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Reproductive Biology of Commercially Valuable Squid, *Sepioteuthis lessoniana* (Lesson, 1830) Taken as By-Catch in a Tropical Trawl Fishery

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Abstract

Some aspects of the reproductive characteristics of the commercially important squid *Sepioteuthis lessoniana* (Lesson, 1830) in the coastal waters of Mandapam, Palk Bay was studied with a view to provide possible management measures in this region. A total of 984 individuals (508 males and 476 females) were collected between April, 2009 to March, 2010. The size of specimens ranged from 40 mm to 290 mm in mantle length. Sex ratio was not significantly different (p>0.05) from the expected ratio of 1:1 except for months of July, October and December. Spawning season as revealed by seasonal maturity stages, gonadosomatic index of sexes and nidamental gland length (NGL) and dorsal mantle length (DML) ratio of females, lied between January to June with peak at February. Size at maturity as determined by graphical method was 83.5 for males and 112.5 for females.

Keywords: Mandapam waters, Palk Bay, reproductive biology, *Sepioteuthis lessoniana*

Introduction

In India, cuttlefishes, squids and octopuses commonly known as cephalopods are principally caught as by-catch from shrimp and fish trawls employed by the trawlers. Squids are an important by-catch in trawl fisheries in Indian waters, forming approximately 42% of total cephalopods catch (CMFRI, 2010). The main squid species landed are *Sepioteuthis lessoniana, Loligo duvaucelii, L. uyii, L. edulis, L. singhalensis, Loliolus investigatoris, Symplectoteuthis oualaniensis and Thysanoteuthis rhombus,* of which only the first one is normally available in Palk Bay and Gulf of Mannar waters (Mohamed, 2008).

All squids are semelparous, which means they spawn once in life time and die (Boyle and Rodhouse, 2005), or repeatedly over an extensive period, ranging from a few days to several months (Sauer *et al.,* 1997). Their reproductive output, the spawning strategy and success are critical since these would affect the continuity of the next population in terms of the strength of next generation. Sexual maturation in cephalopods appears to be largely under the influence of a gonadotropic hormone originating from the optic glands (O'Dor and Wells, 1978). Little is known about the spawning seasonality of tropical and subtropical squid and cuttlefish (Jackson and Moltschaniwskyj, 2001)

Species supporting major loliginid fisheries, such as *L. gahi* in the Southwest Atlantic (Guerra and Castro, 2004), and *L. duvaucelii* in Thailand (Chotiyaputta, 1993) and India (Asokan, 2000), have been studied in relation to their reproductive biology in a view to provide management measures in their respective regions. In view of the economic importance of the squid fishery in this area (Mandapam, Palk Bay), basic knowledge on the reproductive biology is necessary to provide the biological basis for implementation of possible management measures which aimed at sustainable exploitation of the resource. Except the study of Rao (1954), there was no detailed information regarding reproductive biology of *S. lessoniana* carried out from the Palk Bay water. The aim of the present study were to study some aspects of the reproductive characteristics of this species from the Mandapam area.

Materials and methods

Random samples of *S. lessoniana* were collected at monthly interval from commercial trawl landings of Mandapam centre (Fig. 1). A total of 984 specimens (508 males and 476 females) were investigated during April 2009 to March 2010. Total weights and dorsal mantle length (DML/ML) were accurately weighed / measured to 0.01g and 0.1mm respectively in fresh animals. DML values were between 40 mm and 290 mm for both sexes. Animals were sexed based on morphological characters. After dissecting, gonads of both sexes were weighed; length (NGL) and weight of the nidamental glands were taken in case of females.

