STUDIES ON THE MATURATION AND SPAWNING OF THE FISHES OF THE FAMILY LEIOGNATHIDAE FROM THE SEAS AROUND INDIA

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ABSTRACT

The paper deals with the maturation, spawning habits, spawning seasons and fecundity of 17 species of leiognathids from the seas around India. Most of the species appear to spawn over a prolonged period (*L. fasciatus, L. jonesi, L. bindus, L. daura. L. leuciscus, L. blochii, L. brevirostris, L. berbis, L. lineolatus, S. ruconius, S. insidiator, G. minuta* and *G. achlamys*); a few spawn continuously over a short period (*L. equulus* and *L. smithursti*); *L. splendens* spawns in batches in quick succession over a short period; and *L. dussumieri* spawns twice in a year for a short time in two distinct periods. Four species *L. fasciatus, L. bindus, L. daura* and *L. berbis* spawn fractionally. Except for *L. brevirostris*, which spawns almost throughout the year, the species spawn mostly during March-April and November-December periods.

Fecundity was found to increase with length at a higher rate in *G. minuta, L. bindus* and *S. insidiator;* at a lower rate in *L. berbis, L. brevirostris, L. daura* and *S. ruconius.* But it was found to decrease with length in *L. leuciscus* and *L. splendens*. The pooled equation was found to be $Y = 0.00745\ X^{3.0202}$ indicating that in leiognathids fecundity on length is a cubic relationship.

INTRODUCTION

Although the family Leiognathidae is commercially important, only a few studies have been made so far on the biology and fishery of certain species. Arora (1951) studied the biology of *L. splendens*, Balan (1963) studied the biology of *L. bindus*, James and Badrudeen (1975) gave an account of the biology and fishery of *L. brevirostris*. Pillay (1972) studied the spawning habits and fecundity of few species of leiognathids. James (MS) gave an account of the biology and fishery of *L. jonesi*, and James and Badrudeen (1981) studied the biology and fishery of *L. dussumieri*. While the above mentioned papers cover some aspects of maturity, spawning and fecundity of some species of Leiognathidae, no information is available on this subject for all the other species. Therefore, the present authors, during the course of their investigations on this group of fishes from the Palk Bay and Gulf of Mannar, collected data on these aspects for the available species and the results of the analyses are given in this paper.

Material and Methods

The material for this study is mainly collected during the period 1967-69 from the trawl catches from Palk Bay and Gulf of Mannar in the vicinity of Mandapam. Material of some species was also collected from other gears like drift nets and shore-seines operated in the area. Samples of certain species were also obtained for examination from other places along the Indian coast.

The maturity stages designated in this study are based on macroscopic appearance of the gonads and the microscopic structure of the ova. The ova-diameter studies have been made according to the method of Clark (1934). Fecundity estimations were made by the gravimetric method using advanced or prespawning stages of the ovaries. The number of mature ova in a small piece of the ovary of known weight was enumerated and the total number computed for the total weight of the ovary.

Excluding the species (*Leiognathus brevirostris, L. Jonesi* and *L. dussumieri*) studied earlier by the present authors for maturity, spawning and fecundity, in the present study, data have been collected on 14 other species of leiognathids, namely *Leiognathus fasciatus, L. equulus, L. smithursti, L. splendens, L. bindus, L. daura, L. leuciscus, L. blochii, L. berbis, L. lineolatus, Secutor ruconius, S. insidiator, Gazza minuta* and *G. achlamys*. While it has been possible to collect a number of maturity stages in majority of the species, for a few species only few of the stages could be collected. The classification of the maturity stages is restricted to the females and was followed as in the earlier publications of the present authors. (James and Badrudeen 1975, 1981).

Observations

Development of Ova to Maturity and Spawning Habits

L. fasciatus (Fig. 1): Fish in the stage I to VII A have been recorded.

In stage I, the ova range in size up to a maximum of 0.126 mm. In stage II the size of the ova increases to 0.189 mm. In stage III in addition to the immature ova (max. Of 0.126 mm), a distinet group of large ova is formed with a maximum size of 0.504 and a mode at 0.294 mm. In stage IV, in addition to the immature ova, two modes are formed at 0.294 and 0.420 mm, the maximum size of ova being 0.504 mm. In stage V the two advanced modes seen in stage IV at 0.294 and 0.420 mm progress to 0.357 and 0.672 mm respectively. The maximum size of ova in this stage is 0.882 mm. In stage VII a single prominent mode is found at 0.420 mm, the maximum size of ova being 0.546 mm.

Since two distinct modes of ova are found in addition to immature stock in stage V, it is likely that the species spawns fractionally over a prolonged period. This is supported by the fact that partially spawned fish (stage VIIA)

contains a group of well advanced ova which are likely to be spawned immediately after the most advanced group of ova found in stage V is eliminated.

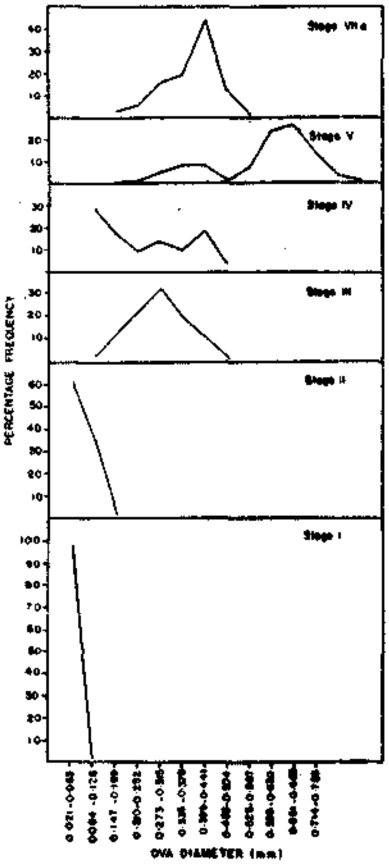

FIG. 1. Ova-diameter frequency polygons for various stages of maturity of *L. fasciatus*.

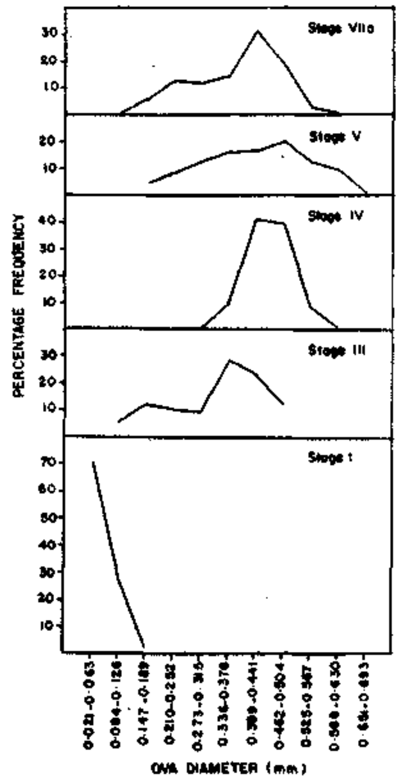

FIG. 2. Ova-diameter frequency polygons for various stages of maturity of *L. equulus*.

L. equulus (Fig. 2): Maturity stages I, III, IV, V andVIIA have been recorded, In stage I ova range in size up to 0.189 mm. In stage III, in addition to immature ova, two modes are found at 0.168 and 0.357 mm. The maximum size of ova range up to 0.504 mm. In stage IV a single prominent mode of advanced group of ova is found at 0.420 mm which is distinctly separated from the immature stock. The maximum size of the ova range up to 0.630 mm. In stage V the mode of the largest group of ova further shifts to 0.483 mm with the maximum size reaching up to 0.693 mm. In stage VIIA there are two modes at 0.231 and 0.420 mm which are not distinctly separated. The maximum size of ova range up to 0.630 mm.

As seen in the ova-diameter-frequency curves for stage V and VIIA the mature stock of ova show a very wide range in size from 0.126 to 0.693 mm, forming a single group demarcated from the immature stock of ova, though not distinctly. This indicates that the fish spawns continuously for a short period.

L. smithursti (Fig. 3): Stage I and V have been recorded during this study. The maximum size of ova in stage I reaches up to 0.126 mm. In stage V, in addition to immature stock of ova, there is a single large group of ova with a mode at 0.420 mm and a maximum size of 0.567 mm.

While the progression of ova to maturity could not be traced through various stages, the presence of a single large group of ova ranging in size from 0.147 to 0.567 mm indicates that this species probably spawns continuously over a short period.

