DISTRIBUTION OF LARVAL SQUID, *LOLIGO OPALESCENS*, IN VARIOUS NEARSHORE LOCATIONS

CONRAD W. RECKSIEK AND JERRY KASHIWADA
Moss Landing Marine Laboratories
P.O. BOX 223, Moss Landing, CA 95039

ABSTRACT

Three distinct sampling efforts employing different plankton-collecting gears aimed at collecting California market squid, *Loligo opalescens*, in nearshore waters from San Diego to Monterey Bay are described. Larval *Loligo opalescens* occurrence in the hauls was low and patchy, corroborating the experience of past workers. Over the Monterey spawning grounds, the use of a specially designed bottom-fishing plankton net was found to be more generally effective than the other gears.

INTRODUCTION

The early life history of *Loligo opalescens* is unclear. Fields (1965) suggests that the newly hatched larvae may be carried long distances by coastal currents. McGowan (1954), from 10-minute tows with a 0.40-m net in the vicinity of La Jolla, California, encountered few larval squid, even though the area harbored considerable quantities of hatching egg capsules. He concluded that the larvae were swept away by currents. Okutani and McGowan (1969) in their studies of CalCOFI samples collected 1954-1957 encountered *Loligo opalescens* (3.5 to 7 mm dorsal mantle length) at only 93 of 2,029 inshore stations (1,193 individuals). Offshore stations yielded 42 individuals from 1,866 tows.

The abundance of *L. opalescens*, though ranked third relative to other squid species, was less than 1% of northern anchovy, *Engraulis mordax*, larvae. Okutani and McGowan (1969) state that the CalCOFI plankton-sampling scheme may have been inadequate for estimating absolute abundance of larval *L. opalescens*. By contrast, Mais (1974), reporting the results of pelagic fish surveys (1966-1973), using midwater-trawl gear, found juvenile and adult *L. opalescens* in 36.3% of 1,375 tows. The apparent scarcity of larval *L. opalescens* in plankton hauls is surprising considering an apparent high juvenile-adult biomass (Gulland 1971; Baxter et al. 1968; Voss 1973; Mais 1974). This paper describes our progress in determining distribution patterns of *L. opalescens* larvae in an attempt to understand the scarcity of larvae and post-larvae in standard plankton samples.

METHODS AND MATERIALS

Several distinct gear types were used in collecting larval *L. opalescens*. In Monterey Bay (Figure 1, inset), an opening-closing net with a square-mouth (1.8-m) opening, as described by Hopkins et al. (1973), was used in an attempt to delimit vertical distribution. Depths were estimated using an inclinometer and metered block. Mesh size decreased from about 6 mm at the mouth to a cod-end liner of 1 mm. This gear was fished from Moss Landing Marine Laboratories research vessels *Artemia* and *Oconostota*.

Nearshore oblique tows in the upper 100 m were taken from San Diego to Morro Bay (Figure 1) in an attempt to define geographical concentrations of larvae. These tows were made with a continuously open net similar in design to that used in Monterey Bay but with slightly larger mesh. In the case of operation in shallow water, the maximum safe operation depth was shifted upward. In general, the net was allowed no lower than about 25 m from the bottom. Mesh sizes decreased from 9 mm to a cod-end liner of 1 mm. The tows were taken from the California Department of Fish and Game research vessel *Alaska* (Cruise 76A4).

Larval squid were also collected over the traditional spawning grounds near Monterey (Figure 1, inset) adjacent to the bottom by mounting a standard 0.5-m plankton net to a specially designed frame fitted with sled-like runners. This device enabled fishing the net in such a way that the lower rim was approximately 10 cm off the substrate surface. It was used in shallow (20-30 m) water. Tows in which egg cases were caught on the sled were not included with the data presented, since it could not be determined if squid hatched during the process of capture. A midwater comparison sample was obtained by fastening a 0.5-m plankton net to the wire. A rough calculation based on wire angles was used to place the comparison plankton net at mid-depth. The research vessel *Tage* of Hopkins Marine Station was used to deploy this gear.

