# MATURITY, SPAWNING AND FECUNDITY OF THE STREAKED SEER, *SCOMBEROMORUS LINEOLATUS* (CUVIER & VALENCIENNES), IN THE GULF OF MANNAR AND PALK BAY

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ABSTRACT

The ovary of streaked seer passes through 12 finer maturity stages,-A to L, of which all but A show bimodality in the ova-size-frequency distribution. The growth of the advanced mode (first batch) through successive stages takes place at slightly less than two times the growth of the preceding mode (second batch) except from stage G to H when the growth of the advanced mode is nearly five times the growth of the preceding mode. After most of the ova in the first batch are spawned at the first ripe stage J, the second batch of ova at stage K, which resembles the advanced mode of stage G, grows abruptly (like the growth from G to H) into and is spawned at the second ripe stage L. The duration of 96 days taken for the growth from stage B to L includes 75 days from B to J and 21 days from J to L. Gonad index values separating the spawning from the nonspawning females range from 3 at the 441-480 mm length group to 5 at the 961-1000 mm group. The fish attain first maturity when about 700 mm total length when they are about 2 years old. Each year class is composed of one weak brood produced in the period January to early March, a dominant brood during mid-March to end of May and another weak brood in late June to late July. Spawning takes place in inshore waters up to a distance where the ciepih is about 25 m. There is no lunar periodicity in spawning. Males and females occur in the ratio of 40.5 : 59.5. The increase in fecundity per 10 mm body length is 65,998, whereas the fecundity per ton of spawning females is 570 million.

## INTRODUCTION

There is virtually no study on the breeding biology of the streaked seer, *Scomberomorus lineolatus,* owing mainly to the fact that, despite its wide distribution in the Indo-Malayan archipelago, this species is the least abundant of the common and familiar species of seerfishes occurring in this region. The interesting notes by Williams (1964) on the spawning habits of the East African kanadi, which he believed to be *S. lineolatus*, actually pertain to *S. plurilineatus* Fourmanoir (1966), as shown by van der Elst and CoUette (1984). The description

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of juveniles given by Kuthalingam (1959) as of the streaked seer does not fit into any species of *Scomberomorus* (Jones 1961). The present account deals with the spawning biology of the streaked seer from the Gulf of Mannar and Palk Bay in detail for the period July 1967 to July 1969, together with a comparitive discussion of reproduction in seerfishes of the Indian seas.

## MATERIAL AND METHODS

Samples of gonads of streaked seer taken from the commercial dritf gillnet catches at twice or thrice-a-week intervals during July 1967 to July 1969 formed the basic material for the study. Maturity stages were determined by a gross examination of the gonads of 131 females and 105 males, the ova-size-frequency distribution of 84 ovaries and the gonad indices of 84 females. Frequency of spawning was ascertained from the multiplicity of modes in the ova-size-frequency curves, the growth of successive egg groups and the relative number of eggs in different batches. The time taken from the onset of maturity to the final act of spawning in a given season was determined by monitoring the growth of the primary and secondary batches of ova through time. The possible relation between the phases of the moon and spawning was investigated by examining the distribution of advanced maturity stages in relation to lunar cycle. 236 fish were examined for determining sex ratio. Samples for fecundity estimation included 32 maturing and mature ovaries. Simple straight-line relations were used for fitting fecundity-fish length and fecundity-fish weight relations. Methods used in this study are described in much greater detail in a similar study of the king seer (Devaraj 1983) and the spotted seer (Devaraj MS).

## RESULTS AND DISCUSSION

### *Maturity Stages of Ovary (Gross Examination)*

i) *Immature:* The immature ovaries are thin, elongate and light meat-coloured, and exhibit a series of ovarian lamellae through the surface of the ovisac. The ova are transparent, < 5 m.d ( < 0.0835 mm) in diameter, and the nucleus clearly discernible under the microscope. Fish < 600 mm in total length were immature.

ii) *Spent recovering:* The spent recovering ovary is dull grey to light red in colour, and occupies 1/8 to 1/4 the body cavity. Most of the ova are about 5 m.d. (0.0835 mm) in diameter. Recovering females were common during June-December.

iii) *Intermediate:* The ovary occupies about 1/4 the body cavity, and is of a light red colour. Besides the stock of immature ova, there develops a batch of ova 12 m.d. (0.2004 mm) in size, and the nucleus gets slightly masked by the yolk granules just being deposited.

iv) *Maturing:* The maturing ovary is characteristically yellow and fills up nearly 2/3 Ihe visceral cavity at the advanced maturing stage. Two well-defined groups of ova are present, and the mode of the most maturing group increases from 15-20 m.d. (0.2505-0.3340 mm) at the onset of maturity to 32-48 m.d. (0.5344-0.8016 mm) at the advanced maturing phase. The zona radiata of the maturing ova are concentrically striated and subdivided into rectangular sections by means of cross bars. Maturing females were dominant during January to May. •

v) *Ripe:* The ripe ovary assumes a dull sandal colour, and occupies nearly 3/4 the body cavity. Two categories of ripe ovaries are met with; in one category, there are two well defined batches of ova of which the mode of the advanced group increases from 52-69 m.d. (0.8684-1.1523) at the ripening stage to 64-76 m.d. (1.0688-1.2692 mm) at the fully ripe stage; in the other category, there is a well defined batch of ripe ova, and only very few number of smaller yolked ova. The ripe ova are translucent, they lie loosely in the ovarian lamellae, and possess each a golden brown oil globule, about 20 m.d. in size (0.3340 mm). Ripe fish were met with during January-April.

vi) *Spent:* Ovaries which have fully emitted their gonadial products, and consequently showing all the characteristics of a typically spent condition, did not occur in the samples, because of the presence of a secondary batch of fully yolked ova after spawning the primary batch. Fully spent ovaries resulting after spawning the secondary batch of ova were also absent in the samples.

*Maturity Stages of Testis (Gross Examination)*

i) *Immature:* The immature testis is very thin, streak-like, faintly grey, and weighs about 1.86 g (mean weight of 24 paired testes; range : 0.2 to 7.0 g). Immature males measured up to 708 mm total length.

ii) *Intermediate:* The testis is still streak-like and grey, but weighs about 5.18 g (mean weight of 33 paired testes; range: 1.2 to 12.0 g). Both virgin and spent recovering males are included in this stage. Intermediate males measured 557 to 710 mm in length.

iii) *Maturing:* The testis occupies well over 1/4 the body cavity, it is lobular and milky white, and exudes milt on pressing the abdomen. It weighs about 10.49 g (mean weight of 14 paired testes; range: 4.8 to 21.8 g). The maturing fish ranged from 670 mm to 979 mm in length.

iv; Ripe: The ripe tests fills nearly 1/2 the body cavity, it is milky white, milts at ease on gently pressing the abdomen, and weighs about 28.63 g (mean weight of 6 paired testes; range: 11.0 to 50.0 g). The length of the ripe -fish ranged from 703 mm to 976 mm.

v *Spent:* A remarkably shrunken and blood-tinged appearance characterises the spent testis, which weighs about 8 g (mean weight of 3 paired testes). The length of the spent fish in the samples ranged from 768 mm to 842 mm. The pooled distribution of gross maturity stages according to months is illustrated in Fig. 1.