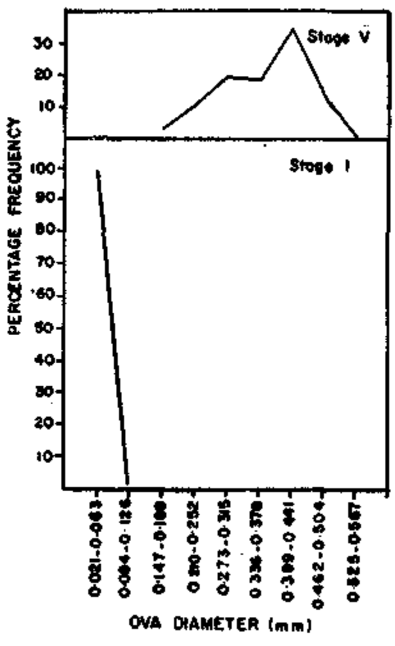

FIG. 3. Ova-diameter frequency polygons for various stages of maturity of *L. smithursti.*

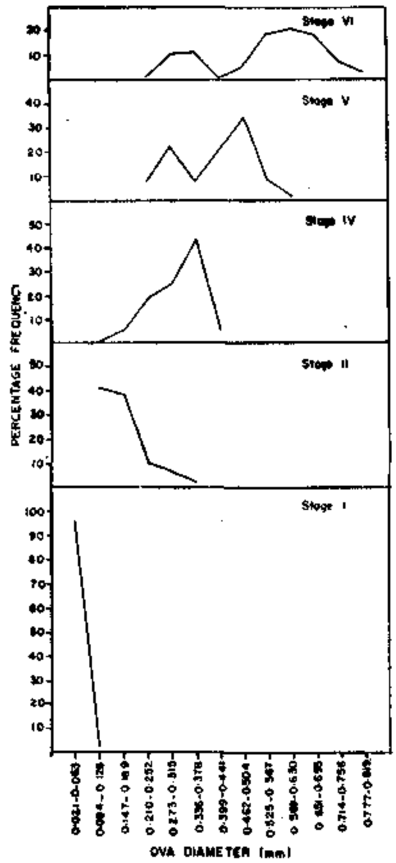

FIG. 4. Ova-diameter frequency polygons for various stages of maturity of *L. splendens.*

L. splendens (Fig. 4): Stages I, II, IV, V and VI were recorded in the present study. In stage I the maximum size of ova is 0.126 mm and in stage II the maximum size reaches to 0.378 mm. In stage IV, in addition to the immature stock of ova, there is a single group of large ova with mode at 0.357 mm and a maximum size of 0.441 mm. In stage V, in addition to the immature stock ova, two groups of ova are present with modes at 0.294 to 0.483. These two groups are not distinctly separated from one another. The maximum size of ova in this stage has further progressed to 0.630 mm. In stage VI also, in addition to the immature stock of ova, two groups of larger ova are present with their modes shifted to 0.357 and 0.609 mm. The maximum size of ova in this stage is 0.819 mm.

The presence of two distinct modes of large ova one following the other as seen in ova-diameter-frequency curves for stage V and VI indicates that this species spawns in batches in quick succession over a short period.

L. bindus (Fig. 5): During the present study, stages I, II, III, VIIA and VIIB have been recorded. In stage I the maximum size of ova is 0.126 mm. In stage II a small batch of large ova gets separated from the general stock with a mode at 0.294 mm. The maximum size of ova at this stage is 0.378 mm. In stage III there is a further increase in size of the larger group of ova which shows a mode at 0.357 mm. This is followed by a group of ova indistinctly separated from the larger group but having a mode at 0.168 mm. Thus there are two groups of large ova in addition to the general stock of ova in stage III. In stage VIIA (partially spent), in addition to the immature stock of ova, there are three groups of larger ova with modes at 0.168, 0.294 and 0.672 mm. Whereas the two groups of ova with modes at 0.168 and 0.294 mm are not distinctly separated from one another, the two groups with modes at 0.294 and 0.672 mm are somewhat separated from one another. The maximum size of ova is 0.945 mm. In stage VII B (fully spent), in addition to the immature stock of ova, a small group of ova is present with a mode at 0.294 mm. The maximum size of ova in this stage is 0.378 mm.

The ova-dia-meter-frequency curve of the partially spent stage indicates some residual ova of recent spawning followed by a distinct group of large ova with a mode at 0.672 mm further followed by two groups of ova with modes at 0.294 and 0.168 mm. This indicates that this species spawns continuously in batches over a prolonged period. The ova-diameter-frequency curve of stage VIIB indicates a fully spent condition, where most of the large groups of ova found in stage VIIA have been eliminated due to spawning.

L. daura (Fig. 6): During the present study stages I, III, IV, V and VIIB have been recorded. In stage I the maximum size of ova is 0.126 mm. In stage III, in addition to the immature stock of ova, a single large group of ova with mode at 0.294 mm is present. The maximum size of ova is 0.378 mm. In stage IV,

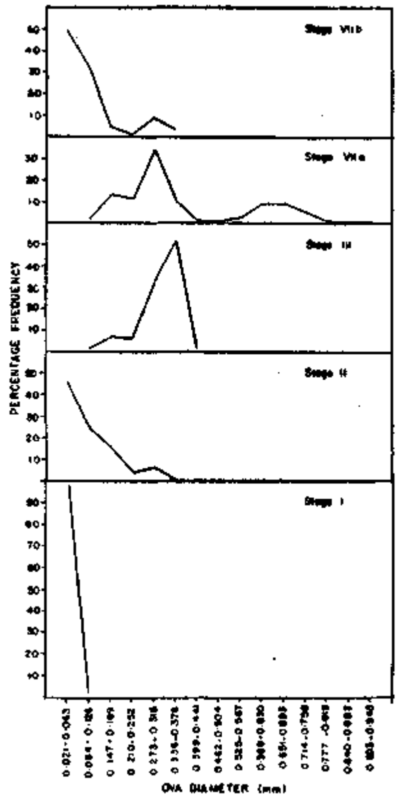

FIG. 5. Ova-diameter frequency polygons for various stages of maturity of *L. bindus.*

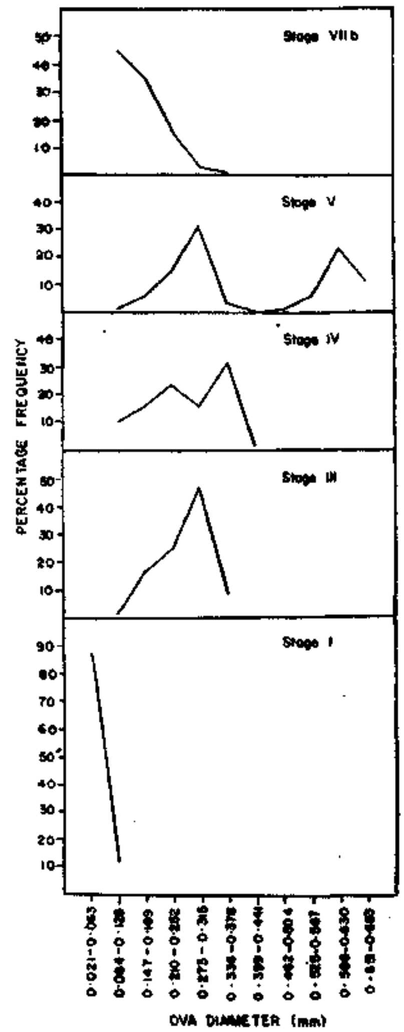

FIG. 6. Ova-diameter frequency polygons for various stages of maturity of *L. daura.*

in addition to the immature stock, two indistinctly separated groups of ova with modes at 0.231 and 0.357 mm are present. The maximum size of ova is 0.441 mm. In stage V, in addition to the immature stock of ova, two distinct groups of ova are present with modes at 0.294 and 0.609 mm. These two groups of ova are very widely separated. The maximum size of ova is 0.630 mm. In stage VIIB, in addition to the immature stock of ova, there are some large ova of a maximum size of 0.378 mm which do not form a distinct group.

The ova-diameter-frequency curves for stage IV indicate that batches of ova are initially withdrawn in quick succession from the general stock, but as seen in the ova-diameter-frequency curve for stage V, only one batch advances further and gets distinctly separated from the following. This indicates that this species spawns in batches at certain intervals. At a time, spawning may be of a short duration. The ova-diameter-frequency curve of stage VIIB indicates that spawning is complete.

