MATURITY, SPAWNING AND FECUNDITY OF THE SPOTTED SEER, *SCOMBEROMORUS GUTTATUS*, IN THE GULF OF MANNAR AND PALK BAY

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ABSTRACT

The ovary of spotted seer passes through 10 finer maturity stages, A to J, besides a partly spent stage (S) and a quick transitory stage (G') between stages G and H. There is only one batch of maturing ova in B to F stage ovaries, whereas G to I stage ovaries possess two batches. In all, 2.23 batches of ova are spawned each season, 1 (first), 0.23 (second) and 1 (third) at stages H, I and J, respectively. Stage C takes 90 days to attain stage G and 112 days to attain stage H. After spawning the first batch at stage H, the ovary assumes stage S. which resembles stage D. and takes 92 days to attain stage J for spawning the third batch. Each adult female thus takes about 204 days to complete the spawning process. Gonad indices above the value of about 7 to 8 represent maturing ovaries, whereas those below this value represent immature or intermediate ovaries. First maturity is attained when the fish is about 400 mm in total length, i.e., when the age is about 20 months. Spawning extends from January to August, releasing a weak brood in January-February, a strong brood in March-July (peak in April-May) and another weak brood in August. Spawning takes place in areas between 20 m and 60 m depth in the northern Gulf of Mannar. The spent adults migrate to the central Gulf of Mannar coast by November-December. Spawning takes place around the full-moon period. Females far outnumber (60.2%) males (39.5%). Although the males are predominant in size groups between 361 mm and 481 mm, they are scarce or absent in size groups larger than 481 mm, suggesting early senility and death. No real difference in fecundity is observed among stages D, E, F and G. The increase in egg number per 10 mm body length is 34,082, and the fecundity per every ton of spawning female is 359.8 million.

INTRODUCTION

Information on the breeding biology of the spotted seer, *Scomberomorus guttatus*, is scanty, confining mostly to discriptions of eggs and larvae or maturity stages. Observations on the breeding biology of this fish made during July 1967 to July 1969 from the Gulf of Mannar and Palk Bay are dealt with here.

MATERIAL AND METHODS

The study is based on 661 fish sampled from the commercial drift-gillnet catches from the Gulf of Mannar and Palk Bay landed in the Rameswaram

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Island during July 1967 to July 1969. The methods described in Devaraj (1983) for the king seer have been followed in the present study.

RESULTS AND DISCUSSION

Maturity Stages of Ovary — Gross Examination

(i) *Immature ovary*: The ovary is thin, meat-coloured, and extends anteriorly to about $\frac{1}{2}$ to $\frac{3}{4}$ the length of the visceral cavity. The ova are transparent, mostly spherical and measure up to 5 or 6 m.d. (1 m.d. = 0.0167 mm). Fish less than 300 mm in total length were immature and occurred almost throughout the year.

ii) *Intermediate ovary*: The spent-recovering ovary is somewhat baggy and larger than the developing ovary of virgin fish. The ovary occupies nearly 1/8 body cavity. Ova of size 6 to 10 m.d. are more abundant, and those larger than 7 m.d. assume a light yellow tinge as a result of yolk formation. The nucleus is large and vesicular. Intermediate fish were more abundant during the period September-December.

(iii) *Maturing ovary*: The orange-yellow ovary fills up nearly $\frac{1}{4}$ to $\frac{1}{2}$ body cavity. The maturing ova are opaque and thick-walled (zona radiata). The most mature group of ova forms a mode at 8-16 m.d. at the beginning of maturity. As maturity advances, the mode shifts to 12-32 m.d. and then to 34-48 m.d., when the ova are distinctly visible through the glossy surface of the ovisac, and develop a translucent periphery between the zona radiata and the yolk mass, i.e., just before the ovary becomes ripe. Maturing fish were most common during March-May.

(iv) *Ripe ovary*: The ovary assumes a massive size and fills up more than $\frac{3}{4}$ body cavity. It presents a speckled glassy appearance, the large, free, translucent ripe ova showing through the very thin ovisac. The ripe ova, 50 to 80 m.d., possess each an yellowish brown oil globule about 20 m.d. and an inner fertilization membrane, besides the zona radiata. Ripe fish occurred during the period February to July with peak during April and May.

(v) *Spent ovary*: The ovary is shrunken and bloodshot. Spent fish ccurred during February to October with peak from May to August.

Maturing Stages of Testis — Gross Examination

(i) *Immature testis*: The testis is dull grey, streak-like, 65-95 mm long, 1-3 mm wide and 0.5-2.2 g weight. It tapers bluntly at the anterior, and extends to less than half of the visceral cavity, unlike that in the king seer. Fish less than 300 mm TL were normally immature. They occurred almost throughout the year.

(ii) *Intermediate testis*: The testis is dull white and about 70-100 mm in length, 2-5 mm in width and 1.5-3.0 g in weight. This stage occurred throughout the year except during May and June.

(iii) *Maturing testis*: The testis occupies about ¼ body cavity, creamy white in colour and measures 75-100 mm in length, 5-10 mm in width and 3.0-11.4 g weight. This stage was abundant during January-May.

(iv) *Ripe testis*: The ripe testis fills ¼ to less than ½ body cavity, is milky white, milts profusely at gentle pressure and measures nearly the same length as at the preceding stage, but increases in width (5-15 mm) and weight (3.6-36.0 g). Ripe males occurred during March to May.

(v) *Spent testis*: The shrunken testis is of a dull sandal or light reddish tinge. The weight of testis is considerably reduced (2.3-17.0 g). Fully spent males occurred during July and August. The pooled monthly distribution of gross maturinty stages seen in males and females is indicated in Fig. 1.

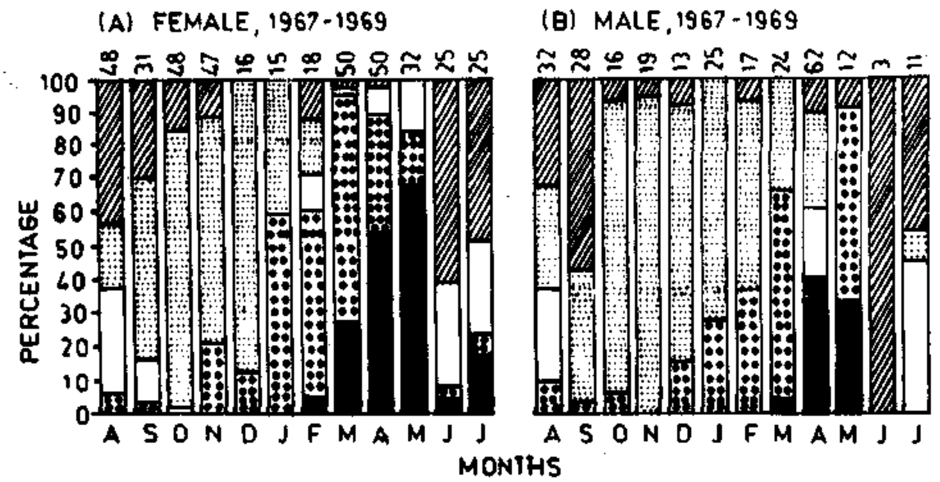


FIG. 1. Percentages of fish in different maturity stager during successive months; numerals denote the number of fish n the samples.

Frequency Distribution of Ova Diameter

According to the position of modes of the most mature and preceding groups of ova in the ova-diameter-frequency polygons, 10 arbitrary stages, designated serially from A to J (Figs. 2 & 3), were recognised in the maturation of females, besides the partly spent ovaries designated as S (Fig. 4) and a controversial stage denoted as G' (Fig. 5) which do not fit into the sequence of stages indicated in Figs. 2 & 3.

(i) *Immature* (*Stage A*): Mode of the immature ova between 2 and 5 m.d. (0.0334 and 0.0835 mm); no ova beyond 15 m.d. (0.2505 mm).

