

REPRODUCTIVE CYCLES AND LIPID LEVELS IN *LEIOGNATHUS SPLENDENS* (CUVIER)*

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INTRODUCTION

In fishes lipids are known to accumulate in some of the organs and later utilized in relation to reproductive activity (Milroy 1898, Bruce 1924, Channon and Saby 1932, Lovern and Wood 1937, Hickling 1947, Bailey 1952, Hoar 1957a, b). The lateral muscles and the liver are the important sites of storage of lipids and the intestine also serves as storage site (Channon and Saby 1932). In *Clupea harengus* (Milroy *loc. cit.*, Lovern and Wood *loc. cit.*) *Sardina pilchardus* (Hickling *loc. cit.*) and *Onchorhynchus tshawytscha* (Greene, 1926) lipids have been found to accumulate in lateral muscles and decrease during maturation and it has been considered that lipids stored in lateral muscles are transferred to maturing gonads. In *Clupea harengus* of Manx and Clyde areas (Bruce 1924, Channon and Saby 1932) it has been noted that lipids accumulated in lateral muscles during the immature stages show a fall in percentage only in spent fish and it has been stated that stored lipids are utilized as a source of energy at the time of spawning. In view of the divergent findings in regard to the period of utilization of lipids in storage sites a study of this aspect in a tropical fish *Leiognathus splendens* (Cuvier) would be of interest. The accumulation of lipids in gonads of the fish during maturation has also been studied in the present investigation.

MATERIAL AND METHODS

Specimens of *Leiognathus splendens* were collected from fresh boat-seine (turi-valai) catches of Madras Coast. Random samples of 20 to 50 fish ranging in weight between 12 gms. and 30 gms. (total length 82 mm.-122 m.) were obtained every month between October 1963 and June 1965.

The stages of maturity of the fish were noted using the stages followed by the International Council for the Exploration of the Sea. The gonad index method of Lasker and Giese (1954) expressing the weight of gonads as percentage of the total weight of the fish was also used for studying reproductive cycles. The changes in weight of liver of fish in different reproductive stages were studied by following the method of Immers (1953) expressing the weight of liver in relation to the total weight of fish as 'liver index'.

The gonads, liver, intestine and lateral muscles of fish were dried and the lipid content of the tissues estimated by the methods mentioned by Rao (1966). The percentage of lipid is expressed in terms of dry weight of tissue.

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Standard deviation was determined and Student *t* test applied to test the significant difference between mean values of gonad and hepatic indices and lipid levels in different successive stages of maturity in the samples at 5% level using the Table of Fisher and Yates (1938).

$$t = \frac{x_1 - x_2}{\sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2} \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

Where x_1 is the mean of first sample, x_2 the mean of second sample, s_1 the standard deviation of the first sample, s_2 the standard deviation of the second sample, n_1 the size of first sample and n_2 the size of second sample.

OBSERVATIONS

A. Reproductive Cycle :

Seven stages of sexual maturity were distinguished in the case of *Leiognathus splendens* by the following characteristics : stage I with immature gonads which are small in both sexes ; stage II immature gonads which are slightly larger than in previous stage, with a few spermatocytes in males and oocytes (diameter 0.087-0.121 mm.) with large nuclei and without or with very little yolk in females ; stage III gonads maturing, testes thick, and grayish, ovary also thick, a little yellowish with ova visible to the naked eye and containing fair amounts of yolk (dia. 0.226-0.261 mm.) ; stage IV mature with gonads in both sexes as long as body-cavity, with large amounts of milt in testes and large opaque ova (dia. 0.400-0.539 mm.) in ovaries ; stage V gonads large and thick, ovaries yellowish, ova large, translucent or hyaline, testes white ; stage VI with flowing milt in males and oozing ova in females (not observed) and stage VII spent with gonads empty but for residual germ cells, ovaries reddish and testes grayish red.

It will be seen from Table I and Fig. 1 that the females show a better indication than the males regarding reproductive periodicity and the immature and maturing stages are found from October to January. In both sexes mature or ripe stages occur in all the months excepting July, August and November. The occurrence of advanced stages of sexual maturity in most of the months suggests prolonged breeding.

Intra-ovarian eggs and spawning periodicity :

It is known that a study of the abundance of ova of different sizes in ovaries in penultimate stages of maturation helps in determining the spawning periodicity (Clark 1934, Hickling and Rutenberg 1936, De Jong 1939, Karandikar and Palekar 1950, Prabhu 1956). About a thousand ova were taken from ovaries of six specimens of female *L. splendens* in stage V in January 1965. Their size distribution represented as percentage polygons is shown in Fig. 2. It will be seen that there are three modes A, B and C. The mode A is formed of immature ova, mode B of maturing ova and mode C of mature and ripe ova. The stock C being composed of mature or ripe ova may be expected to be spawned immediately i.e. in January and the succeeding few months. The stock B will naturally take a few months to become mature and spawning of these will therefore be a little later than the stock C. Stock A will take more time than C and B to mature and these A in due course

will contribute to the formation of stock C which will be spawned in January of the following year.

TABLE I

Gonad index values of Leiognathus splendens in different stages of maturity occurring in various months.

| Stages of maturity of fish | Months in which the fish occurred | Range of gonad indices | Mean gonad index with standard deviation | Increase (+) or decrease (-) in mean gonad index and level of significance |
|----------------------------|---|------------------------|--|--|
| <i>Males</i> | | | | |
| I and II | October 1963-January 1964, November 1964, June 1965 | 0.02-0.37 | 0.15 ± 0.06 (18) | |
| III | December '63, February '64, September-November '64, February and April '65 | 0.70-0.95 | 0.81 ± 0.09 (12) | + ; significant |
| IV | October '63 December '63 January-May '64, September '64, October '64, January, February and April '65 | 0.74-2.87 | 1.63 ± 0.38 (19) | + ; significant |
| V | June '64, January, March and June '65 | 0.64-2.59 | 1.73 ± 0.64 (12) | + ; not significant |
| VII | July and October '64 and June '65 | 0.40-1.27 | 0.87 ± 0.19 (10) | - ; significant |
| <i>Females</i> | | | | |
| I and II | October '63, January, October and November '64 | 0.03-0.70 | 0.19 ± 0.05 (15) | |
| III | December '63, January, October and November '64 | 0.34-0.84 | 0.56 ± 0.18 (12) | + ; significant |
| IV | December '63, January-May '64, September and October '64, February, April and June '65 | 0.32-4.23 | 2.17 ± 1.39 (16) | + ; significant |
| V | June '64, January, March and June '65 | 0.86-5.36 | 2.47 ± 0.78 (16) | + ; not significant |
| VII | July '64 | 0.80-1.25 | 1.03 ± 0.26 (12) | - ; significant |

Numbers in parentheses are the numbers of individual fish.