The squid captured by the various gear were measured from the posterior to the anterior ends of the mantle on the dorsal side (dorsal mantle length). Squid caught on the spawning grounds near Monterey were dissected to determine if the squid were feeding.

RESULTS AND DISCUSSION

Our initial purpose in studying larval squid was to describe patterns of spatial distribution. We were interested in ascertaining the feasibility of using larval squid abundance as an index of recruitment. Initially, it was decided that a relatively fast-moving plankton sampler was required in order to increase fishing success over the 1-m CalCOFI net, as reported by Okutani and McGowan (1969). We presumed that avoidance of the CalCOFI

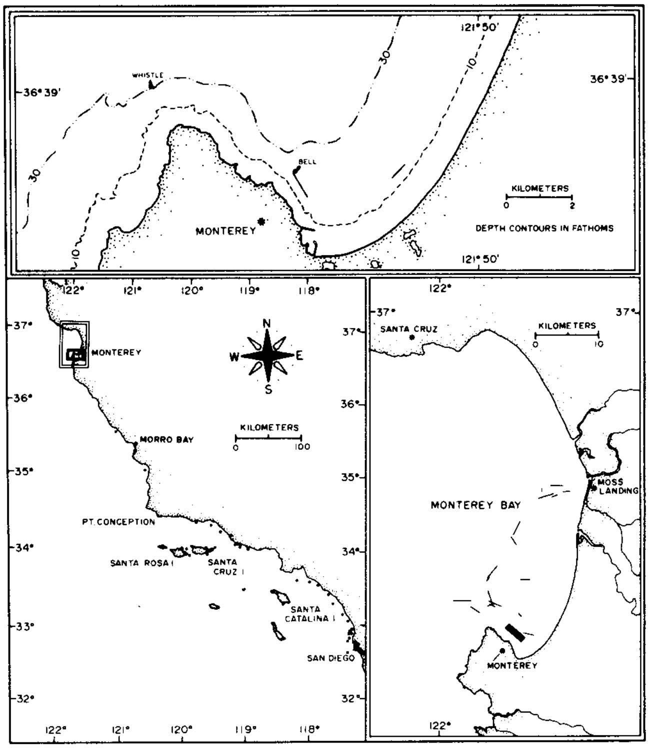

Figure 1. Sampling locations for three methods of collecting larval *Loligo opalescens*. Central figure: 1.8-m square-mouth trawl, open oblique tow, 30 May 1976 to 14 June 1976; inset: Monterey Bay, opening-closing 1.8-m square-mouth trawl, 15 September 1975 to 10 March 1976; inset: South Monterey Bay, bottom and midwater 0.5-m nets, 21 July 1976 to 31 August 1976.

net was responsible for poor fishing success.

In an effort to delimit patterns of vertical distribution, 29 trawls of 10- to 30-minutes duration, day and night, using the opening-closing net, were accomplished September 1975 through March 1976 at various stations in southern Monterey Bay and over the axis of the Monterey Submarine Canyon. An attempt was made to corroborate Okutani and McGowan's (1969) inference that the larvae could be expected in the 25- to 40-m stratum. Of 29 trawls, 14 occupied that layer. The two most successful tows contained 9 and 11 squid. These were encountered at 40 m and 30 m, respectively.

Only 58 larvae, an average of 2 squid/tow, were collected (Table 1). Since the small size of the samples did not appear to justify the data-gathering effort, we decided to attempt locating concentrations of animals before investigating further the problem of favored strata. We therefore planned to use similar gear but over a much more extensive area and throughout the upper 100 m.

For thirty tows at various nearshore stations (depths generally shallower than 200 m, except over submarine canyons or escarpments), an average of 1.77 squid/tow was collected (Table 1). These tows were accomplished at night, late May to mid-June 1976. Of the thirty tows

TABLE 1

Larval *Loligo opalescens* Collected with Three Distinct Sampling Strategies and Locations in Monterey Bay and Nearshore Waters between La Jolla and Morro Bay, California.