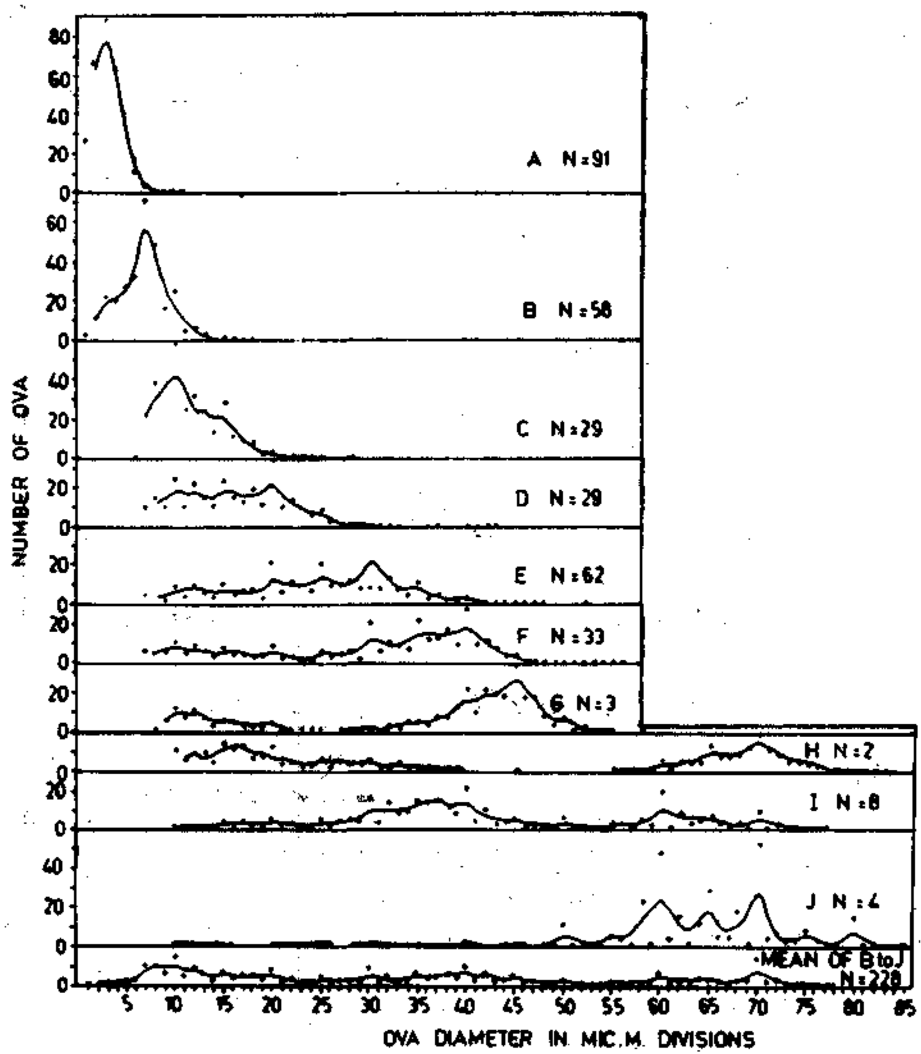


FIG 2. Scatter diagram of ova-diameter-frequency polgons for successive stages from A to J; the lines represent the values smoothed by the formula

(ii) *Intermediate* (*Stage B*): Mode of the most mature group of ova between 5 and 10 m.d. (0.0835 and 0.1670 mm); normally no ova beyond 18 m.d. (0.3006 mm), but rarely up to 23 m.d. (0.3841 mm).

(iii) *Maturing* (*Stages C-G*): *Stage C*: Mode of the most mature group of ova between 7 and 12 m.d. (0.1169 and 0.2004 mm), overlapping stage B; no ova beyond 28 m.d. (0.4675 mm).

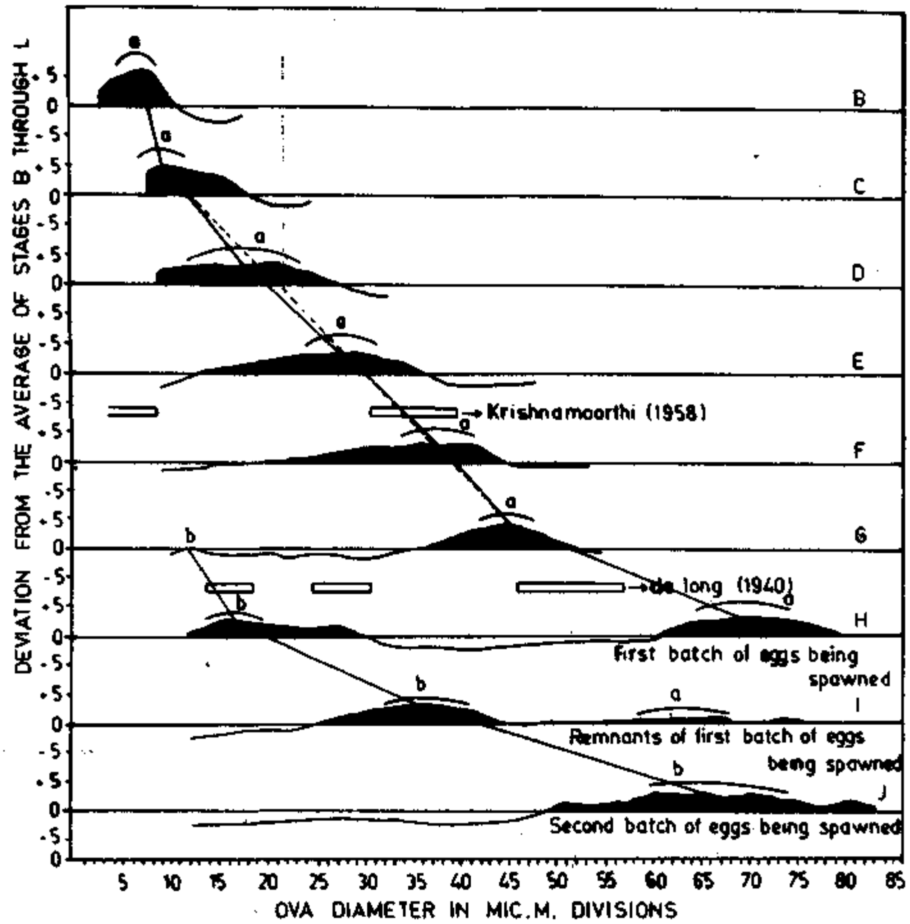


FIG. 3. Standard deviations (i.e., the square root of variance from the mean) from the average frequency polygon of stages B to J; the standard deviations are smoothed twice by a running average of three to remove chance fluctuations.

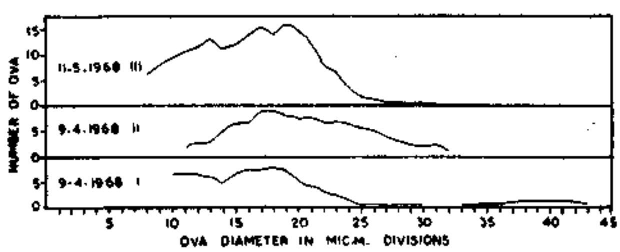


FIG. 4. Ova diameter frequency polygons for three fish after spawning their first batch of eggs.

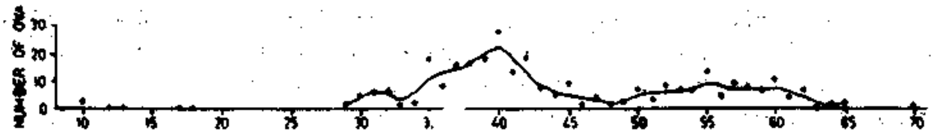


FIG. 5. Ova diameter frequency polygon for a stage G' (transient stage) fish; the line represents the values smoothed by the formula

Stage D: Mode of the most mature group of ova between 12 and 24 m.d. (0.2004 and 0.4008 mm), less sharp; no ova beyond 43 m.d. (0.7181 mm).

Stage E: Mode of the most mature group of ova between 24 and 32 m.d. (0.4008 and 0.5344 mm), less sharp with long ascending limb; no ova beyond 52 m.d. (0.8684 mm).

Stage F: Mode of the most mature group of ova between 34 and 42 m.d. (0.5678 and 0.7014 mm), less sharp with long ascending limb; no ova beyond 56 m.d. (0.9352 mm); ova larger than 50 m.d. begin to be translucent.

Stage G: Mode of the most mature group of ova between 42 and 48 m.d. (0.7014 and 0.8016 mm), sharp with symmetrical limbs; no ova beyond 58 m.d. (0.9686 mm). Preceding mode between 11 and 13 m.d. (0.1837 and 0.2171 mm), insignificant.

(iv) *Ripe* (*Stages H-J*): *Stage H*: Mode of the most mature group of ova between 64 and 74 m.d. (1.0688 and 1.2358 mm), dominant; no ova beyond 85 m.d. (1.4195 mm); preceding mode between 14 and 20 m.d. (0.2338 and 0.3340 mm).

Stage I: Mode of the most mature group of ova between 58 and 68 m.d. (0.9686 and 1.1356 mm), rather insignificant and appears to be caused by the remnants of first batch of ripe ova that were spawned since the previous stage; no ova beyond 11 m.d. (1.2859 mm); preceding mode between 32 and 41 m.d. (0.5344 and 0.6847 mm), dominant with long ascending limb.

Stage J: Mode of the only batch of ova between 58 and 74 m.d. (0.9686 and 1.2358 mm); no ova beyond 85 m.d. (1.4195 mm); distinguishable from stage H or I by the absence of a preceding mode.

(v) *Partly spent* (*Stage S*): Characterized by collapsed, shrunken and bloodshot appearance; ova-size-frequency distribution unimodal or bimodal; if unimodal, mode at 14-21 m.d. (0.2338-0.3507 mm), if bimodal, one prominent mode of size as above and the other significant mode at 37-42 m.d. (0.6179-0.7014 mm), supposedly succeeding stage H after the complete extrusion of the ripe ova; distinguishable from stage D by the external appearance of ovary (Fig. 4).

