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Maturation and spawning of the whitefish, *Lactarius lactarius* (Bloch and Schneider, 1801) (Family Lactariidae) along the Karnataka coast, India

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Abstract

Maturation and spawning of the whitefish, *Lactarius lactarius* was studied by collecting samples from Mangalore, Malpe and Karwar landing centres. Monthly Gonado-Somatic Index values of males and females were found to increase from August and reach the highest in February indicating breeding activities. The K_n values showed an increasing trend from October reaching a minor peak in February which coincides with the peak spawning.. Higher percentage of fully mature testes and ovaries occurred during November-April indicating peak spawning activities. K_n values were the lowest in the length group 130-139 mm for both males and females. Length at first maturity was determined as 131 mm for males and 133 mm females. Sex ratio indicates dominance of males up to 155 mm and females were present above 215 mm only. Fecundity varied from 7,042 to 53,275 eggs. Relationship of fecundity to ovary weight, body weight and total length exhibited a linear trend.

Key words: Maturation and spawning, Gonado-Somatic Index, fecundity, size at first maturity, Relative Condition Factor

Introduction

The whitefish *Lactarius lactarius* (Family: Lactariidae) forms an important fishery along the east and west coasts of India. Information on the maturation and spawning of *L. lactarius* is available from the Arabian Sea off Mangalore (James *et al.,* 1974) and Karwar (Neelakantan *et al*., 1980; Neelakantan and Pai, 1985; Neelakantan *et al.,* 1986) along the west coast and from the Bay of Bengal off Waltair (Rao, 1966) and Andhra Pradesh-Orissa coasts (Reuben *et al.,* 1993). The present study was undertaken on the reproductive biology of *L. lactarius* distributed along the Mangalore coast after a lapse of about three decades (James *et al.,* 1974). Additional information was collected from Karwar to assess the status of the fishery along the Karnataka coast.

Materials and methods

Samples of *L. lactarius* caught by the fishing gears namely, trawlers, seine nets and gillnets were collected every week from fisheries harbours at Mangalore, Malpe and Karwar (Fig. 1) for two years from September 1997 to August 1999. The samples were brought to the laboratory, washed thoroughly to remove mud, sand and other attached forms. After removing the surface moisture by a blotting paper, the length and weight of individual fish were taken to an accuracy of 1 mm and 1 mg respectively. Each fish was then cut open to record the sex and stage of maturity. While the maturity stages of females were recognized based on the macroscopic appearance of the ovary in the body cavity and microscopic structure of ova, in males only the macroscopic appearance of testes was considered. Seven stages of maturity were fixed for males and females based on ICES scale (Lovern and Wood, 1937) with suitable modifications.

For ova diameter studies and fecundity estimation, ovaries were preserved in 5% neutral formalin. Measurement of ova diameter was carried

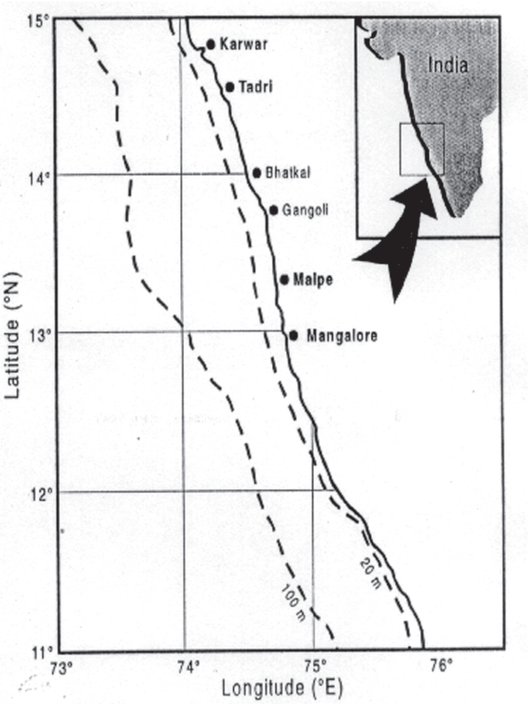


Fig. 1. Map showing (Mangalore, Malpe and Karwar) from where samples of *L. lactarius* were collected