The sex ratio was computed for each month and also for each length group (class size =10 mm). The left 4rd arm was modified into hectocotylised in males only and sex was determined based on this arm. The homogeneity in the distribution of both sexes was tested using the chi

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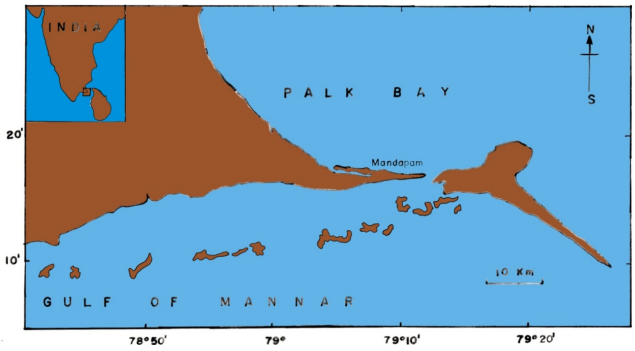

Fig. 1. Map showing the location of sampling site (Mandapam, Palk Bay)

square formula ($\chi^2 = \Sigma (O-E)^2 / E$ where, χ^2 - Chi square; O - Observed frequency; E - Expected frequency).

The maturity stages of specimens were determined by assessing its internal organ visually (Fig. 2) by following the four point maturity scale developed for squid (Silas, 1985 a). The maturity scale could not be applied to individuals (juvenile) that are not distinguished by sexual characteristics.

The gonad somatic index (GSI) for males and females (Joy, 1989) was calculated (GSI = 100 GW/BW where, GW- gonad weight; BW- body weight) and NGL/DML ratio for females were also computed for assessing the reproductive status of individuals.

The size at first maturity defined here as the size (using cumulative frequency distribution) at which 50% of the individuals in the sample size are mature (stage III and IV) and was determined using the graphical methods Udupa (1986)

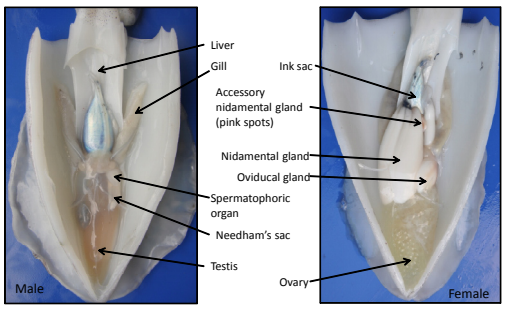

Fig. 2. Mantle cavity of (a) male and (b) female squid *S. lessoniana* showing the reproductive structures

Results

Sex ratio

Analysis of chi square values indicated that the sex ratio was not significantly differ from the expected ratio of 1:1 except for months of July, October and December. This gives mean sex ratio of 1: 1.03 with a chi square value of 3.54, which is not significantly different from the expected 1:1 ratio (Tab. 1). Tab. 2 gives the details of the sex ratio with respect to the different size groups. Proportion of males present in the samples was dominant in larger size group. Chi square test results indicated that in smaller size groups; the ratio was not significantly differ from the expected ratio of 1:1, whereas in higher size groups; the ratio differs significantly from the expected ratio of 1:1.

Monthly variation in maturity stages

The occurrence of different maturity stages of gonads was examined throughout the period of study in order to determine the spawning season. Fig. 3 and 4 illustrate the monthly percentage composition of the maturity stages of both the sexes for *S. lessoniana*. Male gonads were observed in mature condition, with spermatophores in Needham's sac, throughout the year indicating a year round reproductive activity.

In female squid, immature ovaries were more during April-June and maximum percentage of mature ovaries were recorded during the months of October - December and June. Spawning/spent animals were observed throughout the study. Occurrence of maturity stages indicate that squid of various stages of maturity occurred in most of the months. It can be thus inferred that *S. lessoniana* has a prolonged breeding season extending from December to July with peak spawning activity during January - March.