Spawning commences in *Leiognathus splendens* in January. Fish with spent ovaries occur in July. It is likely that stock B attains maturity and is spawned in June. Ripe ovaries or ovaries in advanced stages of maturity are met with in almost all the months. The spawning activity shows a major peak in January-February and a minor one in June.

Gonad indices and reproductive cycle :

The ranges of gonad indices of both male and female *L. splendens* in any stage of maturity show a marked extent of variation (Table I, Fig. 1) and overlap slightly sometimes when any two successive stages are compared. For instance, the range

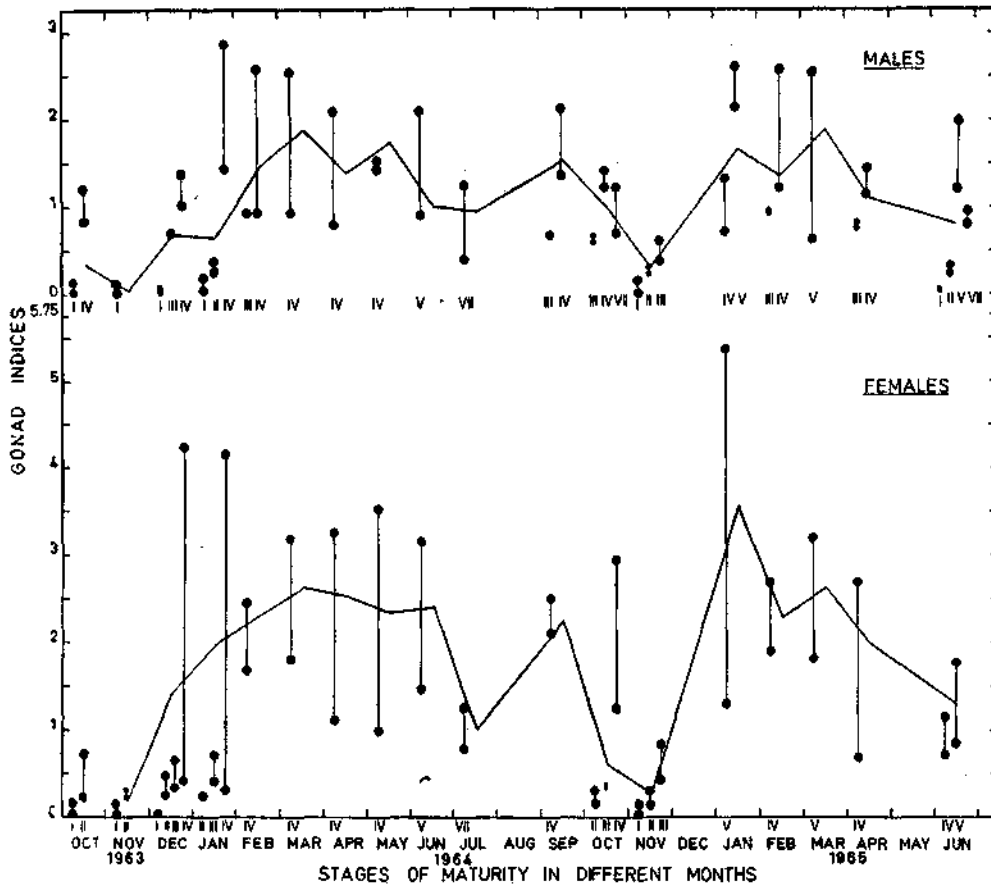


FIG. 1. Mean values and ranges of gonad indices of male and female *Letognathus splendens* in different stages of maturity during the period October 1963-June 1965.

of gonad indices of maturing stage III males is 0.70-0.95 and that of mature stage IV males is 0.74-2.87. However, it will be observed that the mean gonad indices of fish in the various stages of sexual maturity given with standard deviation show a clear trend increasing progressively with statistically significant difference from stages I and II through stage III to stage IV. Between the mature stage IV and ripe stage V there is no significant increase in the mean values of gonad index in both sexes. There is a well-defined fall in the mean gonad index between stage V and spent stage VII following spawning of spermatozoa in males and ova in females. The maximum individual gonad index of ripe stage V female recorded 5.36 is nearly double that in the male. This is due to the fact that the ripe ovary usually attains a much larger size than the ripe testes following deposition of large quantity of yolk in the ova.

B. *Lipids in the storage sites of Leiognathus splendens in different stages of maturity : In lateral muscles :*

In both sexes of *L. splendens* the lipid content of lateral muscles is the highest in immature stages (Table II) and progressively decreases with statistically significant

TABLE II
Lipid content of lateral muscles of Leiognathus splendens in different stages of maturity.

| Stages of maturity of fish | Months | Mean lipid content of lateral muscles (%) with s.d. | Increase or decrease in lipid content and level of significance |
|----------------------------|--------------|---|---|
| <i>Males</i> | | | |
| I | October 1963 | 18.87 ± 2.32 (5) | |
| IV | April 1964 | 10.99 ± 0.69 (8) | — ; significant |
| V | June | 7.43 ± 0.83 (8) | — ; significant |
| VII | July | 3.69 ± 0.61 (6) | — ; significant |
| <i>Females</i> | | | |
| I | October 1963 | 19.79 ± 1.23 (5) | |
| IV | April 1964 | 9.03 ± 1.04 (10) | — ; significant |
| V | June | 5.76 ± 0.31 (6) | — ; significant |
| VII | July | 3.72 ± 0.23 (6) | — ; significant |

difference as the fish pass through the maturing, mature and spent stages. In this respect *Leiognathus splendens* resembles *Clupea harengus* of the Scottish coast (Milroy 1898, Lovern and Wood 1937) in which depletion of lipids in lateral muscles takes place during maturation of gonads. On the other hand, in *C. harengus* of Manx area (Bruce 1924, Channon and Saby 1932) there is no change in the lipid content of lateral muscles until the time of spawning.