out following the methods of Clark (1934) and Prabhu (1956) using an ocular micrometer. One ocular micrometer division (omd) was equal to 15 µm. Samples of ova from anterior, middle and posterior regions of both the lobes of ovary were examined. As there was no difference in the size of ova from different parts of the ovary, the ova were sampled from middle region of the ovary only. Ova measuring less than 3 omd (45 µm) were measured only from immature ovaries (Stages I and II) as they were in large numbers in ovaries of all stages representing the general egg stock. A total of 103 ovaries at different maturity stages were analysed and from each ovary the diameters of about 300 ova were measured. The ova diameter from different ovaries of identical stage were pooled and grouped into 3 omd intervals for plotting the graph.

Spawning season of the species was determined based on the availability of mature and spent individuals in the commercial landings during different months and the monthly gonado-somatic indices (GSI). The GSI was calculated (June, 1953; Yuen, 1955) using the formula:

$$GSI = \frac{\text{Weight of gonad}}{\text{Weight of fish}} \times 100$$

A total of 705 males (355 from Mangalore, 236 from Malpe and 114 from Karwar) and 596 females (293 from Mangalore, 211 from Malpe and 92 from Karwar) were considered separately to determine the monthly mean GSI values.

The monthly and size related relative condition factor (K_n) was estimated (Le Cren, 1951) using the formula,

$$K_n = \frac{W}{aL^n} \quad \text{or,} \quad K_n = \frac{W}{\overline{W}}$$

where W = observed weight, aL^n or $\overline{W}$ = calculated weight obtained from the length-weight relationship. The K_n values were estimated for 831 males and 607 females separately. The K_n value was also calculated in relation to size of the fish by grouping them into 10 mm class interval.

To estimate the length at first maturity (L_m), males and females were grouped separately into 10 mm class interval and fish in stage III and above were considered mature. Maturity curves were drawn to the scatter plots to estimate the length at which 50% of fish mature.

To find out the sex-ratio (male: female) during different months and in different size groups, 4,827 males (90-215 mm TL) and 3,795 females (90-265 mm TL) of *L. lactarius* were examined. The sex-ratios during months and in different size groups were tested for significance by chi- square formula.

$$\chi^2 = \frac{\sum (O-E)^2}{E}$$

where, O = observed number of males and females in each month/length group

E = expected number of males and females in each month/length group.

To estimate fecundity, 71 ovaries in stage - V were utilised. From formalin preserved ovary of known weight, a small portion was removed and weighed to the nearest 0.001 g in an electronic balance and then kept in modified Gilson's fluid (Simpson, 1951) for two days. All the mature eggs in the sample ovary were counted under binocular microscope using a counting chamber. The fecundity was estimated using the formula

$$\text{Fecundity} = \frac{\text{total weight of the ovary}}{\text{weight of the sample}} \times \text{number of ova in the sample}$$

The relationship between fecundity and different variables like total length, fish weight and gonad weight was worked out by the least square method, $F = aX^b$ where, F = Fecundity, a = constant, X = variable (fish length, fish weight or ovary weight) and b = correlation coefficient. The exponential relationship was transformed into a straight line logarithmic form based on the equation,

$$Log\ F = log\ a + bLogX$$

Results

Structure of ovary and testis: The ovary is situated in the lower abdominal cavity as a pair of sac-like structure. The left lobe of the ovary is always shorter than the right one indicating the asymmetry of the organ. Both the lobes are free at the anterior while a connecting membrane holds them at the posterior. Both the ovaries join together and open directly to the exterior by a common genital aperture. The inner wall of the ovary is lined by germinal epithelium, which proliferate the ova.