(vi) *Controversial case* (*Stage G'*): The ova-size-frequency distribution of the only ovary in stage G', taken on the 29th April 1969, did not fit into the sequence of maturity stages shown in Fgs. 2 & 3. Mode of the most mature group of ova between 52 and 58 m.d. (0.8684 and 0.9686 mm) slightly less prominent than the sharp preceding mode between 37 and 42 m.d. (0.6179 and 0.7014 mm); no ova beyond 70 m.d. (1.1690 mm); position of advanced mode intermediate between that of G and H, and hence designated G', but origin and fate of preceding mode not traceable with reference to stages illustrated in Figs 2 & 3; gonad index (G.I.) highest (68.5), much higher than that of subsequent stages, and, hence, no eggs lost yet, either due to spawning or handling (Fig. 5). The pooled monthly frequency distribution of the finer maturity stages, A to J, is illustrated in Fig. 6.

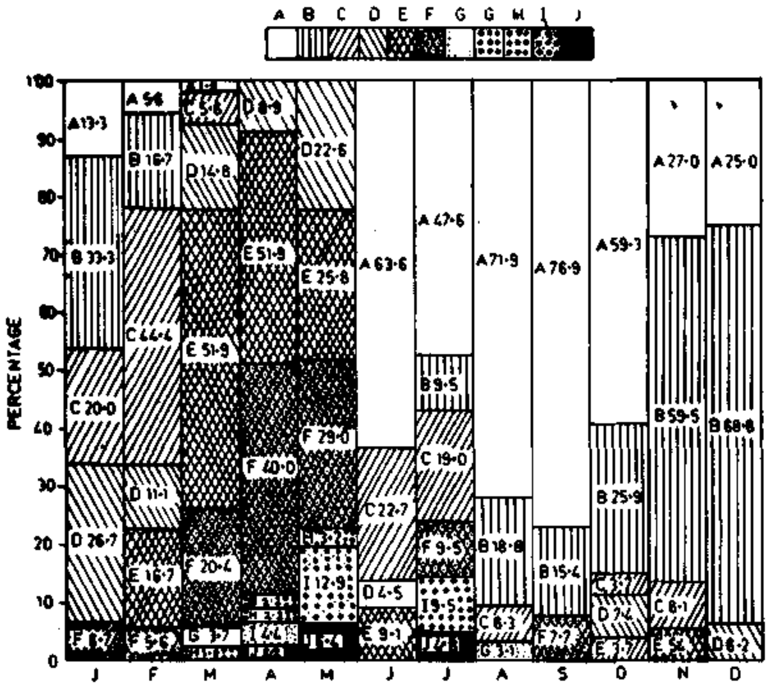


FIG. 6. Percentage of maturity stages A to J during successive months based on the pooled data for the period August, 1967 through May, 1969.

Gonad Index (*G.I.*)

During the quarter October-December (Fig. 7D), 87% of fish were in immature or resting stage. The straight line at the bottom of Fig. 7D is a regression line of G.I. on fish length (L),

$$G.I. = 3.8056 + 0.0023\,L \qquad \text{.............. (1)}$$

based on the data for 74 females in immature or resting stage (this excludes one G.I. value of 37.4). The upper line is 3 standard errors (3 x 0.598 = 1.794) above this regression line, and is reproduced in all other sections (A, B and C) of the same figure, for, according to Orange (1961), all gonad indices below this line correspond to immature or resting stages, and those above it

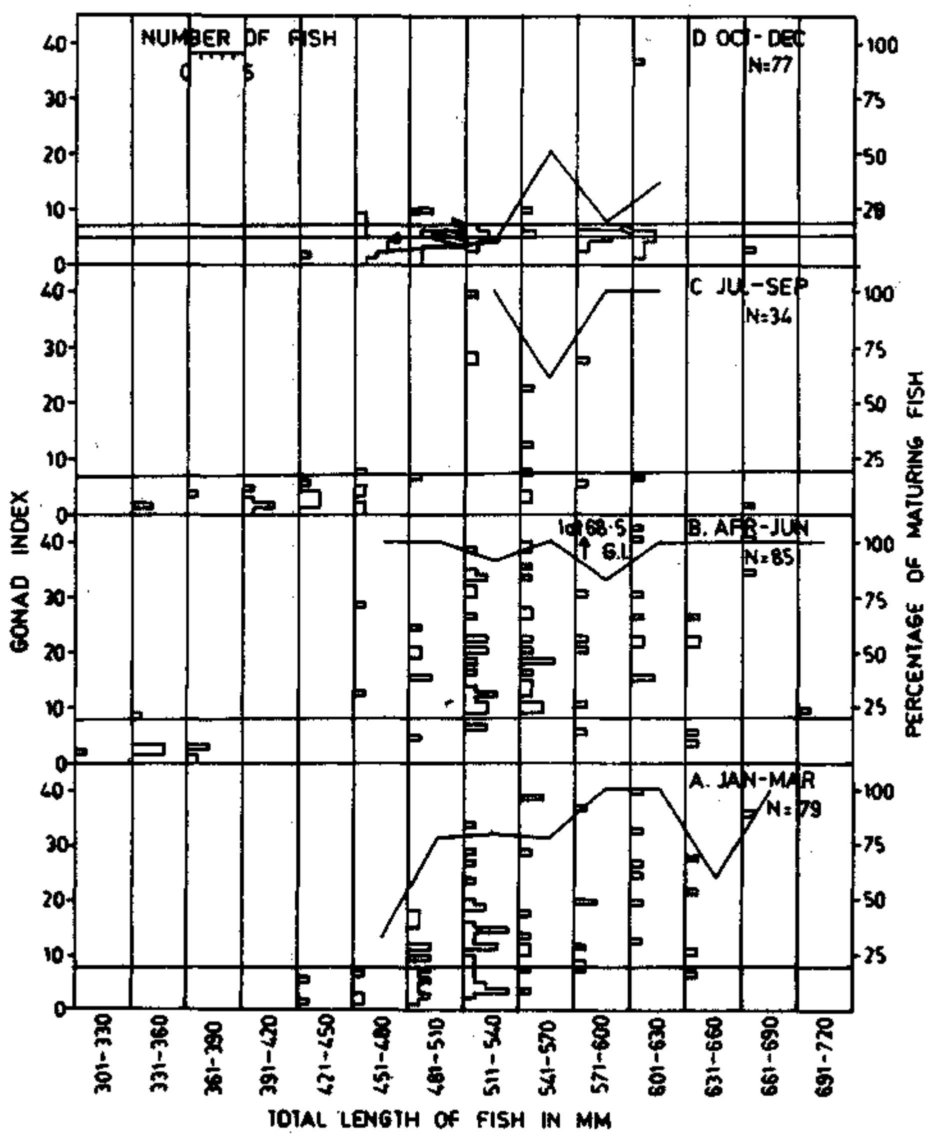


FIG. 7. Relation between total length of fish and gonad index for the four annual quarters based on the pooled data for the period August, 1967 through May, 1969.

to the maturing ovaries. The G.I. values along the course of this line range from 7 at the 301-330 mm group to 8 at the 691-720 mm group.

In order to help determine the maturity stage with reference to the G.I. alone, the relation between the variables gonad indices (x) and maximum ova diameters, or m.o.d. (y), is shown in Fig. 8, in which all the scatter values except those for the ripe stages (H, I and J) conform to a parabola, and, hence, the following second degree curve was fitted to the data comprising fish of maturity stages A to G,

$$y = -0.0148 \times^2 + 1.9043 \times + 4.9582 \quad \ldots\ldots\ldots\ldots (2)$$

The G.I. reached the maximum value of 68.5 only for the controversial G' stage. In spite of the exclusion of this stage from the data used for fitting the above equation, the fitted curve passes very close to the value for G' in Fig. 8. From stage H onwards, despite the considerable increase in the size of the ova within the most mature group, the G.I. falls back to a level characteristic of D to G stage ovaries, apparently because of egg loss due to spawning or handling. It is the newly developing secondary batch of eggs that compensate for the partial loss of ripe eggs at stage H and near-total loss at stage I so that their G.I. is maintained at a level not lower than that of stage D. The G.I. at stage J is naturally more variable as it is accounted for mostly by the ripe eggs (Fig. 8). Therefore, stage G', at which the G.I. reaches the peak just before the decline during H, I and J, seems to be a quick transitory stage between G and H, and the two closely situated modes of G' are likely to merge together in order to form a single batch of ripe eggs (a) at stage H, apparently an adaptive device to mature as many eggs as possible for the ensuing spawning.

