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Reproductive biology of *Leiognathus splendens* (Cuvier) from Kochi, south-west coast of India

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ABSTRACT

The reproductive biology of *Leiognathus splendens* (N = 2112) was studied using the samples collected from the Kerala coast during 1998 - 2000. A separate scale of five stages of maturation has been developed for the first time for any Indian marine fish and applied in the present study. Analysis of data on the ova diameter in different length groups showed that spawning takes place in batches at regular intervals after the juveniles undergo the process of maturation and reach ripe stage. Spawning takes place almost round the year. The length at first maturity was 75 mm. The estimated fecundity ranges from 5715 (88 mm TL) to 37160 (106 mm TL).

Keywords: Fecundity, *Leiognathus*, Length at first maturity, Maturation, Silverbelly, Spawning

Introduction

Determination of the timing of spawning and the total output of eggs is necessary for assessing the reproductive potential of a population. These studies along with information on the survival of early and vulnerable stages in the life history would facilitate determination of the short term and long term fluctuations in the production of year classes and their recruitment to the fishery as exploitable stocks. Thus, the success or failure of spawning in any one year in a population, affects the fishery. Hence studies on maturation, spawning and fecundity become essential in formulating management strategies of exploited fish stocks. The peculiarities of reproduction in a species are adaptations for preservation of species and its abundance (Nikolsky, 1963). The size and quality of the replenishment of the population are determined by the quality and abundance of the spawning population and also by the environmental conditions under which the eggs and larvae have to survive and grow.

Several studies have been conducted on maturation and spawning in silverbellies, along the Indian coast. Arora (1952) studied the length at maturity and spawning period of *Leiognathus splendens* from Rameswaram Island, off the coast of Tamil Nadu. Balan (1963) studied the biology of *L. bindus* off Calicut in the west coast. Rao (1967) gave an account of the lipid levels associated with the reproductive cycles in *L. splendens* off Madras. The spawning habits and fecundity of four species of silverbellies from Tuticorin were studied by Mahadevan Pillai (1972). James (1986) as well as James and Badrudeen (1975, 1981, 1986) reported on spawning of selected silverbelly species from the Palk Bay and Gulf of Mannar. Murty (1983, 1990) studied the maturation and spawning in *L. bindus* from Kakinada. Spawning biology of *L. splendens* from Porto Novo has also been reported (Jayabalan, 1986; Jayabalan and Ramamoorthi, 1986). It is clear from the earlier studies that except for the work of Balan (1963), there has been no study on the spawning biology of silverbelly species off Kerala. The present study was undertaken to fill the gaps in the knowledge on maturation and spawning in *L. splendens* from the west coast of India with special reference to Kerala coast.

Materials and methods

The study is based on 2112 specimens of *L. splendens* (length range 34 to 115 mm) collected during 1998-2000 from Cochin and Neendakara Fisheries harbours at fortnightly intervals. After measuring the length and weight of each specimen, the belly was cut open to note the sex, colour and general appearance of the gonads, which were then carefully removed and preserved in 5% formalin, in labelled bottles.

Classification of ovaries into different stages of maturation

The appearance of the ovaries in fresh condition, the proportion of the area occupied by them in the body cavity and the structure and diameter range of the intraovarian ova were considered for quantification of ovaries into different stages of maturation.

Ova diameter frequency distribution

For measurement of ova diameters, transverse sections were taken from the anterior, middle and posterior regions of the ovary, the ova were teased out on micro slides taking utmost care to separate out all the ova in the samples. The ovadiameters were measured by placing the micrometer in a horizontal position across the field of microscope and then reading the diameter of the egg in the same plane, irrespective of the shape of the ova, following Clark (1925) and De Jong (1940). All the ova in each sample spread on the slide were measured without any selection. The ovadiameters were grouped into three micrometer division (md) class intervals (*i.e.*, 1-3, 4-6, 7-9 *etc*.) to determine the frequency distribution of ova in the ovary. About 800 - 1000 ova were measured from each ovary.

Determination of length at first maturity

For determining the length at first maturity (L_{50}), specimens with ovaries in stages IV and V of maturation were considered as mature and the proportion of such mature fish in each length group determined. The length at which about 50% of the fish are mature, has been taken as the $L_{50.}$

Spawning

The periodicity of spawning has been determined using the ova diameter frequency distribution in mature ovaries following Hickling and Rutenberg (1936) and De Jong (1940). For this purpose, only fishes of and above the length at first maturity (L_{50}) were considered as this would help in determining the peak spawning period more satisfactorily. The gonado-somatic index has also been studied for the purpose following the method by De Vlaming *et al*. (1982).