L. leuciscus (Fig. 7): Stages I, II, III, VI, VIIA and VIIB were recorded during the present study. In stage I the maximum size of ova is 0.126 mm. In stage II the size further increases up to 0.315 mm. In stage III a group of larger ova show a mode at 0.294 mm. The maximum size of ova in this stage is 0.378 mm. In stage V the group of larger ova further increases in size to show a mode at 0.420 mm. The maximum size is 0.504 mm. In stage VIIA, although two groups of ova may be seen with modes at 0.168 and 0.357 mm in addition to the immature stock, the two groups of larger ova are not distinctly separated. The maximum size of ova in this stage is 0.441 mm. In stage VIIB the immature stock of ova is distinctly separated from the larger ova which form a mode at 0.231 mm. The maximum size of ova is 0.441 mm.

The ova-diameter-frequency curves for stages V and VIIA indicate that the mature group of ova has a wide range in size and do not form distinct groups. In view of this it is likely that this species spawns over a prolonged period.

L. blochii (Fig. 8): During the present study, stages I, III and VIIB were recorded. In stage I the ova range in size up to 0.126 mm. In stage III, in addition to the immature stock of ova, one group of larger ova are seen with a mode at 0.294 mm. The maximum size of ova in this stage is 0.378 mm. In stage VIIB, in addition to immature stock of ova, a few large ova are present with a maximum size of 0.315 mm.

Because of the limited material at the disposal of the authors it has not been possible to obtain other stages of maturity of this species to trace the progress of development of ova. However, the ova-diameter-frequency curve of stage III indicates indistinct separation of a single group of large ova from the immature stock of ova, thus implying a prolonged spawning for this species. This however needs further confirmation based on more material.

L. berbis (Fig. 9): Stages I, II, III, VI, VIIA were recorded in the present study. In stage I the maximum size of the ova range up to 0.126 mm. In stage II the maximum size of ova range up to 0.315 mm. There is no distinct mode for the larger group of ova ranging in size from 0.147 to 0.315 mm. In stage III, in addition to the immature stock of ova, two groups of larger ova are present with modes at 0.168 mm and 00357 mm. The maximum size of

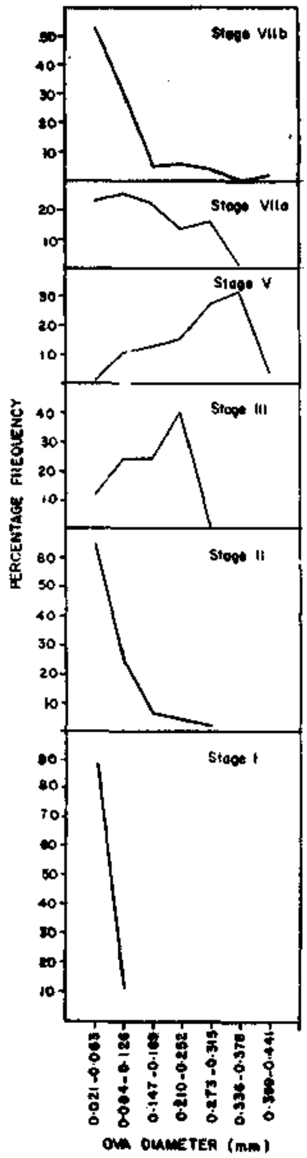

FIG. 7. Ova-diameter frequency polygons for various stages of maturity of *L. leuciscus*.

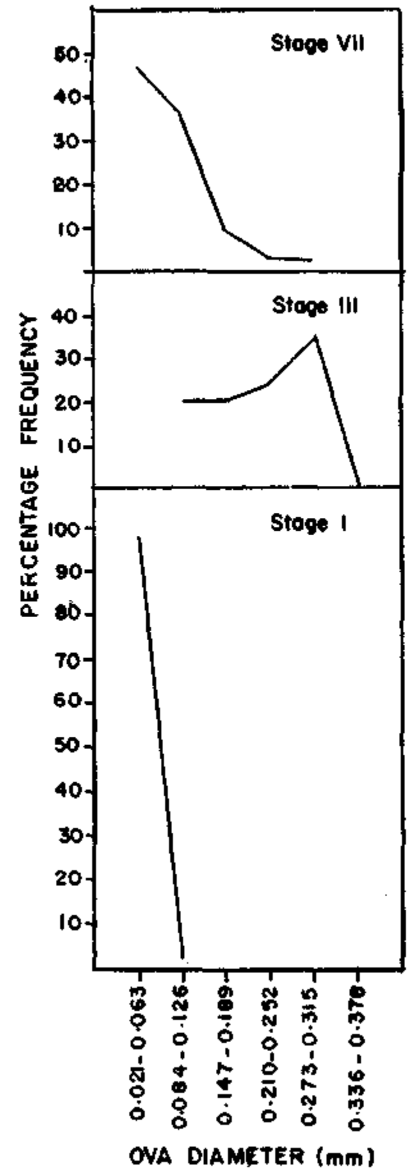

FIG. 8. Ova-diameter frequency polygons for various stages of maturity of *L. blochii*.

ova in this stage is 0.504 mm. In stage VI, in addition to the immature group of ova, there are two distinctly separated larger groups of ova with modes at 0.231 and 0.546 mm. The maximum size of ova in this stage is 0.693 mm.

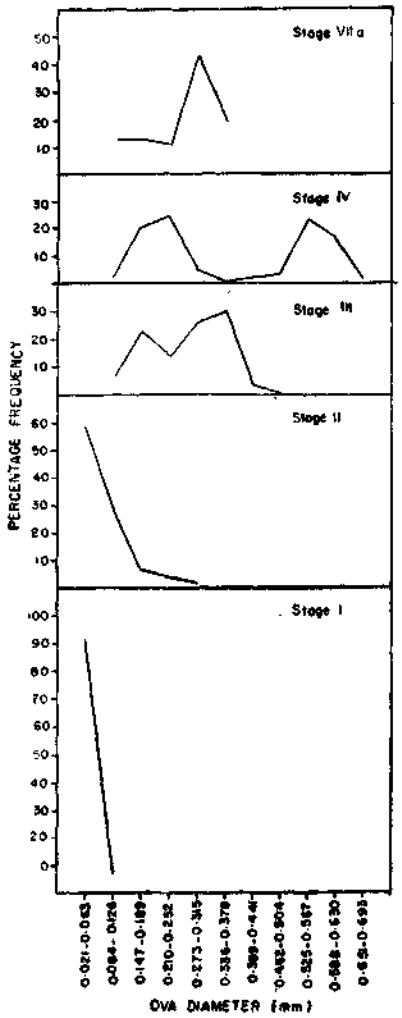

FIG. 9. Ova-diameter frequency polygons for various stages of maturity of *L. berbis*.

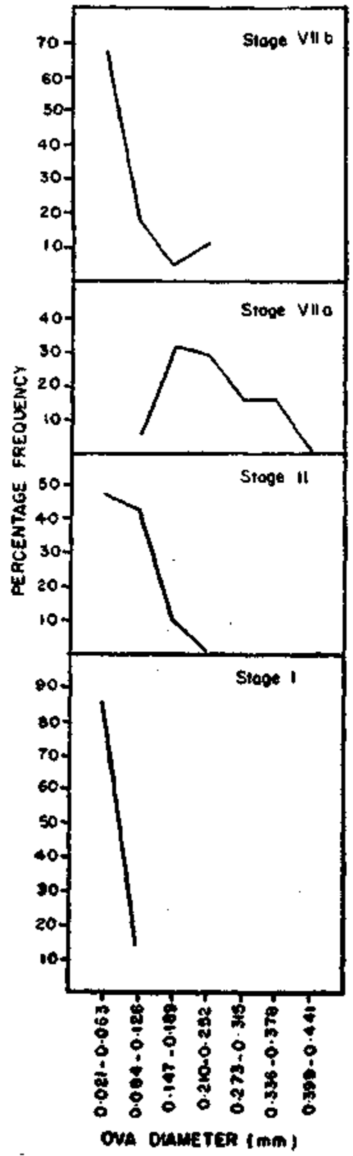

FIG. 10. Ova-diameter frequency polygons for various stages of maturity of *L. lineolatus*.

In stage VIIA, in addition to the immature stock of ova, a group of larger ova with a mode at 0.294 mm is present. The ova range in size up to a maximum of 0.378 mm.

The ova-diameter-frequency curve of stage III indicates two modes at 0.168 and 0.357 mm, which are not distinctly separated. But in stage VI the corresponding two groups of ova which have further increased in size are distinctly separated from one another. This indicates that the maturation process is continuous leading to prolonged spawning. Spawning at a time seems to be of short duration. This is further supported by the fact that the largest group of ova which has a mode 0.357 mm (in stage III) progressed rapidly to a mode at 0.546 mm (in stage VI) whereas the next mode of ova which was at 0.168 mm (in stage III) had progressed only to a mode at 0.231 mm (in stage VI).

