *Abraliopsis felis* followed by *Gonatus fabricii* and *Loligo opalescens*. For comparisons among species, the abundance and frequency are ranked in table 12.

SEASONAL ABUNDANCE AND POPULATION PATTERNS

Abraliopsis felis.—The larvae of *Abraliopsis felis* occurred throughout the entire area surveyed. There are, however, large variations in its areal abundance and frequency. The area may be arbitrarily divided into three sections: *North* (north of line 80 at Point Conception [fig. 1]); *Central* (between line 80 and line 120 at Punta Eugenia [fig. 1]); and *South* (south of Punta Eugenia [fig. 1]). Although these divisions were chosen as a matter of convenience, they have some biological basis. Studies of the zooplankton of the California Current have shown that north of Point Conception (34° 30’ N.) the fauna has affinities with the Subarctic and Transition Zone species assemblages (McGowan, 1960; Brinton, 1962).

TABLE 12

SPECIES RANKS OF CALCOFI COLLECTION BY ABUNDANCE AND FREQUENCY

Species	Abundance	Abundance of species as percent of *Abraliopsis felis* abundance	Frequency
Abraliopsis felis	1.275	100.0	0.158
Gonatus fabricii	0.434	33.9	0.092
Loligo opalescens	0.317	24.9	0.026
Pterygioteuthis giardi	0.116	9.1	0.023
Onychoteuthis banksii	0.101	8.0	0.022
Pyrgopsis pacificus	0.081	6.3	0.020
Chiroteuthis veranyi	0.074	5.9	0.019
Helicocranchia pfefferi	0.046	3.6	0.016
Octopodoteuthopsis sp.	0.028	2.8	0.011
Teuthowenia megalops	0.026	1.6	0.008
Rhynchoteuthion larvae	0.019	1.4	0.004
Meleagroteuthis heteropsis	0.006	0.4	0.002
Liguriella sp.	0.000	0.0	0.001
Ctenopteryx sicula	0.000	0.0	0.000

TABLE 13

SEASONAL CHANGES OF ABUNDANCE AND FREQUENCY FOR NINE SPECIES IN CALCOFI COLLECTION

Species	Abundance				Frequency			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Abraliopsis felis	1.168	2.330	1.355	1.154	0.166	0.238	0.072	0.042
Gonatus fabricii	0.534	0.557	0.239	0.162	0.097	0.120	0.033	0.061
Loligo opalescens	0.431	0.134	0.235	0.435	0.020	0.019	0.033	0.048
Pterygioteuthis giardi	0.164	0.202	0.091	0.080	0.015	0.048	0.024	0.015
Onychoteuthis banksii	0.083	0.194	0.042	0.005	0.022	0.034	0.018	0.003
Pyrgopsis pacificus	0.034	0.210	0.048	0.041	0.010	0.035	0.018	0.015
Chiroteuthis veranyi	0.046	0.145	0.054	0.019	0.016	0.038	0.021	0.008
Helicocranchia pfefferi	0.062	0.043	0.000	0.026	0.022	0.015	0.000	0.015
Teuthowenia megalops	0.017	0.018	0.018	0.035	0.007	0.008	0.009	0.001

From Point Conception south to Punta Eugenia (27° 51′ N.) the zooplankton is highly mixed, in the sense that it contains Transition Zone, Central Water Mass, endemic (to this area), neritic, and occasionally Equatorial Water Mass species. South of Punta Eugenia the number of Equatorial Water Mass species increases until, at approximately the latitude of Magdalena Bay (24° 38′ N.), the zooplankton is essentially Equatorial. These faunal breaks do not entirely follow the latitudinal lines cited above. Lines normal to the coast were used in this report, however, to simplify the presentation of the data.

A tabulation of the three years of data for this species shows that for the entire period the larvae tended to be more abundant in the North sector, but more frequent in the Central sector (table 15). Both the abundance and the frequency were low in the South. A breakdown of these data by month (table 14) reveals

TABLE 14

Areal Abundance and Frequency of *Abraliopsis felis* Larvae by Cruise

Cruise	North			Central			South		
	Number of stations	Abundance	Frequency	Number of stations	Abundance	Frequency	Number of stations	Abundance	Frequency
5404.......	24	6.00	0.375	134	0.32	0.007	38	0	0
5405.......	25	3.52	0.360	142	4.72	0.457	38	0.26	0.053
5406.......	42	7.95	0.572	132	2.93	0.333	35	0.06	0.029
5407.......	24	3.40	0.640	118	1.47	0.137	20	0.10	0.050
5408.......	29	1.45	0.311	74	0.70	0.189	19	0	0
5410.......	8	0.75	0.125	77	0.37	0.117	20	0.10	0.050
5412.......	5	0	0	79	0.11	0.038	37	0.05	0.027
5501.......	5	0.80	0.200	69	0.20	0.058	38	0.05	0.026
5502.......	4	0	0	75	0.31	0.093	38	0.05	0.026
5503.......	5	0.40	0.200	85	0.38	0.118	52	0	0
5504.......	6	0	0	94	1.03	0.256	25	0.24	0.040
5505.......	22	0.46	0.136	138	1.44	0.363	23	0.17	0.043
5506.......	34	2.53	0.413	132	1.53	0.258	25	0.08	0.040
5507.......	29	14.41	0.553	141	0.97	0.170	25	0.08	0.040
5510.......	25	0.56	0.200	66	0.06	0.033	17	0	0
5512.......	6	0	0	70	0.06	0.013	30	0.20	0.067
5601.......	6	0.33	0.167	70	0	0	35	0.57	0.021
5602.......	6	0.66	0.333	73	0.04	0.036	49	0	0
5603.......	6	0.33	0.167	107	0.49	0.103	28	0	0
5604.......	33	0.36	0.093	99	0.67	0.153	46	0.04	0.022
5605.......	59	1.00	0.136	150	1.21	0.240	24	0.29	0.125
5606.......	58	2.04	0.224	130	2.48	0.393	25	0	0
5607.......	40	9.48	0.475	139	1.72	0.158	23	0.35	0.130
5608.......	0	0	0	12	0	0	14	0	0
5609.......	0	0	0	12	0	0	14	0.71	0.071
5610.......	0	0	0	42	0.38	0.012	0	0	0
5701.......	0	0	0	36	0.17	0.083	20	0.60	0.150
5703.......	0	0	0	71	0.95	0.155	43	0	0

TABLE 15

Total Areal Abundance and Frequency of *Abraliopsis felis* by Sector

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
3.60	0.106	1.19	0.208	0.10	0.032

that the above summary is somewhat crude in that it does not show that during certain seasons of the year *both* the abundance and frequency may be higher in either the North or Central sectors. The South also had a few highs of abundance and frequency. These were usually during the winter.

Although it is a convenient way to express data, the arbitrary division of the California Current into these three sectors tends to mask certain interesting features of the actual distribution of the larvae. Figures 20–22 show these distributions,

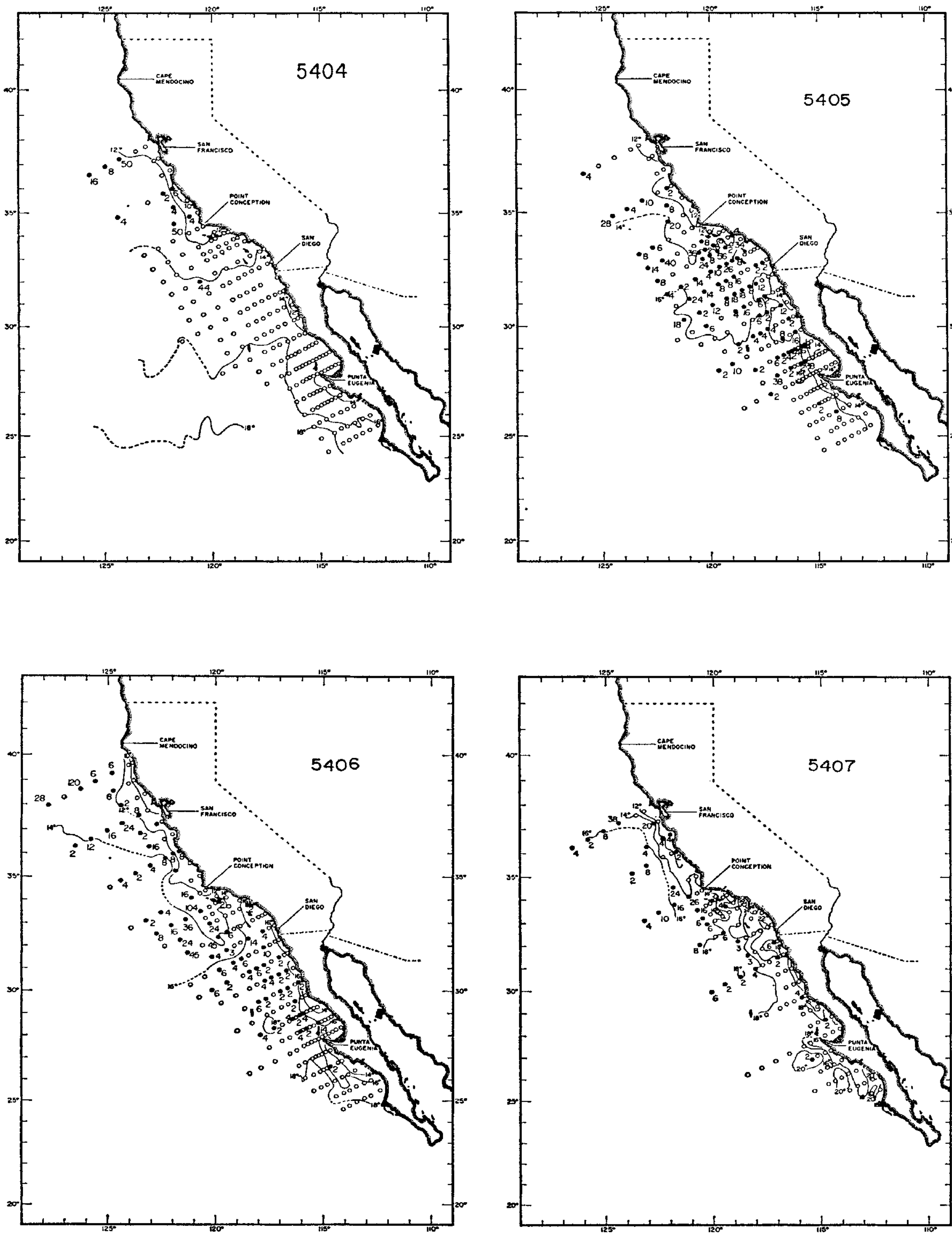

Fig. 20. Distribution and abundance records for *Abraliopsis felis*. The black dots represent positive stations. The circles are negative stations. The numbers just below the black dots are the numbers of individuals captured per 1,000 m^3 water strained. The 10-meter isotherms are also shown. The temperatures are given in degrees Celsius. The large number in the upper right is the year and month in which the samples were taken (see table 1).