Fecundity

Estimation of fecundity is based on the mature ovaries as all the ova destined to be spawned during the ensuing season are mature in such ovaries (Bagenal, 1968). The estimated number of mature ova in such ovaries represents the fecundity. After separating all the ova from the ovarian tissue, they were transferred to a counting chamber (divided into 100 small squares by transverse and longitudinal lines) and all the mature ova having a fully yolked structure, were counted under the microscope. Using the number of mature ova in the sample, the fecundity was estimated as:

(Total weight of ovary/weight of the sample) X Number of mature ova in the sample

Results and discussion

Maturation

In the present study, the ovaries were classified on the basis of the external appearance of the fresh ovary, as well as the intraovarian ova diameter and structure.

Description of ovaries and ova

The ovaries of *L. splendens* are rounded unpaired structures lying in the middle of the body cavity attached to its dorsal wall. The mature ovary is compact, more or less spherical and occupies the bulk of the body cavity. It is bright yellow in colour with ova of different sizes.

Four groups of ova are distinguished in ripe ovaries

Type I (Immature ova): Irregular shape, a few larger ova spherical, translucent, yolkless, nucleus clearly visible; ova diameters ranging from 3 to 12 md.

Type II (Maturing ova): More or less spherical in shape, almost opaque. Nucleus not visible, ova diameters range from 12 to 33 md.

Type III (Mature ova): Spherical in shape; opaque due to deposition of yolk; a clear space present around the periphery, ova diameters range from 24 to 44 md.

Type IV (Ripe ova): Ova large and spherical, translucent, a large fat globule present; ova diameters above 39 md.

Maturity stages

The following maturity stages have been recognised

Stage I (Immature female): Ovaries occupy 1/4th of the body cavity, pale yellow and translucent in appearance. The ova diameter ranges from 2-9 md.

Stage II (Immature female): Ovaries occupy less than 1/3rd of the body cavity. Pale yellow and translucent in appearance (Fig. 1a). Eggs are slightly visible with the naked eye on teasing the ovary. Ova diameter ranges from 3-12 md with mode at 6 md.

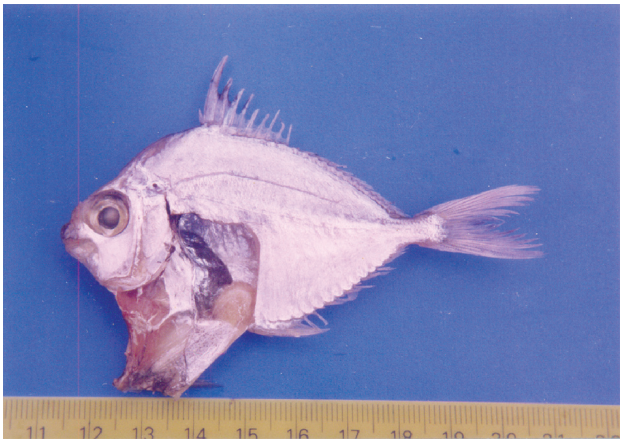

Fig. 1a. Stage II ovary of *L. splendens*

Stage III (Maturing female): Ovary occupying 1/3rd – 1/2nd of the body cavity, eggs visible with the naked eye. Yellow in colour. Ova diameter ranges from 12-33 md with the modal class at 27-30 md.

Stage IV (Mature female): Ovaries occupying 1/3rd – 3/4th of the body cavity. Yellow in colour. Eggs granular and clearly visible in the ovary (Fig. 1b). Ova diameter ranges from 24-45 md with the modal class at 33 md.

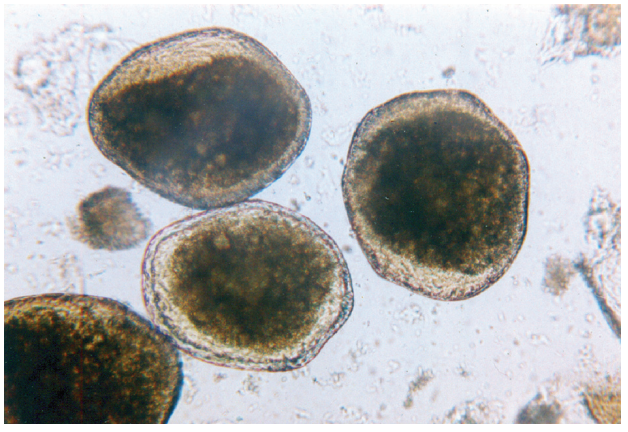

Fig. 1b. Mature eggs of *L. splendens*

Stage V (Ripe female): Ovaries occupying 3/4th to nearly full body cavity. Bright yellow in colour (Fig. 2a). Translucent eggs clearly visible in the ovary (Fig. 2b). Ova diameter ranges from 39 to 71 md with the modal class at 48-51 md.