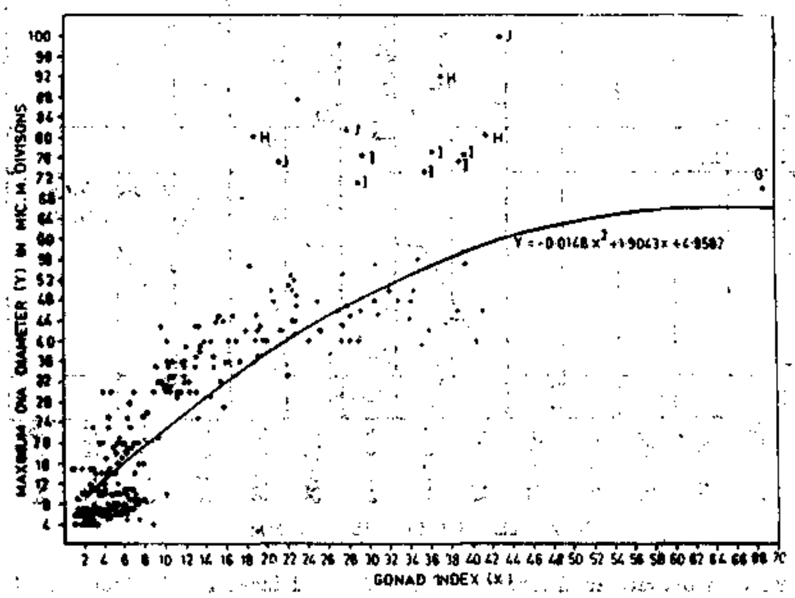


FIG. 8. Relation between gonad index and maximum ova diameter.

Size at First Maturity

The first length group in which the G.I. increased to a value above the line separating the maturing and resting fish is 331-360 mm (or 345 mm) (Fig. 7). But it was only in the 451-480 mm (or 465 mm) group and beyond that most of the fish were in maturing stages in all but the last quarter, and, hence, the length at first maturity may be taken as the average of 345 mm and 465 mm, i.e., 405 mm, when the fish is about 20 months old (Devaraj 1981). The minimum size at first maturity computed by inserting $\underline{y} = 0$ in equations (6), (7), (14) and (15) for the relation between fecundity ($\underline{y}$) and fish length (x) is 399 mm, 399 mm, 394 mm and 398 mm, respectively. The average of these four values, 398 mm, is considered the minimum size at first maturity, when the fish is about 20 months old.

Spawning

Multiplicity of modes: The multiplicity of modes in the frequency distribution of ova diameter for the advanced-maturing and ripe ovaries suggests that individual spotted seer spawns more than once each spawning season. The following of the spawning season (January to July, when 36.3-100% of the F to J stage ovaries were met with) by a distinct postspawning period (August to December, when only 6.2-14.8% C to E stages occurred) suggests that the secondary modes of ova are spawned in the same season. In the ova-diameter-frequency polygon for *S. guttatus* from the Java sea given by de Jong (1940) there are three modes of maturing ova which would be spawned successively at stages corresponding to H, I and J of the present study (Fig. 3). The ova-size-frequency polygon for the spotted seer from the present study areas given by Krishnamoorthy (1958) corresponds to that of stage F (Fig. 3).

Growth of successive egg groups: Up to stage D, the ascending limb of the mode of maturing ova remains undefined from the immature category owing to continuous addition of maturing ova from the immature stock. The ascending limb progressively demarcates itself from the immature group through stages E and F, until the mode attains a perfect symmetry at stage G. This suggests a progressive decrease in the addition of ova from the immature to the mature stock through the successive stages from A to G. The development of a secondary batch of eggs (b) first becomes evident at stage G, at which the primary batch (a) is fully defined. After stage G, the ovary enters the ripe phase. The reduction in number of ripe ova at stage I due to spawning the primary batch during the course of transformation of stage H into stage I, the simultaneous increase in the size and number of ova of the secondary batch (b) of stage I and the absence of a secondary mode at stage J, whose only batch of ripe ova results apparently from the growth of mode b of stage I, indicate that the secondary batch of ova is spawned in a subsequent spawning in the same season.

The high correlation ($r = 0.9041$) between the progressions of modes of the most mature (x) and preceding (y) batches of ova of G and H stages described by (Fig. 9)

$$y = 0.92 + 0.2105\,x \qquad \ldots\ldots\ldots\ldots \quad (3)$$

demonstrates a close relation between the progressions of the two modes. The value of the slope of this line (0.2105) indicates that until the largest group of eggs reaches stage H, the preceding batch increases in size at a rate of about ¼ the rate of increase in size of the most mature batch. Stage H leads either directly to stage I or through an intermediate stage S. The secondary batch of eggs is spawned at stage J. The regression of the preceding mode (y) on the most mature mode (x) in respect of the bimodal S and I stages is fitted by

$$y = -6.9920 + 0.9920 + 0.6787\,x \qquad \ldots\ldots\ldots\ldots \quad (4)$$

where the correlation coefficient is high ($r = 0.7417$). The regression coefficient (0.6787) indicates that the growth rate of the preceding mode from stage S to I is more than half that of the advanced mode. This quickening of growth of the preceding mode when compared to the growth from G to H seems to be the consequence of spawning of the first batch at H. Changes in the rates of growth are also evident from the trend lines fitted in Fig. 3.

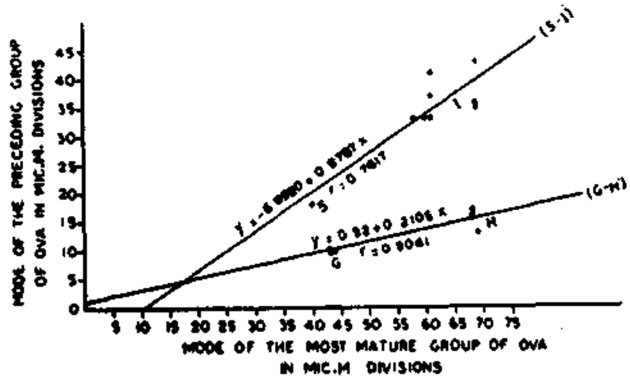


FIG. 9. Scatter diagram showing the relation between succeeding modes in the ova diameter frequency polygons for 16 fish; one regression line for stages G-H and another for S-I.

Growth of primary and secondary batch through time: The modal points in the ova-size-frequency curves of each of G, H, I, J and S stage ovaries were determined by smoothening the data by a running average of five, and represented by the symbol X in Fig. 10 against the dates on which these ovaries were sampled. The modal positions are distributed in three distinct size groups or stages—(1) between 10 and 19 m.d. or clearly maturing, (2) between 33 and 44 m.d.

or advanced maturing and (3) between 58 and 69 m.d. or ripe. For the ovaries with a bimodal distribution of ova, the two modes (indicated by X) are enclosed (1) in dotted circles and connected each other by dotted lines, or (2) in closed circles and connected by continuous lines, or (3) in squares and connected by dashed lines, or (4) left free and connected by continuous lines. All the ovaries included in any one of these four categories are considered homogeneous with regard to the dates on which maturity began to set in, and, by the arrangement of their modes in Fig. 10, the progressive sequence in the growth of the ova right from the attainment of bimodality at stage G or from any other subsequent stage to final spawning at stage J could easily be traced for each of the four categories. The guiding factor for fitting the arrow lines (Fig. 10) indicating the probable course of growth of the ova is the regression coefficients of Eqs. (3) and (4), which indicate that the growth of the preceding mode may take place at 0.2105 and 0.6787 times the growth of the advanced mode from stage G to H and S to I, respectively. For example, if the batch of stage G ovaries occurring on 8th March is presumed to have given rise to the stage H ovaries of 26th March, the advanced mode has grown by 24 m.d. in 18 days, during which the preceding mode has gained only 7 m.d., which is $0.29 = \left(\frac{7}{24}\right)$ times the growth of the former, and, therefore, in conformity with the relative growth of the two batches as revealed by a slope of 0.2105 in Eq. (3).

The preceding modes of stage G (10 m.d.) and H (17 m.d.) resemble the unimodes of C and D respectively. Therefore, the number of days involved in the growth from C to D should be the same as that between G and H (18 days). The continuous line connecting the modal points of all stages between C and G does not deviate significantly from the dashed line connecting the modal point of stage C directly with that of G, indicating uniform growth rate from C to G (Fig. 3). Therefore, at the rate of 7 m.d. per 18 days, stage C ovaries with the modal point at 10 m.d. would take 90 days to gain a growth of 35 m.d. in order to attain stage G, at which the modal point is 45 m.d. The monthly growth of the secondary modes ranged from 8.71 m.d. to 15.00 m.d., resulting in a mean monthly growth of 11.79 m.d. On this basis, the time involved in the transformation of stage C to G is estimated to be 89 days (Table 1), which confirms the first estimate beyond doubt. The monthly growth of the advanced modes ranged from 18.75 to 40.00 m.d. and the mean monthly growth was 26.00 m.d. (Table 1), which is 2.2 times $\left(\frac{26}{11.79}\right)$ the mean monthly growth of ova from stage C (mode 10 m.d.) to G (mode 45 m.d.).

