MATURITY, SPAWNING AND FECUNDITY OF THE KING SEER, *SCOMBEROMORUS COMMERSON* (LACEPEDE), IN THE SEAS AROUND THE INDIAN PENINSULA

M. DEVARAJ*

Central Marine Fisheries Research Institute, Regional Centre, Madapam.

ABSTRACT

Based on the modes of ova, 12 progressive stages are identified in the maturation of ovaries of king seer. A line, 3 standard errors above the regression of Gonad Index on total length of fish in resting or immatures stages, L (G.I. = −0.195 + 0.002046 L), is found useful in the separation of spawning fish from nonspawning fish. Estimation of maturity on the basis of the regression of maximum ova diameter (m.o.d.) on G.I. holds only up to a G.I. of 7.2, beyond which m.o.d. is in the range of 34 to 47 m.d. (1 m.d. = 0.0167 mm) irrespective of G.I. The length at first maturity (701-800 mm or the median 750 mm) shows considerable agreement with the values reported for the Papua New Guinea and East African regions. Spawning season extends from January to September, during which a weak brood results in January-February, a strong brood during the peak spawning in April-May and another weak brood in July-August. The three batches of ova in the spawn-ripe ovaries (stage L) are spawned successively at an interval of a month or even less. The number of ova in the first, second and third batches are in the ratio of 1 : 1 : 0.27. Spawning grounds are located along strictly inshore and protected coves, as those close to Panaikulam on Palk Bay and Pudumadam on the Gulf of Mannar. Males, females and indeterminates are in the ratio 52.3 : 43.2 : 4.5. Males are dominant up to a length of 1300 mm, and females, beyond this length. There is no significant difference in the fecundity between different maturity stages (F to L) or between estimates by different formulae. The relation between absolute fecundity, defined as the total number of ova spawned in one season over the three spawning acts (y in thousands), and total length of fish (x in mm) is found to be, $y = -2273 + 3.5793\ x$. Fecundity-fish weight relation reveals that, for every ton of spawning females, 291.9 million eggs are produced. For most of the maturity stages, egg size-fish length relation exhibits negative correlation.

INTRODUCTION

Information on the spawning habits of the king seer along its distributional range in the Indo-Pacific is quite fragmentary (Kishinouye 1923; Munro 1942; Jones 1961; Silas 1964; Whitley 1964; Williams 1964; and Lewis et al 1974). The present study gives a fairly comprehensive picture of the reproductive biology of this fish for the Indian peninsular waters.

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* *Present address*: Central Institute of Fisheries Education, Versova, Bombay 400061.

Material and Methods

The study is based on regular, twice- or thrice-a-week samples of gonads of the king seer from Palk Bay and the Gulf of Mannar, landed in the Rameswaram Island, near Mandapam and Tuticorin, and from the southeast Arabian Sea along the coast between Cape Comorin and Colachel, during the period July 1967 to July 1969 and occasional samples taken subsequently.

Maturity stages were ascertained (1) by a gross examination of the gonads of 578 females and 706 males, (2) by studying the ova-diameter frequency distribution of 279 ovaries, and (3) by estimating the gonad indices of 270 females. In the first method, the 5-stage classification given by June (1953) for the yellowfin tuna was adopted for describing the gross maturity stages. A few ovaries belonging to each of the gross stages were examined microscopically for the size of the ova and the extent of yolk deposition. The testes were not examined microscopically for such a classification. In the second method, the measurements of ova made to the nearest micrometer unit [one micrometer division (m.d.) = 0.0167 mm] were restricted to 100 ova for an immature ovary, 200 for an intermediate ovary and 300 for a maturing or ripe ovary (Clark 1934; June 1953; Yuen 1955; and Otsu and Uchida 1959). In order to bring out the natural sequence of the finer maturity stages which the ova pass through before becoming fully ripe, the individual ova-diameter-frequency polygons were classified according to the nature of the size-frequency distribution of ova and the positions of the mode of the most mature as well as the preceding groups of ova, and not according to regular size intervals of the mode of most mature group of ova alone, as done by Clark (1934) and McGregor (1957). The frequency polygons of several fish of the same maturity classification were then converted to pooled frequencies, which were then reduced to the basis of 300 ova. In the third method, the gonad index (G.I.) which is useful for separating the spawning from the nonspawning fish was estimated by the expression given by Orange (1961),

$$G.I. = (W/L^3)\ 10 \ldots\ldots (1)$$

where W = weight of the paired ovaries in grams and L = total length of fish in millimeters. The relationship between G.I. and ova diameter (either the mode of the most mature group of ova or the largest egg) was also established, with a view to estimating the size of the ovarian eggs, and hence the degree of maturity, from the G.I. data alone (Orange 1961).