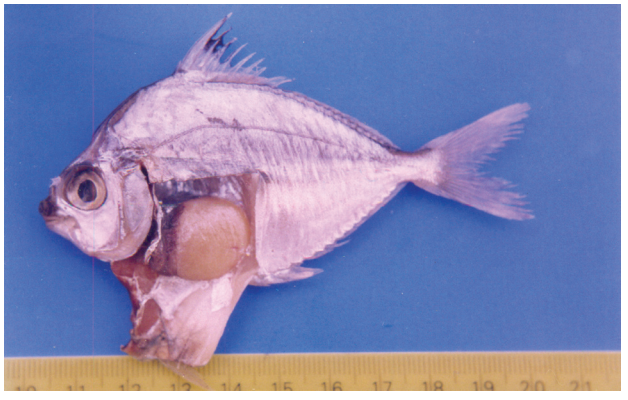

Fig. 2a. Ripe ovary of *L. splendens*

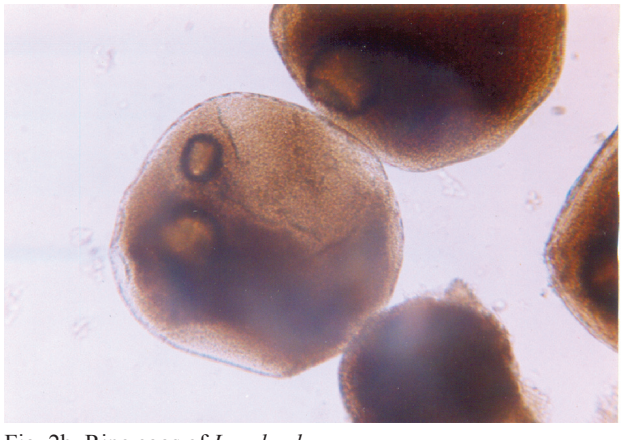

Fig. 2b. Ripe eggs of *L. splendens*

Testes were classified as immature, mature and ripe on the basis of the colour and size.

Earlier studies on the classification of maturity stages in silverbellies reveals that except Arora (1952) who recognised only three stages of maturity in the ovaries of *L. splendens,* all the subsequent workers (Balan, 1963; Rao, 1967; James and Badrudeen 1975; Jayabalan and Ramamoorthi, 1985; James, 1986; Jayabalan, 1986, 1988) followed a seven-point scale of maturity in silverbellies. Murty (1983), followed the maturity classification of James and Badrudeen (1975), for *L. bindus*.

In view of the inadequacy of the available scheme of classification, a separate scale of five stages has been developed for quantifying the gonads of *L. splendens* in the present study on the basis of external appearance of the ovaries, the ova diameter frequency distribution and the microscopic structure of the ova.. The 'spent' stage has not been designated here since no such ovary was encountered in the present collections.

There is need to recognise the fact that the scale of maturation stages is not a physical entity but a biological scale which is different in different groups of species and in different regions. It also needs to be recognised, particularly in the Indian marine fishes that a unique stage of maturation cannot be attached to any ovary after maturation starts because such ovaries contain ova in different stages of maturation. The present study indicates that a clear, distinguishable scale has to be developed for each species on the basis of the presence of most advanced ova in the ovary besides the external appearance and size of ovaries.

Distribution of ova in the ovary

Since different types of ova are present in the mature and ripe ovaries, it needs to be ascertained whether there is localisation of any particular type of ova in any region of the ovary or whether the ova are randomly distributed in the ovary. This was done by measuring 300 ova from the anterior, middle and posterior regions of the ovary separately, and measuring 300 ova pooled from the 3 regions of the ovary, from an adult *L. splendens* of 96 mm TL, and calculating the percentage frequency distribution of ova of different sizes in each of the samples. The data from the 3 regions of the ovary and the pooled data show that the ova in the different stages of maturation are randomly distributed in the ovary and there is no evidence to suggest that the ova of any particular size are concentrated in any particular region of the ovary (Fig. 3 and 4). Hence ova were taken only from the middle of the ovary throughout for measurements of ova diameters in each ovary.