The period taken for the transformation of successive stages between stages C and H, which involves a total of 112 days, is given in Table 2. After spawning the primary batch at stage H, the ovary assumes stage S; in other

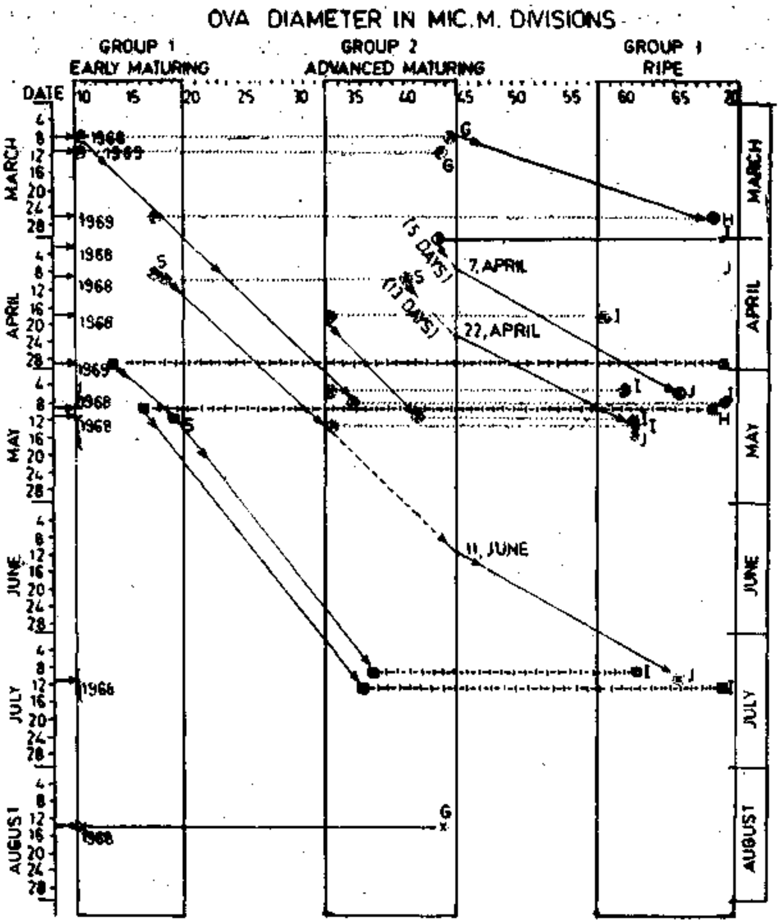


FIG. 10. Growth of ova (as represented by the progression of modes in the ova diameter frequency polygons for stages G to J) in relation to time.

words, its conditions (with reference to the preceding mode) would revert back to one resembling stage D, which would take another 92 days to attain stage J for spawning the secondary batch. In the meantime, any late-maturing ova of the primary mode, of remnants of ripe ova of H, are spawned at stage I. Thus, each female expends an average of 204 days to complete the whole spawning process involving two major spawning acts and an intervening minor spawning.

Remnants of ova from previous spawning: None of the eggs within mode a' of stage I showed any symptom of disintegration, and, therefore, they are likely to be spawned either as a separate batch or as a continuation of the previous batch before the commencement of the spawning of the secondary batch. Clark (1925, 1929) demonstrated multiplicity of spawning in the grunion and the

TABLE 1. *Duration of growth of modal positions in the secondary and primary batches of ova through sucessive maturity stages.*

S. No.	Date	Nature of mode	Modal position (m.d.)	Maturity group	Increment (m.d.)	Period involved (days)	Growth per month (m.d.)
A. Growth within group I and from group I to group II ova.							
1.	8, Mar. to	Secondary mode of stage G	10	I	7	18	11.67
	26, Mar	Secondary mode of stage H	17	I			
2.	26, Mar to	Secondary mode of stage H	17	I	18	44	12.27
	9, May	Secondary mode of stage I	35	II			
3.	9 Apr. to	Secondary mode of stage S	18	I	15	32	14.06
	11, May	Secondary mode of stage I	33	II			
4.	29, Apr. to	Secondary mode of stage H	13	I	6	12	15.00
	11, May	Unimode (secondary of stage S)	19	I			
5.	11, May to	Secondary mode of stage S	19	I	18	60	9.00
	11, Jul.	Secondary mode of stage I	37	II			
6.	9, May to	Secondary mode of stage H	16	I	18	62	8.71
	11, Jul.	Secondary mode of stage I	36	II	Mean growth per month		11.79
B. Growth from group II to III ova							
1.	8, Mar. to	Primary mode of stage G	44	II	24	18	40.00
	26, Mar.	Primary mode of stage H	68	III			
2.	7, Apr. to	Secondary mode of stage I	45(e.v.)	II	20	32	18.75
	9, May	Unimode of stage J	65	III			
3.	22, Apr. to	Primary mode of stage S (remnants)	45(e.v.)	II	16	19	25.26
	11, May	Primary mode of stage I (remnants)	61	III			
4.	11, Jun. to	Secondary mode of stage I	45(e.v.)	II	20	30	20.00
	11, Jul.	Unimode of stage J	65	III	Mean growth per month		26.00

TABLE 2. *Period involved in the transformation of one stage to the other from C to H, (rate of growth* 11.79 *m.d. per month from C to G, and* 26.00 *m.d. per month from stage G to H*).

Stage	Modal point (m.d.)	Difference between succeeding stages (m.d.)	Period involved for growth to succeeding stages (days)
C	10	8	20.35
D	18		
E	28	10	25.45
F	38	10	25.45
G	45	7	17.81
H	65	20	23.08
Total No. of days for growth from C to H			112.14 (3 months and 22.14 days)

jack smelt based on the presence of a few ripe ova in the oviduct, besides a second lot of ripening eggs in the ovary. Multiplicity of spawning in the California sardine was suggested by the degenerating mature ova and the second batch of maturing ova existing side by side (Clark 1934).

Relative number of eggs in each group: The lower size limit of ova included in the smaller yolked ova is 15 m.d. Although the ratios of the number of all smaller yolked ova to the number of ova in the most advanced mode range from 0.1 to 2.0, most of the values are centred between 0.1 and 0.6. The mean ratios for stages D, E, F and G are 0.46, 0.49, 0.46 and 0.23, respectively. The great similarity in the values for stages D, E and F is clear proof that no additional ova were being added to the group of smaller yolked ova while the advanced mode was developing from stage D to F. The reduction of the ratio to 0.23 at stage G may suggest rapid growth of about half of the smaller yolked ova of stage F and their incorporation within the most mature mode of G. The mean of the ratios for the four stages is 0.43 (Table 3). The ratios for all but three length groups range narrowly between 0.40 and 0.54. However, the variations from the mean (0.43) met with in three length groups do not seem to hold any special significance (Table 4).

The average of 0.43 to 1 suggests that an average of 1.43 batches would be spawned if all the yolked ova were matured and spawned. However, since at

TABLE 3. *Frequencies of ratio of all smaller yolked ova to the number of yolked ova in the most advanced group (taken as unity), grouped by maturity stages.*

	Stage of most advanced group of maturing ova				
	D	E	F	G	Total
Range in diameters of the most advanced group (m.d.)	18-43	24-52	30-56	36-58	18-58
Range in diameters of the smaller yolked ova (m.d.)	15-17	15-23	15-29	15-35	15-35
Ratio	Frequencies				
0.1	—	7	9	—	16
0.2	10	3	6	2	21
0.3	11	6	9	1	27
0.4	7	11	8	—	26
0.5	—	7	4	—	11
0.6	4	8	2	—	14
0.7	2	—	—	—	2
0.8	2	4	1	—	7
0.9	1	2	—	—	3
1.0	—	2	—	—	2
1.1	—	1	—	—	1
1.2	—	1	1	—	2
1.4	1	—	—	—	1
1.8	—	—	1	—	1
2.0	—	—	1	—	1
Number	38	52	42	3	135
Mean ratio	0.46	0.49	0.46	0.23	0.43

stage G a quick transfer of a part of the smaller yolked ova into the most mature group is evident by the reduction of the ratio to 0.23, the number of batches of ova spawned is taken as 1.23. It is inferred that the 1.23 batches would be spawned successively in the order of 1 and 0.23 batches at stages H and I,

TABLE 4. *Frequencies of ratios of all smaller yolked ova to the number of yolked ova in the most advanced group (taken as unity), grouped by fish size (total length).*

	Fish length in millimeters											
Ratio	391-420	421-450	451-480	481-510	511-540	541-570	571-600	601-630	631-660	661-690	691-720	Total
0.1	—	—	1	1	8	3	—	2	—	1	—	16
0.2	1	—	—	5	7	4	1	2	1	—	—	21
0.3	—	—	1	4	8	8	2	2	1	1	—	27
0.4	—	—	—	4	7	7	2	4	1	—	1	26
0.5	—	—	—	3	3	2	—	1	2	—	—	11
0.6	—	—	—	—	9	4	1	—	—	—	—	14
0.7	—	—	—	—	2	—	—	—	—	—	—	2
0.8	—	—	—	1	2	2	—	2	—	—	—	7
0.9	—	—	—	2	—	—	1	—	—	—	—	3
1.0	—	—	—	—	2	—	—	—	—	—	—	2
1.1	—	—	—	—	—	1	—	—	—	—	—	1
1.2	—	—	—	—	—	—	1	—	1	—	—	2
1.4	—	—	—	—	—	—	—	—	—	—	—	1
1.8	—	—	—	—	—	—	—	—	—	1	—	1
2.0	—	—	—	—	—	—	—	1	—	—	—	1
Number	1	—	2	21	48	31	8	14	6	3	1	135
Mean ratio	0.20	—	0.20	0.45	0.40	0.40	0.54	0.49	0.52	0.73	0.43	0.43

respectively. The new batch of ova (mode at 11-13 m.d.) developing at stage G are spawned at stage J within the same spawning season. Therefore, the potential batches of ova that one female is capable of spawning in each season are 2.23.