L. lineolatus (Fig. 10): Stages I, II, VII A and VII B were recorded during the present study.

In stage I the ova range in size up to 0.126 mm. In stage II, in addition to the immature stock, a few large ova are present, the maximum size being 0.252 mm. In stage VII A, in addition to the immature stock of ova, a single group of large ova with a wide size range and a mode at 0.168 mm is present. In stage VII B, in addition to the immature stock of ova, only a few large ova measuring up to 0.252 mm are present.

The ova-diameter-frequency curve in stage VII A indicates that the groups of larger ova are indistinctly separated from the immature stock ova. They also show a wide range in size. These two factors indicate that this species is likely to spawn over a prolonged period.

Secutor ruconius (Fig. 11): In the present study, stages I, II IV and VII A were recorded. In stage I ova range in size up to 0.252 mm. In stage II a few large ova are present with a maximum size of 0.315 mm. In stage IV, in addition to the immature stock of ova, two groups of large ova are present with modes at 0.231 and 0.357 mm. In the partially spent stage, in addition to the immature stock of ova, only a single group of large ova is present with a mode at 0.231 mm.

The ova-diameter-frequency curve for stage IV indicates that the two groups of larger ova are indistincly separated from the immature stock ova. This indicates that the maturation process is continuous and hence this species may exhibit prolonged spawning. The partially spent stage shows one group of large ova in addition to the immature stock. This indicates that at least one batch of larger ova had already been spawned.

S. insidiator (Fig: 12): Stages I, II and III have been recorded in the present study. In stage I the size of ova ranges up to a maximum of 0.126 mm. In stage II the maximum size of ova reaches up to 0.189 mm. In stage III, in addition to the immature stock of ova, two groups of larger ova which are

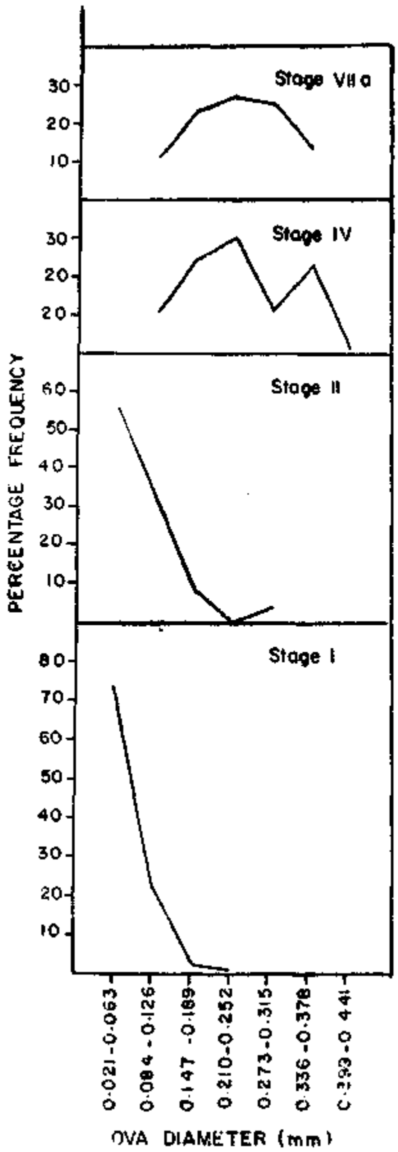

FIG. 11. Ova-diameter frequency polygons for various stages of maturity of *S. ruconius*.

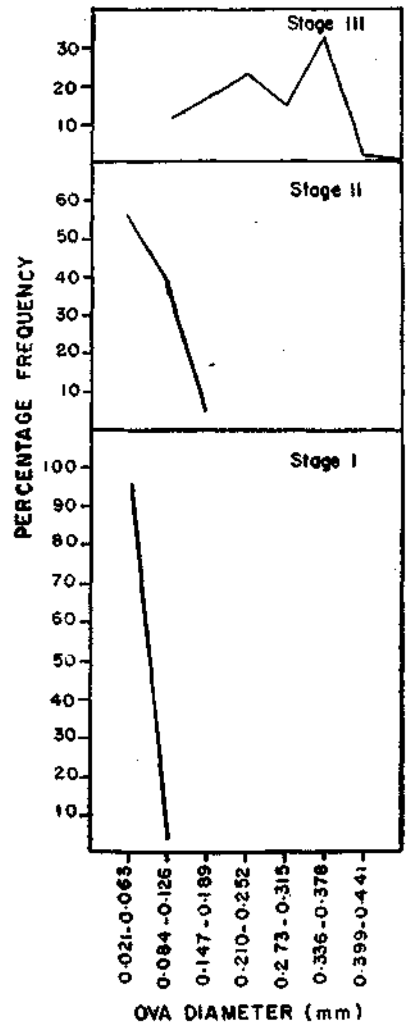

FIG. 12. Ova-diameter frequency polygons for various stages of maturity of *S. insidiator*.

indistinctly separated from one another and also from the immature stock of ova are present with modes at 0.231 and 0.357 mm. The maximum size of ova in this stage is 0.504 mm.

The ova-diameter-frequency curve of stage III indicates that the maturation process is continuous and hence this species is likely to spawn over a prolonged period.

Gazza minuta (Fig. 13): During the present study, stages I, III and VIIA were recorded. In stage I the ova range in size up to 0.126 mm. In stage III, in addition to the immature stock of ova, there are two groups of ova with modes at 0.168 mm and 0.357 mm. The maximum size ova in this stage is 0.441 mm. In stage VII A, in addition to the immature stock ova, a single group of larger ova is present with a mode at 0.231 mm. The maximum size of ova in this stage is 0.378 mm.

The ova-diameter-frequency curve in stage III indicates that the largest group of ova is followed by another smaller group of ova without any clear demarcation. Therefore, it is likely that this species spawns over a prolonged period.

G. achlamys (Fig. 14): Stages I, III, IV, VII A and VII B were recorded in the present study. In stage I the ova range in size up to 0.126 mm. In stage III, in addition to the immature stock ova, there are two groups of larger ova with modes at 0.231 and 0.357 mm, which are not distinctly separated from immature stock of ova. The maximum size of ova in this stage is 0.441 mm. In stage IV the modes of two larger groups of ova found in stage III progress further to show modes at 0.294 and 0.483 mm. The maximum size of ova in this stage is 0.567 mm. In stage VII A there are two modes of larger ova at 0.231 and 0.420 mm in addition to the immature stock of ova. The maximum size ova in this stage is 0.504 mm. In stage VII B, in addition to the immature stock of ova, there is a single group of large ova with a mode at 0.168 mm. The maximum size of ova in this stage is 0.315 mm.

The ova-diameter-frequency curve for stage IV indicates that the larger groups of ova are indistinctly separated from one another as well as from the immature stock of ova. The large ova have a wide size range. These two factors indicate that the maturation process is continuous and that the species is likely to spawn continuously over a prolonged period. The ova-diameter-frequency curves of partially spent and fully spent stages also indicate that the fish releases the ova in batches.

A summary of size range of ova mode of largest groups of ova in different stages of maturity for various species of leiognathids is given in Table 1.