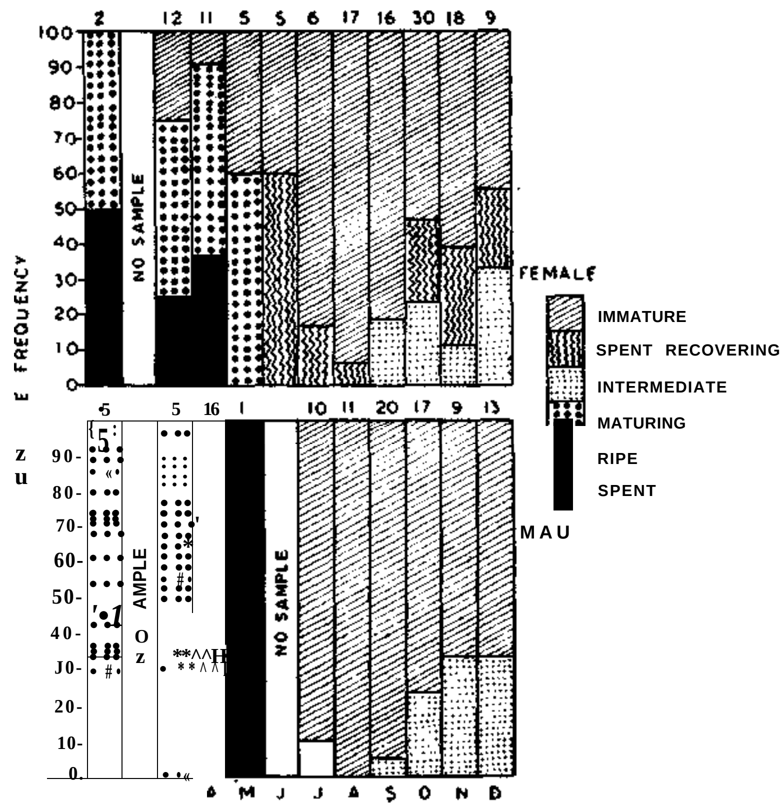


**FIG. 1. Percentage of fish in different maturity stages during successive months based on the pooled data for the period August, 1967 to May, 1969; numerals denote the number of fish in the samples.**

### *Frequency Distribution of Ova Diameter*

With reference to the position of the modes in the ova-size-frequency polygons, the ovaries of the streaked seer are grouped under 12 categories named serially from A to L. The positions of the advanced and preceding batches of ova increased progressively through these stages until both were fully matured and evidently spawned successively. The pooled frequency distribution of ova for a number of ovaries of each of these stages reduced to the basis of 300 ova, and smoothed by the equation $\frac{a + 2b + c}{4}$ is illustrated in Fig. 2.

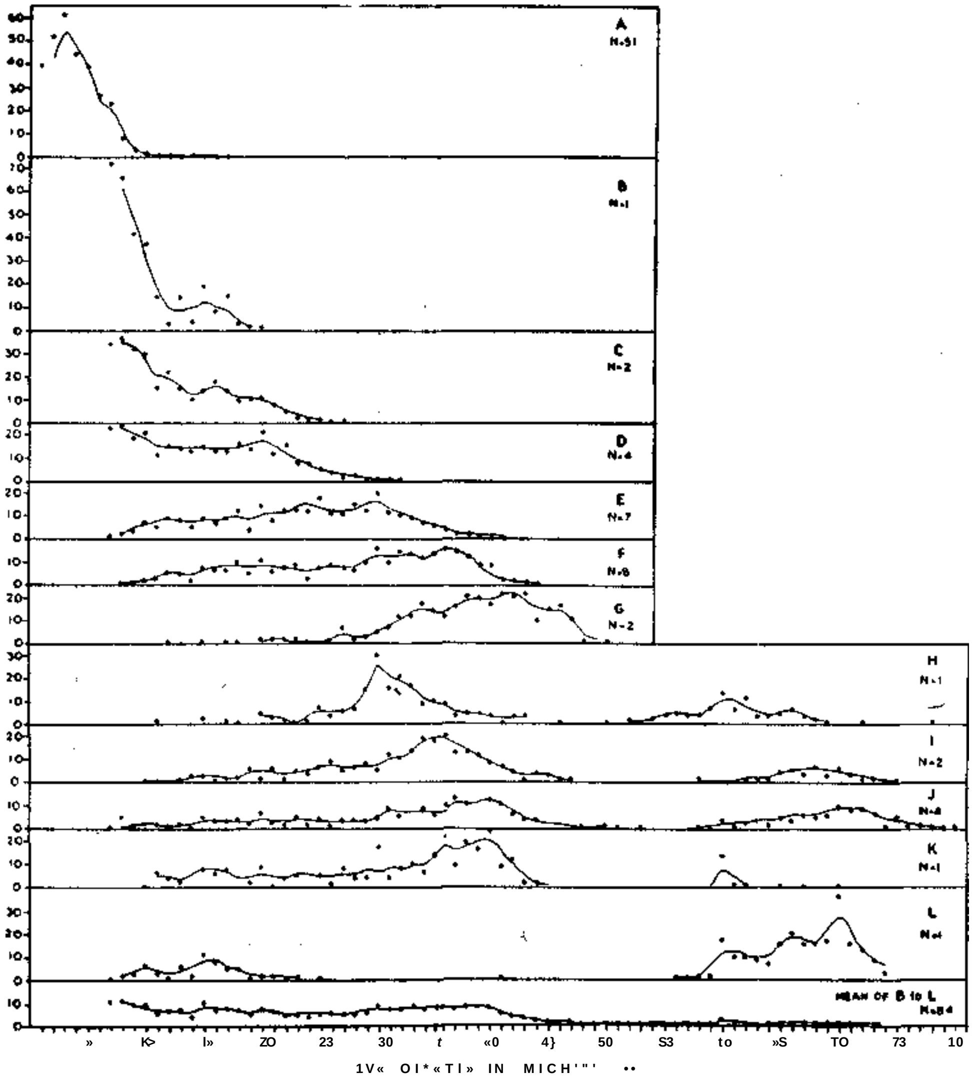


FIG. 2. Scatter diagram of ova-diameter-frequency polygons for successive stages from stage A through L; the lines represent the values smoothed by the formula.

Frequency distribution for the mean of stages B through L is also shown in **the** figure. The deviations of the frequency polygons of each of these stages from that of the mean for stages B to L, smoothed twice by a running average of 3. is expressed in Fig. 3. The pooled percentage distribution of these stages according to months is shown in Fig. 4. A brief description of these stages is given below.

i *limmature: (Stage A):* Mode between 2 and 6 m.d. (0.0334 and 0.1002 mm); no ova beyond 17 m.d. (0.2839 mm).

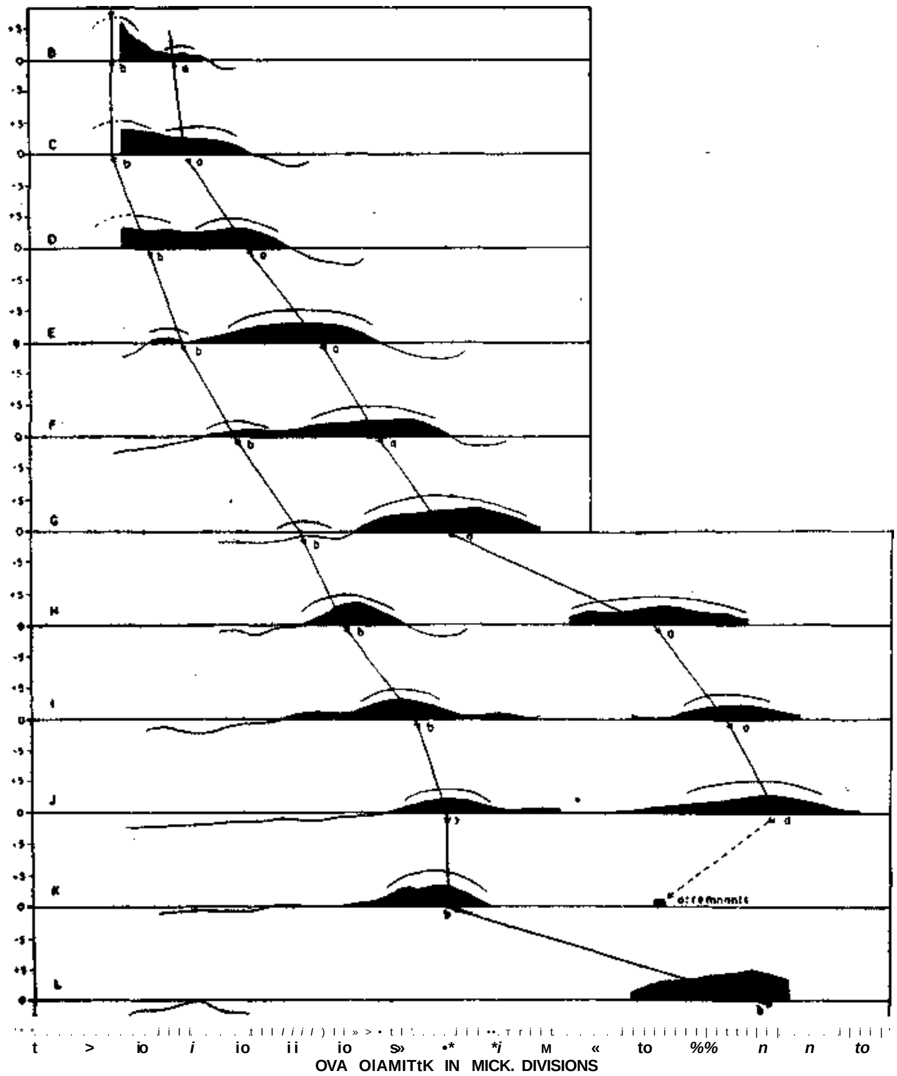

FIG. 3. Deviations from the average frequency polygon of stages B through L; the deviations are smoother twice by a running average of three to minimise chance fluctuations.

ii) *Intermediate: (Stage B):* Mode of the most mature group of ova between 14 and 17 m.d. (0.2338 and 0.2839 mm); preceding mode at < 9-12 m.d. ( < 0.1503-0.2004 mm); no ova beyond 20 m.d. (0.3340 mm).

iii) *Maturing: (Stage C):* Mode of the most mature group of ova between 14 and 20 m.d. (0.2338 and 0.3340 mm); preceding mode at < 9-13 m.d. ( < 0.1503-0.2171 mm ); no ova beyond 27 m.d. (0.4509 mm).