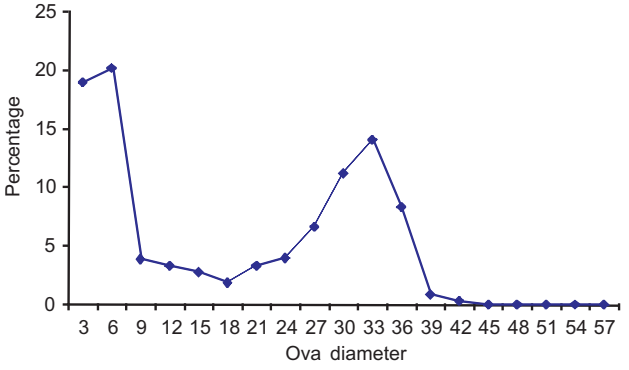

Fig. 3. Pooled ovadiameter frequency distribution in the anterior, middle and posterior regions of the ovary of *L. splendens*

According to De Jong (1940) the conditions in the tropical seas make it probable that specimens, which contain ripe ovaries, will be found throughout the year, so that periodicity in the individual may be obliterated in the species as a whole. However, he remarks that, although fishes with ripe ovaries may be found in every season, the species as a whole may show a rather definite periodicity. From the ova diameter frequency distribution, it may be concluded that *L. splendens* is a continuous spawner, spawning eggs in batches over an extended spawning season.

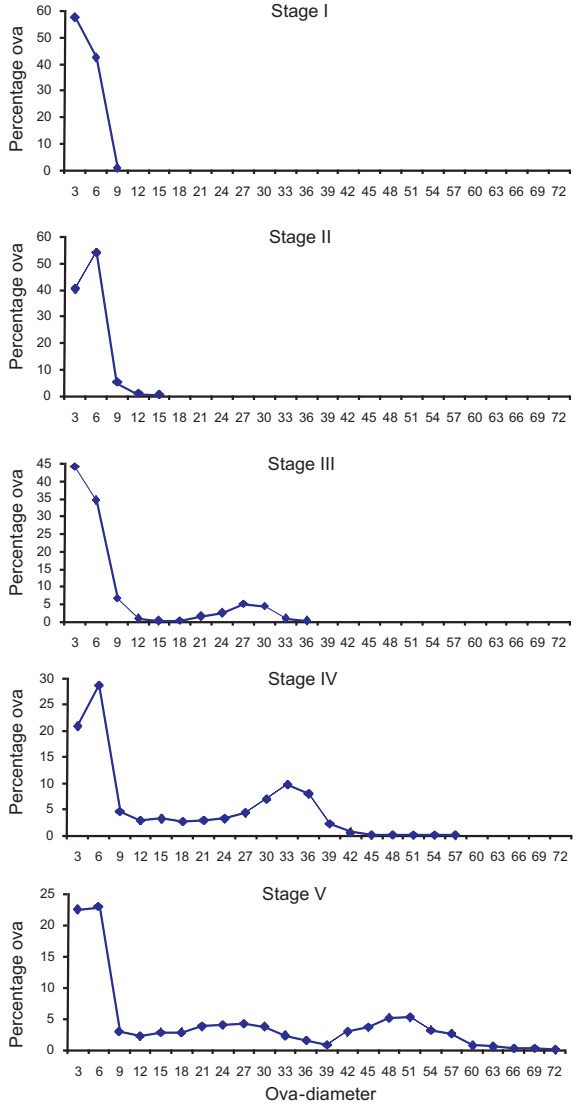

Fig. 4. Ova diameter frequency distribution in the different stages of maturation in *L. splendens*

Development of ova to maturity

The study is based on 12 specimens of *L. splendens* ranging in length from 82 to 109 mm TL shows the progression in the ovadiameter distribution from an immature stage I ovary through different stages, to a ripe stage V ovary. In an ovary beginning to undergo the maturation process, small, immature translucent ova are seen. The ovadiameter ranges from 2 to 9 md, with the mode at 1-3 md group. In stage II ovary, the maximum ovadiameter is 14 md with the mode in the diameter distribution at 4-6 md. In this ovary, immature stock present in the stage I ovary, with modal class at 1-3 md is also present. In the stage III ovary, which characterises the maturing female, the largest group of ova ranges from 15 to 36 md, with the mode at 27-30 md. Further development of the ova results in the modal class of the ova being shifted to 30-33 md, in the stage IV female, with the ovadiameter ranging from 24 to 44 md. In the ripe female *i.e.*, stage V, there is considerable increase in the size of the ova due to hydration and the diameter of the large ova ranges from 39 to 71 md (438 - 798 μ) with the modal class at 45-48 md. Another modal class is also seen in the ripe ovary with the ova size range of 15-39 md and the mode at 24-27 md representing both maturing and mature oocytes. In all the ovaries of different stages examined, a batch of small eggs is consistently present with a modal class of 1-3 md. They represent the immature stock from which the eggs to be spawned are withdrawn.