Frequency of spawning was determined on the basis of the multiplicity of modes in the ova-diameter frequency curves, growth of the successive egg groups and the relative number of eggs in the different groups, more or less following the guidelines in Clark (1934) and MacGregor (1957). The relationship between lunar cycle and spawning has also been investigated. The study on sex ratio included 1364 fish.

Samples for the fecundity estimation consisted of 51 F to L stage ovaries (F = 15; G = 15; H = 5; I = 11; J = 1; K = 3; L = 1). From each paired ovaries considered for fecundity, the diameters of 300 ova of size > 15 m.d. in a Sedgewick-Rafter counting chamber were measured, and then weighed together with the smaller reserve oocytes (< 14 m.d.) and fragments of connective tissue, to the nearest 0.001 gram in a physical balance, and the fecundity was estimated as follows,

$$\text{Fecundity} = \frac{300 \times \text{weight of paired ovaries}}{\text{Weight of the sample}}$$

Measurements of ova diameters in the fecundity sample helped relate fecundity with the precise stage of maturity. Four simple models (Eqs. 2, 3, 4 and 5) used by MacGregor (1957) and an exponential equation (Eq. 6) used by Raitt (1933) were followed in expressing the relationship of fecundity (y) with length (x). In the relationship with weight (W) a straight line equation (Eq. 7) recommended by Kandler and Priwitz (1957), the same without intercept (Eq. 8) and an exponential equation (Eq. 9) given by Raitt (1933) were followed.

$$y = a + b\,x \qquad \ldots\ldots \qquad (2)$$
$$y = a + b\,x^2 \qquad \ldots\ldots \qquad (3)$$
$$y = a + b\,x^3 \qquad \ldots\ldots \qquad (4)$$
$$y = b\,x^3 \qquad \ldots\ldots \qquad (5)$$
$$y = a^b \qquad \ldots\ldots \qquad (6)$$
$$y = a + b\,W \qquad \ldots\ldots \qquad (7)$$
$$F = b\,W \qquad \ldots\ldots \qquad (8)$$
$$F = a\,W^b \qquad \ldots\ldots \qquad (9)$$

The wet weight of 100 maturing ova from each paired ovaries of the king seer in F to I stages was used for computing the relationship of fish length with egg size (E) and egg mass (M). Egg size is defined as the average weight (mostly dry weight) of the ripe eggs of a fish, while the product of absolute egg number and egg size is designated as egg mass (Schopka 1971).

Results and Discussion

I. *MATURITY*

1. *Maturity stages* (*Gross examination*)

a) *Ovary*

(i) *Immature ovary*: The ovary is flesh-coloured, 1 to 3 mm in width and elongated up to the posterior level of the oesophageal region. The transparent ova measure from a fraction of a micrometer division (1 m.d. = 0.0167 mm) to 6 m.d. The nucleus is prominent and centrally located. Fish up to 600 mm in total length were immature.

(ii) *Intermediate ovary*: Both virgin and spent-recovering females are included in this category. The process of yolk deposition begins when the ovum is about 7 m.d. in diameter. In most of the ova between 9 and 15 m.d. the zona radiata is discernible.The nucleus is large, vesicular and occasionally granular.

(iii) *Maturing ovary*: The ovary attains a very large size and occupies ¼ to ½ the visceral cavity. It is characteristically yellowish with prominent blood vessels on the surface, and the ova show through the ovisac on attaining a size of about 37 m.d. Ova within the size range of 16-19 m.d. are incompletely yolked and semiopaque, and those above 30 m.d. are fully yolk-laden and opaque. The diameter-frequency distribution of a maturing ovary is illustrated in Fig. 1.

