Spawning congregations of Indian squid *Loligo duvauceli* (Cephalopoda : Loliginidae) in the Arabian Sea off Mangalore and Malpe

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Two successive spawning congregations of *Loligo duvauceli* occurred along the southern Karnataka coast during 1990 and 1991. The congregations took place during the postmonsoon months (Sept.-Oct.) and resulted in steep increase in catch rates of squids in trawlers and purse seiners operating from Mangalore and Malpe. Occurrence of such notable quantities of large sized mature squids during September-October of 1990 and 1991 is attributed to the increase in seawater temperatures along the inshore areas during the period. Further, new evidences like, low gonadosomatic index and tangible growth after reaching sexual maturity are presented to highlight a non-semelparous reproduction in this tropical inshore squid.

Indian squid *Loligo duvauceli* Orbigny, a commercially important cephalopod, constitutes about 5-10% of the total trawl landings at Mangalore (lat. 12°50'N; long. 74°51'E) and Malpe (lat. 13°21'N; long. 74°42'E) in Karnataka along the southwest coast of India. The trawling season in the region generally commences by November and lasts till end of May[1]. June to August is the closed season for trawling due to rough sea conditions prevailing in the southwest monsoon. During September-October trawl operations are generally not carried out due to lack of abundance of demersal resources. However this is the peak period for the purse seine fleet fishing for pelagic species. During this period, small quantities of squids (up to 50 kg unit^{-1}) are normally taken along with other pelagic fishes by purse seines.

Information on the spawning biology of this species is scanty although semelparity (producing only one batch of offspring followed by post-spawning mortality) is suspected among females[2]. Rao[3] has given empirical evidence for semelparity and reported that *L. duvauceli* spawns from December to May off Mangalore. Squids are known to form large congregations in inshore waters during the spawning season[4]. However there are no reports of such congregations in Indian waters except for a brief mention of a spawning population of *L. duvauceli* along Alleppey coast[5] during Sept.-Oct. 1978.

During the observations on the biology of *L. duvauceli* at Mangalore and Malpe, unusual abundance of this species in trawl and purse seine gears were observed during Sept.-Oct. of 1990 and 1991. Hence a detailed investigation on the catch, effort and biology of the species was carried out during 1990-91 to gain a better understanding of its spawning pattern.

Materials and Methods

Estimates of squid catch (tonnes) and effort (trawling hours) were made based on biweekly observations at Mangalore and Malpe landing centres. The observed catch and effort were raised by the number of boats landed on the day to obtain the day's estimate, and all such figures were pooled and raised by the number of fishing days in the month to get the monthly catch and effort estimates. For studying the biology, weekly samples of the squid were taken and the individual dorsal mantle length (DML) in mm and maturity stage by sex were recorded. From the length frequency data, the monthly mean lengths and their standard deviation were calculated for both sexes separately. For recording maturity stages, a 4-point maturity scale[6] (I = immature; II = maturing; III = mature and IV = spent) was used. The gonadosomatic index (GSI) of males and females was obtained by weighing the individual gonad (to nearest mg) and finding its percentage in total body weight. To examine whether the monthly sex ratio was 1:1 or not, the chi-square test[7] was applied.

Results and Discussion

Estimated monthly trawl catch (in tonnes) and catch rate (in kg.h^{-1}) of *L. duvauceli* during 1990 and 1991 from both Mangalore and Malpe (pooled) are given in Fig. 1. The annual squid production by trawls during 1990 was 1521 tonnes and it increased by 47%

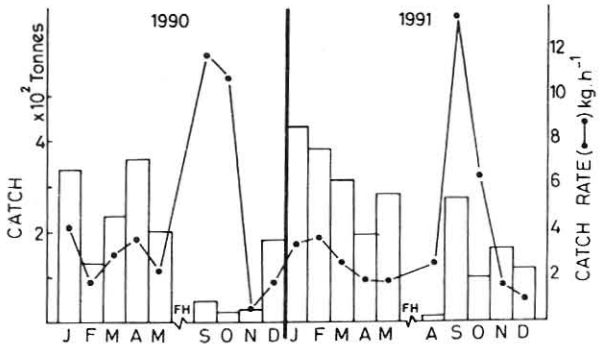

Fig. 1— Estimated monthly trawl catch and catch rate of *L. duvauceli* at Mangalore and Malpe (pooled) during 1990 and 1991 (F.H. indicates fishing holiday)