The mean lipid content of lateral muscles of male *L. splendens* decreases from 18.78% dry wt. in stage I to 10.99% in stage IV, 7.43% in stage V and to 3.69% in stage VIII. The lipid content of female *L. splendens* shows very similar trends. In *Clupea harengus* lipids amount to 54.73% in immature fish (both males and females combined) and decrease to 41.1% in ripe stage V and 29.2% in spent fish (Lovern and Wood, 1937). The higher lipid content of the herring compared to *L. splendens* in different stages of maturity may be due to the higher lipid content of diet or more intensive accumulation of lipids from digested food in the former species. The work of Lovern (1938) and Phillips *et al* (1950) shows that the lipid content of diet influences the lipid content of fish. Therefore, it is considered that the lipid content of diet is responsible for the differences in lipid contents of the above fish.

Liver indices of L. splendens :

The individual liver indices as well as the mean liver indices of *L. splendens* of the two sexes (Table III, Fig. 3) do not show well-defined, statistically significant differences when fish in different reproductive stages are compared except in two cases, *viz.*, (i) between stage II and stage III females in January 1964 there is statistically significant difference in liver index but this is with reference to only a single

specimen in stage II, (ii) there is a significant fall in the liver index in spent male and females in July 1964.

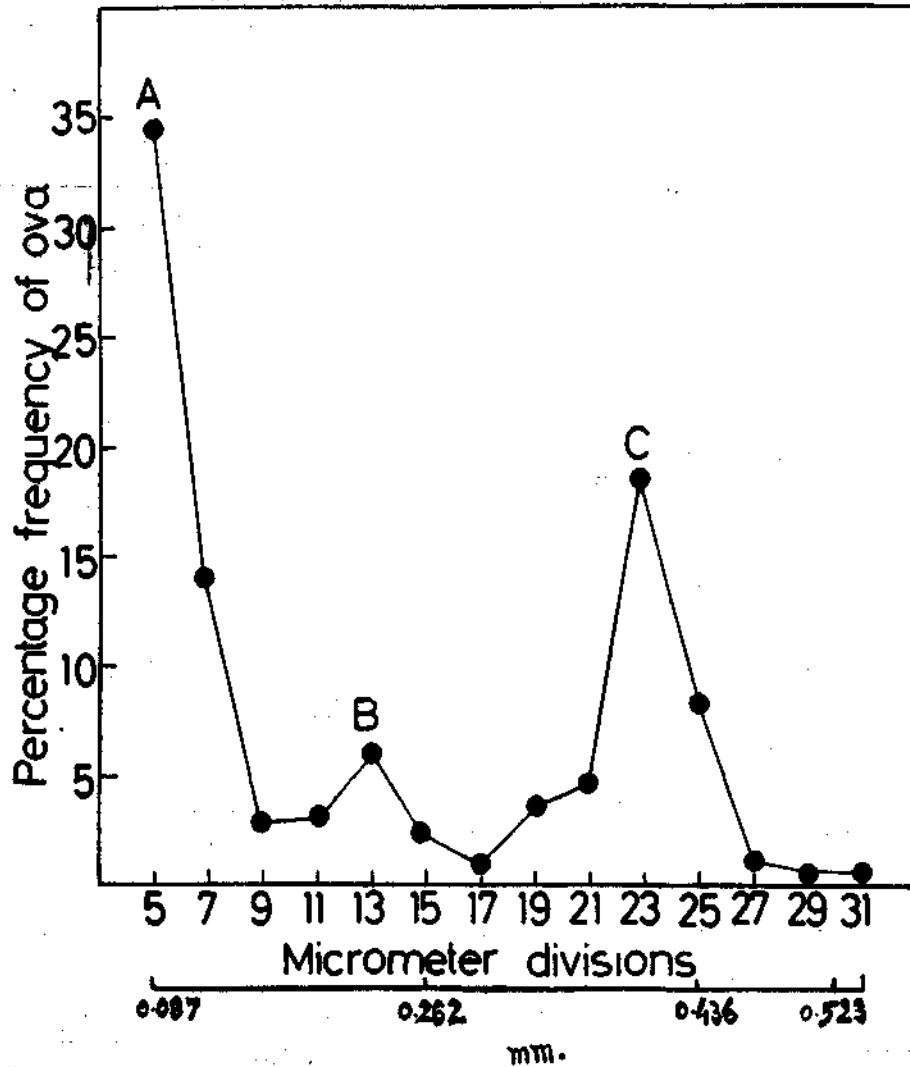


FIG. 2. Percentage frequencies of ova of different sizes in stage V ovary of *Leiognathus splendens* (Mean of values in six individuals).

In the absence of well-defined changes in liver in relation to maturation of gonads *Leiognathus splendens* resembles *Phoxinus laevis* studied by Immers (1953) and differs from *Gastrosteus aculeatus* studied by the same author in which there is a well-defined decrease in liver index during maturation of gonads and it has been suggested by him that some reserve materials in the liver may be utilized for the growth of maturing gonads.