Spawning Season and Number of Broods

The annual spawning cycle begins with the sporadic occurrence of C, D and E stage fish during October-December, whose frequencies together with that of F begin to increase in January, reach the maximum during March-May and gradually decline to the minimum in September (Fig. 11). If the growth of ova of the maturing stages is traced at the rate of 11.79 m.d. per month from stage C to G, spawning season is found to extend the whole year except December (Fig. 11). However, the growth of maturing ova (e.g., modes at 16 and 19 m.d. Table 1) is retarded to 8.71-9.00 m.d. per month after the middle

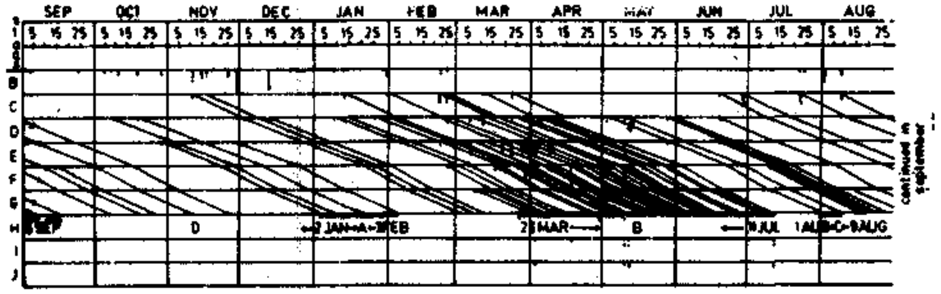


FIG. 11. Progression of maturity stages C to G to spawn ripe stage; dots represent B to J stages and crosses represent stage S.

of May, as against the growth rate of 11.67 to 15.00 m.d. per month during March to early May (Table 1). Therefore, the possible duration of occurrence of ripe ovaries as indicated by the terminals of the fitted growth lines (Fig. 11) seems valid only for the period from 2nd January to 9th August. Within this period, 3 distinct periods of spawning spurts are evident—very light spawning between 2nd January and 3rd February (section A), intense spawning from 26th March to 11th July with peak in April-May (section B), and a period of light spawning between 1st and 9th August (section C). Perhaps, maturation of the few D, E, F and G stages occurring from late May to middle August may continue till 6th September, and the period from 7th September to 1st January (section D) should be considered as the postspawning season, because of the retarded growth of ova during this period. The light spawning during the periods corresponding to sections A and C in Fig. 11 is responsible for two weak broods a and c, respectively, while the intense spawning in section B results in a very strong brood b, all consituting one-year class (Devaraj 1981).

The percentages of maturing fish during the first, second, third and fourth quarters, namely 77.2, 84.7, 26.5 and 13.0 (Fig. 7), also indicate that the spawning season lasts through the whole of the first and second annual quarters (January to June) and probably extends into the earlier half of the third quarter, with peak in the second quarter. The monthly percentages of maturing fish from January to December 1952, namely 32, 37, 52, 70, 79, 88, 94, 90, 82, 69, 41 and 33, occurrence of ripe fish in May and June and the ova attaining a maximum size of 64 m.d. in June reported by Krishnamoorthy (1958) for the spotted seer from the present areas indicate that spawning season had extended from March through October with peak in May-June, differing only slightly from the present results. The occurrence of late postlarval and juvenile spotted seer in large numbers at Vizhinjam in the southwest coast of India during February to May (Jones 1961) too conforms to the present observation.

Spawning Ground

The occurrence of spawn-ripe females suggests that the Gulf of Mannar south of Rameswaram Island between 20 and 60 meter depth lines is the spawning ground for the spotted seer. Similarly, spawning close to the shore is indicated by the postlarvae occurring during the breeding season at Vizhinjam, on the southwest coast of India (Jones 1961).

Among the maturing spotted seer in the Gulf of Mannar, E and F stage fish were the most abundant in the drift gillnet catches; with the advance of maturity, there was a sharp decline in the incidence of stage G or ripe fish in the same grounds. On no instance the adult spotted seer had been observed or reported in the shore seine catches during the period of the present study, and hence near shore migration is ruled out. Perhaps a short sojourn to the shallow areas around the chain of islands in the Gulf of Mannar may take place for the purpose of spawning, probably because of competition from king seer (*S. commerson*) for favourable breeding grounds close to shore. Consequently, the spotted seer juveniles ($<$ 200 mm) are scarce if not absent in shore seine catches (Table 5). This is probably why the abundance of spotted seer juveniles does not agree with the prevalence of maturing and ripe fish in the driftnetting grounds, in contradistinction to a positive relationship in the case of the king seer and the streaked seer. However, the simultaneous occurrence of a large number of postlarvae and juveniles of the king seer and spotted seer (Jones 1961) may point to common breeding grounds at Vizhinjam.

Spawning Migration

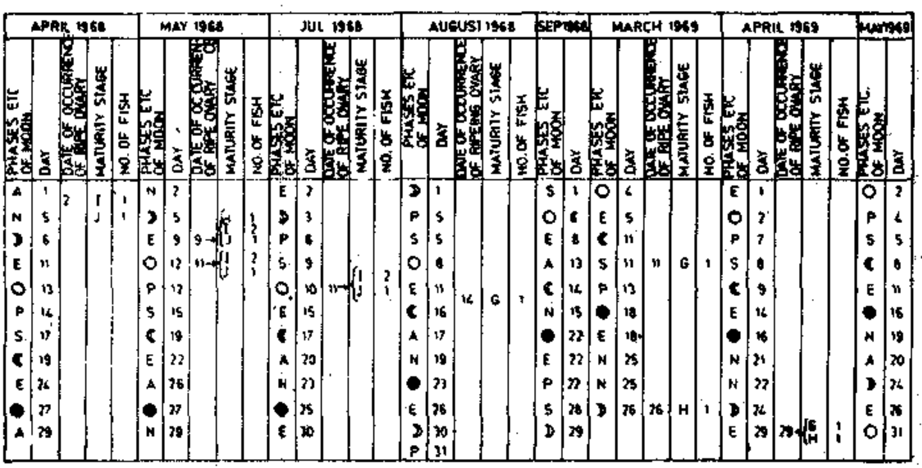
An abrupt increase in the catch per unit effort (cpue) of spotted seer (invariably of maturing and ripe fish) is observed during March-April each year in the drift gillnet catches from the northern Gulf of Mannar landed in the Rameswaram Island, and this level is maintained in the peak spawning period extending up to June. By about November or December, when the south flowing N.E. monsoon surface currents become very strong, the spent recovering fish migrate southwards to about 50 miles off the coast of Mundal, or even further, and, consequently, there is a decline in the cpue in the Rameswaram island, and an enormous increase of cpue at Mundal. The recurrence of this cycle each year signifies an annual spawning migration, first to the main fishing grounds south of Rameswaram island and, from where, seemingly to the nearby protected shallow waters around the smaller islands at the time of actual spawning. This is followed by emigration from the fishing ground into areas far south of Rameswaram.

TABLE 5. *Percentage of juveniles of three species of seerfishes caught in shore seines from Palk Bay and the Gulf of Mannar.*

	Palk Bay			Gulf of Mannar		
Species	King seer	Streaked seer	Spotted seer	King seer	Streaked seer	Spotted seer
1967-68	36.7	58.8	4.5	31.5	68.5	Nil
1968-69	100.0	Nil	Nil	89.0	5.6	5.4

Sexual and Lunar Rhythms in Spawning

Of the sixteen H, I and J stages distributed in a lunar cycle of about 28 days, twelve (75%) occurred during three days immediately preceding and one day following the full-moon. One of the remaining four occurred in the third quarter (quarter following the full-moon) and the rest three in the first quarter (that following the new-moon); and there was none in the fourth quarter. Stage G fish occurring on the 7th and 8th day following the full-moon would take 23 days (Table 2) to develop into H around the full-moon time. The very high incidence of ripe fish around the full-moon period indicates a regular lunar rhythm in the sexual maturity of the spotted seer (Figs 12 & 13).



P = perigee A = apogee ● = new moon ☽ = first quarter O full moon, ☾ = last quarter, E = moon on equator
N = maximum declination north S = maximum declination south.

FIG. 12 Relation between the phases of the moon and the occurrence of G to J stage fish.

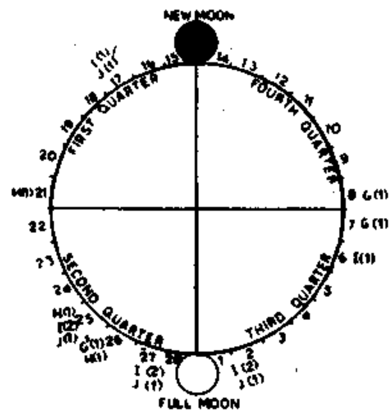


FIG. 13. Relation between lunar cycle and occurrence of G to I stage fish.