Testis is paired, elongated, laterally compressed and grows anteriorly with advancement of maturation. A common genital opening leads the testes to the exterior. The testis, which is thread-like and reddish in the initial phases, becomes thick, fleshy and milky white on maturation.

Microscopic studies of ova: Development of ova was studied by recording ova diameter from ovaries of all stages (Fig. 2). In stage I, majority of ova were in the size range of 1-3 omd. This may be considered as the general egg stock. Few large ova measuring 7-9 and 10-12 omd were also seen. In stage II, besides the ova of 1-3 omd, a batch of ova forming a mode at 13-15 omd got separated

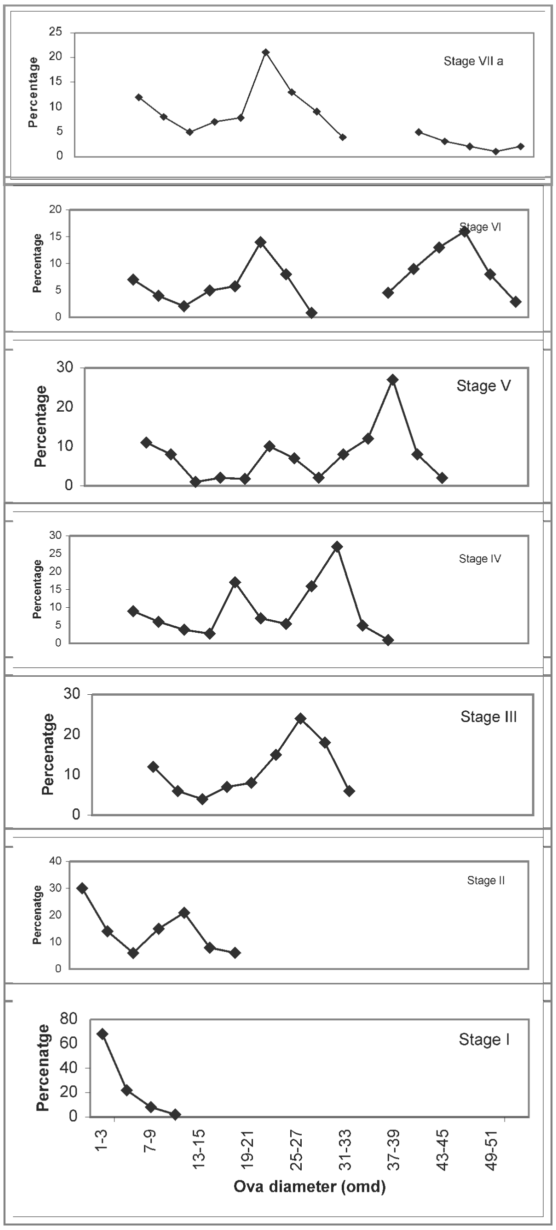


Fig. 2. Ova diameter frequency polygons of *L. lactarius*

from the general egg stock. Some large ova measured up to 19-21 omd. After stage II, the development of ova for maturity was rapid. In stage III, the batch of ova forming a mode at 13-15 omd in the stage II grew further to form a mode at 25-27 omd and a few ova measuring up to 31-33 omd were also seen. Another small mode was seen at 7-9 omd. In stage IV, the maturing mode (25-27 omd) shifted to 31-33 omd and the largest ova measured up to 37-39 omd. Another mode at 19-21 omd was also present. In stage V, the mature ova measuring 37-39 omd formed a prominent mode and also one maturing group of ova forming a mode at 22-24 and was evident. The larger ova measured 43-45 omd. In stage VI, there was a clear separation of a group of ova measuring 37-57 omd with a mode at 46-48 omd. This was the batch of ripe ova with an oil globule measuring 13-14 omd. The mode at 22-24 omd in stage V was stationary. In partially spent condition (stage VII a), majority of the ripe ova were already shed and lesser number of ova measuring 37-57 omd were present. A mode of ova measuring 22-24 omd was seen in this stage. The photomicrographs of immature, maturing and mature ova are given in Figs. 3a, 3b and 3c. Fig. 3d shows a fish with mature ovary.