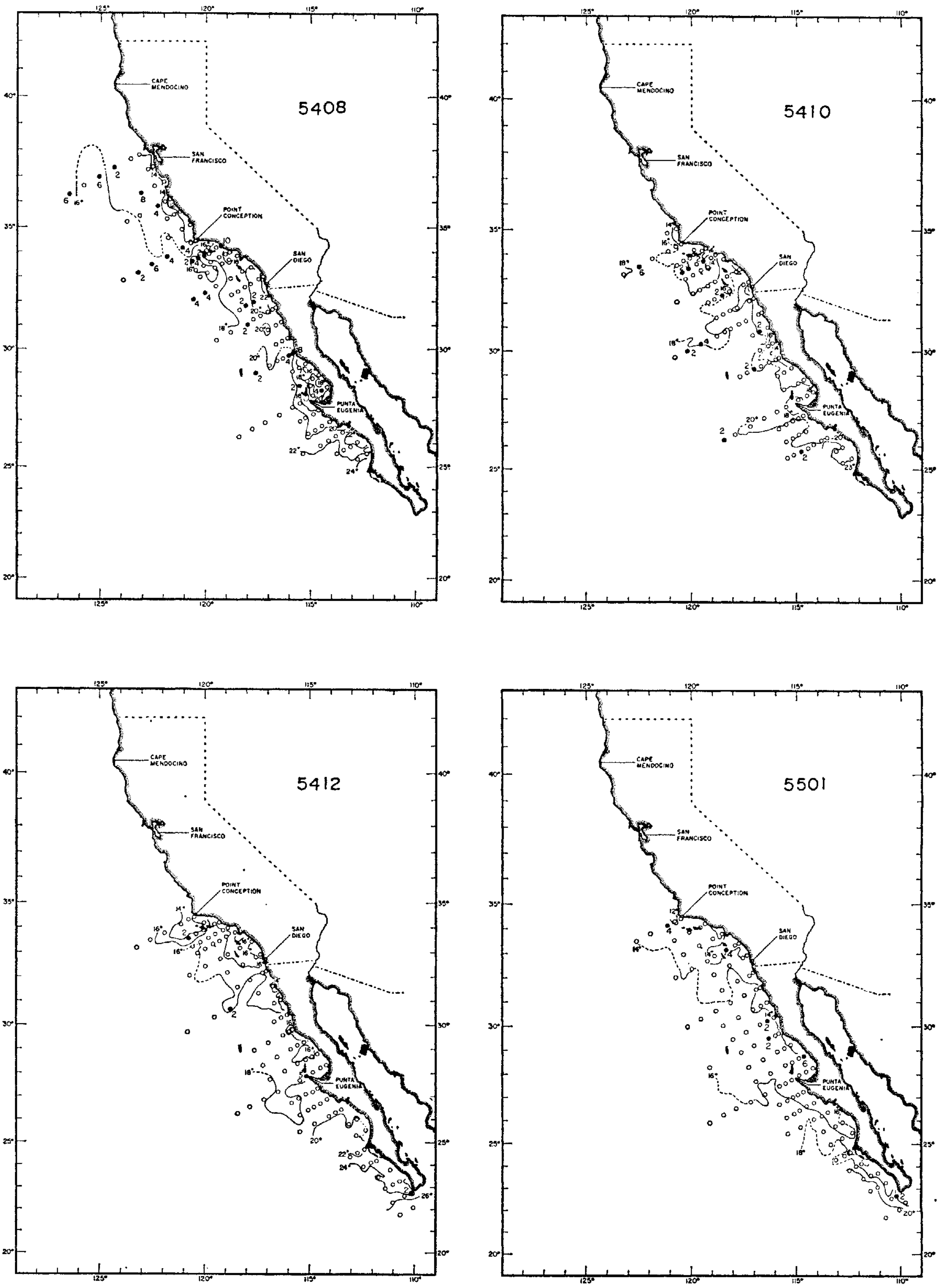

Fig. 21. Distribution and abundance records for *Abraliopsis felis* (symbols as in fig. 20).

by month, for the years 1954 and 1955, and it may be seen that the larvae appear in the northwest early in the year, and then tend to spread to the rest of the North and Central sectors. It is also evident (fig. 20, 5406) that, on occasion, certain stations in the North and Central sectors had relatively large swarms of larvae.

A further feature of the occurrence of this species is its preference for offshore waters. This may be seen in a general way by examining the charts of distribution (figs. 20–22). A graphic indication of this is shown in figure 23. For the purposes

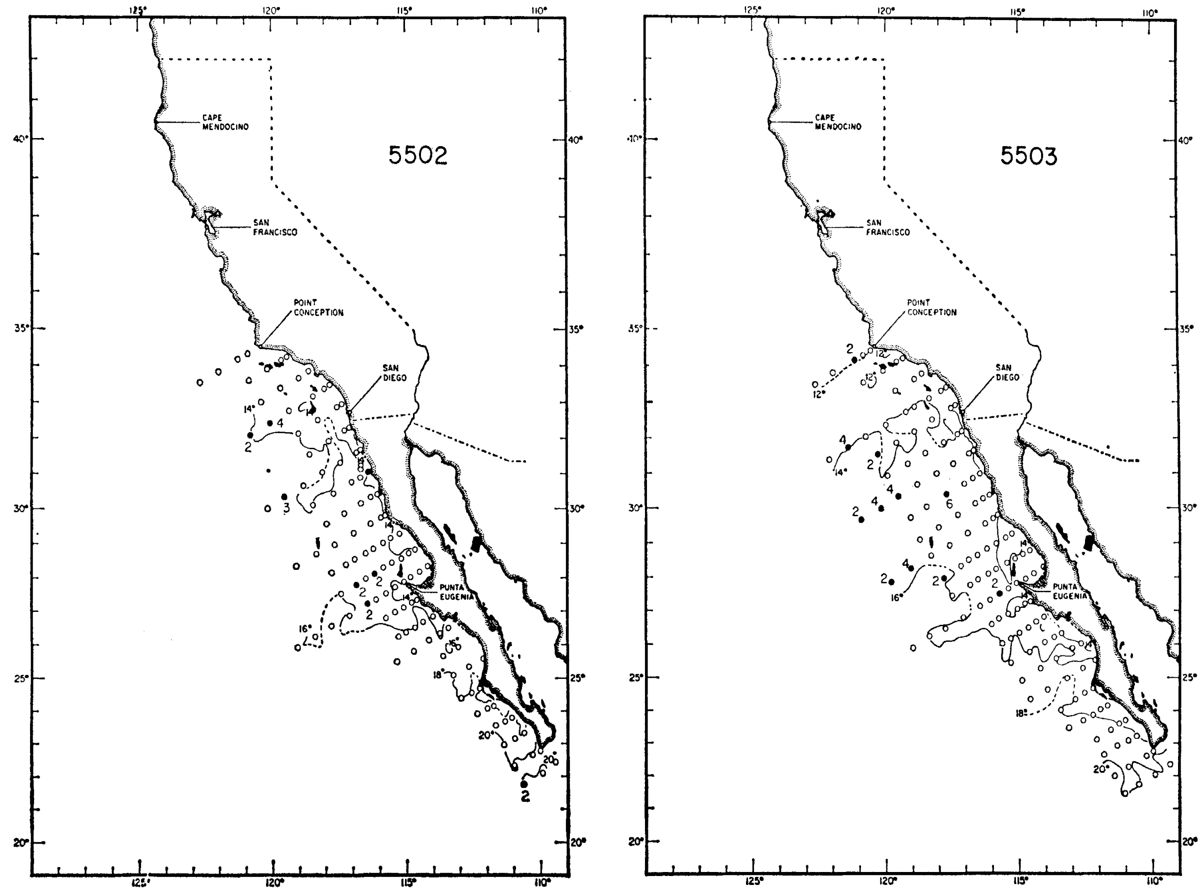

Fig. 22. Distribution and abundance records for *Abraliopsis felis* (symbols as in fig. 20).

of this study, the inshore-offshore boundary was arbitrarily set at 50 miles off the coast. It is obvious from the graph that, throughout the year, *Abraliopsis felis* larvae are more abundant offshore than inshore.

The larvae of this species showed a marked seasonal cycle of abundance. (fig. 24). If all the occurrences for all sectors are totaled, the peak months of abundances are May, June, and July. The sharp decline in abundance in August may owe in part to larval mortality, but it also seems likely that it could be attributed to avoidance of the net by larvae that have grown large enough to swim rapidly. The larvae that occur in the winter show no particular pattern and seem to be found in all sectors.

Gonatus fabricii.—The larvae of *Gonatus fabricii* occurred generally throughout the California Current but are somewhat more patchy in distribution than *A. felis* (figs. 25–27). A tabulation of their abundance and frequency, by sector (table 16), shows that they are both more abundant and more frequent in the North than in the other sectors. There is, however, probably no real difference between Central and South sectors.

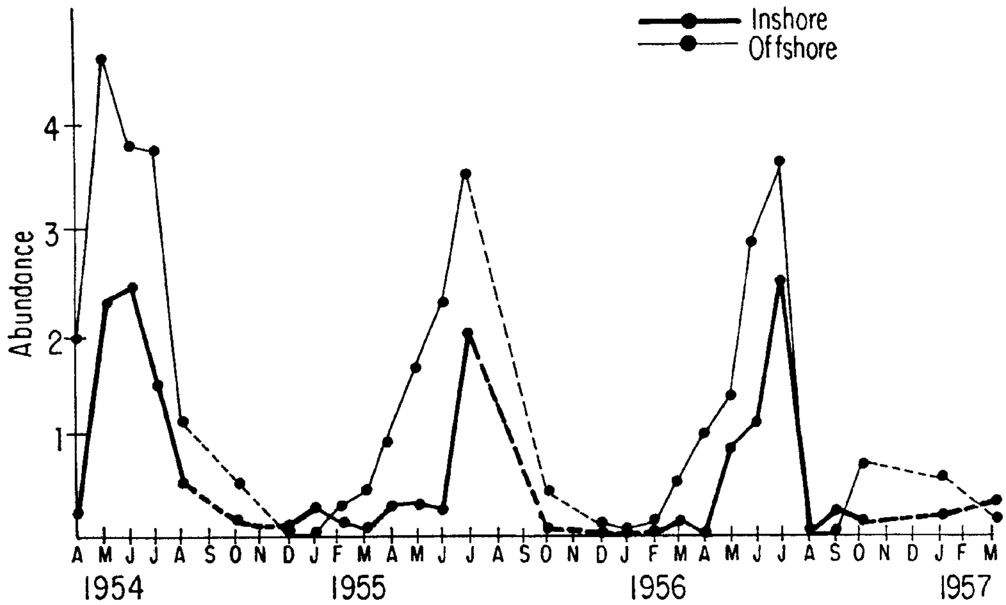

Fig. 23. Seasonal and yearly fluctuations in abundance of *Abraliopsis felis* in offshore and inshore waters. The broken lines are interpolations of the curves where there are no monthly data. The black dots represent months during which samples were taken.

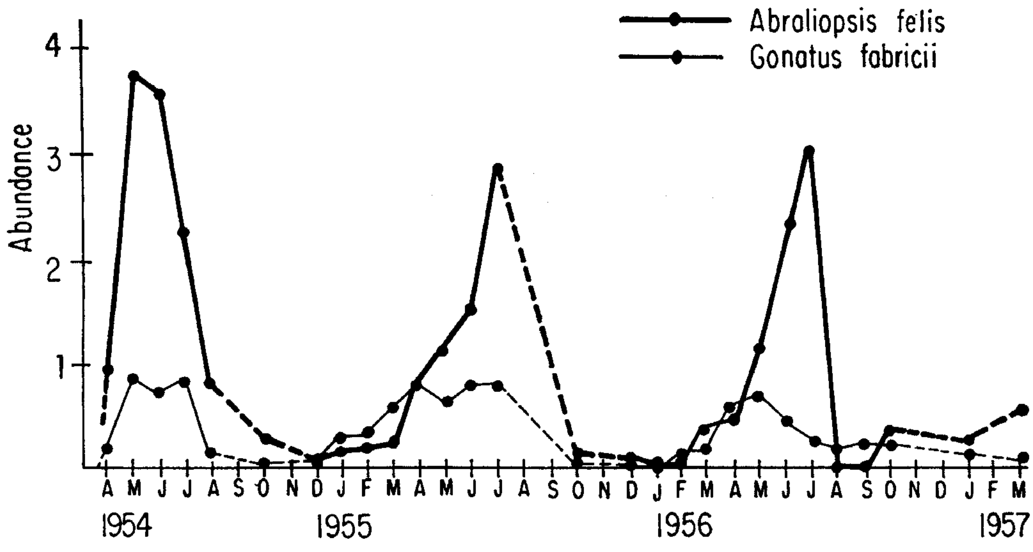

Fig. 24. Seasonal and yearly periods of abundance of *Abraliopsis felis* and *Gonatus fabricii* (symbols as in fig. 23).

There are no very marked trends in inshore-offshore abundance (fig. 28). The years 1954 and 1955 show a peak in abundance offshore in the spring and inshore in the summer, but this did not occur in 1956. In that year the offshore abundance was similar in spring and summer.