The presence of two distinct modes, one of ripe ova and the other of maturing and mature ova in the ripe ovary of *L. splendens* suggests that immediately after releasing the batch of ripe ova, the ovary returns to the mature stage (stage IV). The fact that a group of mature ova follows the ripe group shows that another spawning takes place soon; naturally yet another group of mature ova will follow this, as the withdrawal of eggs is in batches, for undergoing maturation and that is a continuing process. James and Baragi (1980) made similar conclusions in their studies on the ovadiameter frequency distribution of three marine fishes.

Length at first maturity

In *L. splendens*, the data of October '98 to January '99 were considered on the basis of the abundance of mature fishes during these months in comparison to other months. The estimates were also made using all the data of 13 months (Fig. 5 and 6). In *L. splendens,* the length at first

maturity was estimated as 75 mm (beginning of the length range of 75-79 mm) with the data of all 13 months and 72 mm by taking the data of four months.

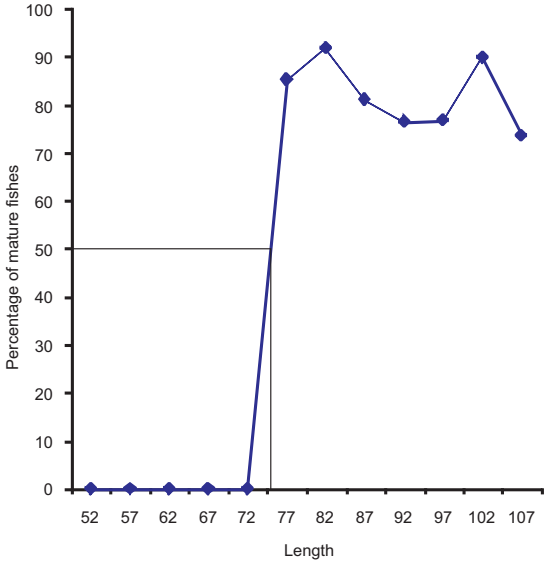

Fig. 5. Proportion of mature fishes in different length groups in *L. splendens* (data of one year considered)

Arora (1952) estimated the length at first maturity of *L. splendens* from Rameswaram, by considering the fish collected only during the period of peak spawning. In his study all the females above 68 mm in length were found to be mature; he stated that *L. splendens* matures first at an average length of 60 mm or at the end of the first year of its life. Jayabalan (1986) reported that in *L. splendens* from Port Novo, mature females first appear in the length group 76- 80 mm and all the females above 111 mm were fully mature. Hence females were found to mature at any length between 76 and 111 mm TL. This result is comparable with the present study in which length at first maturity of *L. splendens* was estimated at 75 mm TL, where in, only the peak spawning season was considered for the estimation.

Spawning

Occurrence of gravid fishes

In *L. splendens*, fishes with mature ovaries occurred in considerable quantities in all months (except June-July when there was trawl ban and August when there was no landing of these fishes) the proportion of mature fishes was above 50% in all the months (Table 1) except April, May and September. This may be due to several reasons; in many marine species the ripe stage is of very short duration, in some cases lasting only for about a few hours.

On the basis of the observation that there are two distinct groups, one of maturing ova, and another of ripe ova in a ripe ovary, in *L. splendens* Jayabalan (1986) concluded that the spawning is restricted to a short period

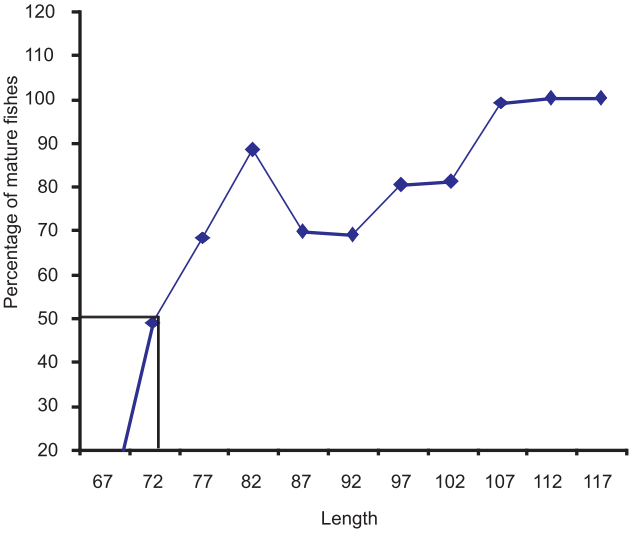

Fig. 6. Proportion of mature fishes in different length groups in *L. splendens* (data of October 1998 - February 1999 considered)