TABLE III

Liver indices of Leiognathus splendens in different stages of maturity

| Stages of maturity of fish | Months | Mean liver index with s.d. | Increase or decrease and level of significance | Stages of maturity of fish | Months | Mean liver index with s.d. | Increase or decrease and level of significance |
|----------------------------|-------------|----------------------------|--|----------------------------|-------------|----------------------------|--|
| <i>Males</i> | | | | <i>Females</i> | | | |
| I | October '63 | 1.07 ± 0.32 (11) | | I | October '63 | 1.16 ± 0.39 (6) | |
| IV | " | 1.72 ± 0.34 (4) | | II | " | 1.21 ± 0.15 (9) | + ; not significant |
| I | November | 1.03 ± 0.58 (8) | | I | November | 0.97 ± 0.09 (6) | + ; not significant |
| I | December | 0.82 ± 0.28 (5) | | II | " | 1.02 ± 0.16 (4) | + ; not significant |
| III | " | 0.83 ± 0.21 (4) | + ; not significant | I | December | 0.97 ± 0.11 (4) | + ; not significant |
| IV | " | 0.71 ± 0.17 (4) | - ; not significant | II | " | 1.15 ± 0.31 (4) | + ; not significant |
| I | January '64 | 0.77 ± 0.32 (5) | | III | " | 1.00 ± 0.09 (3) | - ; not significant |
| II | " | 0.85 ± 0.46 (4) | + ; not significant | IV | " | 1.13 ± 0.26 (3) | + ; not significant |
| IV | " | 0.76 ± 0.04 (4) | - ; not significant | II | January '64 | 0.82 (1) | |
| IV | February | 0.70 ± 0.07 (4) | - ; not significant | III | " | 1.12 ± 0.05 (7) | + ; significant |
| IV | March | 0.54 ± 0.23 (12) | - not significant | IV | " | 1.07 ± 0.09 (5) | - ; not significant |
| IV | April | 1.09 ± 0.36 (16) | + ; not significant | IV | February | 1.15 ± 0.03 (5) | + ; not significant |
| IV | May | 1.05 ± 0.04 (2) | + ; not significant | IV | March | 1.12 ± 0.64 (7) | |
| V | June | 1.50 ± 0.36 (12) | + ; not significant | IV | April | 1.39 ± 0.36 (5) | + ; not significant |
| VII | July | 1.04 ± 0.32 (12) | - ; significant | IV | May | 1.62 ± 0.07 (3) | + ; not significant |
| III | September | 0.71 | | V | June | 1.78 ± 0.29 (9) | + ; not significant |
| IV | " | 0.71 ± 0.09 (7) | | VII | July | 1.03 ± 0.47 (9) | - ; significant |
| | | | | IV | September | 0.84 ± 0.06 (4) | |

Though there are no well-defined changes in liver index between the immature and mature stages, an attempt has been made to study the quantitative changes in lipid in liver.

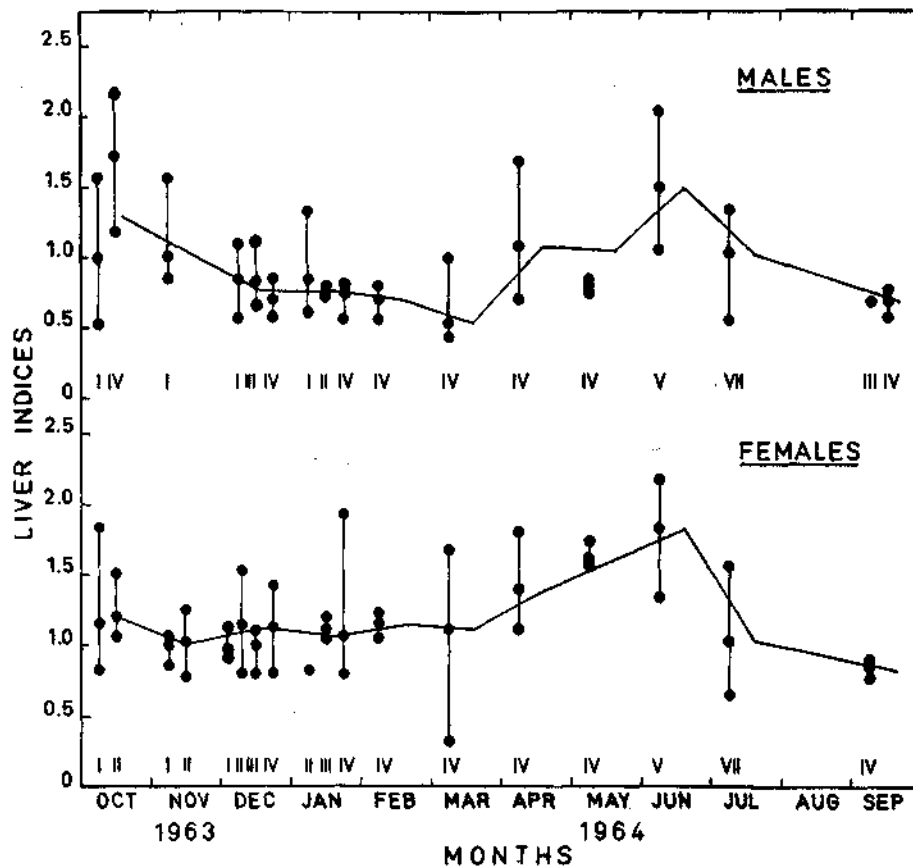


FIG. 3. Mean values and ranges of liver indices of male and female *Liognathus splendens* in different stages of maturity.

Lipid content of liver :

The lipid content of liver of immature males in stage I *L. splendens* is 28.10% (mean value) in October (Table IV, Fig. 4) and decreases to 26.16% in stage II in January and 22.37% in maturing stage III in February. There is still further decrease to 14.38% in stage IV in March. The values of lipid content of males of stage IV in April and May are more or less similar to that in March; there is a significant increase in lipid content of liver in the ripe stage V males in June compared to liver of stage IV males in April (the former are not compared with fish got in May as only one estimation was made for that month). The increase is indicative of re-accumulation of lipid in stage V. There is marked accumulation of lipid (26.35%) in liver in spent stage VII males.