Sex Ratio of the Spawning Population

The 661 spotted seer sampled from the catches of drift-gillnet from Gulf of Mannar and Palk Bay landed in Rameswaram Island during the period July 1967 to May 1969 comprised 0.3% indeterminates, 39.5% males and 60.2% females (Table 6), in contrast to the slight dominance of males that had been noticed in the king seer populations (Devaraj 1983). After an initial low incidence in the 301-360 mm length groups, the males dominated the females in the 361-481 mm groups. Beginning with the 481-510 mm group, the incidence of males decreased steadily from 30.7% to a minimum of 6.5% in the 601-630 mm group. In none of the last three length groups were there any males. Since the growths of the male and female spotted seer are not significantly different from each other (Devaraj 1981), the abrupt decrease of males from 481-510 mm group onwards and their total absence after 601-630 mm group may suggest the male attaining senility and death at an age earlier than females, as is in the case of king seer (Devaraj 1983).

Relation Between Fecundity and Length

Based on maturing ovaries (D to G): For the 126 fecundity (ova of > 15 m.d. size) observations (D = 24; E = 59; F = 40; G = 3) a common straight line regression equation is fitted (Fig. 14), using the following equation:

$$y = -974 + 2.2443 \, x \qquad \ldots\ldots\ldots\ldots \quad (5)$$

where y is the number of yolked ova in thousands and x the total length of fish in mm, the correlation coefficient (r) being 0.4588. No better correlation between the variables was evident when curves were fitted using the equations: $y = a + bx^2$, $y = a + bx^2$, $y = a + bx^3$, $y = bx^3$, $y = ax^b$. Fecundity estimated by using these equations for 14 length groups (total length) at 30 mm interval from 390 mm to 780 mm reveals significant difference only at the first three groups (390, 420 and 450)

TABLE 6. *Sex ratio in the samples from Palk Bay and the Gulf of Mannar.*

Length group (mm)	Male (%)	Female (%)	Indeterminate %	N
271-300	—	50.0	50.0	2
301-330	22.2	77.8	—	9
331-360	37.5	58.3	4.2	24
361-390	51.5	48.5	—	33
391-420	70.7	29.3	—	58
421-450	66.0	34.0	—	97
451-480	59.2	40.8	—	98
481-510	30.7	69.3	—	101
511-540	22.9	77.1	—	96
541-570	16.9	83.1	—	59
571-600	13.9	86.1	—	36
601-630	6.5	93.5	—	31
631-660	—	100.0	—	9
661-690	—	100.0	—	7
691-720	—	100.0	—	1
Total	39.5 (261)	60.2 (398)	0.3 (2)	661

mm) and negligible differences beyond the 450 mm group. Fecundity estimated for different length groups separately for stages D, E and F using different models show only very narrow differences between models for the same stage, except for the estimate by equation $y = ax^b$ for the length groups larger than 660 mm at stage D (Table 7).

Based on ripe ovaries (H to J): At stage J, the smaller yolked ova are very scarce and do not form a definite batch (Table 8). A generally good correlation is seen in the relationship of the number of ova in different batches ($\underline{y}$) with the total length of fish ($\underline{x}$) (Table 9).

TABLE 7. *Comparison of some possible fecundity-length relationships for stages D to G.* (a = y-axis intercept; b = regression coefficient; Syx = standard error; r = correlation coefficient).

Stage	Parameter	$y = a + bx$	$y = a + bx^2$	$y = a + bx^3$	$y = bx^3$	$y = ax^b$
D	a	—1890.5	—678.8	—280	0	0.00000000000000000001444
(N = 24)	b	4.0664	0.003374	0.000003713	0.000002250	7.7412
	Syx	358	305	305	314	4.412
	r	0.5488	0.5374	0.5260	0.48	0.6169
E	a	—1200.5	—409.2	—139.7	0	0.0000001847
(N = 59)	b	2.8926	0.002624	0.000003113	0.000002288	3.3688
	Syx	225	224	224	226	5.737
	r	0.5052	0.5107	0.5127	0.4944	0.5048
F	a	—423.2	—47.7	—125.5	0	0.006825
(N = 40)	b	1.4523	0.001385	0.000001473	0.000002119	1.7103
	Syx	184	183	184	187	5.725
	r	0.3664	0.3862	0.3723	0.4588	0.2589
D to G	a	—974	—300	—47	0	0.0000002249
(N = 126)	b	2.4430	0.002200	0.000002453	0.000002187	3.3306
	Syx	230	229	231	229	5.3020
	r	0.4588	0.4652	0.4535	0.4804	0.4412

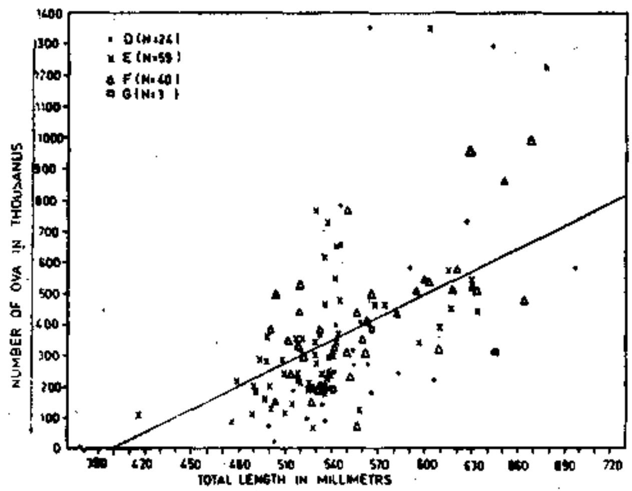


FIG. 14. Scatter diagram showing the relation between total length of fish and fecundity for maturing fish (stages D, E, F and G); fitted line is based on all three stages.

Fecundity at different spawnings and absolute fecundity: The stock of eggs (fecundity) at D to G stages (column a of Table 10) is spawned successively as 1 and 0.23 batches at stages H and I, respectively. Therefore, the estimated fecundity is split up into batch 1 (column b) and batch 0.23 (column c), and the relationship of each (y) with the total length of fish (x) fitted by,

for bach 1 : $y = -792 + 1.9872\,x$ .... (6)

for bach 0.23 : $y = -180 + 0.4562\,x$ .... (7)

Theoretically, the estimated number of ova in batch 1 should represent the number of ova in the advanced mode of H before the commencement of spawning, while the number of ova of batch 0.23 would represent the number of ova in the advanced mode of I. The number of ova actually observed in the advanced mode of H is expressed by the equation:

$y = -528 + 1.1607\,x$ .... (8)

and the estimated number for the different length groups is given in column d of Table 10. Therefore, by subtracting column d from column b, the number of ripe ova already spawned or mechanically discharged at stage H could be derived for each length group in column a, for which is fitted the regression equation:

$y = -205 + 0.8275\,x$ .... (9)

Similarly, the number of ova actually observed in the advanced mode of I is described by the equation:

TABLE 8. *Number of ova in the advanced and preceding batches at maturity stages H, I and J. (figures in parentheses are the size ranges in m.d. of the ova).*

			Number of ova in thousands		
Stage	No.	Fish length (mm)	Advanced batch	Preceding batch	Total
H	1	548	48 (60-83)	17 (15-45)	65
	2	604	113 (60-80)	52 (15-25)	165
I	1	480	36 (54-71)	108 (15-51)	144
	2	529	46 (57-73)	139 (15-45)	185
	3	530	59 (56-70)	59 (15-54)	118
	4	535	55 (55-76)	144 (15-49)	209
	5	535	41 (57-76)	76 (15-54)	117
	6	536	68 (55-75)	226 (15-53)	294
	7	547	22 (55-77)	172 (15-51)	194
	8	530	75 (55-77)	134 (15-53)	209
	9	581	94 (60-83)	207 (15-45)	301
J	1	491	38 (50-75)	0.4 (15-40)	38
	2	532	48 (49-81)	2 (15-48)	50
	3	579	49 (50-85)	1 (15-45)	50
	4	618	220 (50-100)	9 (15-48)	229

TABLE 9. *Fecundity* (y)-*length* (x) *relationship* (y = a + bx) *for stages H, I and J.*

Stage	Parameter	Advanced mode	Preceding mode (lower limit, 15 m.d.)	Total
H	a	—588.1	—325.0	—914
(N 2)	b	1.1607	0.6250	1.7857
	Syx	0	0	0
	r	1.0	1.0	1.0
I	a	—214.0	—401.6	—615
(N 9)	b	0.5012	1.0114	1.5126
	Syx	18.6	52.0	57.6
	r	0.6039	0.4807	0.5228
J	a	—607	—27	—634
(N 4)	b	1.2541	0.5040	1.3081
	Syx	104.0	2.6	68.0
	r	0.7911	0.8142	0.7924

$$y = -214 + 0.5012\,x \qquad \ldots\ldots\ldots \quad (10)$$

and the estimated number using Eq. (10) is given in column f for the different length groups. Subtracting column f from c, the number of ova already discharged from the advanced mode of I is derived in column c for which is fitted the equation:

$$y = +\ 30 - 0.0428\,x \qquad \ldots\ldots\ldots \quad (11)$$

The remarkable similarity between the number of ova given under column c and f conclusively proves that spawning of the 0.23 batch takes place at stage I. It also reveals that, at stage I, not much of the ova had been spawned already or the mechanical impacts suffered by the fish after capture had little effect on the discharge of the too small number of ripe ova present.