Gonado somatic index

Seasonal variation in mean GSI was pronounced for both sexes (Fig. 5 and 6). Male GSI increased in December and peaked in January, February and March; this coincided with the peak percentage of specimens in spawning condition. This index declined gradually starting from June, and reached its lowest values between July and November. Female index exhibited the gradual increase in November and reached its highest level during December to April, followed almost the same trend as in males; this coincided with the peak incidence of individuals in spawning condi-

Tab. 1. Monthly variation of sex ratio of *S. lessoniana*

Months	No. examined	Male (M)	Female (F)	Sex ratio	χ^2	*p*-value
Apr	53	21	32	1.52	2.28	<0.05
May	--	--	--	--	--	--
Jun	107	47	60	1.28	1.58	<0.05
Jul	62	46	16	0.35	14.52	>0.05
Aug	77	41	36	0.88	0.32	<0.05
Sep	163	89	74	0.83	1.38	<0.05
Oct	78	27	51	1.89	7.38	>0.05
Nov	72	44	28	0.64	3.56	<0.05
Dec	87	54	33	0.61	5.07	>0.05
Jan	91	49	42	0.86	0.54	<0.05
Feb	62	25	37	1.48	2.32	<0.05
Mar	132	65	67	1.03	0.03	<0.05

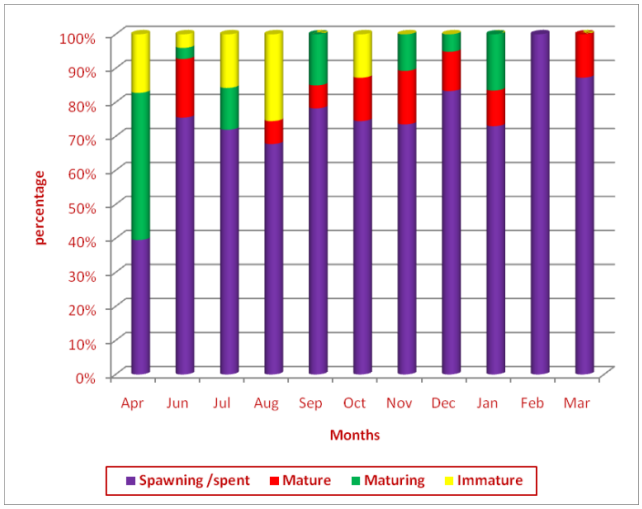

Fig. 3. Monthly stages of maturity of male of *S. lessoniana*

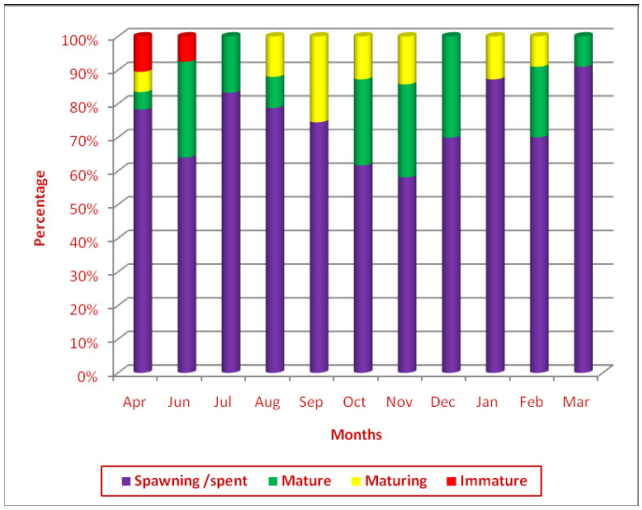

Fig. 4. Monthly stages of maturity of female of *S. lessoniana*

tions. Mean NGL/DML ratio for females was calculated and mean values are plotted in Fig. 7. NGL/DML ratio showed the similar trend as in female GSI.

Size at first maturity

To determine size at first maturity, squids were grouped sex wise into 5 mm size groups and percentage of maturity in each size group was calculated. Size at first maturity of *S. lessoniana* of both sexes is given in Fig. 8. All the males were immature up to 64.5 mm ML. In 65.5 - 79.5 mm size groups, 41.9% were mature condition. The percentage matured squids increased gradually from 80.5 - 110.5 mm size groups where 98.6% of the specimens were mature and all the specimens above 115.5 mm ML were mature. Up to 99.5 mm ML, all the females were in immature stage. In 100.5 - 104.5 mm size groups, only 11.8% were in mature condition. In 105.5 - 109.5 mm size class, 29.3% were found as mature. The percentage matured squids increased suddenly above this size group and in 119.5 mm size class the percentages of immature stage is very less and 68.9% were in mature group. The percentage matured squids gradually increased further and at 125.5 mm size group, 98.5% were mature. The size at first maturity was estimated 83.5mm ML for males and 112.5 mm ML for females.