and that it spawns twice in a season. James and Badrudeen (1986), indicated that the species spawn in batches in quick succession over a short period based on the presence of two distinct modes of large ova, one following the other in the ovadiameter frequency curve for stage V –VI. Arora (1952) concluded that *L. splendens* spawns more than once in a season, based on the presence of both maturing and mature eggs in the ripe ovary. The present study however suggests that *L. splendens* spawns continuously in a season at intervals, but the time gap cannot be stated.

Most of the accounts of the spawning season of *L. splendens* are from the east coast. According the Arora (1952), the spawning season of *L. splendens* in Rameswaram extends from March – August with peak in April and August. Jayabalan (1986) concluded that *L. splendens* spawns throughout the year with peaks in April-May and October- January along the Port Novo coast. Rao (1967) indicated a prolonged spawning at Madras with peaks in January, February and June. Kuthalingam (1958) was able to collect large number of juveniles during September - December from Madras. The only probable conclusion about the spawning of *L. splendens* from the west coast is given by Bhimachar and Venkataraman (1952) who obtained post-larvae and immature specimens of the species during April-June and December- March, with a peak in March, from Calicut. In the present study, based on the presence of mature ovaries in almost every month, it can be concluded that *L. splendens* has a prolonged spawning period, extending almost throughout the year. Studies on the spawning biology of *S. insidiator* are few and absolutely no information is available on the biology of the species from west coast. Mahadevan Pillai (1972), indicated a prolonged spawning period for *S. insidiator* confirmed by the presence of

Table 1. Distribution of females in different stages of maturation in *L. splendens*

Month	No. of females examined	Maturity stages (Percentage)				
		I	II	III	IV	V
Oct	23	0	2.9	8.0	89.1	0
Nov	44	0	0.3	25.6	73.2	1.0
Dec	99	0.1	0	20.2	79.6	0
Jan	103	0	0	11.2	76.1	12.7
Feb	67	16.4	2.5	16.1	65.0	0
Mar	132	9.6	2.2	12.2	76.0	0
Apr	130	51.3	6.7	4.0	37.5	0.6
May	32	72.0	10.0	4.6	13.4	0
Jun	40	46.5	12.6	41.0	0	0
Jul			No fishing and			
Aug			No landings			
Sep	30	53.9		8.7	37.4	0
Oct	100	38.7		7.8	53.5	0
Nov	80	19.7		2.8	77.1	0.4
Dec	102	0		8.6	90.8	0.6

juveniles in shoreseine catches for most part of the year. Jayabalan and Ramamoorthi (1985) indicated that the spawning of *S. insidiator* takes place between July and November and again during March - April. James and Badrudeen (1986) concluded from the ovadiameter frequency curve of the mature ovary that in *S. insidiator,* the maturation process is continuous and that the species is likely to spawn over a prolonged period. Murty (1990) was also of the same opinion, asserting that the spawning season is protracted, running almost throughout the year, with a peak during January to March period. Based on the results of the data analysed, it may be concluded that *L. splendens* and *S. insidiator,* along Kerala have a protracted spawning season extending almost throughout the year.

Gonadosomatic index

The gonadosomatic index for the different maturity stages of *L. splendens* are presented in Table 2. The average monthly gonadosomatic index (pooled data of Cochin and Neendakara), plotted against the respective months (Fig. 7) shows that in *L. splendens*, the value is high during December 1998 - January 1999 and during November -December 1999, corresponding to the months of peak spawning.