Gonado-Somatic Index (GSI): The monthly mean values of GSI for males and females (Fig. 4) increased rapidly from August to January and reached a peak in February. The highest GSI values for males and females were 0.8116 and 3.6199 respectively during February. Thereafter, the values declined to reach the lowest during June-August. The appearance of individuals with high GSI indicates breeding activities during October-March. The fall in GSI values during April-June was mainly due to presence of spent gonads.

Relative Condition Factor (K_n): The seasonal variation of the K_n values in females showed two peaks, a minor one in February and a major one in May. In males, the minor peak was during April and a major one was in June (Fig. 5). During January-June, the K_n values was above 1 for females and during the rest of the months the values were less than 1. Lower K_n values (less than 1) were seen in males during July-October and thereafter an increasing trend was observed which attained a minor peak during February, which is the period of peak spawning. The value showed a fall in May, thereafter reached the highest peak in June.

The K_n of males and females showed higher values for smaller length groups (Fig. 6). The K_n value was the lowest in the size class 130-139 mm for both males and females. The K_n values oscillated at regular intervals between 120 and 235 mm indicating factors other than spawning for the oscillation.

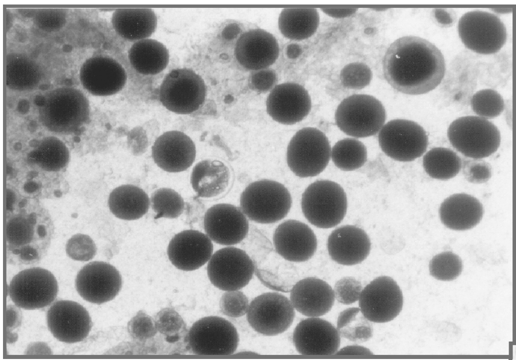
Size at First Maturity: The percentage occurrence of ovaries and testes in different stages of maturity in relation to size (Fig. 7) showed that all the males up to 99 mm were immature. Mature males were recorded (9.7%) from 100-109 mm size group onwards. Fifty per cent of males mature at a total length of 131 mm. In females, the smallest fish with mature ovary was seen at 105 mm (6.8%) and the smallest spent female was 115 mm. The size at first maturity (50%) for females was 133 mm TL.

Spawning Season: Higher percentages of fully mature testes and ovaries (stages V& VI) occurred during November-April indicating peak spawning activities during this period (Figs. 8 and 9). This was further confirmed by the presence of spent specimens in March and small sized (35-60 mm) fish during February and May in the commercial landings.

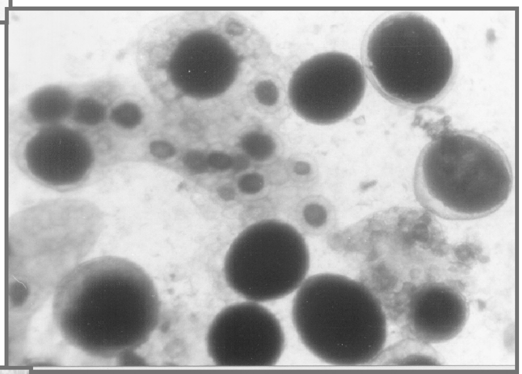
Spawning Frequency: The ripe ovaries of *L. lactarius* are characterized by transparent ova with distinct oil globule and oocytes of different maturity stages. In ripe ovaries, besides a batch of ripe ova, a second largest group of yolked eggs was progressing through the maturation process to become ripe (Fig. 2). This batch may require some more time to become ripe and to spawn in the next spawning season.

Fecundity: The fecundity estimates varied from 7,042 to 53,275 eggs.