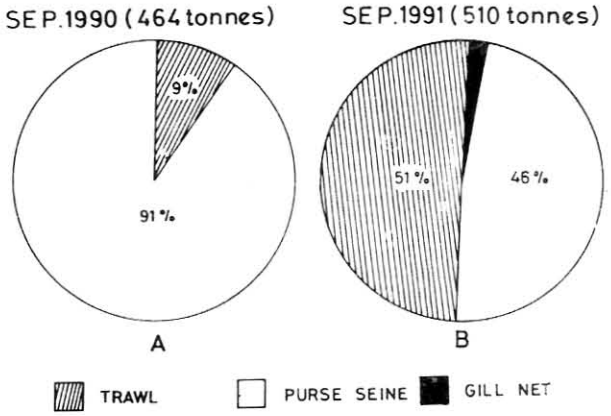

Fig. 2—Percentage contribution by different gears in *L. duvauceli* catch during Sept. 1990 and 1991

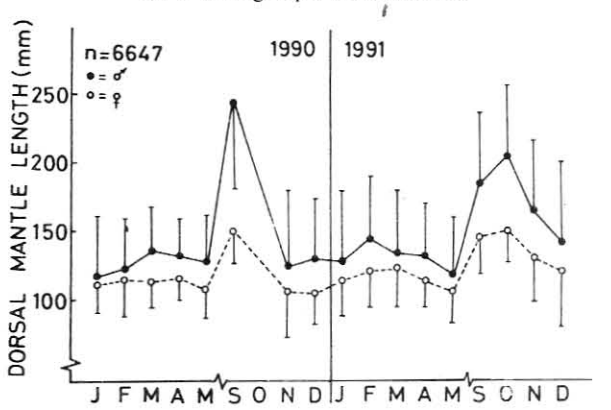

Fig. 3—Monthly mean lengths of male and female *L. duvauceli* (Vertical lines indicate SD; F.H. = fishing holiday)

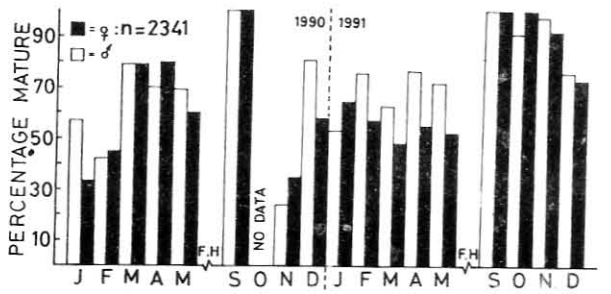

Fig. 4—Monthly percentage of mature males and females of *L. duvauceli*

to 2239 tonnes in 1991. The period January to May was the most productive and after the 3-month (June-Aug.) closed season (fishing holiday), the fishery improved by December only. However, very high catch rates (7-14 kg.h^{-1} were observed in Sept.-Oct. periods of both 1990 and 1991. This increase in catch rates was due to the increased abundance of squids during the period.

The enhanced availability of squids also resulted in their being caught in the purse seine gear. During Sept. 1990, an estimated 464 tonnes of squids were caught at Mangalore and Malpe (pooled) of which 91% was contributed by purse seiners (Fig. 2A). Similarly, in Sept. 1991, 510 tonnes were caught, with purse seine contributing 46%, trawl 51% and gill net 3% (Fig. 2B). The increase in percentage caught in trawls from 9% in Sept. 1990 to 51% in Sept. 1991 was due to a six-fold increase in trawl effort in Sept. 1991. In Sept. 1990 the abundance of squids was limited to the Mangalore-Malpe coast, but in Sept. 1991, steep increase in catch rates was reported at landing centres as far north as Honavar. In contrast to these, Rao[3] did not observe any squid catches during Sept. in 1983-85 period at Mangalore.

The monthly mean lengths of male and female *L. duvauceli* during 1990 and 1991 are given in Fig. 3. The female mean lengths fluctuated between 105 and 150 mm, while those of males ranged from 115 to 245 mm. The mean lengths of both males and females were significantly higher in Sept. 1990 and Sept.-Oct. 1991 indicating the predominance of larger squids in catches during the period.