The larvae of *G. fabricii* show a seasonal peak in abundance (fig. 24, table 17). Although this tendency is less pronounced than for *A. felis*, it is consistent enough

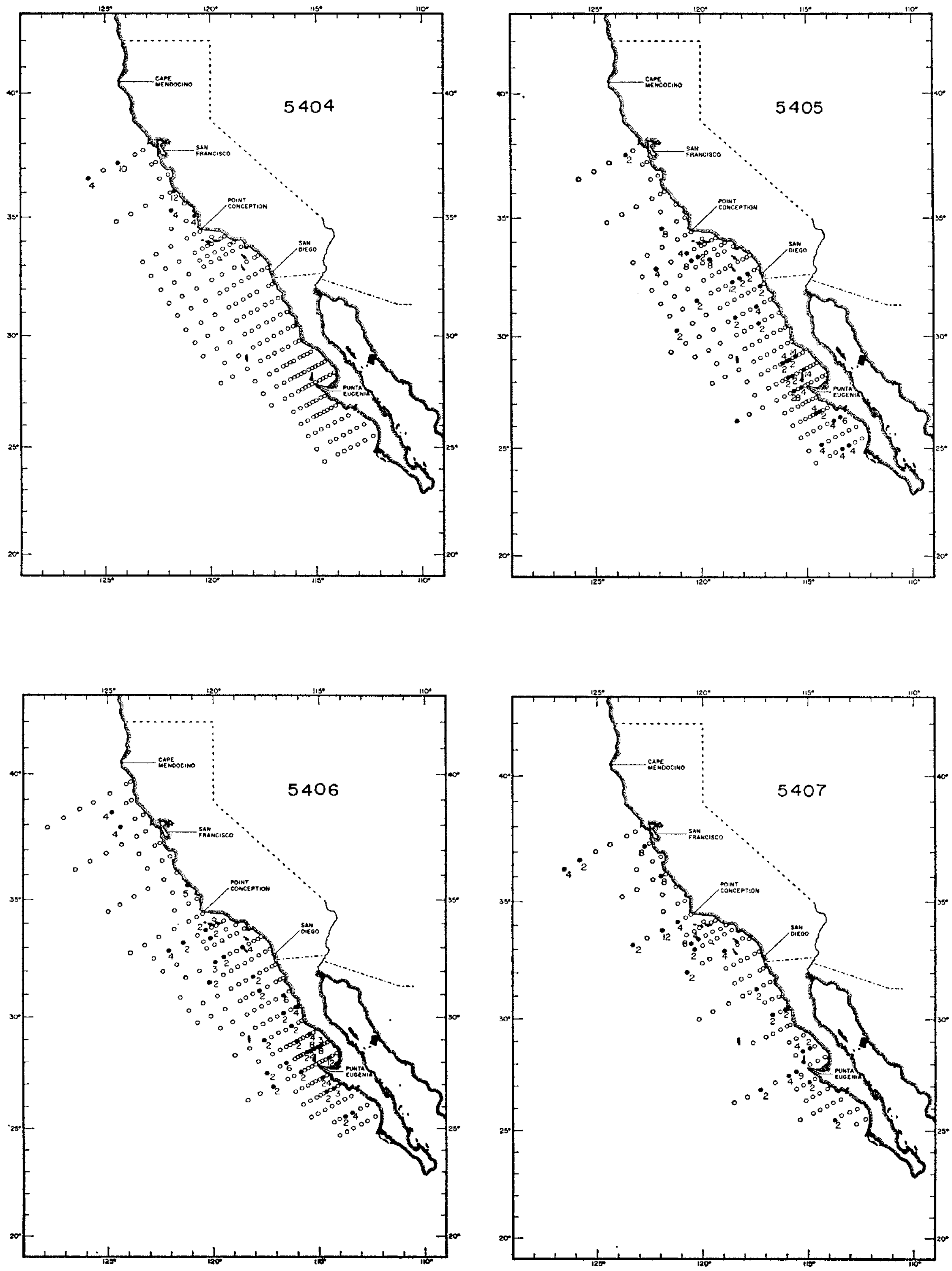

Fig. 25. Distribution and abundance records for *Gonatus fabricii*. The black dots represent positive stations, the circles negative. The numbers below the dots indicate individuals captured per 1,000 m^3 water strained.

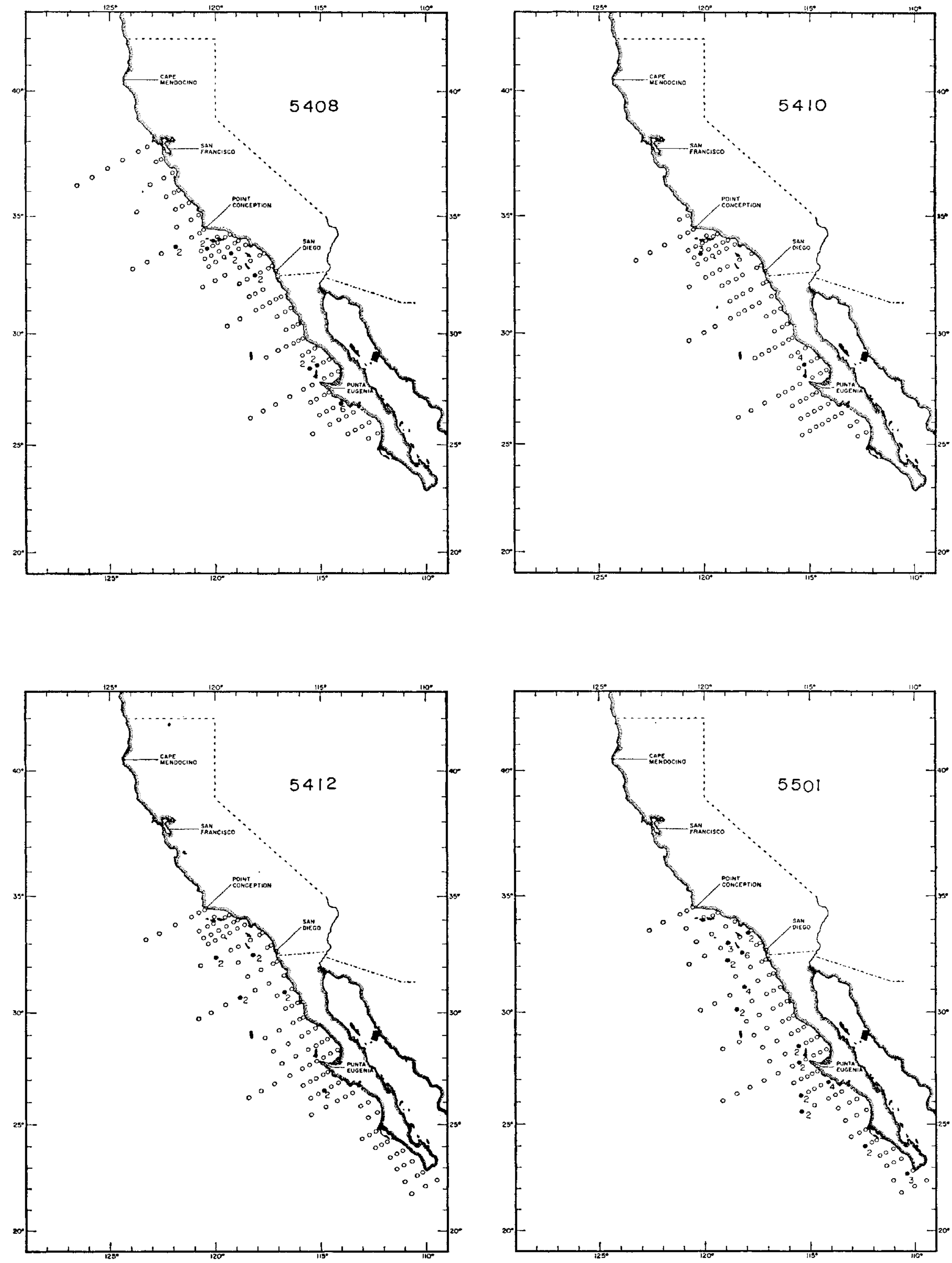

Fig. 26. Distribution and abundance records for *Gonatus fabricii* (symbols as in fig. 25).

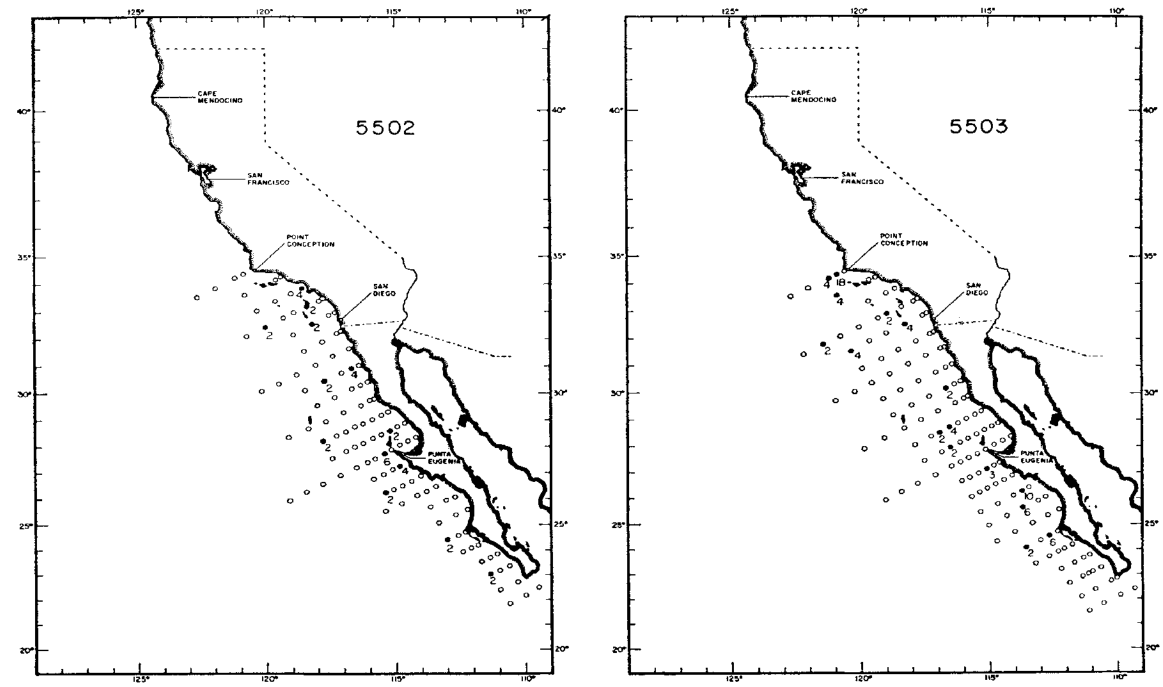

Fig. 27. Distribution and abundance records for *Gonatus fabricii* (symbols as in fig. 25).

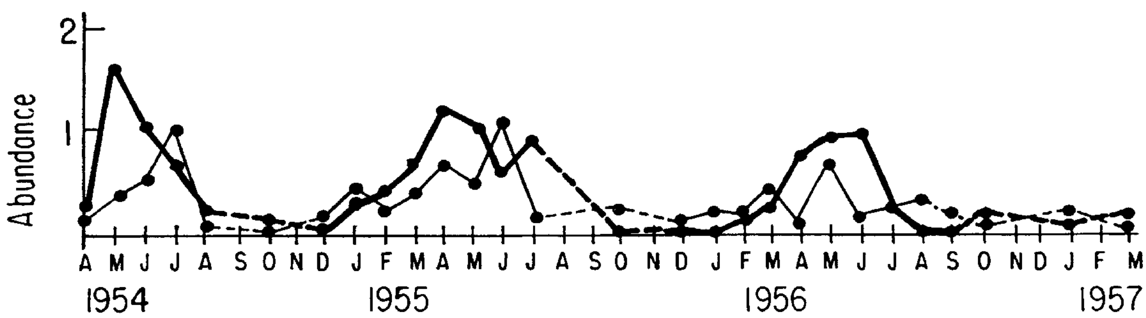

Fig. 28. Inshore-offshore variations in abundance for *Gonatus fabricii* (symbols as in fig. 23).

through the 3-year period to be considered real. The peak spawning months for *G. fabricii* are April, May, June, and in one year (1955) July. A further feature of the seasonal-abundance curve for this species is that peaks are not sharp but somewhat flattened. This feature probably indicates a prolonged period of spawning rather than a short, intense burst as with *A. felis*.