	Opening-Closing 1.8-m Square-Mouth Trawl, South-Central Monterey Bay, 15 September 1975 to 10 March 1976	Open Oblique Tow 1.8-m Square-Mouth Trawl, La Jolla to Morro Bay, 30 May 1976 to 14 June 1976	Bottom and Midwater 0.5-m Plankton Nets, South Monterey Bay, 21 July 1976 to 31 August 1976
Number stations ...	29	30	29
Number positive stations	13	6	20
Range trawl time (min)	10-30	9-18	8-12
Total number squid............	58	52	320
Range squid/tow...	0-11	0-34	0-113
Mean squid/tow ...	2.00	1.73	6.83
Coefficient of variation squid/tow.........	156	374	217
Mean dorsal mantle length (mm)	3.45	8.22	2.10
95% confidence interval of mean dorsal mantle length (mm)	3.1-3.8	7.35-9.09	2.07-2.13

ranging in duration from 9 to 18 minutes, two contained 88% of the squid: 12 and 34 animals. Midway through the cruise, it was decided that the low fishing success did not warrant further effort.

Our results thus far paralleled the experience of others: larval *Loligo opalescens* occurrence in the samples was low and patchy. It appeared that the larvae were either demersal or were elsewhere, perhaps in deep water. To test the former hypothesis, we began fishing 0.5-m plankton nets close to the bottom on the squid spawning grounds off the City of Monterey (described in Fields 1965; Figure 1, inset). The results (Table 1) thus far, 21 July to 31 August 1976, indicate a higher fishing success than with the other gears. Samples from the bottom net

TABLE 2

Bottom (30 m) and Mid-Depth (15 m) Larval Squid Catch from 0.5-m Plankton Nets Near Squid Spawning Grounds, Monterey, California.

	Bottom		Midwater	
Date (1976)	Tows	Total No.	Tows	Total No.
21 July	2	49	–	–
27 July	3	25	2	7
3 August..................	4	181	4	45
10 August	2	0	2	5
17 August	4	3	4	4
31 August	1	1	1	0
Total	16	259	13	61
Catch/Tow...............	16.2		4.7	

have been most encouraging (Table 2) with catch/tow averaging 16.2 in contrast to a midwater mean of 4.7.

One possible explanation for the high catches with the bottom net is that the sled caused eggs to hatch by disturbing them. LaRoe (1971) found that large numbers of the squid *Sepioteuthis sepioidea* hatched following mechanical agitation. This is probably not the case, since on some occasions, squid egg cases were caught on the runners of the sled or in the cod end of the net and the data from such catches were not used. If the sled moved through the egg-case clusters, there would probably be some egg cases on the sled. Many of the most successful tows with the sled had no traces of egg cases.

One interesting result of comparisons with midwater and bottom plankton tows was an increase in catch in the midwater net and a concurrent decrease in the catch in the bottom net as daylight increased (Table 3). This observation might be explained by observations on the behavior of newly hatched squid. Fields (1965) found that squid usually hatch during the night and that they are positively phototactic. Squid hatching at night on the spawning grounds would tend to stay near the bottom where they would be vulnerable to the bottom net. After sunrise, the squid would be attracted to the light at the surface and would be more vulnerable to the midwater net.

It is difficult to make comparisons between the three differing collecting techniques. Since we have no estimates of the volume of water filtered by the nets and the nets were towed at different speeds, comparisons cannot be made of the success of capture/volume filtered, nor the success/minute towed.

One of the new methods of comparison available from our data, the means and confidence limits on the means of dorsal length are, perhaps, the best. These comparisons show that different nets sampled different sizes of squid (Table 1). Since mesh size differed, one explanation for the differences observed is that smaller squid escaped the net with larger mesh. The contrasting catches might also be explained by the locations in which the nets were fished. Nets that sampled away from the spawning grounds probably would be expected to catch larger animals, since some growth would occur during the movement off the spawning grounds.