*Stage D:* Mode of the most mature group of ova between 16 and 24 m.d. (0.2672 and 0.4008 mm); preceding mode at 11-15 m.d. (0.1837-0.2505 mm); no ova beyond 32 m.d. (0.5344 mm).

*Stage E:* Mode of the most mature group of ova between 20 and 32 m.d. (0.3340 and 0.5344 mm); preceding mode at 12-16 m.d. (0.2004-0.2672 mm); no ova beyond 42 m.d. (0.7014 mm).

*Stage F:* Mode of the most mature group of ova between 27 and 39 m.d. (0.4509 and 0.6513 mm); preceding mode at 18-24 m.d. (0.3006-0.4008 mm); no ova beyond 46 m.d. (0.7682 mm).

*Stage G:* Mode of the most mature group of ova between 32 m.d. and 48 m.d. (0.5344 and 0.8016 mm); preceding mode at 24-29 m.d. (0.4008-0.4843 mm); no ova beyond 50 m.d. (0.8350 mm).

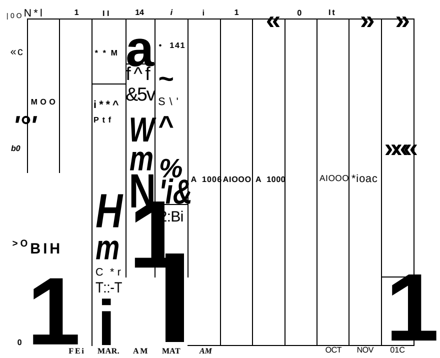


**FIG. 4. Percentages of maturity stages A to K during successive months based on the pooled data for the period October, 1967 to April, 1969.**

iv) *Ripening and ripe (first batch): Stage H:* Mode of the most mature group of ova between 52 and 68 m.d. (0.8684 and 1.1356 mm); preceding mode at 28-34 m.d. (0.4676-0.5678 mm); no ova beyond 69 m.d. (1.1523 mm).

*Stage I:* Mode of the most mature group of ova between 62 and 72 m.d. (1.0357 and 1.2024 mm); preceding mode at 32-40 m.d. (0.5344-0.6680 mm); no ova beyond 75 m.d. (1.2525 mm).

*Stage J:* Mode of the most mature group of ova between 64 and 76 m.d. (1.0688 and 1.2692 mm); preceding mode at 36-44 m.d. (0.6012-0.7348 mm); no ova beyond 80 m.d. (1.3360 mm).

v) *Partly spent (first batch): Stage K:* A few ova, apparently remnants of the recently spawned first batch, form an insignificant mode at 60-61 m.d. (1.0020-1.0187 mm); preceding mode prominent, at 34-44 m.d. (0.5678-0.7348 mm) virtually remaining at the same position as at the preceding stage and resembling the advanced mode of G; no ova beyond 70 m.d. (1.1690 mm).

vi) *Ripe (second batch): Stage L:* Mode of the most mature group of ova between 58 and 73 m.d. (0.9686 and 1.2191 mm); preceding mode of very small, yolked ova at 12-18 m.d. (0.2004-0.3006 mm); no ova beyond 75 m.d. (1.2525 mm).

*Gonad Index (G.I.)*

The distribution of gonad indices according to length groups in the pooled quarterly samples shows that the values of G.I. for all the length groups were the lowest in the third ( < 2.3) and fourth (< 3.7) quarters (sections C and D of Fig. 5). The regression of G.I. on the total length of fish (L) based on the combined data (N = 42) for these two quarters (July to September and October to December) is found to be.

$$\text{G. I.} - -0.98 + 0.003/\ L \qquad \ldots. \quad (1)$$

This regression is fitted in both sections C and D (bottom line). The upper line in sections C and D, expressed in Eq. (2) below, is 3 standard errors (3 X 0.8239 ⇀ 2.4717) about the regression line for Eq. (1).

$$\text{G. ).} = (-0.98 + 2.4717) + 0.0037\ L \qquad \ldots. \quad (2)$$

or

$$\text{G. I.} = 1.491 + 0\ 0037\ L$$

And this line is reproduced in sections A (January to March) and B (April to June) also. Following Orange (1961), the line representing Eq. (2) is considered to be the boundary demarcating the gonad indices for the maturing fish (above the line) from those for the immature (below the line). The G.I. values along the course of this line range from 3 at the 441-480 mm group to 5 at the 961-1000 mm group.

In order to determine the stage of maturity with reference to the G.I. alone, the relationship between G.I. ═ x) and maximum ova diameter, m.o.d. ( = y ), is fitted in Fig. 6. Since the ovary enters the ripening phase after stage G, stages beyond G could not be utilised for fitting this relationship, unless there is evidence to show that they have not yet spawned any of their ova. The distribution of the scatter values of G.I.—m.o.d. (N = 75)—for stage A through G conforms to a parabola, expressed by the equation.

$$y = -0.1098\ x^2 + 5.1522\ x + 0.32 \qquad \textbf{(3)}$$

The crest of the fitted line reads m.o.d. - 61 m.d. at G.I. - 24, while at the highest stage (G) included in the data, the m.o.d. does not exceed 50 m.d.; beyond the crest, the line descends steeply, and hence, the real relationship beyond stage G could not be predicted by extrapolation even for the ripe fish

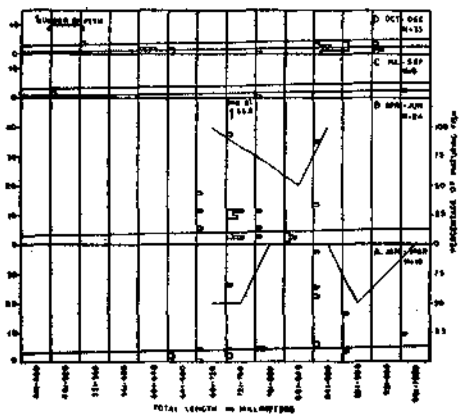

FIG. 5. Relation between total length of fish and gonad index for "the four annual quarters based on the pooled data for the period October, 1977 to April, 1969.

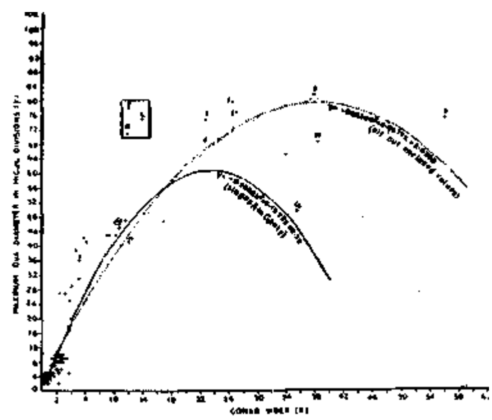

FIG. 6. Relation between gonad index and maximum ova diameter,

which have not yet spawned. The scatter values for stages H to L indicate that the G.I. for three fish, one each in J, K and L stages (shown within the enclosure in Fig. 6) has fallen below 14, definitely because of egg loss. Eq. (4) derived after excluding the above 3 fish from the data, fits the scatter values fairly well except the only fish in stage G (Fig. 6).

$$y \text{ - } -0.0534\, x^2 + 4.0577\, x + 2.6296 \qquad \ldots\ (4)$$

If the ovaries at stages H, I and J included in the above relationship have not parted with a portion of their ova from the advanced batch, the proportion of the number of ova in the advanced batch to the number of all smaller yolked ova should corroborate two spawnings a season deduced on the basis of the number of batches of ova present (Figs 2 & 3). Contrarily, the above proportions recorded 1.89 for stage H (N - 1), 3.13 to 5.66 for stage I (N = 2) and 1.98 to 2.94 for stage J (N = 4) (Table 1) meaning that the streaked seer could spawn 2.89 to 6.66 batches. This denotes partial egg loss from the advanced batch and also addition of a large number of ova from the immature stock to the preceding batch, which are also borne out by a comparison of the two modes of stages H, I and J with those of the earlier stages (Figs. 2 and 3). Thus, the utility of both Eqs. (3) and (4) is limited one way or other, for the determination of m.o.d., and hence, the stage of maturity.