Loligo opalescens.—Because the data for the occurrence and abundance of the larvae of *Loligo opalescens* were so few, they were combined by season for the 3-year period (fig. 29). It is evident that some larvae are present throughout the year some portion of their range. Since it is known (fig. 3) that the adult ranges all the way from Puget Sound in the north (48° 30′ N.) to Punta Eugenia

TABLE 16

Total Areal Abundance and Frequency of *Gonatus fabricii* by Sector

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
0.94	0.134	0.32	0.085	0.46	0.092

TABLE 17

Areal Abundance and Frequency of *Gonatus fabricii* Larvae by Cruise

Cruise	North			Central			South		
	Number of stations	Abundance	Frequency	Number of stations	Abundance	Frequency	Number of stations	Abundance	Frequency
5404	24	1.42	0.208	134	0	0.169	38	0	0
5405	25	0.40	0.080	142	1.02	0.169	38	0.63	0.158
5406	42	0.32	0.072	132	0.76	0.205	35	1.00	0.142
5407	25	1.60	0.280	118	0.39	0.122	20	0.20	0.100
5408	29	0.07	0.034	74	0.14	0.067	19	0.32	0.053
5410	8	0	0	77	0.09	0.026	20	0	0
5412	5	0	0	79	0.10	0.051	37	0.05	0.027
5501	5	0	0	69	0.33	0.116	38	0.32	0.105
5502	4	0	0	75	0.35	0.120	38	0.26	0.105
5503	5	4.40	0.400	85	0.28	0.106	52	0.52	0.096
5504	6	0.67	0.166	94	0.84	0.213	25	1.00	0.080
5505	22	0.46	0.136	138	0.38	0.116	23	2.30	0.043
5506	34	0.68	0.176	132	0.65	0.136	25	1.60	0.160
5507	29	3.11	0.207	141	0.38	0.113	25	1.00	0.240
5510	25	0.08	0.040	66	0.09	0.032	17	0	0
5512	6	0	0	70	0.09	0.029	30	0	0
5601	6	0	0	70	0.06	0.029	35	0.06	0.028
5602	6	0	0	73	0.22	0.067	49	0.08	0.041
5603	6	0	0	107	0.13	0.037	28	0.43	0.143
5604	33	1.94	0.182	99	0.19	0.061	46	0.44	0.082
5605	59	1.85	0.187	150	0.23	0.087	24	0.83	0.125
5606	58	0.72	0.155	130	0.24	0.054	25	1.12	0.200
5607	40	0.45	0.100	139	0.14	0.043	23	0.25	0.044
5608	0	0	0	12	0.25	0.083	14	0.29	0.071
5609	0	0	0	12	0.33	0.167	14	0.43	0.142
5610	0	0	0	42	0.10	0.048	0	0	0
5701	0	0	0	36	0.17	0.084	20	0.10	0.050
5703	0	0	0	71	0.17	0.042	43	0	0

in the south (27° 51′ N.), it is possible that spawning may occur to the north of our sampling area.* There also seems to be an indication that spawning may progress from south to north seasonally. In the spring, no larvae were found north of Point Conception, but were present in the far southern part of the area (fig. 29). By summer, occurrences north of Point Conception are evident, but larvae disappear

* This may also be true of most of the other species discussed in this report.

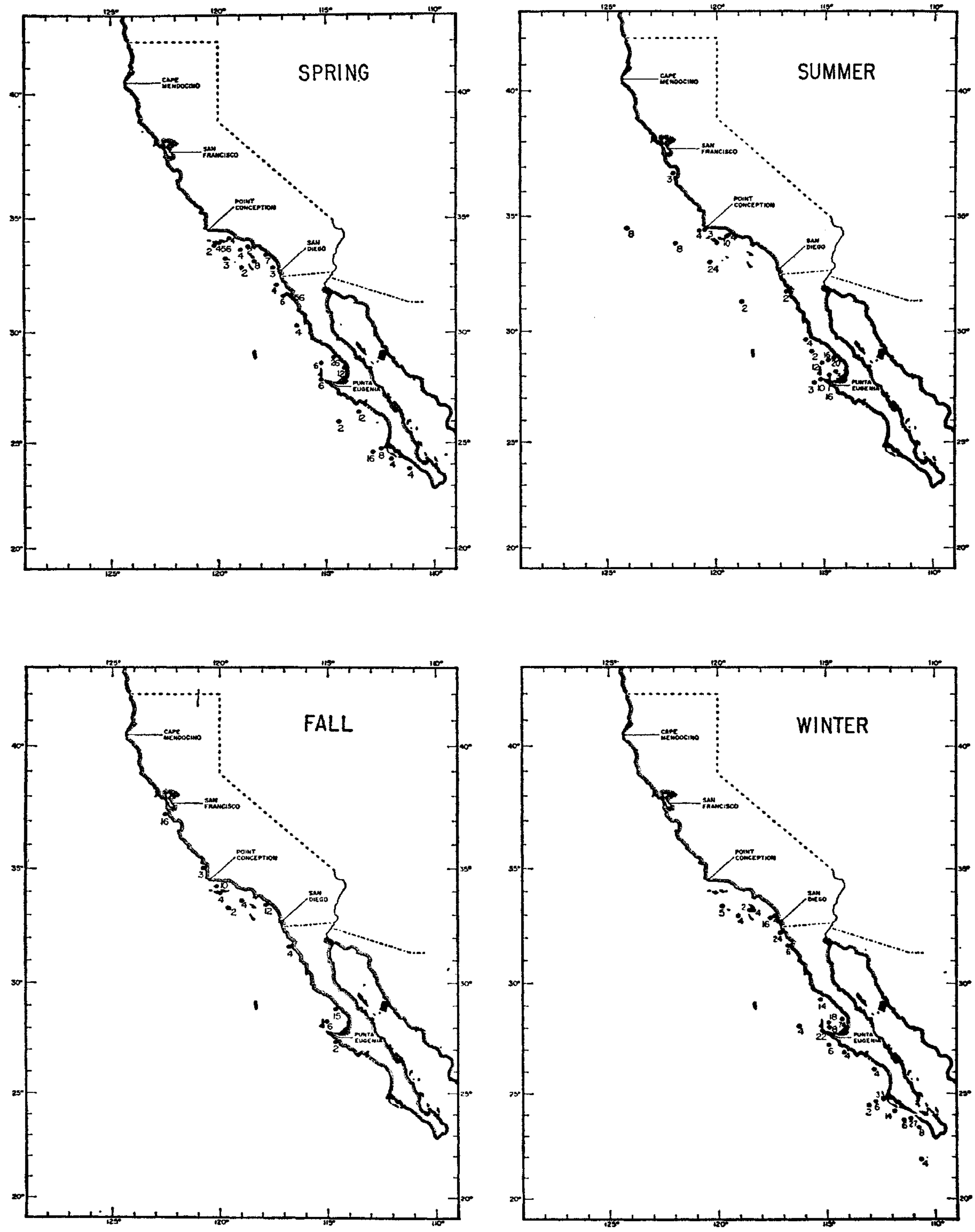

Fig. 29. Distribution and abundance records of *Loligo opalcsccns* by season. All stations listed in table 1 were used in constructing this figure. Only the positive stations are shown (black dots). The numbers under the dots indicate individuals captured per 1,000 m^3 water strained.

from the south. By fall larvae were found as far north as San Francisco, but the entire Baja California section of the coast had relatively few occurrences. Winter records are limited to southern and Baja California. This northward progression of the occurrence of larvae agrees with the observations on spawning activities made by Fields (1950) and McGowan (1954). Fields pointed out that the most intensive spawning period at Monterey, California (36° 35′ N.) was during the spring and early summer. Farther south at La Jolla, California (32° 52′ N.), the period of most intense spawning is earlier in the year, February and March.

TABLE 18

Total Areal Abundance and Frequency of *Loligo opalescens* by Sector

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
0.08	0.012	0.40	0.028	0.19	0.030

TABLE 19

Inshore-Offshore Occurrences of *Loligo opalescens*

Inshore					Offshore				
Total number of stations	Number of positive stations	Number of individuals	Abundance	Frequency	Total number of stations	Number of positive stations	Number of individuals	Abundance	Frequency
2029	93	1193	0.594	0.046	1866	8	42	0.023	0.004

It is evident from table 18 that on an average the larvae of this species are most abundant in the Central sector; the frequency in the Central and South sectors are, however, about the same.

The distribution charts (fig. 29) show that *L. opalescens* larvae tend to be neritic in occurrence; table 19 is a summary of the three years of data.

This species differs from all others described in this study in two important ways: (1) it is a nearshore spawner; (2) it is primarily a winter-spring spawner.

Although there seems to be seasonal northward progression of spawning activities, the graph of abundance (fig. 30) for the entire California Current area surveyed indicates that the most intense spawning activity is generally in the late winter and early spring.

Most of the plankton collections on which this study is based were made by towing nets obliquely from 140 meters to the surface. This type of tow is inadequate for determining the vertical distribution of planktonic organisms, but a brief series of opening-closing tows were made in an area where the larvae of *L. opalescens* were present (table 20). The nets used were 1 meter in diameter; they were towed horizontally and sampled large volumes of water. These data indicate that the larvae of this species are most abundant in the upper 100 meters and are probably concentrated in the 25–40-meter stratum. It is evident, though,

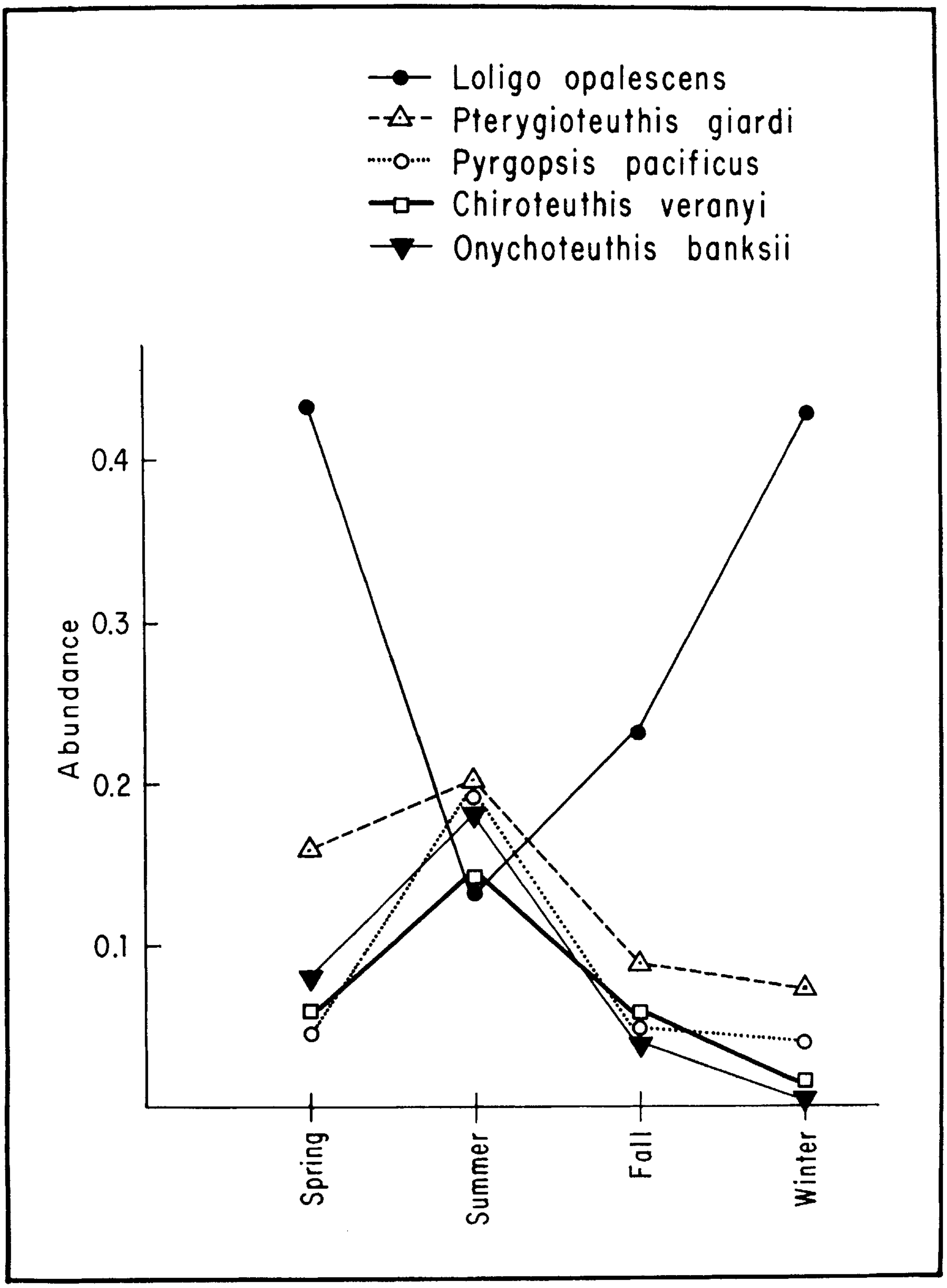

Fig. 30. Seasonal abundance of five species of larval squid.

that much more of this type of data is needed to describe the vertical distibution of this or any other cephalopod larvae.