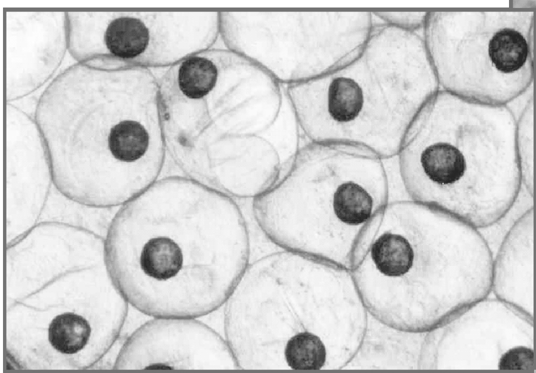
The logarithmic relationship between fecundity (F) and total length (L) of fish was linear (Fig. 10). The calculated relationship was:



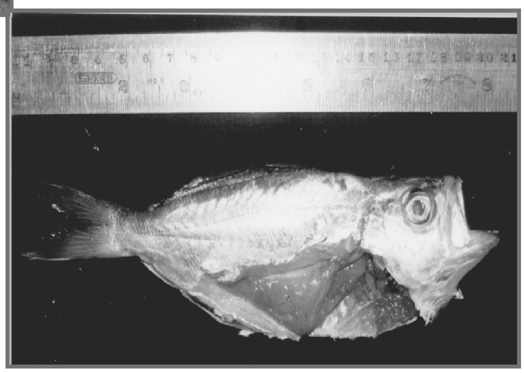
a. Photomicrograph of immature ovary (x 400)



b. Photomicrograph of maturing ovary (x 400)



c. Photomicrograph of fully ripe ovary (stage VI) (x 400)



d. Fish with mature ovary

Fig. 3. Photomicrograph of ova of *L. lactarius* in various stages of development (a-c) and fish with mature ovary (d)

