Follett kindly reviewed some photographs that we took of sharks, thus confirming our identifications, and checked an earlier version of this paper.

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IN SITU OBSERVATIONS ON REPRODUCTIVE BEHAVIOR OF THE LONG-FINNED SQUID, *LOLIGO PEALEI*

There are several published accounts of reproductive behavior, including copulation and egg laying, of the long-finned squid, *Loligo pealei* Lesueur, in the laboratory (Drew 1911; Arnold 1962); but with the exception of Stevenson's (1934) field observations of *L. pealei*'s behavior around an egg mass, no in situ observations of egg-laying behavior have been documented for this species. Field and laboratory observations of reproductive behavior have been made for the California market squid, *L. opalescens* (McGowan 1954; Fields 1965; Hobson 1965; Hurley 1977), the tropical arrow squid, *L. plei* (Waller and Wicklund 1968), *L. bleekeri* (Hamabe and Shimizu 1957), *L. vulgaris* (Tardent 1962), the broad squid, *Sepioteuthis bilineata* (Larcombe and Russell 1971, and *S. sepioidea* (Arnold 1965). However, each species' in situ egg-laying behavior differed from the behavior we observed in *L. pealei*.

Observations

Each summer *L. pealei* and its egg masses are common in shallow coves along the coast of Rhode Island, such as our study site at Fort Wetherill on Conanicut Island in Narragansett Bay. Scuba divers, including ourselves, have observed squid to be numerous in these areas, particularly at night when they occur singly or in small, loosely formed schools.

On 16 June 1979, at 1230 h on an incoming tide (temperature 14.5°-15.0° C, depth 6 m) using scuba we observed a large squid egg mass (50-60 cm across) attached to one side of a small boulder. The surrounding area was a sandy/mud bottom with unattached fragments of the seaweeds *Ulva lactuca*, *Laminaria* sp., and *Porphyra* sp. Because the egg mass was larger than the 12-15 cm masses we regularly see in this area while diving, we spent some time observing it. Squid began to appear at the limit of the water visibility (about 4.0 m) and moved toward the egg mass in a semicircle. They stopped about 2.5-3.0 m from the mass and remained stationary approximately 1-m off the bottom. The squid were in well-defined pairs with the smaller females (mantle length 16-18 cm) parallel to and on the left of each male (20-22 cm) as we faced them (Figure 1). Eight pairs were visible at that time. The animals had moderate pigmentation over the mantles, but we did not observe the distinctive spots of color at the base of the arms as were reported by Arnold (1962), nor did we observe color changes during the observation period. Contrary to McGowan's (1954) observations on *L. opalescens*, all of the animals appeared to be in good condition; no torn epithelium was obvious and no dead or dying individuals had been seen in the area of the egg mass or anywhere else in the cove during the hour-long dive.

One pair of squid at a time approached the egg mass with their arms held forward and tentacles extended. Because of our position directly facing the squid, it was impossible to observe the beginnings of an egg finger protruding from the funnel as Drew (1911) and Tardent (1962) had observed in