TABLE 1. *Size ranges and modes (in parenthesis) of largest group of ova (mm) in different stages of maturity for various species of leiognathids.*

Sl. No.	Species	I	II	III	IV	V	VI	VIIA	VIIB
1	*Leiognathus fasciatus*	0.02-0.13	0.02-0.19	0.08-0.50 (0.29)	0.08-0.50 (0.42)	0.15-0.88 (0.67)	—	0.15-0.57 (0.42)	—
2	*L. equulus*	0.02-0.19	—	0.08-0.50 (0.36)	0.15-0.63 (0.42)	0.15-0.69 (0.48)	—	0.08-0.63 (0.42)	—
3	*L. smithursti*	0.02-0.13	—	—	—	0.15-0.57 (0.42)	—	—	—
4	*L. splendens*	0.02-0.13	0.08-0.38	—	0.08-0.44 (0.36)	0.21-0.63 (0.48)	0.21-0.82 (0.61)	—	—
5	*L. jonesi*	0.02-0.13	0.08-0.31	0.08-0.38 (0.29)	0.08-0.50 (0.36)	0.08-0.63 (0.55)	0.08-0.76 (0.61)	0.08-0.38 (0.29)	—
6	*L. dussumieri*	0.02-0.13	0.08-0.38	0.08-0.38 (0.29)	0.08-0.50 (0.42)	—	—	—	0.02-0.38
7	*L. bindus*	0.02-0.13	0.02-0.38	0.08-0.44 (0.36)	—	—	—	0.08-0.94 (0.67)	0.02-0.38 (0.29)
8	*L. daura*	0.08-0.13	—	0.08-0.38 (0.29)	0.08-0.44 (0.36)	0.08-0.69 (0.61)	—	—	0.08-0.38
9	*L. leuciscus*	0.02-0.13	0.02-0.31	0.08-0.38 (0.29)	—	0.08-0.50 (0.42)	—	0.08-0.44 (3.60)	0.02-0.44
10	*L. blochii*	0.02-0.13	—	0.08-0.38 (0.29)	—	—	—	—	0.02-0.31
11	*L. brevirostris*	0.02-0.13	0.02-0.27	0.08-0.44 (0.36)	0.08-0.57 (0.48)	0.08-0.76 (0.67)	—	—	0.02-0.38
12	*L. berbis*	0.02-0.13	0.02-0.31	0.08-0.50 (0.36)	—	—	0.08-0.69 (0.55)	0.08-0.38 (0.29)	—
13	*L. lineolatus*	0.02-0.13	0.02-0.25	—	—	—	—	0.08-0.44 (0.17)	0.02-0.25
14	*Secutor ruconius*	0.02-0.25	0.02-0.31	—	0.08-0.44 (0.36)	—	—	0.08-0.38 (0.23)	—
15	*S. insidiator*	0.02-0.13	0.02-0.19	0.08-0.50 (0.36)	—	—	—	—	—
16	*Gazza minuta*	0.02-0.13	—	0.08-0.44 (0.36)	—	—	—	0.02-0.38 (0.23)	—
17	*G. achlamys*	0.02-0.13	—	0.08-0.44 (0.36)	0.88-0.57 (0.48)	—	—	0.08-0.50 (0.42)	0.08-0.31 (0.17)

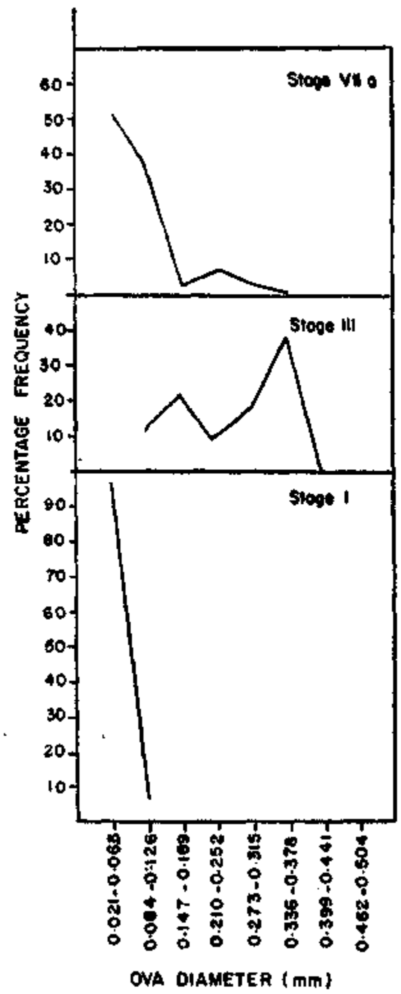

FIG. 13. Ova-diameter frequency polygons for various stages of maturity of *G. minuta*.

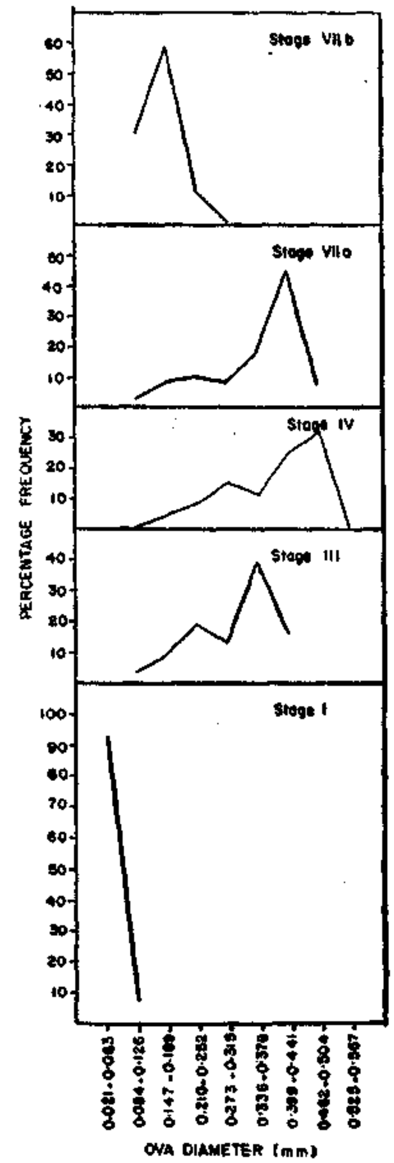

FIG. 14. Ova-diameter frequency polygons for various stages of maturity of *G. achlamys*.

Spawning Season

In this study inferences on spawning seasons of various species are drawn based on the occurence of press-spawning of spawning stages (only in a few cases), the occurence of partially spent and spent stages and the occurence of

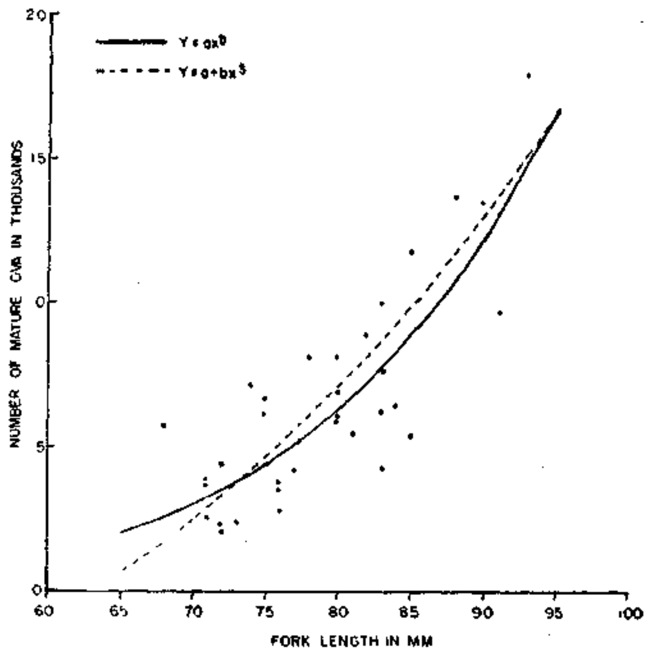

FIG. 15. Comparison of fecundity - length regression lines according to different formulae for *L. bindus*.

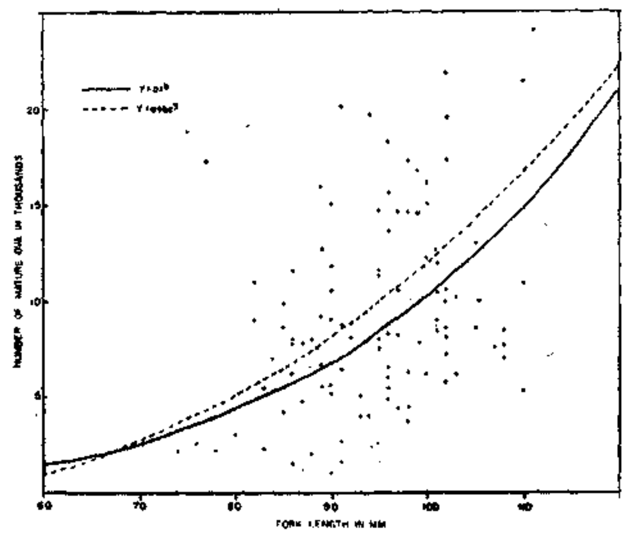

FIG. 16. Comparison of fecundity - length regression lines according to different formulae for *L. dussumieri*.