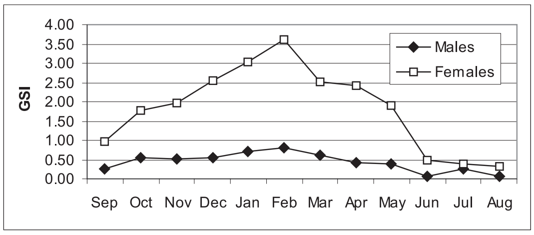


Fig. 4. Monthly mean GSI values of *L. lactarius*

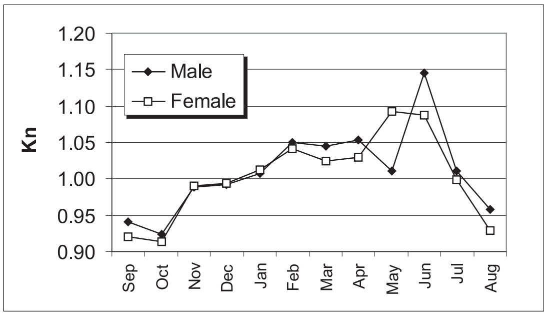


Fig. 5. Monthly variation in K_n values of *L. lactarius*

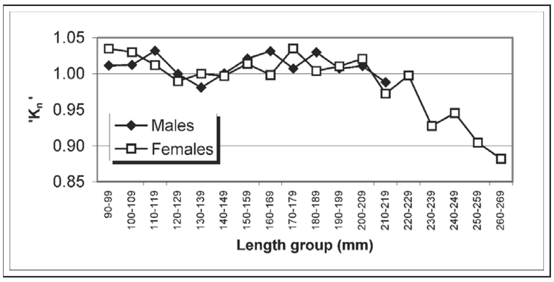


Fig. 6. K_n values in different length groups of *L. lactarius*

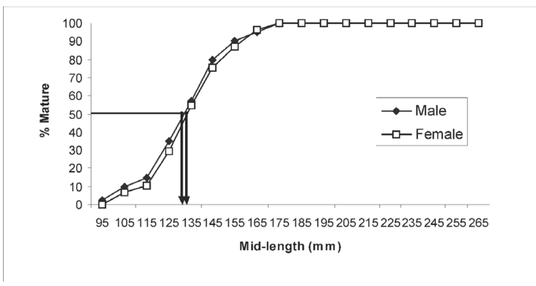


Fig. 7. Maturity curve of *L. lactarius* showing size at first maturity

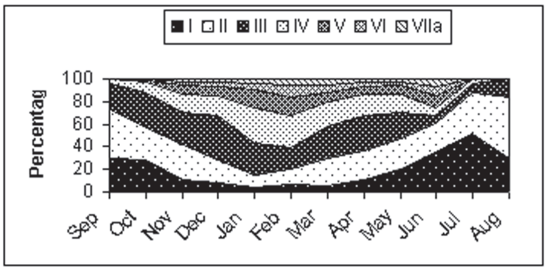


Fig. 8. Distribution of different maturity stages of male *L. lactarius*

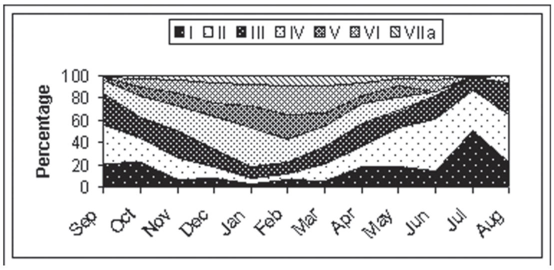


Fig. 9. Distribution of different maturity stages of female *L. lactarius*

$$\text{Log F} = -5.32277 + 4.30955 \log L$$

The correlation coefficient ($r = 0.8889$) indicated a significant ($P < 0.01$) relationship.

The fecundity and body weight also showed a linear relationship (Fig.11). The regression equation of fecundity (F) on body-weight (W) is expressed by the formula, Log F = 1.76815 + 1.42008 log W. The correlation coefficient ($r = 0.881$) indicated a significant relationship ($P < 0.01$).

The logarithmic relationship between fecundity and ovary weight (OW) (Fig.12) could be expressed by the equation:

$$\text{Log F} = 3.8463 + 1.28995 \log OW.$$

The correlation coefficient value (r) was 0.9481 indicating highly significant ($P < 0.01$) relationship between the two variables.

Sex Ratio: As sexual dimorphism is absent in *L. lactarius*, sexes could not be distinguished externally. As the sex of specimens below 90 mm

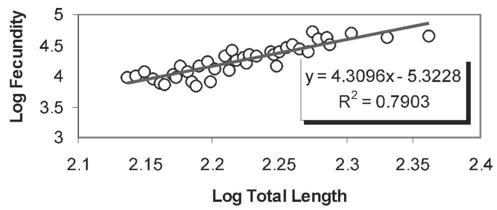


Fig. 10. Relationship between total length and fecundity in *L. lactarius*

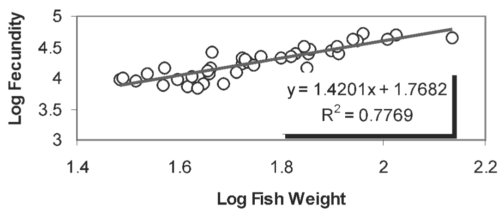


Fig. 11. Relationship between body weight and fecundity in *L. lactarius*

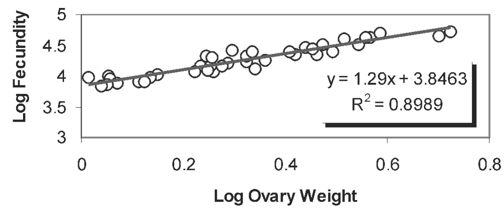


Fig. 12. Relationship between ovary weight and fecundity in *L. lactarius*

could not be differentiated, they were grouped as juveniles (indeterminate). The males were dominant during the spawning period. The overall sex-ratio indicated significant dominance of males (Table 1).