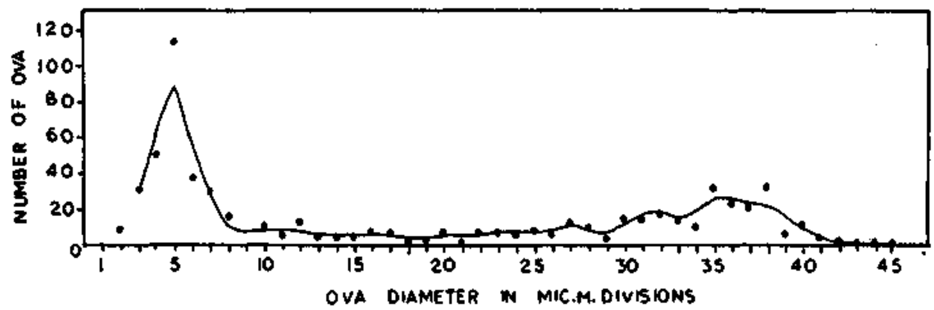

FIG. 1. Frequency distribution of diameter of 630 ova taken from the maturing ovary of a fish caught from Pudumadam on 28-3-1968; ova of size less than 2 m.d. were not measured. The line represents the original data (dots) smoothed by the formula.

(iv) *Ripe ovary*: The ripening or ripe ovary occupies about ½ to ¾ the body cavity. The ripening ova are bout 45-49 m.d. in diameter, not yet fully translucent, and the oil globule may or may not be faintly visible. The ripe ova are translucent, $>$ 47 m.d. in diameter, double-walled (outer zona radiata and inner fertilization membrance) and possess each a brown, spherical oil globule, 18-22 m.d. in diameter. In both the ripening and ripe ovaries, a group of fully yolk-laden opaque ova 22-41 m.d. in diameter with a distinct mode at about 34-37 m.d. and another group of smaller yolked ova are also present.

(v) *Spent ovary*: Recently spawned or spent females were never met with, but spent-recovering ovaries, included under the intermediate stage, were common.

b) *Testis*

(i) *Immature testis*: The testis is long, thin, ribbon-like and faintly whitish.

(ii) *Intermediate testis*: The testis of the virgin males occupies about 1/8 or less and that of the spent-recovering males about 1/8 to ¼ the body cavity. The colour of the testis is dull white.

(iii) *Maturing testis*: The testis is milky white, and attains a very large size, filling up nearly ¼ to ½ the body cavity.

(iv) *Ripe testis*: Typically ripe testis is milky white, much more massive than the maturing testis, occupies about ½ the body cavity, and exudes milt very profusely on gently pressing the abdomen. Ripe males were met with only on 6th March 1974, among a few males landed by shore seines at Panaikulam (Palk Bay), and seldom in the drift-netting grounds.

(v) *Spent testis*: The testis presents a lightly reddish tinge and a shrunken appearance. Of the many males landed by shore seines on 6th March 1974 at Panaikulam, there was one male whose testis showed symptoms of recent spawning. Spent males were seldom met with in the gill-net fishing grounds. Monthly percentage distribution of maturity stages for the period July 1967 to July 1969 is shown in Fig. 2.