Tab. 2. Sex ratio of S. *lessoniana* in various length groups

Length groups (mm)	No. examined	Male (M)	Female (F)	Sex ratio	χ^2	*p*-value
40 - 49	8	4	4	1	0	<0.05
50 - 59	12	3	9	3	3	<0.05
60 - 69	43	21	22	1.05	0.02	<0.05
70 - 79	44	18	26	1.44	1.45	<0.05
80 - 89	36	19	17	0.89	0.11	<0.05
90 - 99	46	31	15	0.48	5.57	>0.05
100 - 109	66	33	33	1	0	<0.05
110 - 119	69	34	35	1.03	0.01	<0.05
120 - 129	63	31	32	1.03	0.02	<0.05
130 - 139	76	39	37	0.95	0.05	<0.05
140 - 149	99	43	56	1.3	1.71	<0.05
150 - 159	87	33	54	1.64	5.07	>0.05
160 - 169	78	32	46	1.44	2.51	<0.05
170 - 179	66	25	41	1.64	3.88	<0.05
180 - 189	47	21	26	1.24	0.53	<0.05
190 - 199	32	21	11	0.52	3.13	<0.05
200 - 209	32	26	6	0.23	12.5	>0.05
210 - 219	26	22	4	0.18	12.46	>0.05
220 - 229	16	15	1	0.07	12.25	>0.05
230 - 239	15	14	1	0.07	11.27	>0.05

Discussion

This squid species exhibited reproductive trait typical of many loliginids. In general, the period of peak reproductive activity for *S. lessoniana* was during post-monsoon months, that is, January to March.

Sex ratio

The sex ratio was not significantly differing in most of the months in this study except July, October and December (Tab. 1). The similar observation was reported for squid *L. duvaucelii* (Sang, 2007). On the contrary, Silas *et al.,* (1985 b) studying in the same species of Gulf of Mannar, India reported that males were dominant in most of the months except January to February; their dominant value for males may be a result of selectively sampling larger animals of commercial catch. Analysis of sex ratio in relation to size groups showed that it is not significantly differ in smaller size groups compared to larger groups (>200 mm ML) (Tab. 2). This may also be a result of selectively sampling larger animals of commercial catch. The variation in the ratio may also be due to various factors like migration associated with sexual maturation and spawning; feeding behavior related to reproduction, post spawning mortality and difference in the growth in both sexes (Mangold, 1983 a).