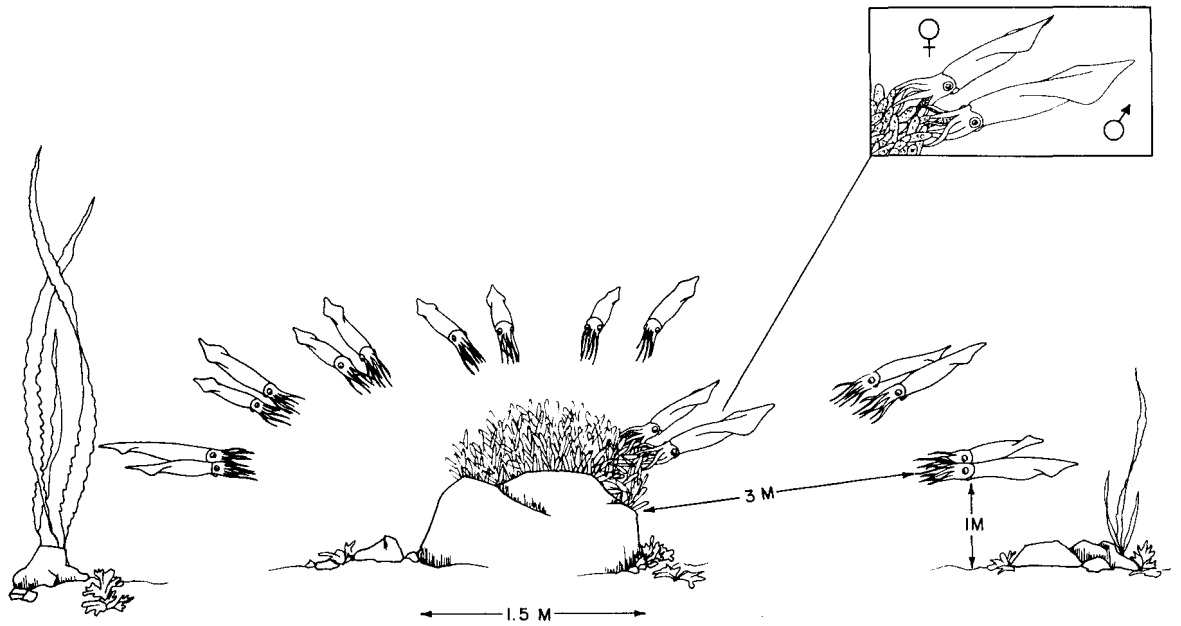

FIGURE 1.—Pairs of squid formed a semicircle and one pair at a time approached the egg mass. The female and male intertwined arms as they extended them into the egg mass. We surmise that the female was depositing an egg capsule and that the male was exhibiting parental care or "grooming" behavior. Water depth was 6 m.

L. pealei and *L. vulgaris* held in aquaria. However, comparing the behavior of the animals with that described in literature on squids' reproductive behavior, we concluded that the females were depositing egg capsules. They intertwined arms as they extended them into the egg mass. The arms of the male appeared to move delicately over and among the existing fingers of eggs (Figure 1). Each pair that approached the egg mass stayed 2-4 s then moved backward into the same position it had previously occupied in the semicircle. At that time another pair moved forward. There did not appear to be any order in which pairs approached the egg mass; however, no more than one pair approached at any given time. The same pair approached more than once.

Although most accounts indicate that copulation occurs just before egg deposition, our observations cannot substantiate this because egg laying had already commenced. No agonistic behavior which is often associated with reproduction was evident during the 10-min observation period.

Discussion

The social hierarchy involving egg deposition differs from species to species. Observations of *L. opalescens* and *L. plei* in the field indicate that once copulation occurs, individual pairs break apart and the female approaches the egg mass and deposits a capsule alone, although Hurley (1977) did observe an *L. opalescens* male pushing a female toward an egg mass. *Sepioteuthis sepioidea* remains paired after copulation, but only the female approaches the egg mass during egg laying (Arnold 1965). Larcombe and Russell (1971) reported that *S. bilineata* also remains paired, but the male escorts the female to the egg mass. However, the male assumes a protective role and follows about 0.5 m behind and above the female so he is between her and the other squid during the 2 s period in which she deposits a capsule. In contrast, *L. pealei* pairs formed and maintained a semicircle throughout egg laying (Figure 1). One pair at a time approached the egg mass; the male did not appear to assume a protective role, but might have been involved in "grooming" such as Tardent (1962) described for *L. vulgaris* held in an aquarium. Parental care or guarding egg masses has been documented for *L. pealei* by Stevenson (1934), who noted that both solitary males and pairs patrolled and guarded an egg mass. Similar guarding behavior has also been reported for *L. opalescens* (Hurley 1977).

Although there are similarities in reproductive behavior among several squid species, our observations of *L. pealei* indicate a social structure which is well defined and different from that described for other species with the possible exception of *S. bilineata* and *S. sepioidea*. Since there are relatively few published accounts of in situ copulation and egg-laying activities, it is difficult to know what is normal and what might be altered behavior patterns due to the presence of human observers, submersibles, lights, etc. However, our observations and those of other divers, including two in the same area a week earlier who reported 12-15 pairs of squids in a semicircle (Turco[1]), indicate that the social structure associated with egg-laying behavior is not an isolated phenomenon, but a pattern which is recurrent in populations of *L. pealei* which frequent New England coastal waters in the summer.

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SPAWNING AND SEXUAL MATURITY OF GULF MENHADEN, *BREVOORTIA PATRONUS*[1]

Earlier studies of egg and larva collections (Turner 1969; Fore 1970; Christmas and Waller[2]) have shown that Gulf menhaden, *Brevoortia patronus*, which range throughout the northern Gulf of Mexico from Cape Sable, Fla., to Veracruz, Mexico, spawn from about October to March from near shore to about 97 km offshore at depths of from 2 to 111 m. There have been two previous studies to determine the age of spawning, the number of ova produced, and the peak time of ovary maturation (Suttkus and Sundararaj 1961; Combs 1969). Our objectives in the present study were to: 1) estimate the minimum number of maturing ova for specific age-groups and size groups, 2) estimate the percentage of fish that spawn at each age, 3) determine the time of spawning, and 4) determine the frequency of spawning.

Gulf menhaden make annual inshore-offshore movements. The larvae spend 3-5 wk in offshore waters before moving into estuaries where they

[1]Southeast Fisheries Center Contribution No. 81-12B.
[2]Christmas, J. Y., and R. S. Waller. 1975. Location and time of menhaden spawning in the Gulf of Mexico. Unpubl. manuscr., 20 p. Gulf Coast Res. Lab., Ocean Springs, Miss. (NMFS contract no. 03-4-042-24).