The lipid values of liver of females also show an identical trend but for two features, viz., (i) though there is a fall in the actual mean lipid content of liver between

TABLE IV

Lipid content of liver of Leiognathus splendens in different stages of maturity

| Stages of maturity of fish | Months | Mean lipid content of liver (%) with s.d. | Increase or decrease in lipid content and level of significance | Stages of maturity of fish | Months | Mean lipid content of liver (%) with s.d. | Increase or decrease in lipid content and level of significance |
|----------------------------|-------------|---|---|----------------------------|-------------|---|---|
| <i>Males</i> | | | | <i>Females</i> | | | |
| I | October '63 | 28.10 ± 0.62 (6) | | I | October '63 | 28.20 ± 0.64 (6) | |
| II | January '64 | 26.16 ± 0.81 (4) | - ; significant | II | November | 27.79 ± 0.41 (4) | - ; not significant |
| III | February | 22.37 (1) | - ; significant | III | December | 20.83 ± 0.51 (3) | - ; significant |
| IV | March | 14.38 ± 2.04 (8) | - ; significant | IV | January '64 | 18.39 ± 1.91 (5) | - ; not significant |
| IV | April | 13.45 ± 1.38 (9) | - ; significant | IV | February | 17.84 ± 0.18 (5) | - ; significant |
| IV | May | 16.60 (1) | | IV | March | 15.93 ± 0.23 (6) | - ; significant |
| V | June | 15.88 ± 2.34 (9) | + ; significant | IV | April | 13.17 ± 2.66 (5) | - ; significant |
| VII | July | 26.35 ± 2.19 (8) | + ; significant | IV | May | 13.50 ± 0.50 (3) | - ; significant |
| III | September | 21.09 (1) | | V | June | 12.82 ± 0.56 (8) | - ; significant |
| IV | " | 17.62 ± 0.42 (5) | - ; significant | VII | July | 20.90 ± 3.13 (8) | + ; significant |
| | | | | IV | September | 17.34 ± 0.92 (4) | - ; significant* |

* Compared to stage III in December 1963.

stage I and stage II this is not significant. It is considered that inhomogeneity of members of the population is responsible for not finding statistically significant change ; a fall in the actual mean value is clearly discernible ; (ii) in females there

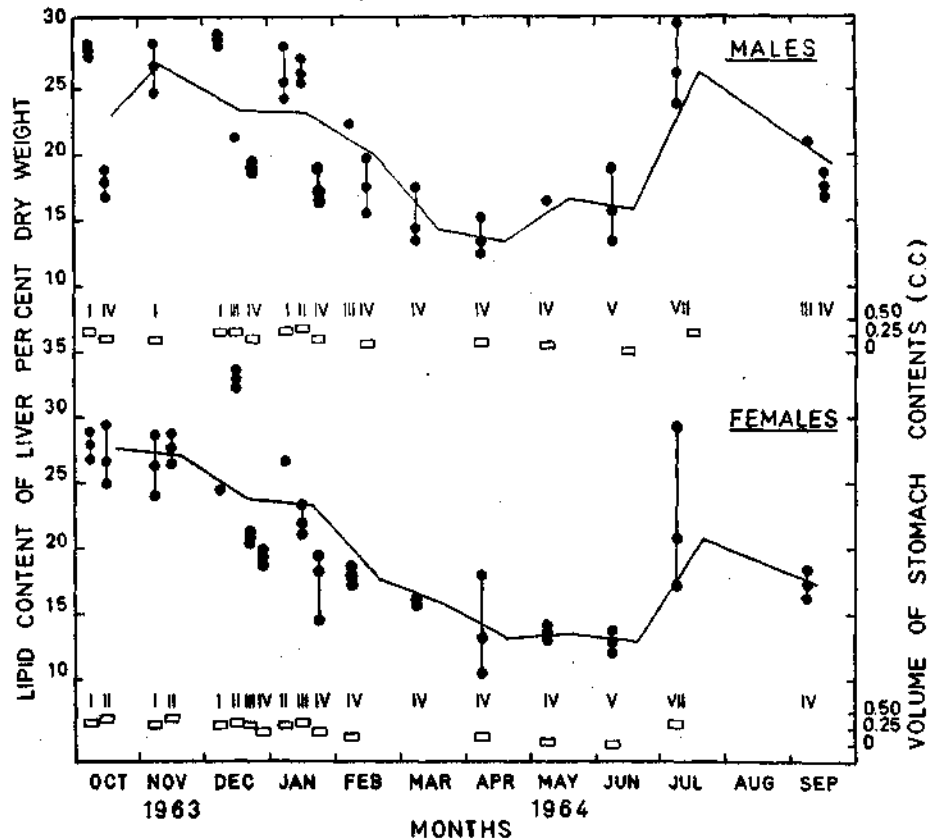


FIG. 4. Mean values and ranges of lipid content (per cent dry weight) of liver of male and female *Leiognathus splendens* in different stages of maturity.

is re-accumulation of lipid in liver only in stage VII and not in stage V as in males. The higher values of lipid content of liver in immature stages and subsequent progressive decrease during maturation of gonads are suggestive of lipids accumulated in liver being utilized in relation to growth and maturation of gonads.

Fig. 4 shows that the lipid levels of liver of immature fish are higher between October and December when they feed intensively and the content decreases in mature and ripe fish observed in different months between October and June when the fish feed progressively on lesser and lesser amounts of food. These data suggest that accumulation of lipids in the liver of immature fish is due to the absorption and assimilation of lipids from food following active feeding. The lipid content of liver increases in spent fish which have resumed intensive feeding showing reaccumulation of reserves from nutrients in digested food.

TABLE V

Lipid content of intestine of Leiognathus splendens in different stages of maturity

| Stages of maturity of fish | Months | Mean lipid content of intestine (%) with s.d. | Increase or decrease in lipid content and level of significance | Stages of maturity of fish | Months | Mean lipid content of intestine (%) with s.d. | Increase or decrease in lipid content and level of significance |
|----------------------------|-------------|---|---|----------------------------|-------------|---|---|
| <i>Males</i> | | | | <i>Females</i> | | | |
| I | October '63 | 30.04+7.72 (6) | | I | October '63 | 33.19±3.47 (6) | |
| II | January '64 | 29.39+1.36 (4) | - ; not significant | II | November | 31.55±1.95 (4) | - ; not significant |
| III | February | 23.46 (1) | - ; significant | III | December | 21.89±0.46 (3) | - ; significant |
| IV | March | 19.54+0.99 (7) | - ; significant | IV | January '64 | 20.73±1.93 (5) | - ; significant |
| IV | April | 18.73+1.85 (8) | - ; significant | IV | February | 17.52±0.98 (5) | - ; significant |
| IV | May | 17.72+1.92 (1) | | IV | March | 17.21±1.25 (6) | - ; significant |
| V | June | 18.65+1.23 (8) | - ; not significant | IV | April | 17.79±0.87 (5) | - ; not significant |
| VII | July | 23.22+1.32 (8) | + ; significant | IV | May | 18.26±0.93 (3) | - ; significant |
| III | September | 25.31 (1) | | V | June | 18.09±1.18 (8) | - ; not significant |
| IV | | 20.56+0.83 (7) | - ; significant | VII | July | 22.40±1.76 (8) | + ; significant |
| | | | | IV | September | 17.36-0.89 (4) | - ; significant* |

* Compared to stage III in December 1963.