Pterygioteuthis giardi.—The larvae of *Pterygioteuthis giardi* were found mainly in the Central and South sectors of the California Current, with only a very few captures north of Point Conception during the summers. It is evident from the distributional charts (fig. 31) that there is a decided preference for the more southerly part of the Central sector. But tabulation of the abundance and frequency

TABLE 20

FOUR EXAMPLES OF VERTICAL DISTRIBUTION OF *Loligo opalescens* LARVAE
(Cruise: C46S; position: Latitude 33° 09′ N., Longitude 118° 26.5′ W.; date: March 4–5, 1953)

Depth (in meters)	Tow no. 1		Tow no. 2		Tow no. 3		Tow no. 4	
	Time	Number of larvae per 1,000 m³	Time	Number of larvae per 1,000 m³	Time	Number of larvae per 1,000 m³	Time	Number of larvae per 1,000 m³
10	2026	0	0402	0	0637	3.5	1620	0
25	2110	2	0441	13.5	0651	6	1711	0
40	2132	14	0507	0	0719	18	....	..
50	..	..	..	..	..	..	1744	2
60	2242	6	..	..	0748	2	..	..
80	2311	0	..	..	0812	3	..	..
100	0017	0	..	..	0848	0	..	..
150	0050	0	..	..	0905	0	..	..
200	..	..	..	..	..	..	..	..
300	0213	0	..	..	..	..	..	..
400	0324	0	..	..	..	..	..	..

TABLE 21

TOTAL AREAL ABUNDANCE AND FREQUENCY OF *Pterygioteuthis giardi*

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
0.01	0.006	0.12	0.025	0.15	0.027

of this species by sector reveals that they are prorbably as abundant and frequent in the South as in the Central sector (table 21). As in the previous cases the sampling intensity is biased toward the Central sector, and this has the effect of making the species appear rare and infrequent in the South when the data are plotted on charts.

The distribution charts (fig. 31) of the larvae of *P. giardi* show that the stations where the greatest numbers of larvae were captured are all nearshore. The frequency of occurrence, however, is not noticeably greater inshore than offshore.

The charts, (fig. 31), the graph of abundance (fig. 30), and the seasonal abundance and frequency data (table 13) all indicate that *P. giardi* is a late spring to early summer spawner in the California Current.

Onychoteuthis banksii.—Larvae of *Onychoteuthis banksii* were present throughout the entire California Current system. There is a higher frequency in the North

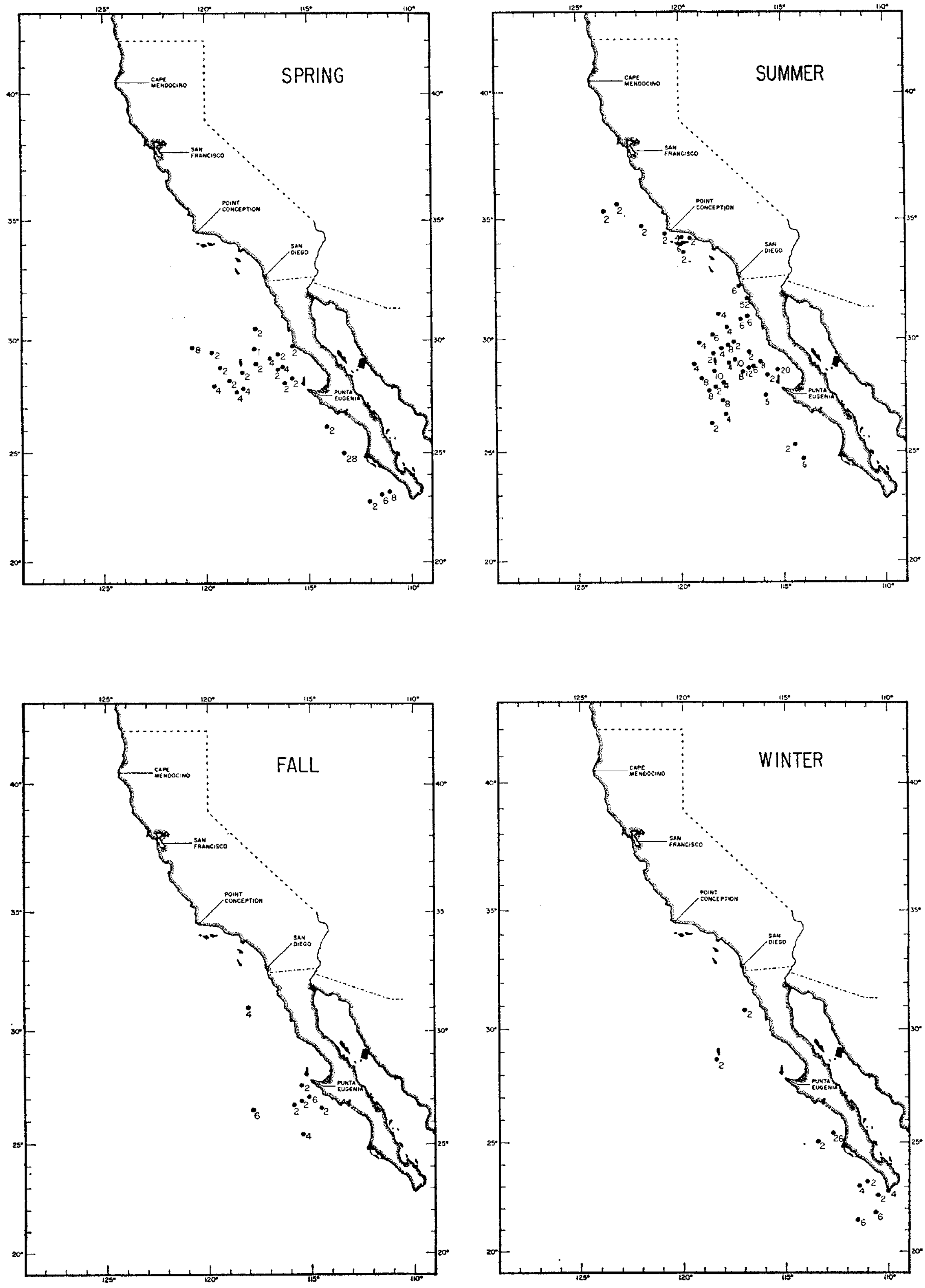

Fig. 31. Distribution and abundance records of *Pterygioteuthis giardi* by season (symbols as in fig. 29).

sector (table 22), but an examination of the distribution chart (fig. 32) shows that within this sector, in the summer, the stations yielding the highest numbers of larvae were in the area off Point Conception. This might indicate a tendency for the species to spawn in the northern periphery of the vast gyre that exists throughout most of the Central sector. Although some larvae are present throughout the year, they are more abundant in the spring and summer than in the fall and winter (figs. 30, 32, table 13).

TABLE 22

Total Areal Abundance and Frequency of *Onychoteuthis banksii*

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
0.44	0.066	0.06	0.016	0.03	0.012

TABLE 23

Inshore-Offshore Occurrences of *Onychoteuthis banksii*

Inshore					Offshore				
Total number of stations	Number of positive stations	Number of individuals	Abundance	Frequency	Total number of stations	Number of positive stations	Number of individuals	Abundance	Frequency
2029	20	76	0.037	0.010	1866	65	318	0.170	0.035

TABLE 24

Total Areal Abundance and Frequency of *Pyrgopsis pacificus*

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
0.02	0.01	0.09	0.013	0.08	0.024

The distribution charts (fig. 32) and the table of inshore-offshore occurrences (table 23) indicate that the larvae of *O. banksii* are clearly of the "offshore" variety.

Pyrgopsis pacificus.—Larvae of *Pyrgopsis pacificus* occurred primarily in the Central and South sectors (fig. 33, table 24). There was only 1 positive station north of Point Conception, and this was well offshore and contained 1 specimen. Even in the Central and South sectors, the abundance and frequency were quite low. There were only 71 positive stations out of the total of 3,895.

Since most of the Cranchiidae are considered to be either meso- or bathypelagic, it might be expected that our nets that sampled only the upper 140 meters would not catch many. There is reasonable doubt, though, that this species of cranchiid is limited to deeper waters. This doubt is based on the fact that a relatively large number of larvae (24/1,000 m^3) were taken at a station in Sebastian Vizcaino Bay,