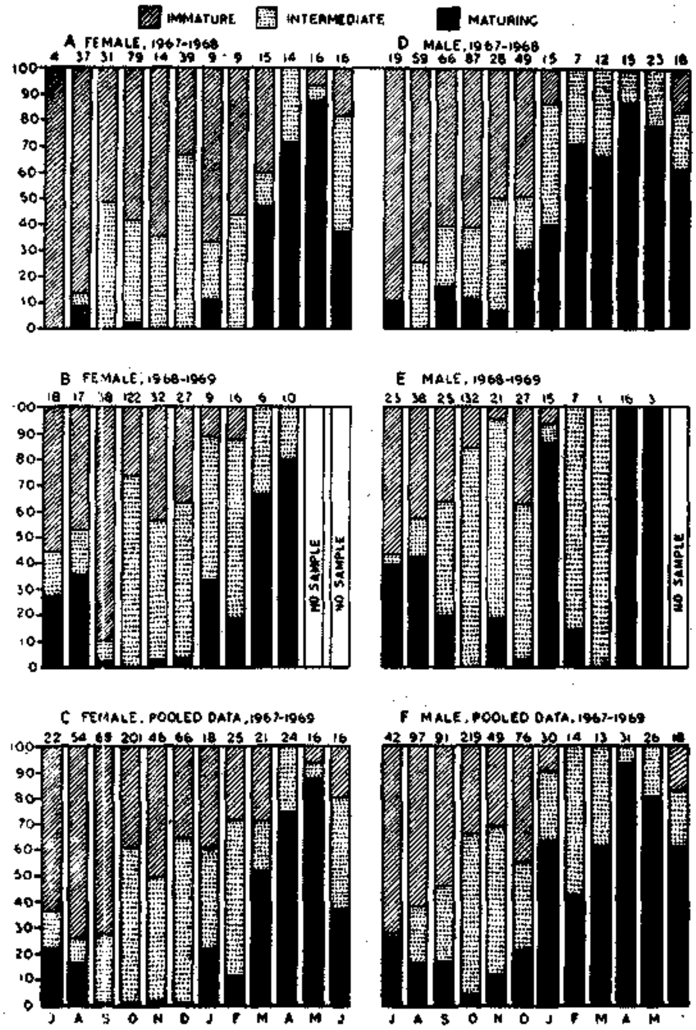

FIG. 2. Percentage of fish in different maturity stages during successive months; numerals denote the number of fish in the samples.

Frequency distribution of ova diameter

On the basis of this analysis, 12 arbitrary stages, designated serially as A to L, were recognized (Figs. 3 and 4), and their percentages in the pooled monthly samples shown in Fig. 5. A brief definition of these stages is given below.

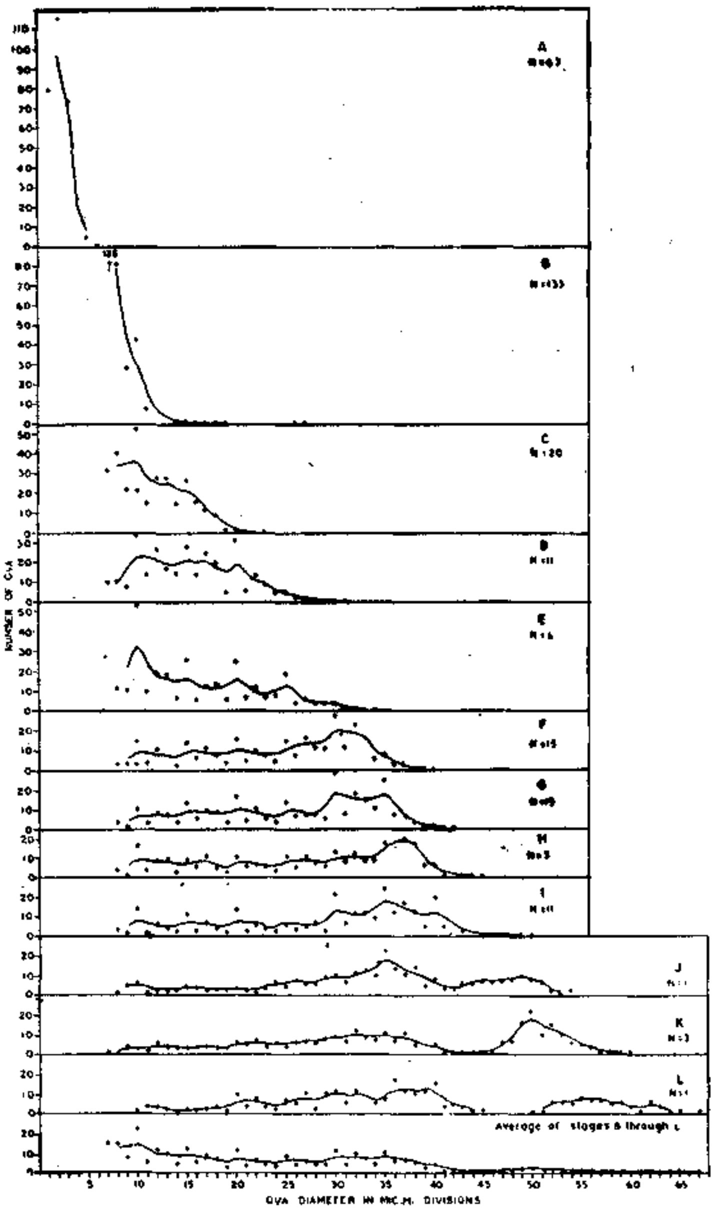

FIG. 3. Scatter diagram-frequency polygon for successive stages from A through L; the lines represent the values smoothed by the formula

Immature

Stage A: Mode at 2 m.d. (0.0334 mm); no ova beyond 6 m.d. (0.1002 mm).