Lipid content of intestine :

There is no significant decrease in the lipid content of male *L. splendens* between stages I and II (Table V, Fig. 5) but there is a significant decrease in the content as the fish pass from stage II to stage III. As the fish attain mature stage IV there is

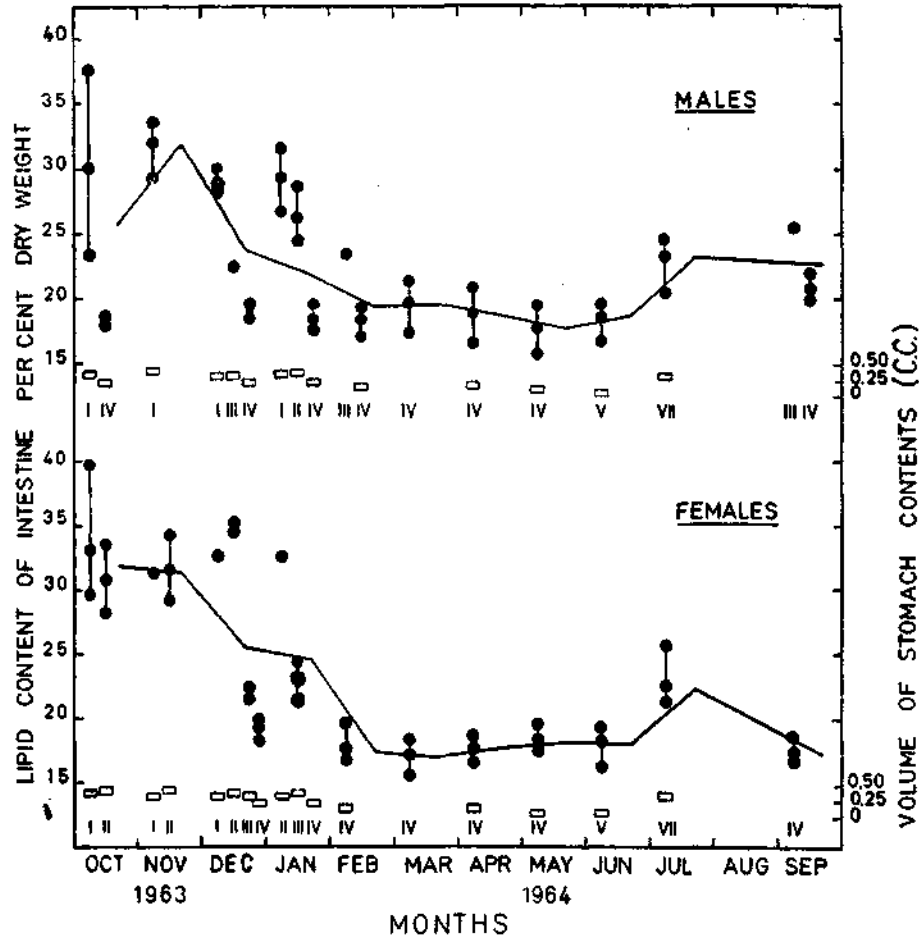


FIG. 5. Mean values and ranges of lipid content (per cent dry weight) of intestine of male and female *Leiognathus splendens* in different stages of maturity.

further decrease in the lipid content. No significant change in content of intestine takes place in stage V as compared with that in stage IV indicating that lipid in the intestinal walls are not drawn between the two stages. In spent stage VII there is a clear increase in the lipid content of intestine. The lipid content of intestine of females exhibits a pattern of changes in relation to maturity stages similar to that recorded in males. Fig. 5 shows that as in the case of liver lipid, accumulation of lipid in the intestine takes place in the immature and spent stages when feeding is intensive and decrease of stored lipid in advanced stages of maturity when feeding becomes lesser.

TABLE VI

Lipid content of gonads of Leiognathus splendens in different stages of maturity

| Stages of maturity of fish | Months | Mean lipid content of testes (%) with s.d. | Increase or decrease in lipid content and level of significance | Stages of maturity of fish | Months | Mean lipid content of ovaries (%) with s.d. | Increase or decrease in lipid content and level of significance |
|----------------------------|--------------|--|---|----------------------------|--------------|---|---|
| <i>Males :</i> | | | | <i>Females :</i> | | | |
| I | October '63 | 27.95+0.32 (5) | | I | October '63 | 22.63 (1) ¹ | |
| II | January '64 | 22.92+0.72 (4) | - ; significant | II | " | 22.63 (1) ² | |
| III | December '63 | 26.22+0.42 (4) | + ; significant | III | December '63 | 22.84+0.87 (3) | |
| IV | " | 18.69+0.67 (4) | - ; significant | IV | " | 17.54+0.63 (3) | - ; significant |
| IV | January '64 | 15.61+0.69 (4) | - ; significant | IV | January '64 | 13.51+0.83 (4) | - ; significant |
| IV | February | 15.84+1.27 (4) | - ; significant | IV | February | 17.34+0.77 (5) | - ; significant |
| IV | March | 13.23+0.65 (8) | - ; significant | IV | March | 15.43+0.83 (6) | - ; significant |
| IV | April | 12.38+0.49 (12) | - ; significant | IV | April | 17.83+0.23 (5) | - ; significant |
| IV | May | 18.60 (2) | - ; significant | IV | May | 15.43+0.91 (3) | - ; significant |
| V | June | 16.61+2.73 (10) | - ; not significant | V | June | 16.80+1.73 (8) | + ; not significant |
| VII | July | 19.79+4.91 (9) | + ; not significant | VII | July | 20.90+1.29 (8) | + ; significant |
| III | September | 25.12 (1) | | IV | September | 16.41+1.32 (4) | - ; significant ³ |
| IV | " | 15.61+1.73 (7) | - ; significant | | | | |

¹ Gonad material pooled from five females.² Gonad material pooled from four females³ Compared to stage III in December 1963.