The number of ova in the preceding mode of stage I ovaries estimated by the equation:

$$y = -402 + 1.0114\,x \qquad \ldots\ldots\ldots \quad (12)$$

for each length group is given under column i of Table 10. These ova would mature into ripe ova for final spawning at stage J, except for some late developing smaller yolked ova, which probably form the smaller yolked ova of stage J. The smaller ova found in stage J are too scarce and are seemingly destined to be resorbed after the final spawning act. They are estimated in column l of Table 10 by using the equation:

$$y = -27 + 0.540\ x \qquad \ldots\ldots\ldots \quad (13)$$

By subtracting column l from i the fecundity at final spawning is derived in column m for the different length groups, and its relationship with fish length is expressed by the equation:

$$y = -380 + 0.9648\ x \qquad \ldots\ldots\ldots \quad (14)$$

TABLE 10. *Estimated number of ova* (y; *in thousands*) *in the different modes at various stages of maturity, ova spawned in different batches, ova resorbed, and absolute fecundity in relation to the length of fish* (x).

Total length of fish in mm (x)	Based on D to G ovaries (all ova 15 m.d. = 1.23 batches) a	To be spawned batch 1 (a/1.23) b	To be spawned in batch 0.23 (a-c) c	In the andvanced mode of H d	Already spawned from the advanced mode of H (a-d) e	In the advanced mode of I f	Already spawned from the advanced mode of I (c-f) g
420	52	42	10	—	—	—	—
450	125	102	23	—	—	12	11
480	199	162	37	—	—	27	10
510	272	221	51	4	217	42	9
540	345	280	65	39	241	57	8
570	419	341	70	74	267	72	6
600	492	400	92	108	292	87	5
630	565	459	106	143	316	102	4
660	638	519	119	178	341	317	2
690	712	579	133	213	366	132	1
720	785	638	147	248	390	147	0
750	858	698	160	283	415	162	—
780	932	758	174	317	441	177	—

a: $y = -974 + 2.4330\ x$ b: $y = -792 + 1.9872\ x$ c: $= y -182 + 0.4562\ x$
d: $y = -588 + 1.607\ x$ e: $y = -205 + 0.8275\ x$ f: $y = -214 + 0.5012\ x$
g: $y = 30 - 0.0428x$

TABLE 10. (Contd.)

In the preceding mode of H h	In the preceding mode of I i	In the advanced mode of J j	Already spawned at J (i-j) k	Smaller yolked ova of J (=resorbed in one season) l	Destined for spawning at J (i-l) m	Absolute fecundity (a+m) n
—	23	—	—	—	23	75
—	54	—	—	—	54	179
—	84	—	—	—	84	283
—	114	35	81	1	113	385
12	145	70	75	2	143	488
31	175	108	67	4	171	590
50	205	146	59	5	200	692
68	236	183	53	7	229	794
87	266	221	45	9	257	895
106	294	258	38	10	286	998
125	327	296	31	12	315	1100
143	357	334	23	14	343	1201
162	387	371	16	15	372	1304

h: $y = -326 + 0.6250\,x$ i: $y = -402 + 1.0114\,x$ j: $y = -607 + 1.2541\,x$
k: $y = 205 + 0.2424\,x$ l: $y = -27 + 0.0540\,x$ m: $y = -300 + 0.9648\,x$
n: $y = -1354 + 3.4082\,x$

By summing the fecundity at batch 1 (column b), batch 0.23 (column c) and final spawning (column m), the absolute fecundity defined as the total number of ova spawned in one spawning season is derived in column n for each length group. The absolute fecundity-fish length relation is expressed by the equation:

$$y = -1354 + 3.4082\,x \qquad \text{.........} \quad (15)$$

The relationships of fish length with fecundity at different spawnings, absolute fecundity and the number of ova resorbed are illustrated in Fig. 15. The increase of egg number per 10 mm body length revealed directly by Eq. (15) is 34,082.

Relation Between Fecundity and Weight

The regression of the number of ova ($\leq$ 15 m.d.) in thousands (y) on the weight in grams of fish (x) for 126 observations is found to be (Fig. 16):

$$y = -45.5 + 0.4\,x \qquad \text{.........} \quad (16)$$

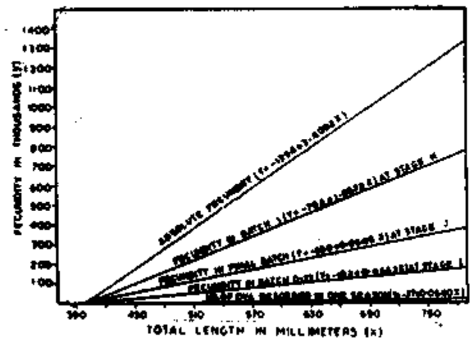


FIG. 15. Relation between total length of fish and number of ova spawned in different batches.

Fecundity has also been estimated by the relation $y = bx$ and $y = ax^b$ for different length groups. As in the case of the king seer (Devaraj 1983), the equation $y = a + bx$ and $y = bx$ agreed closely in the values of b, Syx and r (Table 11), and, hence, the y-intercept may be taken as zero in the fecundity-weight regression without any significant loss of accuracy. The relation $y = bx$ shows that 359. 8 million eggs are produced for every ton of spawning females.

TABLE 11. *Some possible weight(x)-fecundity(y) relationships.*

Stage	Parameter	$y=a+bx$	$y=bx$	$y=ax^b$
D to G	a	—45.5	0	4.3060
(N = 126)	b	0.4	0.3598	0.7035
	r	0.4813	0.4420	0.3594
	Syx	227.0	234.0	0.287

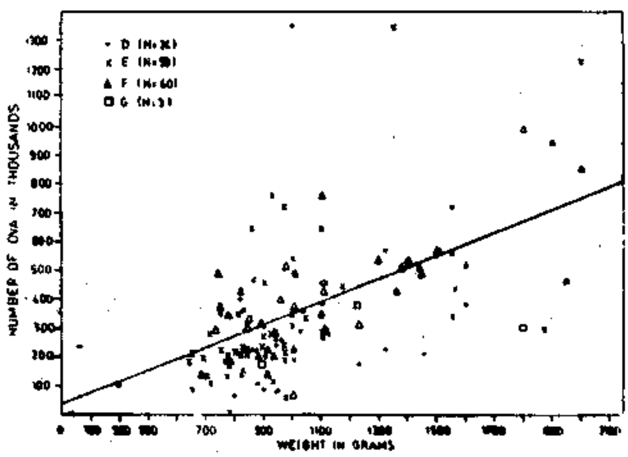


FIG. 16. Scatter diagram showing the relation between fish weight and fecundity for maturing fish (stages D to G); fitted line is based on all these stages.

ACKNOWLEDGEMENT

My sincere thanks are due to Dr. S. Jones, Dr. R. V. Nair and Dr. E. G. Silas, former Directors, and Dr. P. S. B. R. James, Director, Central Marine Fisheries Research Institute, Cochin, for their invaluable advice and encouragement, and to Mr. M. Stephen, fleet owner, for cooperation in the procurement of samples for the study.

REFERENCES

CLARK, F. N. 1925. The life history of *Leutesthes tenuis*, an atherine fish with tide controlled spawning habits. *Calif. Fish Game Comm., Fish. Bull.*, (10): 1-51.

CLARK, F. N. 1929. The life history of the California jack smlet, *Atherinopsis californiensis. Calif. Div. Fish Game, Fish. Bull.*, (16): 1-22.

CLARK, F. N. 1934. Maturity of the California sardine (*Sardina caerulea*) determined by ova diameter measurements. *Calif. Div. Fish Game, Fish. Bull* (42): 1-49.

DE JONG, J. K. 1940. A preliminary investigation of the spawning habits of some fishes of the Java Sea. *Treubia*, 17: 307-330.

DEVARAJ, M. 1981. Age and growth of three species of seerfishes in India (*Scomberomorus commerson, S. guttatus* and *S. lineolatus*). *Indian J. Fish.* 28: 104-127.

DEVARAJ, M. 1983. Maturity, spawning and fecundity of the king seer, *Scomberomorus commerson*, in the seas around peninsular India. *Indian J. Fish.*, 30(2): 203-230.

JONES, S. 1961. Notes on eggs, larvae and juveniles of fishes from Indian waters. VIII. *Scomberomorus guttatus* (Bloch and Schneider). IX. *Scomberomorus lineolatus* (Cuvier). *Indian J. Fish.*, 8(1): 107-120.

KRISHNAMOORTHI, B. 1958. Observations on the spawning season and the fisheries of the spotted seer, *Scomberomorus guattatus* (Bloch & Schneider). *Indian J. Fish.*, 5: 270-281.

ORANGE, C. J. 1961. Spawning of yellowfin tuna and skipjack in the eastern tropical Pacific, as inferred from studies of gonad development. *Inter-Am. Trop. Tuna Comm.* 5(6): 456-526.