Table 2. Gonadosomatic Index in fishes of different stages of maturation of *L. splendens*

Stages of maturity	*L. splendens* (average ± SD)
I	0.2235 ± 0.2097
II	0.2967 ± 0.2631
III	1.2673 ± 1.0560
IV	2.5061 ± 1.5801
V	2.9723 ± 2.1467

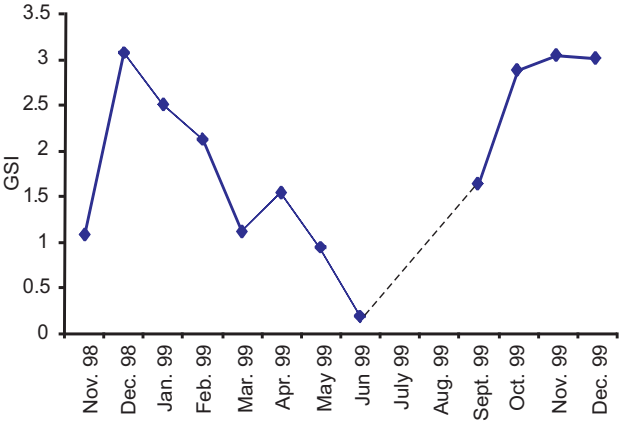

Fig. 7. Gonadosomatic index (GSI) in female *L. splendens* in different months

Fecundity

The estimated fecundity ranges from 5715 in a fish of 88 mm TL to 37160 in a fish of 106 mm TL. The variation in fecundity is considerable even within each length group. Since the scatter plots in these three instances do not reveal clearly the type of relationship, both linear and exponential equations were fitted to the observed data, using the least squares method (Snedecor and Cochran, 1967). The R^2 value in each case reveals that the regression in both cases do not explain the correlation (Fig. 8 - 10) well. Then, the average values of fecundity of fishes of each length group (Table 3) were regressed against the

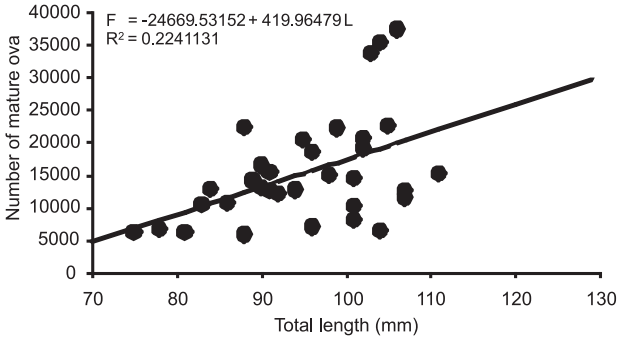

Fig. 8. Plot of estimated values of fecundity against total length in *L. splendens* and the fitted linear curve

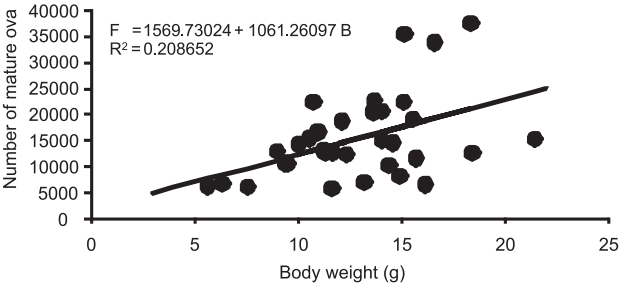

Fig. 9. Plot of estimated values of fecundity against total body weight in *L. splendens* and the fitted linear curve

corresponding average length, body weight and ovary weight (Table 4). Interestingly, however, the R^2 values in these cases, suggest the possibility of a curvilinear relationship (Fig.11 - 13).

Table 3. Estimated average fecundity of *L. splendens* in different length groups

Length groups (mm)	Average length (mm)	Average body weight (g)	Average ovary weight (g)	Estimated average fecundity
75-79	76.5	9.00	0.2209	6316
80-84	82.7	8.73	0.2703	9673
85-89	87.8	10.46	0.4194	13110
90-94	91.3	11.37	0.5659	13607
95-99	96.8	13.65	0.5363	16482
100-104	102.3	15.21	0.5881	18382
105-109	106.3	16.57	0.6388	20873
110-114	111	21.46	0.6729	15063

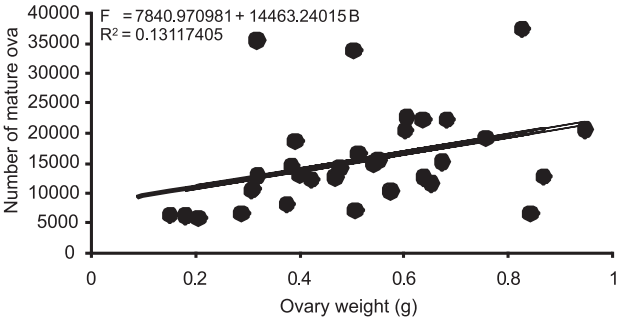

Fig. 10. Plot of estimated values of fecundity against ovary weight in *L. splendens* and the fitted linear curve