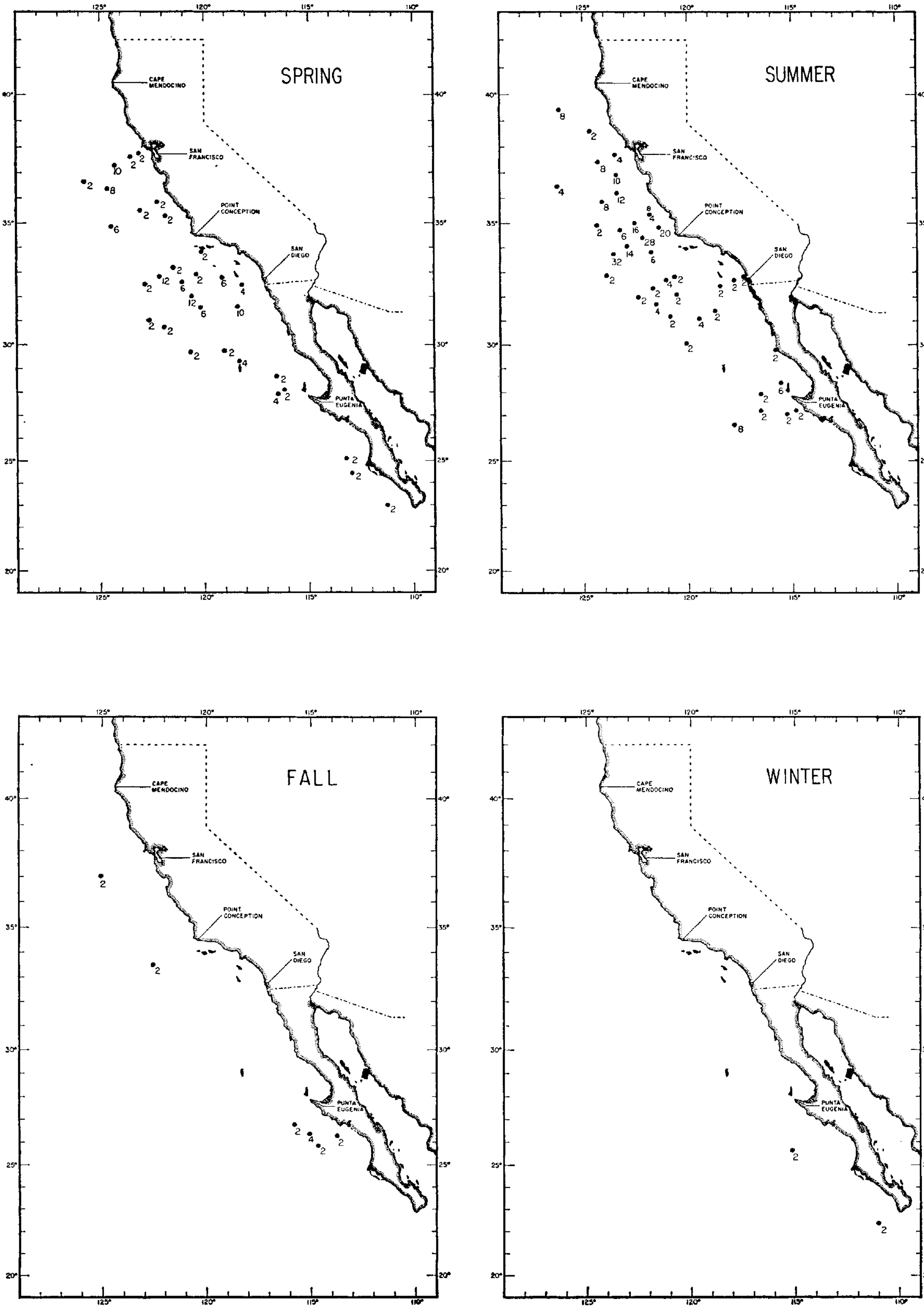

Fig. 32. Distribution and abundance of *Onychoteuthis banksii* by season (symbols as in fig. 29).

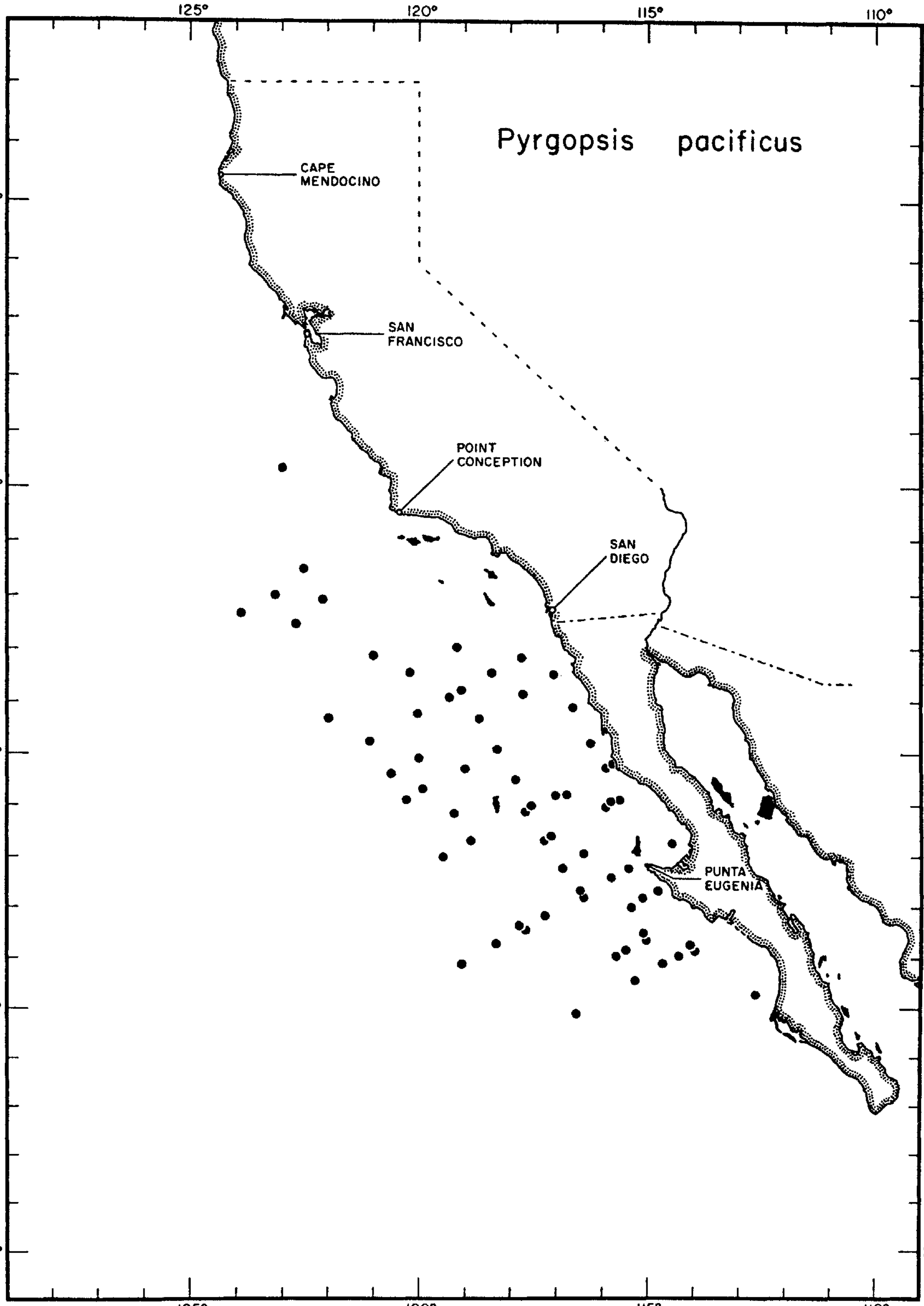

Fig. 33. All distribution records for *Pyrgopsis pacificus* for 1954, 1955, and 1956. Negative stations not shown.

Baja California, which is quite shallow. Furthermore, a number of adults have been taken from time to time, during the CalCOFI program, in standard 0–140-meter-net tows.

There are no apparent inshore or offshore trends. The spawning peak is during the summer (fig. 30, table 13).

Chiroteuthis veranyi.—This species was present in 76 of the 3,895 tows taken. The stations at which it occurred were widely distributed throughout the Central and North sectors (fig. 34, table 25). It was collected only 7 times in the South sector, all near the northern edge of this zone. There were generally only a few individuals per 1,000 m^3, but at 2 summer stations near the latitude of Point Conception (34° 30′ N.), 16 individuals per 1,000 m^3 were recorded.

TABLE 25

TOTAL AREAL ABUNDANCE AND FREQUENCY OF *Chiroteuthis veranyi*

North		Central		South	
Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
0.22	0.054	0.06	0.021	0.02	0.009

The abundance and frequency calculations indicate that *Chiroteuthis veranyi* is primarily a northern spawner. Most of the positive records are well offshore, but a few specimens were taken quite nearshore in the Central sector. The graph of abundance (fig. 30) and the seasonal abundance-frequency data (table 13) indicate that *C. veranyi* is a summer spawner.

Helicocranchia pfefferi.—Of the 34 stations where specimens of *Helicocranchia pfefferi* occurred, 10 were near the boundary of the North-South sector in the summer, 5 were near there in the winter, and 5 were near there in the spring (fig. 35). A few specimens were also taken in the fall. One individual was found in the North sector during the summer. The data are too few to allow a definitive statement about the spawning season, but the abundance calculations (table 13) suggest that it is a spring-summer spawner.

Rare species.—The remaining species, *Octopodoteuthopsis* sp., *Teuthowenia megalops*, Rhynchoteuthion larvae, *Ctenopteryx sicula, Meleagroteuthis heteropsis*, and *Liguriella* sp. were all rare in the sense that their abundances and frequencies were both low (table 12). *Teuthowenia megalops* was found most often in the Central and South sectors and was most abundant in the winter, but most frequent in the fall (table 13). This species and the others listed in this paragraph were so infrequent and rare that there is very serious doubt that our sampling methods and program were adequate for the purposes of estimating their distribution, abundance, and seasons of occurrence. The locations where specimens of these species were collected are listed in the Appendix.

SUMMARY AND DISCUSSION

It is apparent from the discussion thus far that a few larvae of most of the species are present in one or another sector of the California Current during most of

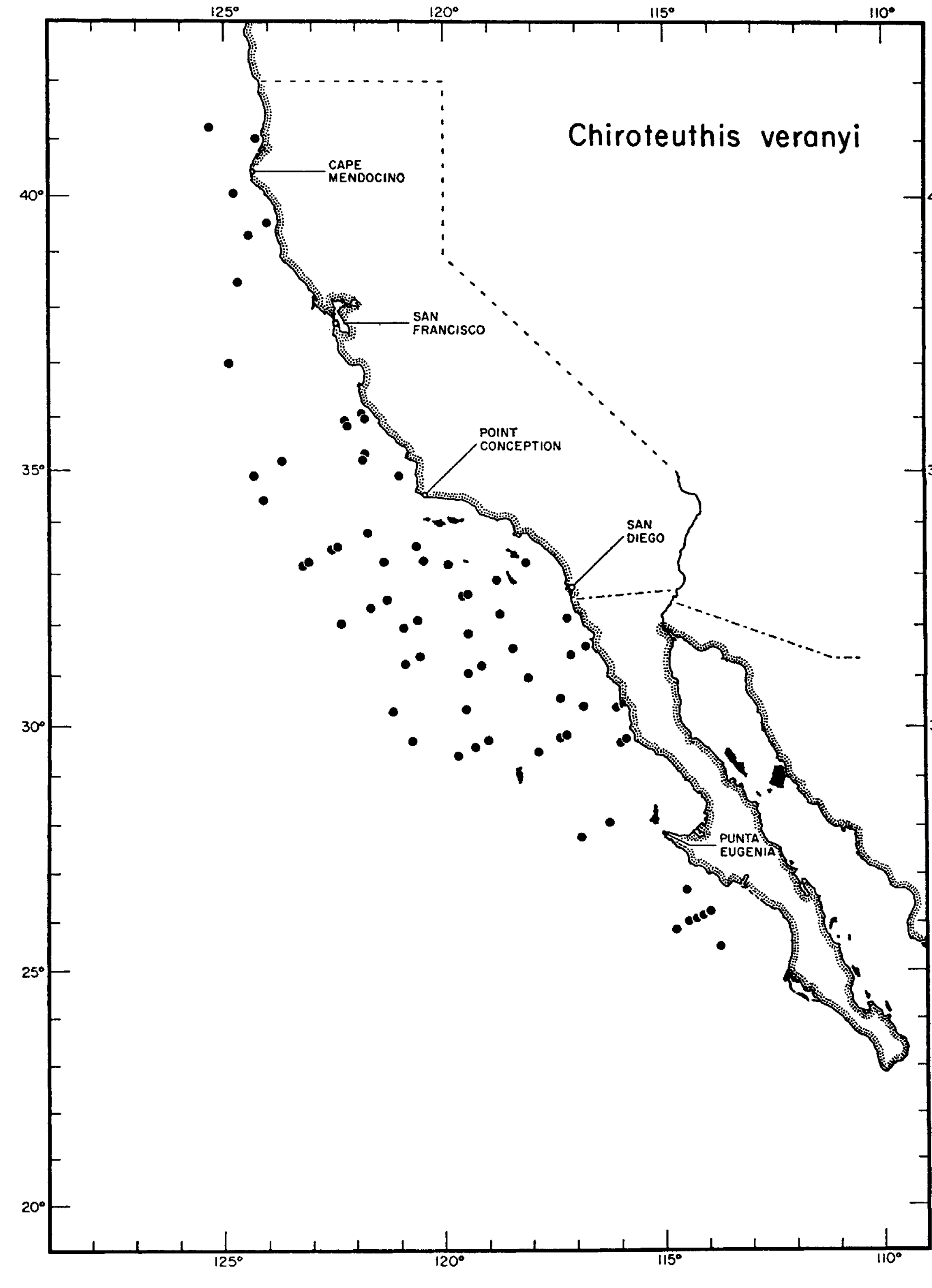

Fig. 34. All distribution records for *Chiroteuthis veranyi* for 1954, 1955, and 1956. Negative stations not shown.