TABLE 1. *Ratios of:* (1) *all smaller yolked ova* (15-25 *m.d.) plus the number of ova in the preceding batch, and* (2) *the number of ova in the preceding batch to the number of ova in the most advanced batch {taken as unity) for each of the ovaries in maturity stages I, J and L.*

| Stage | Position of the group of mnnllpr yolked ova (m.d.) | Position of preceding batch (m.d.) | Position of advanced batch (m.d.) | Smaller yolked plus preceding batch / advanced batch | Preceding batch / advanced batch |
|---|---|---|---|---|---|
| H | 15-25 | 26-43 | 46-78 | 2.27 | 1.89 |
| I | 15-25 | 26-47 | 49-75 | 7.23 | 5.66 |
| I | 15-25 | 26-43 | 62-77 | 3.56 | 3.13 |
| J | 15-25 | 26-50 | 51-76 | 2.94 | 2.51 |
| J | 15-25 | 26-50 | 58-78 | 5.13 | * .2.94 |
| J | 15-25 | 26-48 | 60-82 | 3.45 | 1.98 |
| J | 15-25 | 26-48 | 59-80 | 2.97 | 2.56 |
| L | 15-25 | 41 | 56-75 | 0.17 | 0.0044 |

*Size at First Maturity*

Among the different length groups considered in Fig. 5, G.I. value characterising maturing fish is first noticed in the 681-720 mm group, based on which the streaked seer is considered to attain first maturity at a length of about 700 mm at an age of about 2 years. By inserting y = 0 in the fecundity (y)-fish length (x) relations for C and D stages (Eq. 9) and E to G stages (Eq. 10) for the first batch of ova, the length at first maturity is found to be 716 mm and 665 mm respectively, the average being 691 mm.

*Frequency of Spawning*

*Multiplicity of modes:* Except stage A which includes both immature and spent recovering fish, the ova-isize-frequency polygons far stage B through L are bimodal. The origin, growth and fate of the two batches of ova through succeeding stages from B through L traced in Fig. 3 reveal that the ova within the advanced batch become fully ripe and attain maximum size at J when they are spawned. The remnants of ripe ova are carried to stage K at which the mode of the secondary batch remains at the same position as at stage J, but grows further and forms the product of the secondary spawning at stage L. The absence of K and L stages after May confirms that the secondary batch is matured and spawned the same season.

*Growth of successive egg groups:* The rate at which the two batches of ova grow from B through J is apparent from the modal progression of the two batches of ova in the individual frequency polygons (Fig. 7), prepared by smoothening the data by a running average of 5 (Table 2). The straight line regression fitted to the data (Fig. 7) is,

$$y = 0.5 + 0.5351\ x \qquad \dots\dots \quad (5)$$

where y is the position of the preceding mode in m.d. and x that of the advanced mode in m.d. Correlation between the variables is found to be highly significant (r = 0.9727). The regression coefficient (0.5351) indicates that the growth of the preceding batch takes place at slightly more than half that of the advanced mode; in other words, the growth of the advanced mode has been slightly less than two times the growth of the preceding mode. The growth increments of the advanced and preceding modes from B to J are 56 m.d. and 31 m.d. respectively, and their growth ratio (56/31 = 1.8) confirms the relative growth of the two modes deduced above.

The two trend lines, one connecting the advanced modes and the other connecting the preceding modes of stages B through L shown in Fig. 3, are nearly parallel to each other from B to G and also from H to J, but not parallel between G and H, indicating that the rate of growth of the two batches was not significantly different from each other save between G and H during which alone the advanced mode (increment 20 m.d.) has grown about 5 times (20/4) the preceding mode (increment 4 m.d.); however, the net difference in the growth increments indicates that the overall growth of the advanced mode was slightly less than twice that of the preceding mode, as shown already.

The mean of the preceding modes and the mean of the advanced modes for each of the maturity stages B through L are furnished in Table 3. The mean preceding mode (P) of stage n-1 is plotted against that (P) of stage n (e.g., if stage C is n, then B is n-1) for each pair of successive stages from B-C to I-J (Fig. 8; dots). To this is fitted the regression line,

l»$_n$., = -1-9+0.9211 P„ . . . (6)
( r - 0.9795 )
bj = lan Qi = 0.9211
Q, = lan"$^1$ 0.9211 = 42° 39' ; .\ sec Qi = 1.3596

The regression coefficient (0.9211) is closer to unity indicating nearly steady growth of the preceding mode through successive stages from B to J. Similarly,

TABLE 2. *Stage of maturity and the positions of modes in the ova frequency distribution arranged in the progressive order of dates, pooled for all the years of observations.*

| S.No. | Date | Stage of maturity | Position of preceding mode (m.d.) | Position of advanced mode (m.d.) |
|---|---|---|---|---|
| 1. | 23 December 1968 | B | 8 | 14 |
| 2. | 15 January 1969 | J | 17 & 38 | 71 |
| 3. | 8 March 1969 | J | 39 | 72 |
| 4. | 8 March 1969 | I | 39 | 67 |
| 5. | 11 March 1969 | G | 26 | 39 |
| 6. | 18 March 1969 | C | 7 | 15 |
| 7. | 18 March 1969 | D | 13 | 20 |
| 8. | 18 March 1969 | E | 14 | 26 |
| 9. | 19 March 1969 | E | 14 | 27 |
| 10. | 19 March 1969 | D | 12 | 22 |
| 11. | 23 March 1969 | F | 20 | 34 |
| 12. | 26 March 1969 | J | 20 & 37 | 76 |
| 13. | 26 March 1969 | 1 | 35 | 67 |
| 14. | 27 March 1968 | E | 16 | 27 |
| 15. | 1 April 1969 | C | 9 | 15 |
| 16. | 1 April 1969 | G | 26 | 41 |
| 17. | 2 April **1968** | D | 14 | 23 |
| 18. | 2 April 1968 | F | 23 | 34 |
| 19. | 8 April 1969 | F | 21 | 33 |
| 20. | 9 April 1969 | D | 10 | 20 |
| 21. | 16 April 1969 | E | 12 | 28 |
| 22. | 17 April 1969 | E | 13 | 30 |
| 23. | 17 April 1968 | E | 13 | 30 |
| 24. | 17 April 1968 | F | 21 | 35 |
| 25. | 18 April 1968 | F | 20 | 33 |
| 26. | 18 April 1968 | K | 37 | 61 |
| 27. | 2 May 1969 | E | 16 | 29 |
| 28. | 5 May 1964* | H | 30 | 60 |
| 29. | 8 May 1969 | F | 18 | 33 |
| 30. | 9 May 1969 | L | 15 | 70 |
| 31. | 11 May 1968 | D | 8 | 20 |
| 32. | 29 May 1964* | J | 38 | 70 |

* Collections of Dr. P. T. Thomas

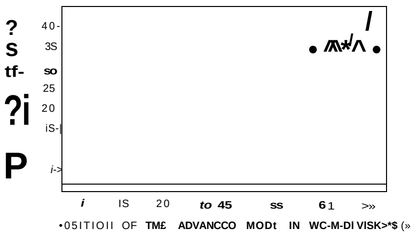

FIG. 7. Relation between the preceding and advanced modes in the ova size frequency distributions for stages B through J.