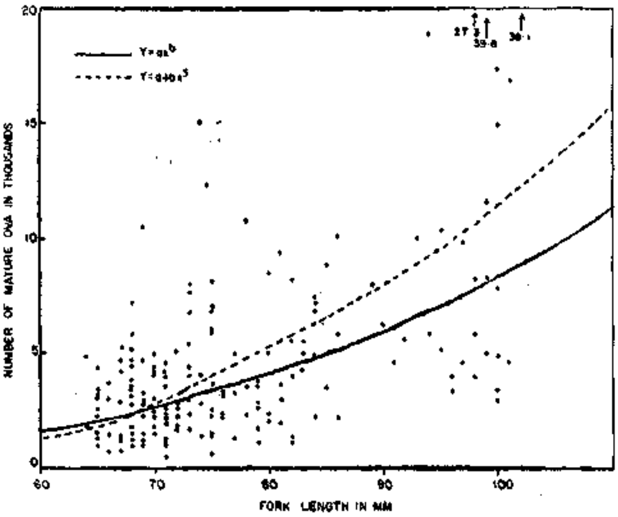

FIG. 17. Comparison of fecundity - length regression lines according to different formulae for *L. jonesi*.

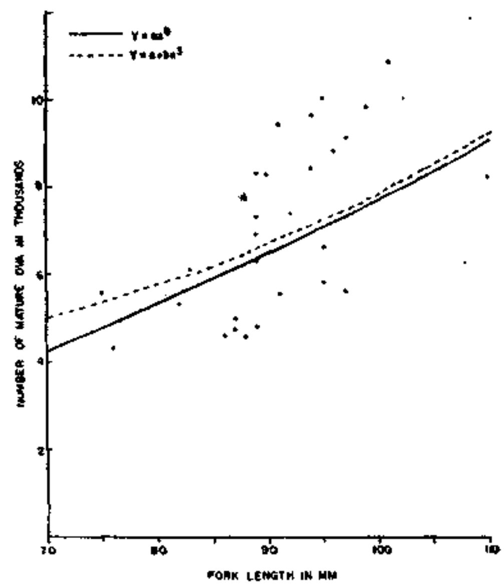

FIG. 18. Comparison of fecundity - length regression lines according to different formulae for *L. brevirostris*.

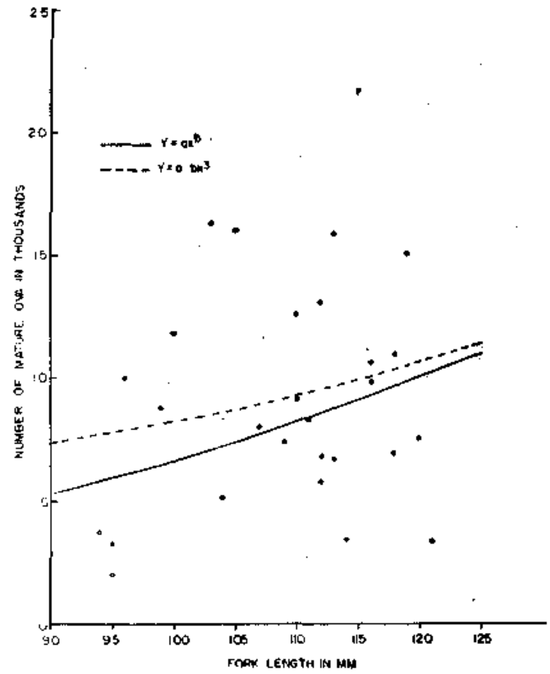

FIG. 19. Comparison of fecundity - length regression lines according to different formulae for *L. daura*.

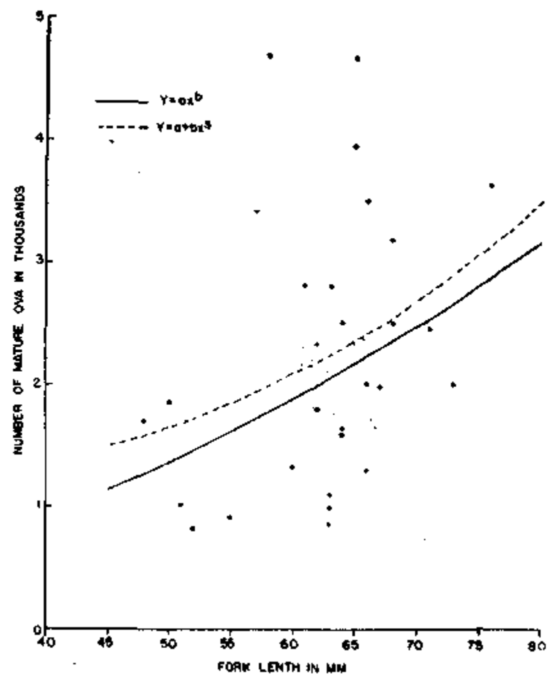

FIG. 20. Comparison of fecundity - length regression lines according to different formulae for *S. ruconius*.

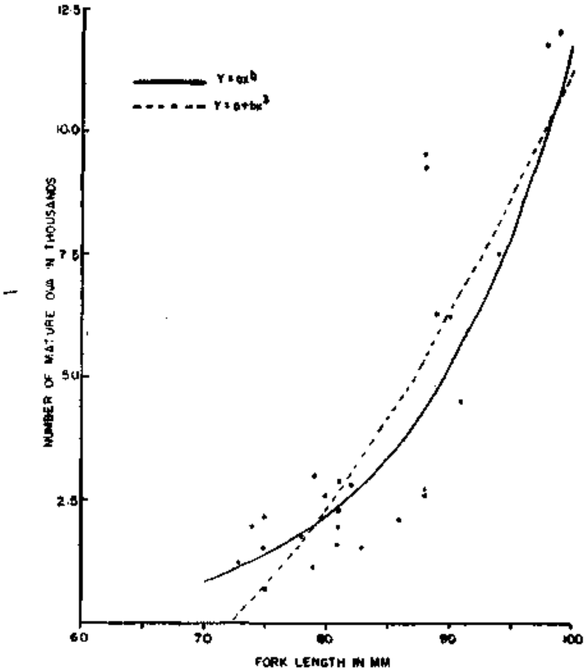

FIG. 21. Comparison of fecundity - length regression lines according to different formulae for *S. insidiator*.

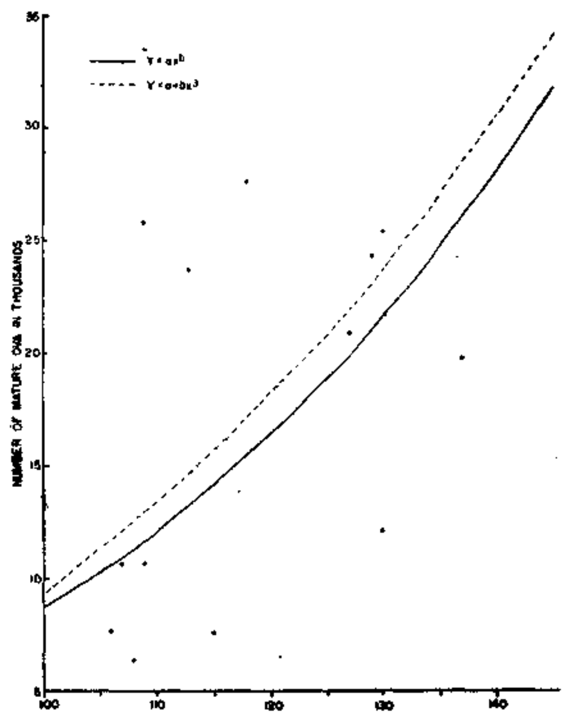

FIG. 22. Comparison of fecundity - length regression lines according to different formulae for *G. achlamys*.

juveniles in the commercial fish catches. These data for *L. brevirostris, L. jonesi* and *L. dussumieri* are drawn from earlier accounts published by the authors. The data indicate that, except for species which spawn throughout the year, the other species seem to spawn in March-April and November-December periods.

Fecundity

In Palk Bay and Gulf of Mannar 16 species of leiognathids occur, of these *Leiognathus jonesi, L. dussumieri, L. bindus* and *L. brevirostris* are the most common. Therefore, a large number of specimens of these species were available for studies on fecundity. In the case of the other species, very few specimens were analysed because of the non-availability of mature fish in the samples.

The snout-fork length measurements were taken to the nearest millimeter and the numuber of ova in the most advanced modal groups was calculated by multiplying the total weight of the ovaries by the number of ova counted in the sample and dividing by the total weight of sample. In all the 16 species of Leiognathids altogether 516 specimens were analysed.

The scatter diagrams of fecundity-length data for *Leiognathus bindus, L. dussumieri, L. jonesi, L. brevirostris, L. daura, Secutor ruconius, S. insidiator* and *Gazza achlamys* are presented in Figs. 15-22. The relationships were studied by using the formulae $Y = a \times {}^{b}$, $Y = a + bX^3$.