C. Lipid in gonads :

1. In testes

The lipid content of testes (Table VI, Fig. 6) decreases from 27.95% (mean value) in stage I to 22.92% in stage II and again increases to 26.22% in stage III. But, as the testes pass from maturing stage III to the mature stage IV there is a marked decrease in lipid content. In stage V testes the mean lipid content does not undergo any significant change. The spent testes show a rise to 19.79% but the increase is not statistically significant.

2. In ovaries

The lipid content of ovaries does not undergo any significant change between the immature stage I and maturing stage III (22.63%-22.84%) but there is a clear fall in the content between stage III (22.85%) and mature stage IV (17.54%). Between stage IV and ripe stage V no significant variation in lipid content of ovaries takes place and in the spent ovaries there is a significant increase to 20.90% in contrast to spent testes.

Though the percentage of lipid content of testes as well as ovaries undergoes a decrease during maturation of gonads the 'productivity' (term used by Giese *et al.*, 1959) of lipids in the gonads that is the 'total turnover' (Barnes, Barnes and Finlayson, 1963) of lipids in the gonads of *L. splendens* increases (Table VI) as the gonads enlarge considerably in size while passing from the immature stage to the ripe stage.

DISCUSSION

The reproductive periodicity of fishes of the Indian region have received considerable attention from previous workers. *Therapon jarbua* and *Chirocentrus dorab* spawn only once a year and the spawning period in each is of short duration. Fish like *Pelates quadrilineatus* also spawn only once a year, but the duration of spawning extends over a long period; *Stolephorus indicus* spawns intermittently throughout the year; *Psammoperca waigiensis* and *Caranx leptolepis* spawn more than once a year but each spawning period is of brief duration (Prabhu, 1956). Karandikar and Palekar (1950) have shown that *Polynemus tetradactylus* spawns twice in a year. *Polydactylus indicus* has a prolonged breeding period and there appears to be one major spawning period followed by a second one of shorter duration (Nayak, 1959). In having a prolonged breeding period with peak spawning in January and a supplementary spawning in June the reproductive cycle of *Leiognathus splendens* resembles that of *Polydactylus indicus*.

Fish of the same species occurring in different regions may exhibit differences in breeding periodicities. *Clupea harengus* of the Southern North Sea has an annual reproductive cycle with a short spawning period between December and February (Hodgson 1929, Hickling and Rutenberg 1936). On the other hand on the coast of Quebec, Canada, it has two spawning seasons one in the spring in May-June and the other in the fall in August-September (Jean 1956). *Leiognathus splendens* of Thangachimadam near Mandapam has been reported (Arora, 1951) to spawn from March till August or September with peaks of spawning in April and August. Along Mandapam Coast also maturing specimens were found almost throughout the year. There are two peak spawning periods on the Mandapam Coast also in *L. splendens* but the peaks are earlier by some months compared to those on Madras Coast.

TABLE VII

Total lipid content of gonads of Leiognathus splendens in different stages of maturity.

| Stages of maturity of fish | Total lipid content of testes of males mg. with s.d. | Increase or decrease in total lipid content of testes and level of significance | Total lipid content of ovaries of females (mg.) with s.d. | Increase or decrease in total lipid content of ovaries and level of significance |
|----------------------------|--|---|---|--|
| II | 0.09+0.0001 (6) | | 5.49+0.43 (6) | |
| III | 6.44+0.25 (8) | + ; significant | 27.86+7.11 (5) | + ; significant |
| V | 14.23+3.23 (6) | + ; significant | 35.35+3.00 (8) | + ; significant |
| VII | 6.93+0.25 (6) | - ; significant | 24.6+6.07 (6) | - ; significant |

In an allied species *Leiognathus bindus* of Calicut, West coast of India maturing fish have been recorded (Balan, 1963) between July and December and spawning during a restricted period between December and February.

It is clear that accumulation of reserve lipids is a factor involved in the maturation of gonads of *Leiognathus splendens* as reserve lipids are concentrated in storage organs, the liver, intestine and lateral muscles in the spent and immature stages