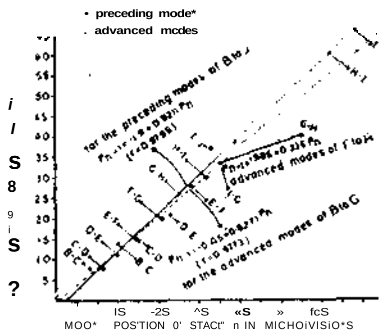

FIG. 8. Rate of progression of the preceding modes in relation to the rate of progression of the advanced modes in the ova size frequency polygons, through successive stages of maturity.

the mean advanced mode (P) of stage n-1 is plotted against that (P) of stage n (Fig. 8; symbol x); the scatter values between B-C and F-G conform to the linear form,

TABLE 3. *Mean of the preceding and advanced modes for each of the maturity stages.*

| Stage | Mean of the preceding modes (m.d.) | Mean of the advanced modes (m.d.) |
|---|---|---|
| B | 8.0 | 14.0 |
| C | 8.0 | 15.0 |
| D | 11.4 | 21.0 |
| E | 14.8 | 28.1 |
| F | 19.8 | 33.3 |
| G | 26.0 | 40.0 |
| H | 30.0 | 60.0 |
| I | 37.0 | 67.0 |
| J | 38.0 | 72.0 |

$P_{n-1} = -0.45+0.8271\ P_n$ . . . . . . . (7)
(r = 0.9773)
$b_2 = \tan Q_2 = 0.8271$
$Q_2 = \tan^{-1} 0.8271 = 39° 36'$ ; $\therefore \sec Q_2 = 1.2978$

The regression coefficient shows that the rate of growth of the advanced mode frpm B to G has been only slighdy greater than that of the preceding mode as already shown by the parallel trend lines (Fig. 3). At G-H, the scatter value for the advanced mode deflects from the course of Eq. (7) denoting an abrupt increase in the growth rate.

The regression fitted to the distance between F-G and G-H is,

$P_{n-1} = 19.95 + 0.335\ P_n$ . . . . . . . (8)
$b_3 = \tan Q_3 = 0.335$
$Q_3 = \tan^{-1} 0.335 = 18° 31'$ ; $\therefore \sec Q_3 = 1.0546$

The ratio of the rate **of change of $P_n$** . i with $P_n$ expressed **by Eq. (7)** to **that** expressed by equation (8) is,

$$\frac{(dy_1/dx_1)}{(dy_2/dx_2)} = \frac{d \tan Q_2}{d \tan Q_3} = \frac{\sec^2 Q_2}{\sec^2 Q_3} = \frac{(1.2478)^2}{(1.0546)^2} = 1.5144$$

where $y_1$ and $x_1$ represent the variables $P_{n-1}$ and $P_n$ respectively of Eq. (7), and $y_2$ and $x_2$ represent $P_{n-1}$ and $P_n$ respectively of Eq. (8). The ratio shows that the growth rate of the advanced mode from G to H has been 1.5144 times the growth rate of the same batch through stages B to G (see the change in the trend line tracing the growth of the advanced mode in Fig. 3). The ratio of the rate of change of the variables expressed by Eq. (6) to that expressed by Eq. (8) is found to be,

$$\frac{(1.3596)^2}{(1.0546)^2} = 1.6620$$

which means that the growth rate of the advanced mode from G to H alone was 1.6620 times the growth rate of the preceding mode through stages B to J. The scatter values for the successive pairs of stages H-I and I-J remain almost on the extrapolated line expressing Eq. (6) and closer to the extrapolated line expressing Eq. (7), denoting thereby a resumption of growth rate to the original level, after the sudden change J>etween G and H.

After releasing the advanced batch of ova, stage J transforms into K. The modal position of the preceding batch of K is similar to the advanced batch of G. Therefore, the same abrupt increase in the growth of the advanced batch taking place from G to H could be expected in the preceding batch also while K transforms into L, and that this really takes place is borne out by the trend line tracing the growth of the preceding mode from K to L.

*Growth of primary and secondary batches through time:* The modes of each ovary are indicated by the symbol x and connected to each other by a straight continuous line in Fig. 9 against the date of sampling. Most of the maturing and ripe fish occurred in the samples taken during the period 11th March to 11th May, but only one intermediate and three ripe fish during the period 23rd December to 8th March. These two periods are differentiated in Fig. 9 by a horizontal line drawn between the 8th and the 11th March, which divides the figure into an upper and lower sections termed A and B respectively.

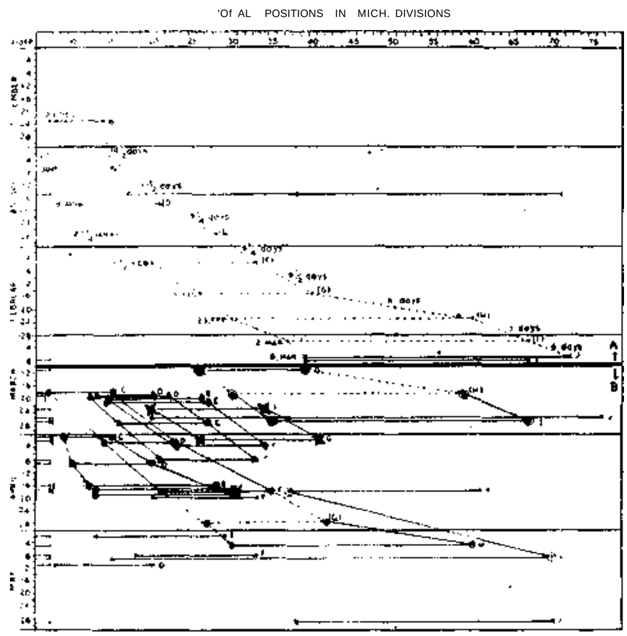


FIG. 9. Growth of ova (as represented by the progression of modes in the ova diameter frequency for stages C through J) in relation to time.

The presentation of the data in the form shpwn in Fig. 9 helped trace the growth of the modes with the progress of time through succeeding stages. While tracing the growth, the stage-date combinations were chosen in such a way that the growth lines connecting the modes of the successive stages have a slope similar to the slope of the trend lines fitted in Fig. 3 and also the regression lines fitted in Fig. 8 although the latter two have no reference to time.

Progress of maturity with the progress of time is first traced in section B for the seven different categories differing from one another with regard to the time of onset of maturity. The categories are differentiated from one another by enclosing their modal symbols X in closed circles, squares, triangles, rhombus, stars, double circles or dotted circles. The time involved in the transformation from one stage to the other, read directly from Fig. 9 for each of the 7 categories is dealt with in Table 4. The range and mean number of days involved between the successive pairs of stages from C through L are derived in Table 5.

The maturity history of the stage J fish sampled on the 8th March (represented in section A of Fig. 9) is traced back through the preceding stages by fitting the results given in Table 5 and the fish in question is found to have been in stage C on the 6th January. There is one stage B fish in section A, sampled on the 23rd December and the gap between this and the stage C of the 6th January is only 141 days, which strongly suggests that the B stage fish occurring on the 23rd December can have matured into stage J fish sampled on the 8th March. The number of days, thus assumed to have been involved in the growth from stage B to C is also presented in Table 5. The period taken by a B stage fish to attain stage J is about 75 days; since K and L resemble G and J respectively, the maturation of the secondary batch is supposed to take 21 days, and thus, the individual streaked seer takes 96 days to complete the whole spawning process each season.

*Remnants of ova from previous spawning:* Only one fish belonging to stage K occurred in the samples; however, the ovary of this fish did not exhibit the shrunken and blood-shot appearance associated with the spent condition; yet, that the first batch of eggs has already been spawned is evident from the presence of remnants of ripe ova, and more concretely, by the position of the preceding mode remaining virtually at the same level as that at the preceding stage J. The ova within the preceding mode of K are so prominent numerically and in size, that no visible change was recognizable in the ovaries consequent on the release of the advanced batch.

*Relative number of eggs in each group:* The modes of the two batches of ova evident at stage B become progressively distinct through the succeeding stages. From the frequency polygon for each maturing stage shown in Figs. 2 and 3, it is clear that the number of smaller yolked ova within the preceding mode were mucn less than the number of ova within the advanced batch up to stage G, after which the number increased markedly, far exceeding that of the advanced mode. Loss of ripening or ripe eggs by mechanical means or spawning at stages H, I and J was already indicated. In view of these difficulties, i.e., the addition of ova from the immature to the secondary stock and egg loss after stage G, the ratios of the number of all smaller yolked ova to that of the most mature batch for stages H, I and J given in Table 1 are so high and variable that they fail to corroborate frequency of spawning deduced by other means.