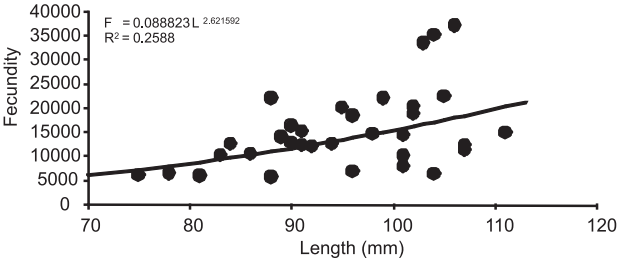

Fig. 11. Plot of estimated values of fecundity against lenght in *L. splendens* and fitted curvilinear relationship.

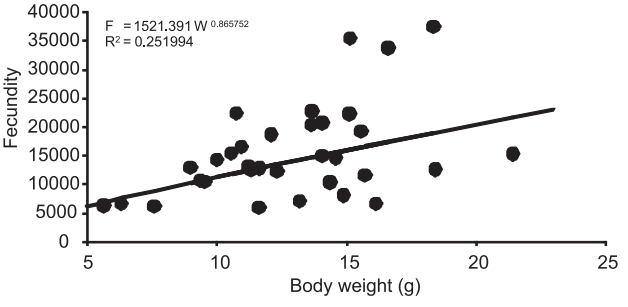

Fig. 12. Plot of estimated values of fecundity against body weight in *L. splendens* and the fitted curvilinear relationship.

The earlier reports on fecundity of *L. splendens* from Indian waters is that of Arora (1952) from Rameswaram, Jayabalan (1986) from Porto Novo and James and Badrudeen (1986), from Palk Bay. Arora examined only a small length range and estimated a fecundity of 10588 ova

Table 4. Estimated values of slope and elevation by fitting exponential and linear regression in *L. splendens*

	Exponential $Y= a X^b$	Linear $Y= a+ b X$
Fecundity against length	a = 0.088823, b = 2.621592, R^2 = 0.2588	a = -24669.53152b = 419.96479, R^2 = 0.2241
Fecundity against body weight	a = 1521.391b = 0.865752, R^2 = 0.2519	a = 1569.73024b = 1061.26097, R^2 = 0.20865
Fecundity against ovary weight	a = 20832.985b = 0.578570, R^2 = 0.2603	a = 7840.970981b = 14463.2401, R^2 = 0.13117

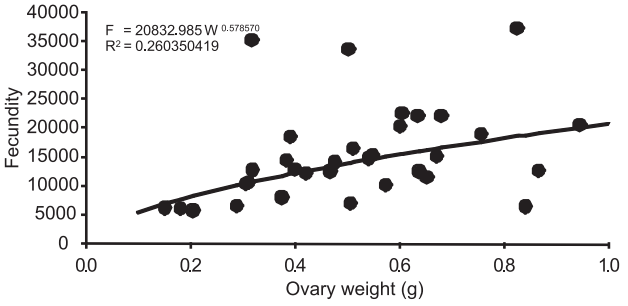

Fig. 13. Plot of estimated values of fecundity against ovary weight in *L. splendens* and the fitted curvilinear relationship.

for a fish of 74 mm length showing comparatively high values of fecundity for fishes of comparable length ranges in the present study. Jayabalan (1986) reported a fecundity of 21507 ova for a fish of 119 mm length, which is comparatively low. Considering the wide range in fecundity even for fishes of the same length range, as shown in the present study, the comparison of fecundity as made above does not lead to any conclusion.

The apparent absence of correlation between fecundity and the three independent variables (*Vide Supra*) as revealed by poor R^2 values could be due to the random variations in fecundity. However, it needs to be noted (*Vide Supra*) that this species spawns in batches during the course of a year and the batch sizes are likely to be different in different batches in fishes of different lengths. More over in the population at any one time, fishes spawning for the first time, second time, third time, and so on are also likely to be present. It may be recalled that after spawning the first batch, the fishes continue to spawn at different intervals; naturally one would expect a wide difference in the batch sizes. It is believed that this situation has led to the absence of correlation (very low values of R^2) between fecundity and length, body weight and ovary weight as otherwise one would expect a significant correlation between these variables. It may be noted, however, that the R^2 values are 0.78 for average fecundity against average length, 0.56 for fecundity against total weight and 0.85 for fecundity against ovary weight, when an exponential equation was fitted, suggesting the possibility of the existence of curvilinear relationship between these variables.

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