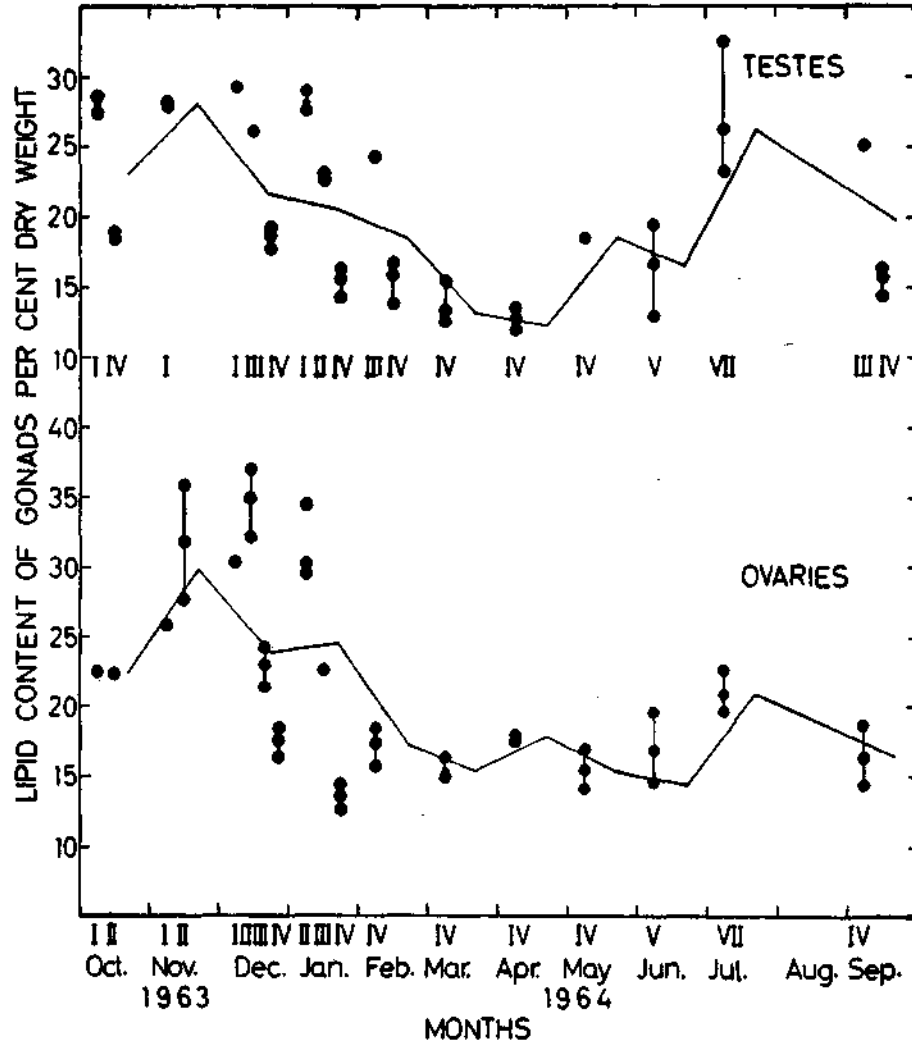


FIG. 6. Mean values and ranges of lipid content (per cent dry weight) of testes and ovaries of *Leiognathus splendens* in different stages of maturity.

during October-December and July and well-defined decrease in the reserves is noticed in maturing, mature and ripe stages in October-December and between April and June. The period of accumulation of reserves in any of the storage organs

is not precisely known. In *L. splendens* mature stages have been observed in almost all the months of the year. This accounts for the difficulty in fixing the exact period of accumulation of reserves in the immature stages during the course of the year. During the maturation of gonads as the gonads grow progressively the reserve lipids in the storage sites viz. lateral muscles, liver and intestine should be drawn upon and this should account for the decrease. There is no direct evidence to show that there is such transfer but from the inverse relation between the changes in the lipid levels in storage organs and those in gonads it has been held by several workers and is accepted (Lovern and Wood 1937, Davidson 1935, Hickling 1947, Bailey 1952, Hoar 1953, 1957a, 1957b) that a transfer of lipids from storage sites to gonads takes place. Hoar (1957a) considers that endocrine glands are involved in the redistribution of lipids during maturation of gonads but the mechanisms by which this is effected are not known.

The fall in the lipid content of lateral muscles between the ripe and spent stages of *L. splendens* of both sexes indicates that stored lipids are utilized as a source of energy at the time of spawning. This view receives support from the fact that feeding is very poor or absent in ripe fish. Feeding intensities and accumulation of lipids in storage organs in *L. splendens* show similar trends in changes as recorded in *Sardina pilchardus* by Hickling (1947) and in *Dussumieria acuta* by Sekharan (1949). Accumulation of lipids does not take place in all storage organs in the same stage in *L. splendens*. Whilst lipids accumulate in liver and intestine in spent stage VII itself, the process takes place in lateral muscles only in stage I some time after spawning activity.

Channon and Saby (1932) have pointed out that in *Clupea harengus* there is accumulation of lipids in the intestine in the immature stages and that the lipid content of the intestine shows decreased values in maturing, ripe and spent stages. The authors have inferred that lipids accumulated in the intestine of *C. harengus* in immature stages are transferred to lateral muscles during maturation (as the latter show an increase in content) for utilization in ripe and spawning stages. It has been suggested that the lateral muscles play a role in synthesis of fatty acids for utilization by gonads. In contrast to what has been reported in *C. harengus*, the lipid content of lateral muscles of *L. splendens* does not increase but decreases during maturation suggesting that lipids in the intestine as well as those in the lateral muscles are utilized during maturation of gonads.

The work of Milroy (1898), Bruce (1924) and Channon and Saby (1932) shows that in the herring of both sexes the lipid content of gonads per unit weight decreases progressively between the immature and the mature stages. By contrast, the gonads of *Leiognathus splendens* reveal certain differences in the early stages; in the testes there is a fall in lipid content between stages I and II, an increase in stage III and a fall subsequently as the testes attain the mature stage; in the ovaries the lipid content shows no significant change between stages I and III and only in stage IV does it fall significantly. The accumulation of lipids in the early developing phases in both sexes evidently helps to meet the greater energy requirements of the growing stages of the gonads. In the latter stages the energy requirements are less and the lipid content per unit weight is less. In the latter stages of maturity the protein content of gonads has been found to increase (Rao, 1965).

Other members of *Leiognathus splendens* of the population from which the samples have been taken are expected to show values of gonad indices, liver indices and lipid levels in relation to stages of maturity similar to those in samples

as the samples got are random samples. In the case of gonad indices, and lipid levels of storage organs and gonads the data shows similar trends and values according to the maturity stages whatever be the month of occurrence of the fish in the year since the samples are random samples. The index values and lipid levels of members of *L. splendens* population of a distant place are expected to show trends in relation to reproductive stages similar to those found in the present work but the actual values of indices and lipid levels may differ if there is difference in the composition of diet with reference to lipid ; for, it is known (Lovern 1938, 1951, Phillips *et al.* 1950) that changes in lipid content of diet results in alteration of lipid levels of fish.

SUMMARY

The reproductive cycles of the fish *Leiognathus splendens* (Cuvier) have been studied with special reference to the lipid content of the gonads. Mature individuals of the fish have been observed during the different months of the year suggesting that the fish breeds through a greater part of the year. There is a peak of spawning activity in January-February and again in June. A study of the gonad indices shows that the values increase during maturation and decrease after spawning. In the ripe stages the gonad indices show high values.

Lipid accumulates in lateral muscles of the fish in immature stages in both sexes and progressively decreases during maturation of gonads and following spawning activity suggesting utilization of stored lipid in relation to maturation of gonads and spawning. Lipid accumulates in the liver and intestine in the spent stage and shows a fall as the fish reach the mature stage. Feeding intensities of the fish and accumulation of lipids in storage organs showed parallel changes (increase and decrease).

The percentage of lipid content of the testes and ovaries of the fish in terms of dry weight is higher in the immature stages and decreases during maturation suggesting that there is accumulation of lipids in the early stages to meet the energy requirements of growth of gonads and the energy requirements are less in the latter stages of maturity.

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