TABLE 4. *Probable duration involved in the transformation from one stage to the other.*

| Categories as per figure 9 | Date of occurrence | Stage | Position of preceding mode (m.d.) | Position of advanced mode (m.d.) | Increment between preceding modes (m.d.) | Increment between advanced modes (m.d.) | Duration involved (days) |
|---|---|---|---|---|---|---|---|
| 1. Modal values enclosed in circle | 18 March | C | 7 | 15 | 7 | 8 | 15 |
| | 2 April | D | 14 | 23 | 7 | 12 | 15 |
| | 17 April | F | 21 | 35 | 6 | 7 | 9 |
| | 26 April | (G)* | 27 | 42 | 3 | 18 | 8 |
| | 5 May | H | 30 | 60 | | | |
| 2. Modal values enclosed in squares | 1 April | C | 9 | 15 | 1 | 5 | 8 |
| | 9 April | D | 10 | 20 | 3 | 10 | 8 |
| | 17 April | E | 13 | 30 | | | |
| 3. Modal values enclosed in triangles | 19 March | D | 12 | 22 | 4 | 5 | 8 |
| | 27 March | E | 16 | 27 | 5 | 6 | 12 |
| | 8 April | F | 21 | 33 | | | |
| 4. Modal values enclosed in rhombus | 18 March | E | 14 | 26 | | | |
| | | | | | 9 | 8 | 15 |
| | 23 April | F | 23 | 34 | | | |
| 5. Modal values enclosed in stars | 23 March | F | 23 | 34 | | | |
| | 1 April | | | | 3 | 3 | 9 |
| | | G | 26 | 41 | | | |
| 6. Modal values enclosed in double circles | 11 March | G | 26 | 39 | | | |
| | 20 March | | | | 4 | 20 | 9 |
| | 26 March | (H)** | 30 | 59 | 5 | 8 | 6 |
| | | I | 35 | 67 | | | |
| 7. Modal values enclosed in dotted circles | 18 April | K | 37 | 61 | | | |
| | 9 May | L | 15 | 70 | | | |
| | | | | | From preceding mode of K to advanceed mode of L | 33 | 21 |

Category 5 shows that F takes 9 days to become G; on this basis a hypothetical (G) is introduced here (see Fig. 9).

Category 1 reveals that G takes 9 days to become H and on this basis a hypothetical (H) is introduced here (see Fig. 9).

The modes of the hypothetically introduced (G) and (H) are marked as dark spots and connected to each other and with the modes of the preceding stage by interrupted lines in Fig. 9.

TABLE 5. *Mean number of days involved in the growth from one stage to the other.*

| | Stage | *Number of days taken* Range | Mean | |
|---|---|---|---|---|
| 1. | Between B and C | 14.5 oi | **14.5*** | |
| 2. | Between C and D | 8-15 | 1.5 | |
| 3. | Between D and E | 8 only | 8.00 | (Corrected mean 9.12 days; see remark for item 5) |
| 4. | Between E and F | 12-15 | 13.5 | |
| 5. | Between D and F | 15-21.5 | **18.25** | (Equally divisible into 9.12 days between D and E. and 9.12 days between E and F). |
| 6. | Between F and G | 9 only | **9** | |
| 7. | Between G and H | 8 only | **8** | |
| 8. | Between H and I | 6 only | 6 | |
| 9. | Between I and J | 6 only | 6 | (Between K and L = 21 days as per Table 4. After spawning the first batch, K and L resemble G and J respectively. Hence between G and J = 21 days. Between G and I is known to be 15 days as per Table 4. Therefore between I and J = 21—15 = 6 days). |

Based on the back calculation of the maturity history of stage I. shown in section A of figure 9.

TABLE 6. *Distribution of sex ratio according to length groups.*

| Length groups (mm) | 361-400 | 401-440 | 441-480 | 481-520 | 521-560 | 561-600 | 601-640 | 641-680 | 681-720 | 721-760 | 761-800 | 841-880 | 881-920 | 921-960 | 961-1000 | Combined | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Males (%) | — | 25 | 56 | 46 | 50 | 43 | 30 | 62 | 61 | 19 | 25 | **40** | — | 33 | 20 | **33** | **40.5** |
| Females (%) | 100 | 75 | 44 | 54 | 50 | 57 | 70 | 38 | 39 | 81 | 75 | 60 | 100 | 67 | 80 | **67** | **59.5** |

*Number of Broods Per Year Class*

Two definite patterns are recognisable in the distribution of maturing and ripe fish during the spawning season (Fig. 9): (1) the occurrence of stray number of ripe fish during the period 15th January to the 8th March, and (2) the occurrence of maturing and ripe fish in abundance during the period 11th March to the 29th May. Consequently, spawning during the period January to early-March might give rise to a weak brood (a), while spawning during the succeeding period would result in the production of a dominant brood (b). No maturing or ripe fish occurred in the samples after May, yet, that they were actually present in the sea is known by tracing the maturation of some of the maturing fish occurring during May; for example, the stage D fish sampled on the 11th March (Fig. 9) would mature the first batch on the 29th June and the second batch on the 20th July, and the production of another brood (c), probably a weaker one, similar to brood a, is thus indicated.

*Spawning Season*

The distribution of maturity stages according to months shown in Figs. 1 and 4 denotes that spawning extends from January through May. There is- no G.I. above the line expressing Eq. (2) in the last two quarters, while most are distributed above the line in the first two quarters (Fig. 5') which constitute the spawning season when maturing and ripe fish ranged from 50 to 100% in the different length groups (fluctuating line in Fig. 5). No maturing fish occurred in the last two quarters. The exact dates of occurrence of the maturing and ripe fish belonging to the different maturity stages (B to L) illustrated in Fig. 9 indicate the spawning season to be extending from January through May with peak from about the middle of March to the end of May. However, that spawning could extend to as late as July or even later is also apparent from the projected time of maturation of some of the early stages occurring in March (Fig. 9).

*Spawning Ground*

The streaked seer formed 68% and 58.8% of the number of seerfish juveniles occurring in the shore seines operated in the Gulf of Mannar (area II) and Palk Bay (area I) respectively during the year 1967-68, but declined to 5.6% in the Gulf of Mannar and totally absent in the Bay samples the following year. Streaked seer juveniles occurred more abundantly along the shore areas such as Dhargavalasai in Palk Bay and between Pudumadam and Mundal in the Gulf.

Among the ripening or ripe fish sampled, one each of H and J stage fish were taken from Palk Bay off Dhanushkodi and all others from the Arichakadal or Musaltivukadal sections of the Gulf where the depth is not more than 25 meters.

These observations reveal that spawning could take place in **the belt** quite close to the shore up to about the 25 meter line, or that the ripe fish might migrate shorewards and spawn at any protected place nearshores, perhaps sharing the breeding grounds with the king seer, both being more compatible with each other than either with the spotted seer, as evident from the coexistance of their juveniles.

*Sexual and Lunar Rhythms*

The months and days on which the various fish belonging to stages G, H, I, J, K and L were sampled, and the moon's phases are illustrated in Fig. 10.

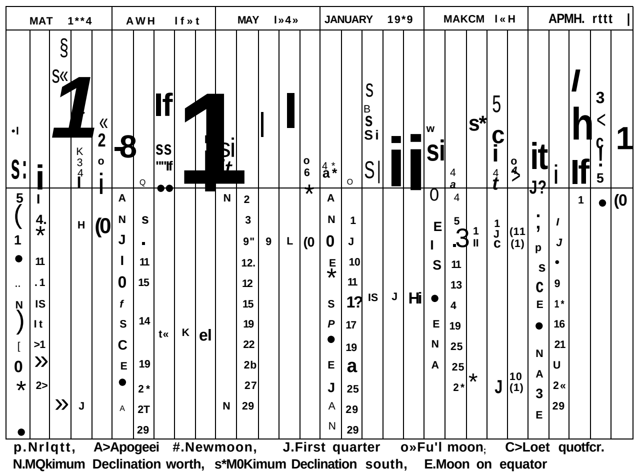

FIG .10. Relation between the phases of the moon and the occurrence of G to L stage fish.