The sums, sums of squares and products for the equation $\log Y = a + b \operatorname{Log} X$ or $Y = a X^b$ for all 16 species are given in Table 2. The regression coefficients *a* and *b* values, standard error of estimate ($b \pm$) correlation coefficient (*r*) for the equations $Y = aX^b$ and $Y = a + bX^3$ are given in Tables 3 and 4 respectively.

TABLE 2. *Sums, sums of squares and products for Log length — Log. fecundity data for 16 species of Leiognathids.*

Species	No.	EX	EX^2	EY	EXY	EY^2
L. berbis	7	13.1594	24.7440	23.6813	44.5201	80.1942
L. jonesi	181	340.7851	642.2272	642.0092	1210.6971	2298.8108
L. bindus	40	75.8731	143.9697	150.8874	286.4951	571.6643
L. lineolatus	9	17.3100	33.3002	32.4824	62.4975	117.4084
L. splendens	8	15.6706	30.7139	30.0106	58.7839	112.7847
L. brevirostris	35	68.6095	134.5422	133.4948	261.7815	510.0191
L. leuciscus	5	9.8456	19.3885	17.3211	34.1009	60.1592
L. dussumieri	104	205.4515	406.0728	407.4241	805.6581	1606.0655
L. daura	28	57.0302	116.1885	109.4755	223.0457	429.6975
L. fasciatus	4	8.5624	18.3374	15.8328	33.9512	63.0945
L. smithursti	8	17.1635	36.8281	33.2453	71.3483	138.7256
L. equulus	7	15.3564	33.7203	32.1975	70.7581	148.8779
S. ruconius	28	50.2062	90.0873	92.4818	165.9405	306.8033
S. insidiator	26	49.9501	95.9963	90.4784	174.0806	317.5696
G. minuta	9	18.4324	37.7562	35.8293	73.4335	143.3033
G. achlamys	17	35.5391	74.3351	72.3350	151.3565	308.8795
Pooled	516	998.9451	1938.2076	1919.1866	3728.4466	7212.0564

TABLE 3. *Comparison of fecundity (Y) — length (X) relationship for the equation* $Y = aX^b$ *for 16 species of leiognathids.*

Species	Regression coefficients a	b	Std. error of estimate (b±)	Correlation coefficient (r)
L. berbis	—2.9953	0.2063	1.7112	0.05
L. jonesi	—2.5003	3.2119	0.3786	0.53
L. bindus	—6.8345	5.5918	0.6712	0.80
L. lineolatus	—2.4796	3.1657	1.4154	0.65
L. splendens	3.9286	—0.0905	1.3799	—0.03
L. brevirostris	—0.0010	1.9462	0.6407	0.47
L. leuciscus	13.2552	—4.9723	5.6550	—0.45
L. dussumieri	—3.7373	3.8749	0.5753	0.55
L. daura	—0.6700	2.2486	1.3998	0.30
L. fasciatus	—10.7700	6.8804	0.9758	0.98
L. smithursti	—6.1440	4.8007	4.0593	0.43
L. equulus	—3.9604	3.9020	0.5730	0.79
S. ruconius	0.1096	1.7809	0.8299	0.39
S. insidiator	—10.9566	7.5145	0.9724	0.85
G. minuta	—15.0101	9.2728	2.0580	0.66
G. achlamys	—3.0291	3.4843	1.0171	0.66

TABLE 4. *Comparison of fecundity (Y) — length (X) relationship for the equation* $= a+bX^3$ *for 16 species of leiognathids.*

Species	Regression coefficients a	b	Std. error of estimate (b±)	Correlation coefficient (r)
L. berbis	2539	—0.0001	0.0031	—0.02
L. jonesi	—1440	0.0130	0.0012	0.62
L. bindus	—6794	0.0272	0.0031	0.82
L. lineolatus	721	0.0059	0.0038	0.51
L. splendens	6331	—0.0003	0.0039	—0.03
L. brevirostris	3125	0.0048	0.0015	0.48
L. leuciscus	8830	—0.0070	0.0072	—0.49
L. dussumieri	—2082	0.0141	0.0024	0.50
L. daura	4987	0.0033	0.0033	0.20
L. fasciatus	—8268	0.0071	0.0014	0.96
L. smithursti	32	0.0060	0.0058	0.39
L. equulus	—0	0.1219	0.0082	0.83
S. ruconius	1075	0.0048	0.0027	0.32
S. insidiator	—6862	0.0182	0.0023	0.85
G. minuta	—2464	0.0241	0.0055	0.86
G. achlamys	—2717	0.0121	0.0039	0.63

For the formula $Y = bX^3$, the sums of squares and products are same as for the formula $Y = a + bX^3$ but the 'Y' intercept 'a' is forced to be zero and the slope 'b' is obtained by using the formula

$$b = \frac{\Sigma (X^3.y)}{\Sigma (X^3)^2}$$

The 'b' values for the following species with adequate number of samples (> 25) are as follows: *L. bindus* = 0.0146; *L. dussumieri* = 0.0119; *L. jonesi* = 0.0105; *L. brevirostris* 0.0085; *L. daura* = 0.0069; *S. ruconius* = 0.0087; *S. insidiator* = 0.0075. And for the other species where the sample size is small (< 25) 'b' values are as follows; *L. equulus* = 0.0119; *L. lineolatus* 0.0071; *L. splendess* = 0.0068; *L. smithursti* = 0.0060; *L. berbis* = 0.0053; *L. fasciatus* = 0.0043; *L. leuciscus* = 0.0038; *G. achlamys* = 0.0109; *G. minuta* = 0.0087.

The correlation coefficient (r) for the equation $Y = aX^b$ and $Y = a+bX^3$ presented in Tables 3 and 4 for 16 species shows slight difference for individual species but the 'r' values for the $Y = aX^b$ formula were better when considered for all species. For the species with lesser sample (<25) the 'r' value ranged from 0.98 to 0.05, and for two species negative correlations (—0.045 & —0.03), due to inadequate sampling and the condition of the ovary, were met with. For the species with good number of samples, the 'r' value ranged only between 0.85 to 0.30. The 'b' values (in the formula $Y = aX^b$) for 16 species were compared by 't' test for the possibility of significant differences from 3 and found only *L. bindus* and *S. insidiator* were significantly higher than 3 at 1% level. In all of the other 14 species, although 'b' values ranged from —4.9723 to 9.2728, they were not significantly different from 3, because of the high standard error of estimate ($b\pm$), which in turn reflected by the high fluctuation of fecundity on length.

Specieswise fecundity and length relationship for the equation $Y = aX^b$ were drawn in Fig. 23 for all the 16 species. The fecundity increased at a higher rate for the species *G. minuta*, *L. bindus* and *S. insidiator* and increased at a lower rate for the species *L. berbis*, *L. brevirostris*, *L. daura* and *S. ruconius*. The fecundity decreased on length for *L. leuciscus* and *L. splendens*.

Analysis of covariance tests were performed for 16 species and found to be significant at 5% level only. So a pooled common relationship was found as follows:

$$Y = 0.00745\, X^{3.0202}$$

The degrees of freedom, sum of squares and products and sum of squares required for covariance test are given in Table 5. Among the 16 species, 3 species

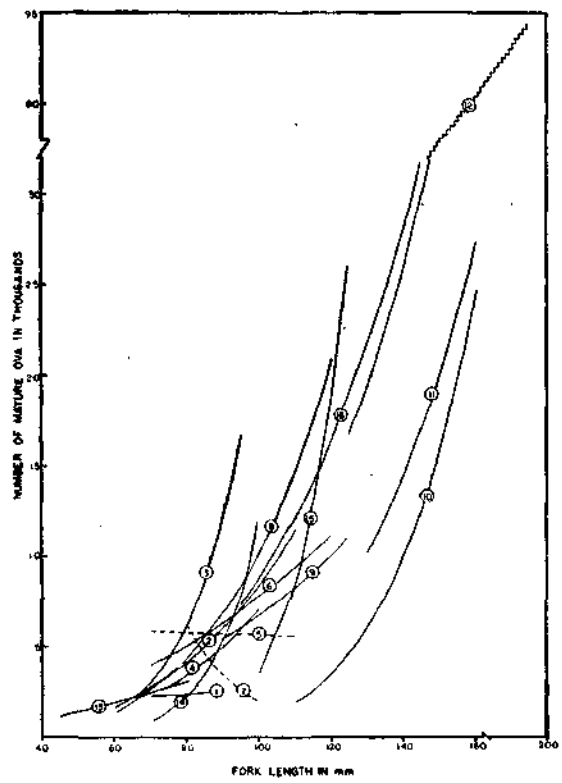

FIG. 23. Species-wise fecundity and length relationship for the equation $Y = X^b$ (Order of species as in Table 2).

viz., L. bindus, S. insidiator and *G. minuta* which have a higher rate of fecundity increase on length have a common relationship of $Y = 0.00252\ X^{3.2724}$. All the other 13 species do not show significant variation ($F = 1.31$, $5\% = 2.31$) at 5% level and the common relationship was found to be $Y = 0.00783\ X^{8.008}$.