Mature males and females of *L. duvauceli* dominated the samples in almost all months of 1990-91 except Feb. and Nov. 1990 (Fig. 4). Throughout the year a small percentage (5%) of mature males were in spent condition, but this condition was never observed in females. During Sept. 1990 and Sept.-Oct. 1991 almost all animals observed were in mature condition. The monthly variation in sex ratio (Fig. 5) indicates that males were dominant throughout the period except Dec. 1990 and May and Dec. 1991. The chi-square analysis showed that males significantly ($P < 0.05$) outnumbered females in May and Sept. 1990 and Sept. 1991. In Sept. 1990, 75% and in Sept. 1991, 65% of the population were males. Females of *L. duvauceli* were dominant along Vizhinjam coast, males along Cochin coast and both sexes were equally distributed along Bombay coast during 1976-80[6]. Rao[3] reported

that, in general, females were dominant in the population during 1984-85 at Mangalore. The GSI values of both males and females showed a rising trend from immature to mature stage (Fig. 6). As no female squids in spent stage were encountered, the value remained high, while among males, the value decreased during the spent stage.

The occurrence of such sizeable quantities of large size mature squids during Sept.-Oct. of 1990 and 1991 indicates that the squids might have congregated for spawning in the eastern Arabian Sea off southern Karnataka. The fact that they were caught by the purse seine, a gear meant principally for schooling species, lends credence to this view. The Indian squid reportedly forms large congregations in inshore waters during the spawning season at which time they are caught by purse seiners in Hong Kong using lights[4]. Nevertheless, congregations of such magnitude have not been previously reported from Indian seas. Fully mature and spawning specimens of both sexes were present in catches throughout the year off Cochin[5] and Mangalore[3] indicating continuous spawning. Earlier studies[4] suggest that spawning peaks of squids usually occur when water temperatures increase. Along the southwest coast of India, the surface and sub-surface seawater temperatures in the inshore areas evince a sudden increase during Sept.-Oct. after the southwest monsoon[8] and this could probably explain the present congregation of squids. Further, short days and/or low light intensity accelerate the maturation of squid gonads through the optic gland system[9]. The monsoon months (June-Aug.) with their prevailing cloudy/rainy days (low light intensity) may provide an ideal condition for gonad maturation of *L. duvauceli* and the subsequent postmonsoon spawning congregation.

Meiyappan and Srinath[5] briefly reported a spawning squid population off Alleppey observed during Sept.-Oct. 1978 comprising mainly of large size males (82%). Since then, the present observation is the only record of spawning congregation of squids. However, reports of spawning congregations of Indian squid at staggered intervals along Kerala-Karnataka coast indicate that it is not an isolated phenomenon. The event must be occurring annually along the southwest coast of India with varying intensities during the postmonsoon period, depending on favourable environmental conditions. Similar spawning congregations have also been reported for various other loliginid squids[9]. In the American market squid, *Loligo opalescens*, large shoals move from the offshore feeding grounds to the coastal waters for spawning during Dec.-March in southern California[10].

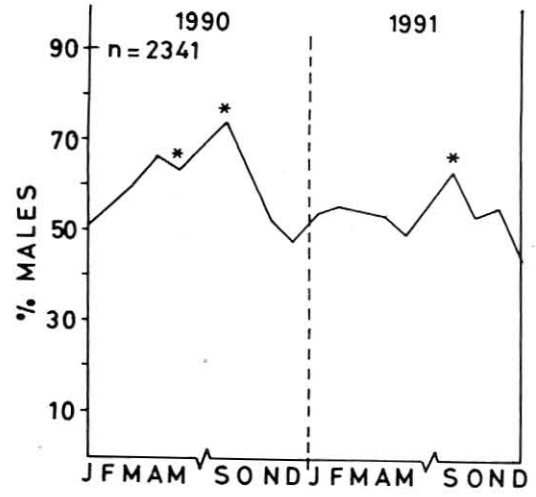

Fig. 5—Monthly sex ratio (as percentage males) during 1990 and 1991. [*indicates significant chi-square values ($P < 0.05$)]