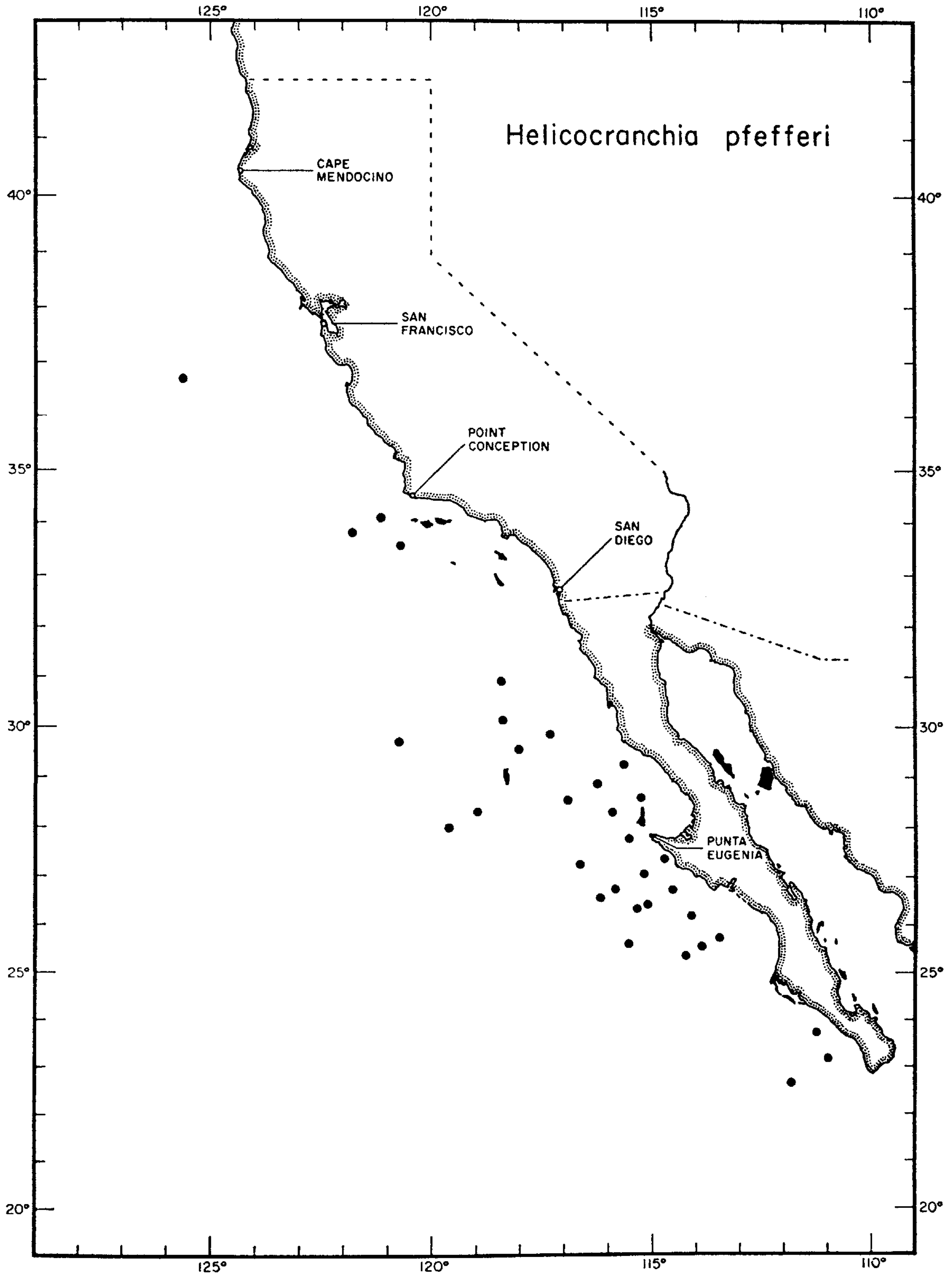

Fig. 35. All distribution records for *Helicocranchia pfefferi* for 1954, 1955, and 1956. Negative stations not shown.

the year. In the case of the more abundant species of larvae, the seasonal changes of abundance are large enough and the data are consistent enough from year to year to leave little doubt that spawning is seasonal and that some preference is shown for various areas. Since only 2 of the more abundant forms (*Abraliopsis felis* and *Loligo opalescens*) are believed to be endemic to this current system, it is entirely possible that the main spawning areas for those species that range more widely are well outside the area of our sampling. Further, because our net tows went only to depths of approximately 140 meters, it is possible that only portions of the larval squid population of some of the species were sampled. The data and calculations on our survey's effectiveness in measuring the abundance of *L.*

TABLE 26

COMPARISON OF ESTIMATES OF LARVAL ABUNDANCE FOR SIX CRUISES IN 1954

Total squid larvae six cruises		Total fish larvae six cruises	
Species	Abundance estimate[a]	Species	Abundance estimate[a]
Abraliopsis felis	2,079	*Engraulis mordax*	63,532
Gonatus fabricii	487	*Sardinops caerulea*	16,691
Loligo opalescens	516	*Trachurus symmetricus*	13,674
		Pneumatophorus diego	1,086

[a] Sums of the numbers of individuals per 1,000 m^3 as estimated from each positive net tow (for the species listed) taken on cruises 5404, 5405, 5406, 5407, 5408, and 5410. The data used for the larval squid come from this report. The larval fish data are from Ahlstrom and Kramer, 1956.

opalescens presented earlier may be an indication of the magnitude of this problem. For these reasons, then, it is difficult to drawn any more detailed conclusions than those offered.

Since all oceanic squid seem to be predators, it would be desirable to make estimates of the population sizes of the adults, as well as of the larvae. But since mortality rates from larvae to adult stages are not known, there seems to be no feasible way at present of obtaining measures of the population sizes of the adults.

In spite of our inability to actually make estimates of population sizes of these predators, there are indications that the adults may be abundant enough to be considered quite important ecologically. Belyayev (1962) has shown that squid beaks in the sediment may be as numerous as 10,000 per m^2 in some areas of the North Pacific, and there have been many reports that squid make up a large fraction of the stomach contents of various marine mammals, birds, and some predatory fishes. Squid are also frequently observed under the night-lights of research vessels that are hove to on oceanographic stations.

Since our knowledge of these animals is so fragmentary, it is of interest to compare our estimates of their larval abundance with those of herbivorous and carnivorous. pelagic fishes (table 26). It is evident that the larval fish far outnumber the larval squid estimates.

It should be remembered that the CalCOFI sampling program was designed to catch fish larvae, not squid. It is also generally true that populations of predators are smaller than their prey and it has recently been shown experimentally that larval *Loligo opalescens* may eat as many as 5 fish larvae per day (McGowan and Fraundorf, unpublished). Judging from the appearance of their tentacular armature and mouth parts, *Abraliopsis felis* and *Gonatus fabricii* might be even more effective as predators.

OCEANOGRAPHIC RELATIONSHIPS

The areas and times at which larval squid are most frequent and most abundant have been discussed. The environmental conditions in the places and at the times listed are somewhat more difficult to define clearly. The California Current is, oceanographically, a complex area, and simple, straightforward relationships between the physical properties of its waters and the biology of its populations are difficult to demonstrate.

Reid, Roden, and Wyllie (1958) have described the hydrography of this area and have pointed out that the California Current system is part of the great clockwise circulation pattern of the entire North Pacific Ocean. Water entering the California Current comes from four great water masses* which are distinguished by certain of their physical-chemical properties. The offshore waters of the northern part of the California Current are derived from the Subarctic Water Mass and the North Pacific Drift. As this water moves to the south (east of 147° W.), it mixes with waters from the Central Water Mass which is moving in from the northwest and west. A major influx of southern water, from the Equatorial Water Mass, enters the area as a subsurface current from the south. This current tends to be near the coast. The fourth major water source is from the upwelling processes at the coasts. Upwelling is more likely during the spring and early summer, but there is some tendency for it to occur at other times of the year as well.

The circulation pattern resulting from these influxes, and from the wind, density differences, and the rotation of the earth is complex. The water north of Point Conception tends, on an average, to move southward at speeds of 0.5 knots or less. South of here a large eddy is evident for most of the year. Apparently the eddy is made up of mixed northern, western, southern, and upwelled waters; but, it is not well known what the relative proportions of the types of water in this area are. The problems in estimating the amount of admixture have been discussed by Reid (1960). South of this central area the California Current flows to the south and eventually turns westward (at about 24° N.).

The analyses of the frequencies and abundances of specimens in the inshore and offshore zones and in the North, Central, and South sectors indicate the general areas where larvae were most often found. It would be desirable to correlate these occurrences with some factor or factors of the environment. Temperature and to a lesser extent salinity and oxygen have been used by many authors for this purpose. Such an approach is inappropriate in the case of the oegopsid squid data in this report. We do not have data on the vertical distribution of these larvae, but since the adults of most of these species are meso-to bathypelagic, it is probable that the larvae may have a somewhat broad vertical range. For this reason it is rather pointless to attempt to correlate horizontal isotherm distributions with the times and places of occurrences of the larvae. In many cases, the vertical range through which the larvae are distributed from the time they are first spawned (presumably in the mesopelagic), to the post-larval stages, covers a temperature

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* This term is used in the manner defined by Sverdrup, Johnson, and Fleming, 1942:143-146.

range greater than the horizontal temperature range for the entire California Current at the "representative" mixed-layer depth of 10 meters.

An examination of the distributional charts of the larvae of *Abraliopsis felis* (figs. 20-22) on which the 10-meter isotherms are also included, illustrates the difficulties in attempting to make such facile, one-factor correlations. Although this type of correlation is neither possible nor desirable, the relationship of larval occurrences to water "types" can be shown. This kind of analysis has the additional

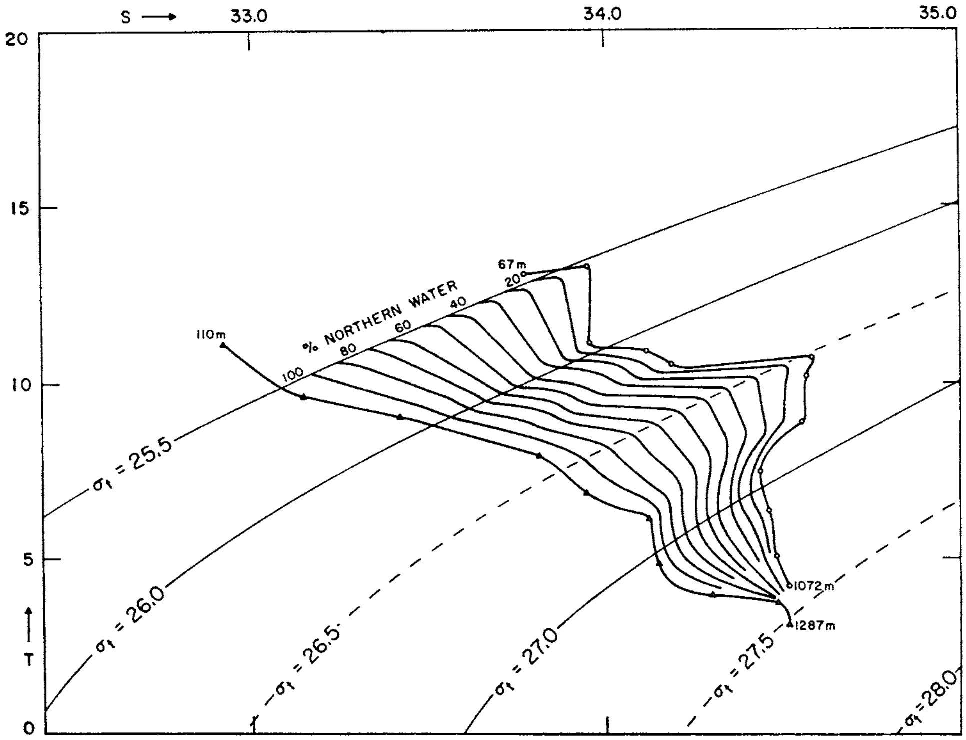

Fig. 36. Diagram showing the most extreme "northern" water on the left, and most extreme "southern" water on the right. The percentage of northern water at intermediate locations may be read from this, using the assumptions of Sverdrup and Fleming (1941).

advantage of comparing a three-dimensional biological distribution with a three-dimensional distribution of physical properties (McGowan, 1960; Brinton, 1962).