The common relationship is depicted in Fig. 24 with mean length and mean fecundity for 16 species numbered in order. In leiognathids, fecundity on length is a cubic relation and in individual species the relation varies depending upon number of samples and the stage of maturity of the ovary.

Discussion

The maturation, fecundity and spawning habits of some species of silver-bellies have been described by earlier authors from different locations along the Indian coast. Brief details on these aspects are given by Arora (1951) for *L. splendens*, Balan (1963) for *L. bindus*, James and Badrudeen (1975) for *L.*

TABLE 5. *Analysis of variance for the 16 species of leiognathids.*

Species	Degrees of freedom	Sum of squares and products			Degrees of freedom	Sum of squares
		EX^2	EXY	EXY^2		
L. berbis	6	0.0054	0.0011	0.0792	5	0.0787
L. jonesi	180	0.6002	1.9278	21.5949	179	15.4029
L. bindus	39	0.0514	0.2876	2.4889	38	0.8804
L. lineolatus	8	0.0072	0.0229	0.1743	7	0.1016
L. splendens	7	0.0179	—0.0016	0.2052	6	0.2050
L. brevirostris	34	0.0491	0.0956	0.8516	33	0.6655
L. leuciscus	4	0.0013	—0.0064	0.1553	3	0.1235
L. dussumieri	103	0.2043	0.7917	9.9655	102	6.8977
L. daura	27	0.0297	0.0667	1.6661	26	1.5161
L. fasciatus	3	0.0086	0.0593	0.4247	2	0.0164
L. smithursti	7	0.0047	0.0224	0.5695	6	0.4618
L. equulus	6	0.0318	0.1240	0.7806	5	0.4837
S. ruconius	27	0.0637	0.1135	1.3432	26	1.1411
S. insidiator	25	0.0342	0.2573	2.7101	24	0.7770
G. minuta	8	0.0058	0.0534	0.6653	7	0.1707
G. achlamys	16	0.0396	0.1379	1.0943	15	0.6139
Total	500	1.1549	3.9532	44.7687	484	29.5360
					499	31.2370
Difference for testing among regression coefficients $F = 0.1134/0.0610 = 1.86$					15	1.7010

dussumieri, Mahadevan Pillai (1972) for *S. insidiator, S. ruconius, L. dussumieri* and *G. minuta* and Satyanarayana Rao (1968) for *L. splendens*, Chacko (1944 a & b) also mentioned the spawning seasons for silverbellies in general but specific details are lacking.

In the present study, the maturation, fecundity and spawning habits of 14 species of leiognathids have been studied. The present authors have studied the spawning habits of *L. brevirostris, L. dussumieri* and *L. jonesi* earlier. A summary of the size ranges of ova in different stages of maturity and the spawning habits of various species of leiognathids is given.

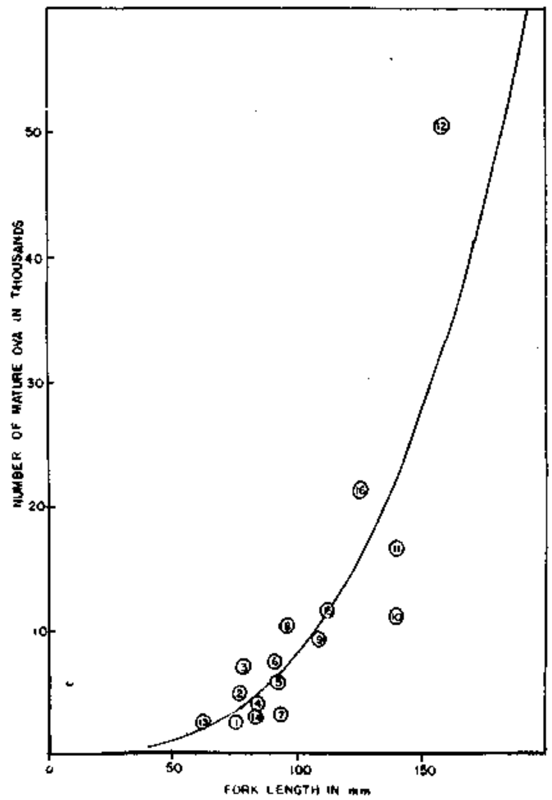

FIG. 24. Common relationship with mean length and mean fecundity for 16 species of leiognathids. (Order of species as in Table 2).

It may be seen that *L. fasciatus, L. bindus, L. leuciscus, L. blochii, L. berbis, L. lineolatus, S. ruconius, S. insidiator, G. minuta, G. achlamys, L. brevirostris* and *L. jonesi* spawn over a prolonged period. Within these species, *L. fasciatus, L. bindus, L. daura* and *L. berbis* spawn fractionally over a prolonged period. However, in the case of *L. daura* and *L. berbis* this fractional spawning at a time may be of a short duration. The species *L. equulus, L. smithursti,* and *L. splendens* spawn continuously for a short period. Of these three species, *L. splendens* appears to spawn in batches in quick succession. *L. dussumieri* seems to spawn for a short time twice in a year, in two distinct periods.

Since the identity of *L. splendens* reported by Arora (1951) is doubtful, it is not possible to compare his data with Satyanarayana Rao (1968) data for *L. splendens* and also the present observations for *L. splendens*. However, the observations of Satyanarayana Rao (1968) and those of the present authors regarding the spawning habits of *L. splendens* are in agreement. The conclusion drawn by Mahadevan Pillai (1972) on the spawning habits of *S. insidiator, S.*

ruconius and *L. dussumieri;* that these species have a prolonged spawning is coroborated by the present observations. However, Mahadevan Pillai stated that *G. minuta* has a restricted spawning period. This conclusion is also not supported by the ova-diameter-frequency curve given by him (Mahadevan Pillai 1972; Fig. 1) for this species since the curve clearly indicates a multiplicity of modes which implies continuous maturation and spawning. Further, the ova diameter frequency curves given by him for all the four species mentioned above are more or less similar. In the present study it has been found that *G. achlamys* spawns over a long period.

Balan (1963) found that *L. bindus* spawns from December to February. In the present study also this species has been found to spawn fractionally over a prolonged period.

As in the case of many species of fishes in the tropical region, majority of the species of leiognathids from the Indian region also appear to spawn over a prolonged period. Only a few species have been found to spawn for a short duration. Some of the species are also characteristic in spawning fractionally as has been found in a number of other marine fishes of the Indian region.

The 'b' value in the formula $Y = aX^b$ when tested was found to be significatly higher than 3 at 1% level in the case of *L. bindus* and *S. insidiator.* In all the other species, they were not significantly different from 3. Fecundity-length relationship indicated that fecundity increased at a higher rate for *G. minuta, S. insidiator* and *L. bindus.* It increased at a lower rate in *L. berbis, L. brevirostris, L. daura* and *S. ruconius.* Fecundity decreased with length for *L. leuciscus* and *L. splendens.* Analysis of covariance indicated that except for *G. minuta, S. insidiator* and *L. bindus* which show a higher rate of fecundity increase on length, all the other 13 species do not show significant variations at 5% level. In general, in leiognathids, fecundity on length is a cubic relation and in individual species the relation varies depending upon sample size and stage of maturity.

In a limited study of fecundity of silverbellies, Mahadevan Pillai (1972) observed that the number of eggs in *S. insidiator* ranged from 7252-15,700 with an average of 10,621. A fish 105 mm T.L. with an ovary weight of 500 mg was found to have 15,700 eggs. For *S. ruconius* the range in number of eggs was 3,563-11,563 with an average of 7,191. One fish, 87 mm T.L. with an ovary weight of 250 mg contained 11,563 eggs. *L. dussumieri* was found to have a variation of 5,397-32,528 in the number of eggs, the average being 14,299. The mature ovaries of *G. minuta* contained 7,950-28,432 eggs with an average of 13,526 eggs. One mature fish, 130 mm T.L., with an ovary weight of 1,150 g was estimated to contain 28,432 eggs. These observations, however, differ considerably from the present observations for the four species mentioned. This may be attributed to differences in sample size.

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