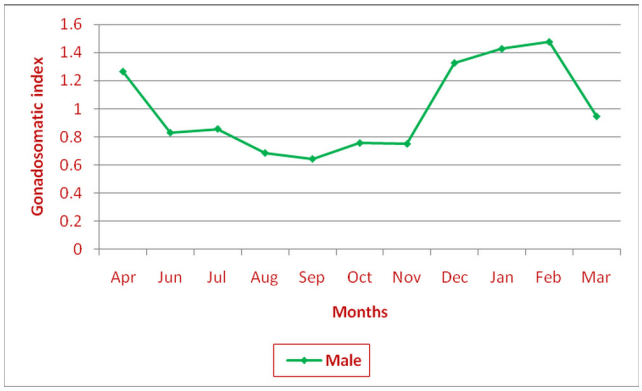

Fig. 5. Monthly variation in mean GSI for male S. *lessoniana*

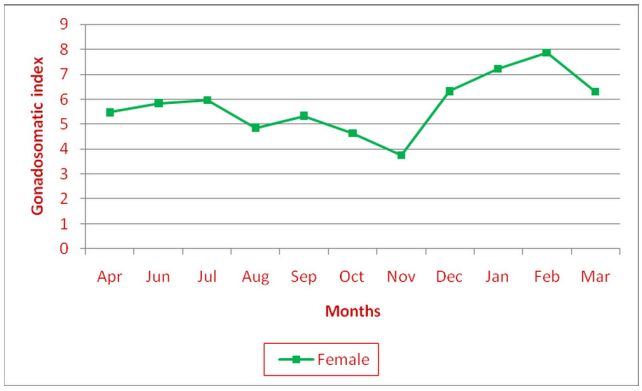

Fig. 6. Monthly variation in mean GSI for female *S. lessoniana*

Sexual maturation

The presence of mature ova in the ovaries is an indication of its spawning activity. Mature reproductive organs were observed throughout the year (Fig. 3 and 4) in this study. These results indicated that this species spawns almost throughout the year. From data, it can be seen that reproductive organs in a stage of fullness were observed during the months of December-February indicating a peak spawning activity of this species at Mandapam waters during these months. This conclusion is supported by the fact that mature females dominated in the samples taken in December (55%), January (67.43%) and February (70.28%). Spawning of *S. lessoniana* as indicated by the presence of mature gonads was observed during the post-monsoon months with peak periods, January to June or July. The reproductive organs were observed to be fully, partially or wholly exhausted in the months of May, June, July and August months. The squid *L. duvaucelii* spawns throughout the year along both the coasts, peak spawning has been observed during post monsoon months (Mohamed, 1993).

In the present study, sexual maturation of *S. lessonaina* occurred from December to February and the spawning period from January to June or July. The same observation has been reported for *S. lessoniana* (Rao, 1954). Mhitu *et al.* (2001) observed that the season of sexual maturation of *S. lessoniana* around Chwaka Bay, Tanzania was from March to June with a peak in May. Segawa (1987) reported on the same species in Japan that sexual maturation takes place from May to mid or late June. Kilada and Riad (2010) reported on the *L. duvaucelii* squid in Red Sea, Egypt that the spawning activity was associated with the relative decline in total somatic weight with maturation. As in many marine invertebrates, sexual maturation and reproduction are the most energy-intense periods of the cephalopod life cycle. Somatic production exceeds gamete production during early life, but is later exceeded by gamete production, which eventually dominates tissue growth (Rodhouse, 1998). Prolonged spawning periods are characteristic of tropical and subtropical species of fishes which exist in lower latitudes, while comparatively shorter spawning seasons characterise the higher latitude temperate species (O'Dor and Wells, 1987). In tropical waters, where variations in sea temperature and food supply are not so well marked, these two factors do not seem to act as trigger stimuli for breeding (Qasim, 1973). However, annual change in temperature and salinity may affect the coastal fishes to some extent in their breeding season.

In the present study, the variations of GSI during different months were used to identify the spawning season of this species. A higher proportion of adults appeared in the study sites during the proposed spawning seasons by evidence of high GSI, higher percentage of mature individuals (maturity III and IV) and high incidence of mated female. The results of this study showed that the GSI values of females increased from mid of November and reached