Sex-ratio for different length groups (Table 2) showed dominance of males in the fishery up to 155 mm and thereafter females became dominant. After 215 mm only females were present in the fishery. Chi-square values were significant in length groups.

Table 1. *Monthly distribution of sex-ratio and chi square test in* L. lactarius *pooled for 1997-'98 and 1998-'99*

Month	No. of specimens	Males	Females	Sex ratio (M:F)	Proportion of males	Chi-square	Significance at 5% level	D.F.
September	420	242	178	1:0.74	0.576	9.752	S	1
October	871	459	412	1:0.89	0.527	2.536	N S	1
November	1389	741	648	1:0.87	0.533	6.227	S	1
December	1165	695	470	1:0.67	0.597	43.455	S	1
January	684	424	260	1:0.61	0.620	39.322	S	1
February	891	523	368	1:0.70	0.587	26.964	S	1
March	1026	649	377	1:0.58	0.633	72.109	S	1
April	868	490	378	1:0.77	0.565	14.452	S	1
May	960	457	503	1:1.10	0.476	2.204	N S	1
June	62	28	34	1:1.21	0.452	0.581	N S	1
July	111	50	61	1:1.22	0.450	1.090	N S	1
August	174	68	106	1:1.56	0.391	8.299	S	1
Total	8621	4826	3795	1:0.79	0.560	123.299	S	1

Table 2. *Length-wise distribution of sex-ratio and chi-square test in* L. lactarius *(1997-'98 and 1998-'99 pooled)*

Mid length (mm)	No. of specimens	Males	Females	Sex Ratio (M : F)	Chi square	Significance at 5% level	D.F
85	22	11	11	1:1.0	0.000	N S	1
95	76	41	35	1:0.85	0.474	N S	1
105	273	155	118	1:0.76	5.015	S	1
115	675	421	254	1:0.60	41.317	S	1
125	1288	806	482	1:0.6	81.503	S	1
135	1568	1011	557	1:0.55	131.452	S	1
145	1505	898	607	1:0.67	56.266	S	1
155	1351	753	598	1:0.79	17.783	S	1
165	913	419	494	1:1.18	6.161	S	1
175	507	189	318	1:1.68	32.822	S	1
185	251	83	168	1:2.02	30.904	S	1
195	111	30	81	1:2.7	23.432	S	1
205	58	9	49	1:5.44	25.136	S	1
215	12	1	11	1:11.0	8.33	S	1
225	5	0	5				
235	2	0	2				
245	1	0	1				
255	2	0	2				
265	2	0	2				
Total	8622	4827	3795	0.79	123.299	S	1

Discussion

Most of the tropical marine fishes mature early and spawn at the age of first or second year of their life (Qasim, 1973). The size at first maturity (L_m) of males and females of *L. lactarius* were 131 and 133 mm respectively. Though these values are in agreement with the earlier studies from Mangalore (James *et al.,* 1974) and Karwar (Neelakantan, 1981), higher L_m (167.5 mm) estimated from Waltair (Reuben *et al.,* 1993) shows that *L. lactarius* along the Karnataka coast matures when the fish is less than one year old.

The presence of yolked oocytes of different sizes in the mature ovary is a criterion for the existence of multiple spawning (Clark, 1934; De Silva, 1937). However, it is not clear whether the advanced groups of yolked oocytes alone or all the yolked oocytes are spawned during the spawning season. It is believed that all the yolked oocytes are capable of development for eventual spawning (De Silva, 1937). In the present study, the distribution of ova in the mature/ripe ovaries (Fig. 2) indicates that spawning in individual *L. lactarius* is more than once. Also as the size range of ripe ova is narrow, fishes may spawn for a shorter duration.

The monthly GSI values in *L. lactarius* of Karnataka coast followed a similar trend in males and females except the change in weight of testes (Fig. 4). During the peak spawning period (November-March), higher values of GSI coincided with spawning. The fluctuations indicate asynchronous maturation of gonads and an extended spawning season. This is evident from the occurrence of gonads in stages V, VI and VII in the commercial catches during most part of the year.