The distribution of these fish in the four quarters of the luner cycle of 28 days is shown in Fig. 11. The first and second batches of eggs are sapwned at stages J and L respectively, therefore, the maturation of any of the preceding stages into either J or L could be traced (using the data in Table 5 and Fig. 9) by concentric lines around the lunar cycle (Fig. 11) to indicate the phase of the moon at the time of maturation, and hence, spawning (dark rectangular areas in Fig. 11).

Of the four J-stage fish sampled, one was taken 6 days before the full moon, two were taken 2 to 3 days following the full moon, while one was taken 2 days preceding the new moon. The only L-stage fish in the sample occurred two days before the full moon. By tracing the maturation of G, H and I stages, two fish are shown to become ripe 6 and 7 days before the full moon, two on the full moon day and one, 4 days preceding the new moon. Thus, out of the 10 ripe fish considered, 5 (50%) were found to or shown to occur 2-3 days preceding or following the full moon, 3 (30%) on the 6th and 7th days before the full moon, and 2 (20%), 2 to 4 days before the new moon and hence, there appears to be no strict lunar periodicity in streaked seer spawning unlike the case of the spotted seer.

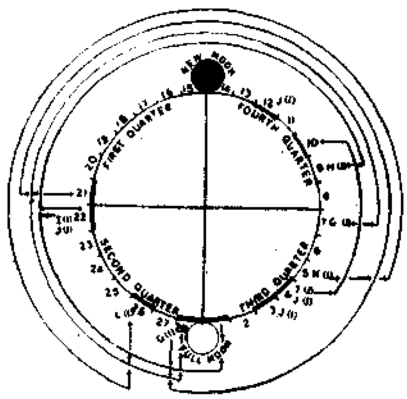


FIG. 11. Relation between lunar cycle and occurrence of G to L stage fish; outer circles trace derivation of J or L stage from preceding stages; black bars indicate probable spawning period.

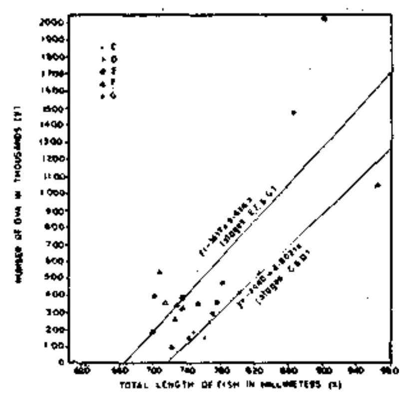

FIG. 12. Relation between total length of fish ,and number of ova in advanced batch separately for maturity stages C & D and E, F, & G.

*Sex Ratio of the Spawning Population*

The distribution of the sex ratio in the length groups ranging from 361-400 mm through 961-1000 mm shows that overall the males formed 40.5% and the females 59.5% of the population. Of the 16 length groups considered, males were dominant only in the 441-480 mm (56%), 641-680 mm (62%) and 681-720 mm (61%) groups, while females were dominant in all the others. The samples did not have any males in the 361-400 mm. and 841-880 mm groups (Table 6).

*Fecundity-Length Relation*

The streaked seer spawn two successive batches of ova each spawning season. C to G stage ovaries were used for the estimation of ova in the advanced or first batch. The lower size limits of ova included in the estimation of the number of ova in the advanced batch at maturity stages C, D, E, F and G are 14 m.d., 16 m.d., 20 m.d., 27 m.d. and 32 m.d. respectively. The scatter diagram giving a plot of the number of ova in the advanced batch (first batch) at stages C to G against fish length (Fig. 12) reveals an increase in the number of ova from the earlier (C and D) to the advanced maturing stages (E, F and G). Therefore, two separate regressions were fitted to the data to explain the apparent increase in the first batch fecundity, one for stages C and D (Eq. 9),

$$y = -34\text{-}10 + 4.8021\ x \qquad (9)$$

and the other for stages E, F and G (Eq. 10),

$$y = -3617 + 5.4360\ x \qquad (10)$$

where y - the number of ova in thousands in the advanced batch and x =•• fish length (total) in mm.

The ova in the advanced batch of H, I, J, K and L stage ovaries are found to be much less in number than those found in C to G stage ovaries, and they show no definite relationship with fish length (enclosed values in Fig. 13) apparently because of egg loss due to spawning or mechanical means or both.

At stages C to G, the full complement of ova in the secondary batch is not yet developed, but present at stages H to K. Therefore, the number of ova to be spawned in the second batch is estimated from ovaries belonging to stages H to K. At stages L at which the second batch of ova is spawned, ova less than 26 m.d. are sparingly present (Fig. 3), and it is most likely that they are resorbed. Therefore, the lower size limit of ova included in the estimation of the fecundity at the second batch is 26 m.d. The relationship of the number of ova in the secondary batch of H to K stage ovaries with fish length is expressed by the equation,

$$y = -444 + 1.1638\ x \qquad (11)$$

where _y is the number of ova in thousands and x, fish length in mm (Fig. 13).

The absolute fecundity (y) - fish length (x) relation for the streaked seer is derived by summing Eqs. (10) and (11) (Fig. 14).

$$y = -4061 + 6\ 5998\ x \qquad (12)$$

Eq. (12) shows the increase in egg number per 10 mm body length to be 65,998.

*Fecundity-Weight Relationship*

The data used for fitting the fecundity-fish length relationship were also used for the fecundity-fish weight relation. The first batch fecundity increased markedly at E-G stages when compared to the C-D stages (Fig. 15). For C-D stages, the first batch ova in thousands (y)-fish weight in grams (x) relation is fitted by the expression,

TABLE 7. *Values of y-intercept* (a), *regression coefficient* (b), *standard error* (Sy),anrf *correlation coefficient* (r) *in the fecundity-length and fecundity-weight regression (fecundity in I000;length in mm; weight in g.).*

| Stage | Fecundity-length relationship a | b | Syx | r | Fecundity-weight relationship a | b | Syx | r |
|---|---|---|---|---|---|---|---|---|
| C and D (advanced batch) | –3440 | 4.8021 | 38 | 0.9778 | –599 | 0.3707 | 131 | 0.6913 |
| E, F and G (advanced batch) | –3617 | 5.4360 | 318 | 0.8064 | –642 | 0.4833 | 293 | 0.8376 |
| H, I, J and K (secondary batch) | —444 | 1.1638 | 92 | 0.6733 | 247 | 0.0855 | 84 | 0.6911 |

y -559 -H\3707x . . . . . . . .C$^3$)'

while for E-G stages, the same relation is expressed by,

y = -642 -;- 0.4833 x . . . . . . .(14)

The second batch ova in thousands (y) - fish weight in grams (x) relation for the fish belonging to H to K stages of maturity (Fig. 16) is expressed by, ;

v -, 247 -L- 0.0855 x . . . . . . .('5.i

values of a, b, syx and r for all the relationships (Eqs. 9 to 15) are given in Table 7. The absolute fecundity (y)-fish weight (x) relation is derived by summing Eqs. (14) and (15),

y = -395 -f 0.5688 x . . . . . . . .(16)

The straight line regression of fecundity (y) on fish weight (x) without y - axis intercept (intercept = 0 ) shows that every ton of spawning females produces about 570 million eggs.

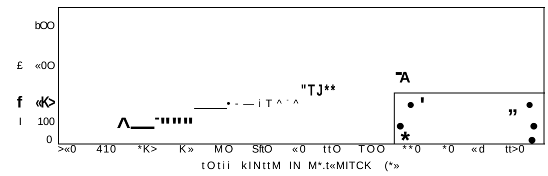

**FIG. 13. Relation between** total length of fish and number of ova in preceding batch, for maturity stages H to K; enclosed values represent ova in advanced batch.

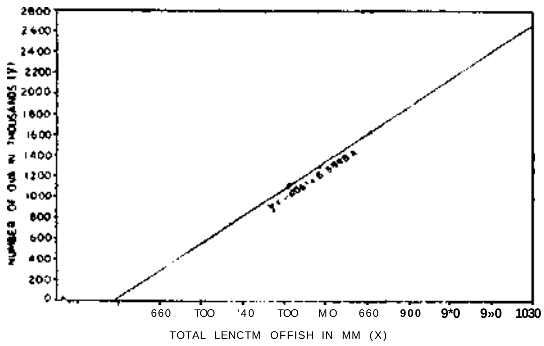

FIG. 14. Absolute fecundity-fish length relation.