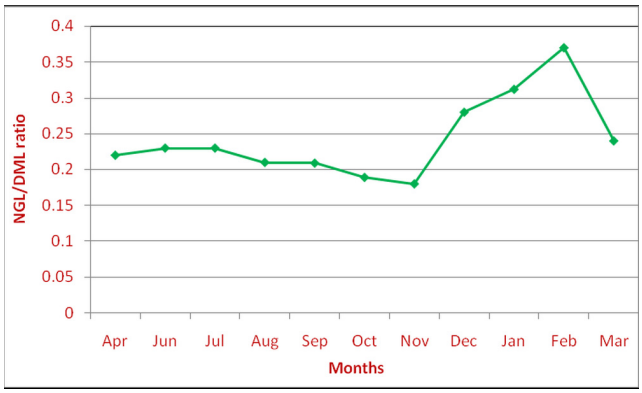

Fig. 7. Monthly variation in NGL/DML ratio for female *S. lessoniana*

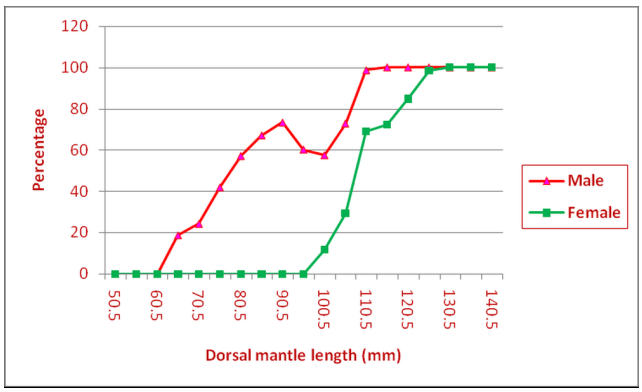

Fig. 8. Size at first maturity of males and females of *S. lessoniana*

a maximum value in February. The high GSI values during these months indicated that the maximum gonadial activity had taken place, indicating a probable spawning period of the species. Low GSI values during July to November showed reduction in the reproductive activity. In males also similar seasonal change was observed in GSI values as female. The ratios GSI and NGL/DML correlated positively with maturation and spawning in *S. lessoniana*. The similar observation has been noted for *S. lessoniana* (Sivashanthini *et al.,* 2010; Mhitu *et al.*, 2001) and *Loligo forbesi* (Boyle and Ngoile, 1993). Results of GSI and NGL/DML are important for determining the reproductive cycle of *S. lessoniana*. Boyle and Ngoile (1993) have shown that the GSI is the best index in assessing maturation and identifying spawning period in *L. forbesi.* The reproductive cycle is reflected by pronounced variations in gonadal size which depends on animal size and stage of gonadal development (de Vlaming *et al.*, 1982). The gonad and the digestive gland that accumulate the necessary resources for egg production as well as oviduct gland that acts as a reservoir for sperms; increases in size with sexual maturation. This explains why maximum values of the indices occur when there is maximum reproductive activity (Mangold, 1983 b). Moreover, females may invest more energy resources in reproduction for oocytes production than males do for sperm production (Ho *et al.,* 2004)

Size at first maturity

Size at first maturity indicates the size at which half of the population mature and ready for reproduction. The size at first maturity in this area obtained by graphical method was 83.5 mm and 112.5 mm DML for males and females respectively. Size at first maturity values for males and females of *S. lessoniana* obtained in the present study agree with those reported by Rao (1954). Rao (1954) reported that males of *S. Lessoniana* reach sexual maturity within the size range of 67.5 mm - 112.5mm and females within 102.5 - 112.5 mm. Mhitu *et al.* (2001) reported on the same species in Tanzania that the size at first maturity values for males and females were 102.5 and 112.5 mm which were higher for male compared to present values. How ever, in both cases; male mature at smaller size compared to females. As temperature is closely related to the growth of squid (Hatfield, 2000), such geographical separation and difference in temperature may have resulted in the different sizes of *S. lessoniana* in the different regions. Silas *et al.* (1985 b) studying in the maturity of squids and cuttlefishes of Indian waters reported that in squid *L. duvaucelii,* males attained sexual maturity earlier than females and in all species spawning is prolonged. Present study reveals that males are more precocious in reproduction than females, reaching sexual maturity at an early size, as in the case of most of the cephalopods. Early maturation and year round maturity of males ensures high rate mating success of the species.

Conclusions

S. lessoniana is one of the commercially important squid distributed in the Palk Bay and Gulf of Mannar region of India (Rao, 1954). The reproductive characteristics of *S. lessoniana* presents scenario of seasonal changes in sex ratio, matury stages, GSI, size at maturity and thereby spawning period can be predicted. Mature reproductive organs were observed throughout the year. Peak spawning of the squid in Mandapam waters is post monsoon months i.e. January to June. As with all commercial species of cephalopods especially squids, little is known concerning the impact of fishing on matured and spawning adults, whose life cycle is known to be very short. If overexploitation occurs, spawning adults could be decreased and subsequently recruitment overfishing occurred or reproductive capacity of population reduced. Such situation can be managed by setting restrictions on number of fishing units or ban on trawl fishing during the peak spawning periods. Hence, the present study would definitely lead to formulate a effective fishery management measures so as to ensure the sustainable fishery.

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