The point of inflexion in the curve of K_n values plotted against length is indicative of the length at which sexual maturity starts (Hart, 1946; Pillay, 1954). The present investigation supports this observation as the point of inflexion was seen in the size group 130-139 mm for both the sexes and the size at first maturity of male and female was estimated at 131 mm and 133 mm respectively.

In the present study, the occurrence of more number of fully mature testes and ovaries in *L. lactarius* during November-April indicates that peak spawning occurs generally during these months along the Karnataka coast. However, *L. lactarius* spawns during February-April along the Waltair coast (Rao, 1966) and during February-July along Andhra-Orissa coast (Reuben *et al.,* 1993). It was also observed that *L. lactarius* spawns during December-March off Karwar, west coast of India (Neelakantan, 1981). This shows that while along the northern part of Karnataka coast the species spawns for a shorter duration (December-March), in the southern part, it spawns comparatively for longer duration (November-April).

While *L. lactarius* is a fractional spawner along the Waltair coast (Rao, 1966), along the Karwar coast, the male *L. lactarius* spawns thrice a year and the female spawns 2-3 times a year (Neelakantan, 1981) and a protracted spawning was observed along Andhra Pradesh-Orissa coast (Reuben *et al.,* 1993). The occurrence of mature gonads and ova-diameter distribution in the present study show that while the individual female spawns for more than once a year, the population spawns during most part of the year.

Fecundity has been shown to increase as square (Clark, 1934) or cube of length (Simpson, 1951; Bagenal, 1957; Pillay, 1958) or a fourth power of length (Farran, 1938) or more than a fourth power of length (Varghese, 1980). In the present study, the exponential value was 4.30 indicating that fecundity increases at a rate above the fourth power of length. This value was higher than the *b* in length-weight relationship suggesting that the fecundity increased at a higher rate than the rate of increase of body weight in relation to length. However, along the Karwar coast the estimated value for *L. lactarius* was 3.9 (Neelakantan, 1981).

While the fecundity of *L. lactarius* ranged from 9,000 to 79,000 in fish of size 163-214 mm from Mangalore (James *et al.,* 1974), the fecundity of the species from Karwar ranged from 17,972 to 63,121 eggs in fishes of total length from 156 to 232 mm (Neelakantan, 1981). In the present study, the smallest fish measuring 139 mm had a fecundity of 9,733 eggs. However, lowest number of eggs of 7,042 was recorded from a fish measuring 154 mm and highest of 53,275 eggs from a fish measuring 188 mm.

A straight-line relationship between fecundity and body weight has been reported by Bagenal (1957), Sarojini (1957), Parulekar and Bal (1971) and Muthiah (1994). A comparison of correlation coefficient values with length, weight and ovary weight indicated that ovary weight and body weight were linearly related and the rate of increase in fecundity was 1.3 times that of body weight of *L. lactarius* along the Karnataka coast. In an earlier study, Neelakantan (1981) estimated the rate of increase of fecundity 1.9 times the weight of fish.

Along the Karwar coast, the males of *L. lactarius* were dominant during 1978-80 (Neelakantan, 1981). It is suggested that males are dominant in waters where spawning occurs (De Martine and Fountain, 1981), and during courtship, a single female was followed by a group of males showing dominance of males (Magnuson and Prescot, 1966; Hunter and Goldberg, 1980). The deviation from normal 1:1 sex ratio might be due to the partial segregation of mature fish through their habitat preference (Parrish *et al.,* 1986) and differences between sexes in behaviour (Baglin, 1982), differential fishing (Kesteven, 1942), differences in growth rate between sexes (Qasim, 1973), differences in age and size at maturity

(Reynolds, 1974) and differences in morphology and physiological activity (Baglin, 1982). The higher percentage of males in the present study throughout the year especially during spawning season may be related either to any one or to a combination of several factors stated above.

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