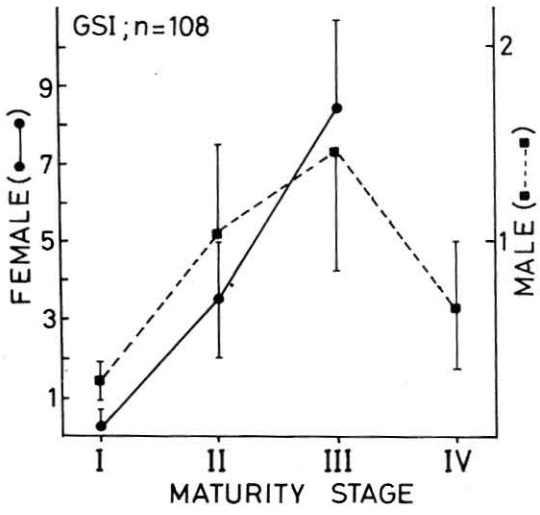

Fig. 6—Mean gonadosomatic index (GSI) values of male and female *L. duvauceli* during different maturity stages (Vertical lines indicate SD)

The females of many squid species are thought to be semelparous[11]. At present nothing is known clearly about post-spawning mortality of female *L. duvauceli*[5]. However, Rao[3] offered tentative evidence for semelparity in the species based on unimodal ova diameter frequency distribution indicating single spawning, and steep decline in the proportion of females beyond 150 mm. The present observation of statistically significant male dominance in the spawning population during 1990 and 1991 could be due to post-spawning mortality of females. Further, the absence of spent females in the samples also supports this view. It is also interesting to note that the proportion of males in the 1978 congregation off Alleppey[5] was also above 80%. In the ommastrephid

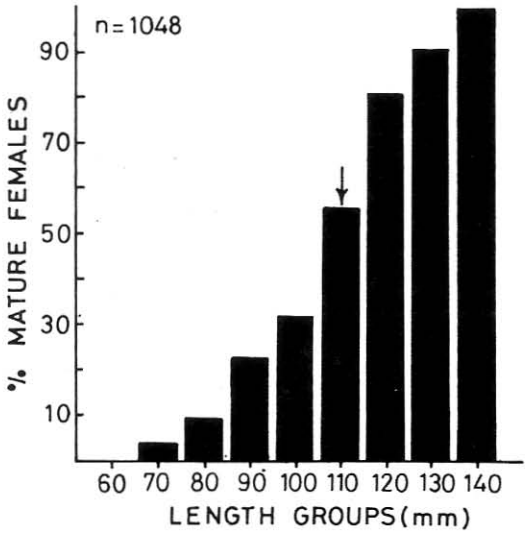

Fig. 7—Percentage mature females in different length groups (10 mm). All females from 140 to 190 mm were fully mature (arrow head indicates size at first maturity)

squid *Illex illecebrosus*, the tendency for segregation of the sexes in schools has been attributed to the cannibalistic behaviour of large females and early emigration of mature males[12]. Therefore, the observation of male dominant sex ratio in *L. duvauceli* could also be due to emigration of females to deeper areas for egg laying. However, concrete evidences for both conclusions are not available at present.

Recently, Harman *et al.*[13] have presented indirect evidences to suggest that the tropical oceanic squid *Stenoteuthis oualaniensis* is a multiple spawner, a reproductive strategy not conclusively proved earlier in squids. One of the evidences that they provided was the low GSI of *S. oualaniensis* (8.8) in comparison to known semelparous squids like *Illex illecebrosus*[12] (23) and *Loligo opalescens*[14] (25-50), thus suggesting that *S. oualaniensis* puts relatively less energy into egg development during maturity and consequently, is able to survive the first spawning to mature and spawn again. In *L. duvauceli* too, the GSI of mature females was low (Fig. 6) ranging from 5-14 with mean at 8.3 ± 2.2 indicating a situation similar to that existing in *S. oualaniensis*.

Another supporting evidence for multiple spawning is the ability to grow after reaching sexual maturity[13]. Along the Mangalore-Malpe coast, mature females of *L. duvauceli* were found to occur over a wide length range (70-190 mm), and beyond 139 mm all females were fully mature (Fig. 7). The size at first maturity (size at which 50% are mature) was 110 mm, indicating that tangible growth does take place in females even after maturation and spawning. However, semelparous squids like *Loligo vulgaris* are thought to grow little, if any, after reaching maturity[15]. Hence, the suspicion of Harman *et al.*[13] that multiple spawning (non-semelparous reproduction) would be the common strategy among tropical squids is most likely to be true in the case of *L. duvauceli*.

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