The method of Sverdrup and Fleming (1941: 285-290) has been used to describe the type of water in the area in which the larvae of *Abraliopsis felis* and *Gonatus fabricii* occur. This method does not indicate the relative proportions of the four kinds of water mentioned above, but is merely an index of the percent of mixing between the two most extreme kinds present within the entire area surveyed (fig. 36). Sverdrup and Fleming's "southern" and "northern" water types (in Sverdrup and Fleming, 1941, fig. 28) are not the same as the southern and northern waters used in figure 36 of this report. Although they used this term in the same sense that it is used here, the northern and southern limits of their area of sampling (40° 20′ N, 31° 10′ N.) were close together and for the most part fall within our Central zone. Since the range of our sampling program was wider, our

T-S curves cover a broader range of values than theirs. In order to describe the environment, T-S curves from stations where larvae of *Abraliopsis felis* and *Gonatus fabricii* occurred, were matched with curves for various percentages of southern and northern types of water. Table 27 shows these results for the peak spawning month of June, 1954, for *Abraliopsis felis.*

The table shows that waters of from 70 percent to 100 percent "northern" water seem to be the habitat where the larvae of *A. felis* are more frequent and more abundant. If we may assume that animals tend to be more frequent and more abundant in "favorable environments," or, rather, in environments that tend to be ones for which the species is best adapted, then T-S curves of this general shape are an index of the presence of this environment. They do not, of course, describe which factors of the environment are of significance. An index such as this does give us an indication of where (i.e., in what type of water) to look for significant factors.

TABLE 27

Occurrences of Various Types of Water for June, 1954 (Cruise 5406) and the Frequency and Abundance of the Larvae of *Abraliopsis felis*

Percentage of northern water present	Number of stations	Number of stations with *Abraliopsis felis*	Percentage of stations with larvae	Number of larvae	Average number of larvae per station
100	9	6	67	58	6.4
90	15	8	53	86	5.7
80	11	4	36	134	12.2
70	15	5	33	14	9.3
60	8	0	0	0	0
50	4	1	25	6	1.5
40	6	3	50	8	1.5
30	0	0	0	0	0
20	2	0	0	0	0
10	5	0	0	0	0
0	2	0	0	0	0

Both the frequency and the abundance of the larvae of *Gonatus fabricii* were too low during cruise 5406 to allow for a similar analysis. The few larvae of this species that did occur (23 individuals) were distributed evenly among waters from 20 percent to 100 percent northern water. It is difficult to interpret such a situation, but it may be that the depth of spawning for this species is somewhat greater than that of *Abraliopsis felis.* Since the T-S-curve definition is not effective in this area in discriminating between types of water at depths much greater than 1,000 meters, it cannot be expected to provide an index for events occurring here unless they are closely related to shallower phenomena. Alternatively, it may be that *G. fabricii* simply has a relatively broad range of environmental factors to which it is adapted. The limits of our sampling program may not have gone very far beyond this range.

Although the data are rather few for the other species of oegopsid larvae, charts of their distributional patterns show that they are frequent in the area of mixedwater types. The intensity of sampling in the Central (mixed) area was greater than in the northern or southern areas (ratios = 0.20 North : 1.00 Central : 0.31

South), and therefore we might expect that organisms that were "rare" everywhere in the California Current would merely appear to be most abundant here. Therefore this apparent abundance may be an artifact of our sampling distribution.

Loligo opalescens is an exception to the generalizations about the oegopsid larvae. Not only does this species spawn at a season of the year different from the others, but it is a demersal spawner in fairly shallow waters (McGowan, 1954; Fields, 1965), and its larvae are limited to the inshore area. Furthermore, there is no clear preference for the Central sector as a spawning area, but rather spawning appears to progress from south to north. It has been pointed out that there was a seasonal northward progression of spawning, accompanied by a disappearance of larvae from the southern extremes of the area. Since *L. opalescens* is known to be a neritic, demersal spawner, it seems appropriate in this case to compare the seasonal movement with the northward shift of the 10-meter isotherms.

A visual comparison of the distribution charts for this larva (fig. 29) and those of the average distribution of 10-meter isotherms (Anonymous, 1963 [CalCOFI Atlas no. 1]) shows that the northward extension of larval occurrence follows the movement north of 12.5° C. or 13.0° C. temperatures. The disappearance of larvae from the south precedes the seasonal movement north of temperatures of from 20° C. to 21° C. These temperature ranges cannot be interpreted to "limit" the spawning activities of *L. opalescens.* Fields (1950, 1965) has reported that some egg cases may be found at Monterey at any time of the year, and Bolin and Abbott (1963) have shown that temperatures lower than 12.5° C. are present here for several months of each year. Furthermore, the offshore limits of the larval distribution are not coincident with these isotherm ranges. It therefore seems unlikely that periods of spawning are strongly influenced by this temperature regime either by acting directly on the adults or secondarily by being necessary for larval survival.

Thus it is difficult, at the present time, to describe in any more detail just what the "oceanographic relationships" are in the spawning of the squid of the California Current. It should be clear that rather inadequate sampling is, in part, responsible for this. Large, stratified net tows to depths considerably greater than the 140 meters used in this study are clearly necessary. Further, some type of sampling of the adult population seems appropriate. This might allow an examination of gonadal conditions and, possibly, some estimate of changes in relative abundance through the seasons.

Studies of the feeding habits (of both adults and larvae) through stomach analysis might provide an indication of the more important food chain relationships with organisms at lower trophic levels. It is curious that the areas of the California Current where the two commonest species of squid larvae tend to be most abundant are *not* the places where the average zooplankton abundance is the highest. This observation is open to a number of interpretations, but it seems best, for the present, to forego speculation until the type of data mentioned above are available. The job of acquiring such information may be made somewhat easier by the fact that we now know where and what to look for.

APPENDIX

Collection Records for Rare Species

Species	Cruise	Stations	Position	
			Lat. N.	Long. W.
Octopodoteuthopsis sp.	5407	63.55	37° 13′	122° 50′
		80.90	33° 09′	123° 13′
		110.45	29° 26.5′	116° 39.5′
	5408	80.80	33° 28.7′	122° 32′
		87.45	33° 30′	119° 19′
		110.60	28° 56.5′	117° 38′
		137.30	25° 20′	112° 46′
	5410	90.70	32° 04.5′	120° 38.5′
		100.45	31° 10.5′	117° 46.5′
		130.50	25° 49′	114° 45′
	5503	113.60	28° 22′	117° 16.5′
	5504	97.80	30° 35′	120° 31′
	5506	103.80	29° 26.5′	119° 44′
	5507	70.90	34° 53′	124° 30′
	5512	80.70	33° 48.5′	121° 51′
		80.80	33° 28.7′	122° 32′
		140.36	24° 35.5′	112° 42.5′
	5601	93.50	32° 10′	118° 52.5′
	5602	90.80	31° 41.5′	121° 19.5′
		97.40	31° 56′	117° 48′
		110.60	28° 56.5′	117° 38′
		117.50	28° 08′	116° 15′
		117.60	27° 48′	116° 53′
		118.39	28° 18.5′	115° 23.7′
	5603	80.90	33° 09′	123° 13′
	5604	90.90	31° 24′	122° 01′
		107.50	29° 50.5′	117° 22′
	5605	40.50	41° 23′	125° 23′
		40.80	40° 23′	127° 40′
		43.42	41° 04′	124° 21′
		43.50	40° 48′	124° 57′
		47.55	40° 04′	124° 55′
		87.60	33° 00′	120° 21.5′
		90.65	32° 14.5′	120° 18′
		93.55	32° 00′	119° 13.5′
	5606	57.65	38° 02′	124° 23.5′
		60.80	36° 56.5′	125° 04′
		83.90	32° 34.5′	122° 47.5′

APPENDIX—*Continued*

Species	Cruise	Stations	Position	
			Lat. N.	Long. W.
	5607	60.90	36° 37′	125° 47′
		87.90	31° 59′	122° 24′
	5608	113.35	29° 11.5′	115° 38′
	5703	83.70	33° 14.5′	121° 26′
		107.40	30° 11′	116° 42′
Teuthowenia megalops	5405	110.90	27° 56.5′	119° 35′
		120.45	27° 43′	115° 33′
		123.45	27° 08′	115° 11.5′
		123.55	26° 48.5′	115° 49.5′
		123.60	26° 38.5′	116° 09′
	5406	100.55	30° 50.5′	118° 27.5′
		120.60	27° 13′	116° 30.5′
		133.45	25° 24′	114° 05′
	5407	60.90	35° 28′	124° 55′
		133.35	25° 44.5′	113° 26.5′
	5410	100.90	29° 40.5′	120° 47′
	5501	143.35	24° 01′	112° 22′
	5502	113.55	28° 32′	116° 57′
		117.45	28° 18′	115° 56′
		123.37	27° 24′	114° 40′
		127.55	26° 13.5′	115° 27′
	5503	123.45	27° 08′	115° 11.5′
		147.25	23° 46′	111° 22′
	5505	130.60	25° 29′	115° 24′
	5506	110.90	27° 56.5′	119° 35′
		113.45	28° 52′	116° 18′
		117.35	28° 38′	115° 16′
		133.40	25° 34.5′	113° 45.5′
	5507	107.50	29° 50.5′	117° 22′
	5602	80.60	34° 09′	121° 09′
		150.25	23° 11.5′	111° 01.5′
	5603	107.60	29° 32′	118° 01.5′
	5604	150.40	22° 41.5′	111° 57′
	5605	83.60	33° 17′	120° 33.5′
		130.35	26° 19′	113° 48′
	5607	127.60	26° 03.5′	115° 46.5′

APPENDIX—*Continued*

Species	Cruise	Stations	Position	
			Lat. N.	Long. W.
	5609	113.35	29° 11.5′	115° 38′
	5610	80.70	33° 48.5′	121° 51′
	5701	127.50 130.40	26° 23′ 26° 09′	115° 08′ 114° 07′
Rhynchoteuthion larvae.......	5410	100.90 123.50 123.55	29° 40.5′ 26° 58′ 26° 48.5′	120° 47′ 115° 31′ 115° 49.5′
	5502	80.80 147.25 157.30	33° 28.7′ 23° 46′ 21° 52.5′	122° 32′ 111° 22′ 110° 37.5′
	5510	130.50	25° 49′	114° 45′
	5512	150.30	23° 02′	111° 20′
	5601	157.30	21° 52.5′	110° 37.5′
	5602	157.20	22° 13′	110° 00′
	5604	150.30	23° 02′	111° 20′
	5606	107.40	30° 11′	116° 42′
	5607	120.80 137.30	26° 32.5′ 25° 20′	117° 49′ 112° 46′
	5609	133.30	25° 54.5′	113° 07.5′
	5701	103.38 117.70	30° 51′ 27° 28′	116° 55′ 117° 32.5′
Meleagroteuthis heteropsis.......	5405	97.40	31° 56′	117° 48′
	5408	90.55	32° 35′	119° 37′
	5505	97.50 117.50 117.75	31° 36′ 28° 08′ 27° 18′	118° 29′ 116° 15′ 117° 51′
	5603	133.40 137.60	25° 34.5′ 24° 20′	113° 45.5′ 114° 39.5′
	5605	87.60	33° 00′	120° 21.5′
	5703	107.50	29° 50.5′	117° 22′
Liguriella sp..................	5504	110.80	28° 16.5′	118° 57.5′
	5609	113.35	29° 11.5′	115° 38′
Ctenopteryx sicula..............	5607	120.50	27° 33′	115° 52.5′

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