Although quantitative comparisons cannot be made, we believe that the relatively high catches with the plankton net towed near the bottom are significant. Since these tows were relatively short (8-12 minutes) and the mouth of the net is much smaller than the nets used previously, the amount of water filtered was much less; the high catches are, therefore, even more pronounced.

Since little variability was noted in the squid caught and all squid examined had large yolk sacs, apparently the animals do not remain on the spawning grounds for a long time or else, presumably, we would have encountered more developed stages. One would expect that catching newly hatched squid on spawning grounds would be fairly simple, yet McGowan (1954) found difficulty in catching them in an area covered with egg capsules. The success of the sled in capturing young *Loligo opalescens* is surprising in the light of past experience (McGowan 1954; Okutani and McGowan 1969).

TABLE 3
Daylight and Dark Bottom (30 m) and Mid-depth (15 m) Larval Squid Catch from 0.5-m Plankton Nets Near Squid Spawning Grounds, Monterey, California

Date (1976)	Light Condition	Bottom Squid Catch	Midwater Squid Catch
21 July		–	–
27 July		–	–
3 August		113	7
10 August	Full Darkness	0	1
17 August		1	1
31 August		1	0
21 July...........		49	–
27 July		25	7
3 August	Daylight	68	38
10 August		0	4
17 August		2	3
31 August		–	–

ACKNOWLEDGMENTS

We would llike to express our sincere thanks to Ronald G. Evans, who organized the collection and identification of squid larvae from Moss Landing Marine Laboratories-sponsored cruises 15 September 1975 to 10 March 1976. We would also thank J. R. Raymond Ally, California Department of Fish and Game, who, as chief scientist, supervised squid plankton tows during R/V *Alaska* Cruise 76A4. Thanks go also to Scott Keck, California State University, Long Beach, who sorted the *Alaska* samples. We would also like to thank Konstantin Karpov and James Harvey of Moss Landing Marine Laboratories for their help in the field. Ross Smart, Moss Landing Marine Laboratories, designed and built the bottom sampler used in this project.

This work is the result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, under Grant No. NOAA 04-6-158-44110, Project Number R/F-15. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notations that may appear hereon.

REFERENCES

Baxter J.L., J.D. Isaacs, A.R. Longhurst, and P.M. Roedel. 1968. Partial review of and projected program for research toward utilization of the California Current fishery resources. Calif. Coop. Oceanic Fish. Invest. Rep., 12:5-9.

Fields, W.G. 1965. The structure, development, food relations, reproduction and life history of the squid *Loligo opalescens* Berry. Calif. Dept. Fish Game, Fish Bull. (131).

Gulland, J.A. 1971. The fish resources of the ocean. FAO Publ. Fishing News (Books), Ltd., Surrey, England. p. 121-130.

Hopkins, T.L., R.C. Baird, and D.N. Milliken. 1973. A messenger-operated closing trawl. Limnol. Oceanogr., 18(3):488-490.

LaRoe, E.T. 1971. The culture and maintenance of the loliginid squids. *Sepioteuthis sepioidea* and *Doryteuthis plei.* Mar. Biol., 9:9-25.

Mais, K.F. 1974. Pelagic fish surveys in the California Current. Calif. Dept. Fish Game, Fish Bull. (162). 79 pp.

McGowan, J.A. 1954. Observations on the sexual behavior and spawning of the squid, *Loligo opalescens,* at La Jolla, Caliofrnia. Calif. Fish and Game, 40(1):47-54.

Okutani, T., and J. McGowan. 1969. Systematics, distribution and abundance of the epiplanktonic squid (Cephalopoda, Decapoda) larvae of the California Current, April 1954 - March 1957. Scripps Inst. Oceanog. Bull., 14:1-90.

Voss, G.L. 1973. Cephalopod resources of the world. FAO Fish. Circ. 75 pp.