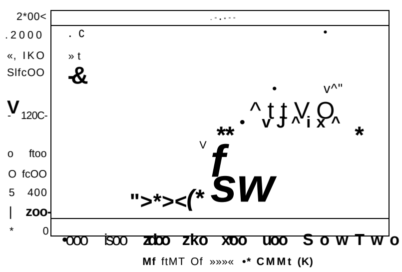

FIG. 15. Relation between fish weight and number of ova in advanced batch, separately for maturity stages C & D and E, F & G.

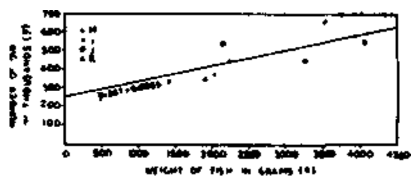

FIG. 16. Relation between fish weight and number of ova in preceding batch, for stages **H** to **K.**

## COMPARATIVE DISCUSSION ON REPRODUCTION IN SEERFISHES

The comparative discussion of the reproductive biology of the seerfishes in the Indian seas follows from a detailed study made by the author on the king seer, *S. commerson,* (Devaraj 1983), the spotted seer, S. *guttatus,* (Devaraj MS) and the streaked seer, *S. lineolatus.* The spent recovering ovaries of the king seer and the spotted seer are indistinguishable from their virgin developing ovaries in terms of the ova size, and hence, both the categories are treated as intermediate in the gross maturity scale of five stages, and as 'B' in the finer maturity scale of 10 to 12 stages (A to L). The spent recovering and immature ovaries of the streaked seer are distinguishable from each other with reference to their external characteristics, but resemble closely each other in their ova size frequency distribution, therefore, it has been found necessary to treat them separately in the gross maturity scale, but together under stage A of the finer scale. But for this, the three species generally agreed one another especially in respect of the gonad colour and gonad size in relation to the body cavity at various stages of maturity, and also the size (35-40 m.d.) at which the maturing ova show through the ovisac. The length and weight of the gonad at comparable maturity stages were the least for the spotted seer, maximum for the king seer and intermediate for the streaked seer, and this gradation is in conformity with the Lex, or Woo of the three species. However, the gonad (ovarian) index recorded the maximum of 68.5 units for the spotted seer, 55.6 units for the streaked seer, and 26.2 units for the king seer. The gonad index values separating the mature females from the immature or intermediate females were also the highest for the spotted seer (7 to 8), but more or less the same for the streaked seer (3 to 5) and the king seer (2.75 to 5.5). The regression of the maximum ova diameter on the gonad index is generally paroblic in form for all the three species, and could be used for the determination of the approximate stages of maturity, except for the ripening and ripe stages because of partial egg loss resulting in a fall in the gonad index.

The five gross maturity categories (immature, intermediate, maturing, ripe and spent) include 12 stages (A to L) for the king seer and the streaked seer and 10 (A to J) for the spotted seer. The immature and intermediate categories of all the three species are classified into A and B respectively. Stages C to I of the king seer and C to G of the spotted seer and streaked seer belong to the maturing category of the gross scale; in other words, the king seer enters the ripening phase at stage J, while the other two do so at stage H. The spotted seer spawn the first batch of eggs at stage H itself, but the king seer spawn the first batch at stage L, and the streaked seer at J. At the time of spawning the first batch, the mode of the most mature group of ova remains at 54-59 m.d. in the case of the king seer and 64-76 m.d. in the other two species. The remains of the first batch ripe ova are carried over to the succeeding stage - I - in the case of the spotted seer and K in the case of the streaked seer. The streaked seer begin to develop the second batch of ova at stage B itself (mode < 9-12 m.d.); this batch is distinctly recognisable in all the subsequent stages especially after stage G, and it is spawned at stage L (mode 58-73 m.d.). The spotted seer develop the second batch at such an advanced maturing stage as G, and spawn the same at stage J (mode 58-74 m.d.). The king seer begin to develop the second batch at stage E (mode 10-13 m.d.) and the third batch at H (mode 21-23 m.d.); these two batches of ova are clearly recognisable, besides the first batch, at the ripening stages (J, K and L) also, and are believed to be spawned successively after stage L at which the first batch is spawned.

The stage B spotted seer take 112 days to spawn the first batch of ova (stage H) followed by another 92 days for spawning the second batch (stage J); any late maturing and left-over ripe ova of the first batch are spawned at stage I in a minor spawning act. The B stage streaked seer take 75 days for spawning the first batch (stage J) followed by another 21 days for spawning the second batch (stage L); the remnants of first batch ova met with at stage K are so little that they do not seem to involve a minor spawning in between the two major spawnings. The king seer seem to spawn all the three batches in about a month's time at comparatively shorter intervals of time. While no appreciable increase in fecundity was observed in the king seer and the spotted seer between the initial and advanced maturing stages, the streaked seer exhibited marked increase in fecundity at the advanced maturing phase.

The spawning season of the three species of seerfishes lasts more or less from January to August. The spawning population of each species seems to mature in three successive groups resulting in the production of 3 broods each season - a minor brood during the commencement (January-February), a major brood during the peak (April-May) and another minor brood towards the culmination (July-August) of the spawning season. The king seer and streaked seer are quite compatible and share common spawning grounds in the shallow protected bays and coves, while the relatively small and less compatible spotted seer spawn elsewhere, e.g., around the islands in the northern Gulf of Mannar. The spotted seer exhibit a regular lunar rhythm in their spawning while the king seer and the streaked seer do not show such a rhythm. While females dominated (60%) the spawning populations of both the spotted seer and the streaked seer, the males were slightly dominant (52.3%) in the king seer population.

The ratios of the length at first maturity (lm ) to the asymptotic lengths (Leo) for the king seer (741 mm/2081 mm = 0.3561), spotted seer (398 mm/1278 mm 0.3114) and streaked seer (691 mm/1683 mm = 0.4105) are very similar to each other as observed by Cushing (1968) in other similar taxonomic groups. The nearer the lm / La, value to unity, the greater the reproductive stress (Cushing 1968), and by this reckoning, the lm *IL**. values for seerfishes give no evidence of reproductive stress being experienced by any of the three species. However, stress due to competition from the king seer and other highly predatory species for the available forage was apparent in the case of the spotted seer (Devaraj MS). The increases in egg number per 10 mm body length was minimum in the spotted seer (34,082) and nearly the same in the case of the king seer (64,612) and the streaked seer (65,998), but the number of egg produced by every ton of spawning females was minimum in the king seer (292 million), intermediate in the spotted seer (360 million) and maximum in the streaked seer (570 million). The fact that the exponential values in the length-weight relation of the king seer (2.8577), spotted seer

(2.8605) and streaked seer (2.9209) (Devaraj 1982) show a similar increasing trend as the fecundity per ton of spawning females seems to suggest that higher fecundity per unit body weight might tend the fish towards isometric growth.

The three species of seer resemble one another in many essential aspects of their breeding such as the spawning season, production of three broods a season, and the production of more than one batch of ova in succession before the close of the season. They differ mainly in respect of the stages at which the secondary batches of ova begin to develop, the stages at which the different batches of ova are spawned, the duration involved between the onset of maturity and the first and subsequent spawning acts and the fecundity per unit body length or weight.

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REFERENCES

GUSHING, D. H. 1968. *Fisheries Biology: A study in population dynamics.* Univ. Wisconsin Press, Madison, Wis.: 1-200.

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

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

KUTHALINGAM, M. D. K. 1959. Observations on the food and feeding habits of post-larvae, juveniles and adults of some Madras fishes. /. *Madras Univ.* pt. B , 29(2): 139-150.

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): 459-526.

VAN DER ELST, R. P. AND B. B. COLLETTE. 1984. Game fishes of the east coast of southern Africa. 2. Biology and systematics of the queen mackerel *Scomberomorus plurilincatus. South African Assoc. Mar. Biol. Res., Oceanogr. Res. Instit., lnvc.it. Rep.* (55): 1-12.

WILLIAMS, F. 1964. The scombroid fishes of Sast Africa. *Mar. Biol. Assoc. India, PI;K. Symp. Scombroid Fish.,* Pt, 1: 107-164.