Intermediate

Stage B: Mode of the most mature group of ova between 7 and 10 m.d. (0.1169 & 0.1670 mm); ordinarily no ova beyond 20 m.d. (0.3340 mm); but in spent recovering ovaries, ova of 26-27 m.d. (0.4342-0.4509 mm) diameter may be present.

Maturing

Stage C: Mode of the most mature group of ova not advanced significantly from that of the previous stage; but may be taken to be between 9 and 12 m.d. (0.1503 & 0.2004 mm); no ova beyond 23 m.d. (0.3841 mm).

Stage D: Mode of the most mature group of ova less sharp, between 12 and 18 m.d. (0.2004 & 0.3006 mm), and no ova beyond 31 m.d. (0.5177 mm).

Stage E: Mode of the most mature group of ova between 18 and 22 m.d. (0.3006 & 0.3674 mm); preceding mode at 10-13 m.d. (0.1670-0.2171 mm); no ova beyond 34 m.d. (0.5678 mm).

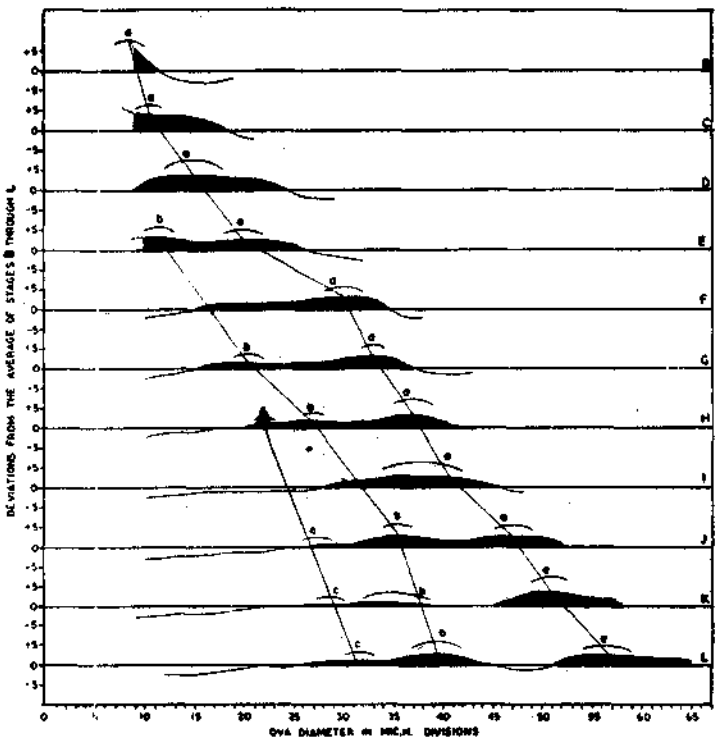

FIG. 4. Deviations from the average frequency polygon of stages B through L; the deviations are smoothed twice by a running average of three to minimise chance fluctuations.

Stage F: Mode of the most mature group of ova between 28 and 32 m.d. (0.4676 & 0.5344 mm); smaller maturing ova do not form a mode; no ova beyond 40 m.d. (0.668 mm).

Stage G: Mode of the most mature group of ova between 32 and 34 m.d. (0.5344 & 0.5678 mm); preceding mode at 19-22 m.d. (0.3173-0.3674 mm) somewhat insignificant; no ova beyond 45 m.d. (0.7515 mm).

Stage H: Mode of the most mature group of ova between 35 and 39 m.d. (0.5511 & 0.6513 mm); two preceding modes, one at 26-28 m.d. (0.4342-0.4676 mm) and another at about 21-23 m.d. (0.3507-0.3841 mm); no ova beyond 45 m.d. (0.7515 mm).

Stage I: Mode of the most mature group of ova symmetrical, but its lower limit remains the same as at stage H (35 m.d. or 0.5511 mm) while the upper limit has advanced slightly to 42 m.d. (0.7014 mm); preceding modes not recognizable; ova between 20 and 30 m.d. (0.3340 & 0.5010 mm) considerably reduced; no ova beyond 50 m.d. (0.8350 mm).

Ripe

Stage J: Mode of the most mature group of ova between 45 and 49 m.d. (0.7515 & 0.8183) and separated from the preceding mode at 34-37 m.d. (0.5678-0.6179 mm) by a distinct trough; another insignificant mode at about 26-29 m.d. (0.4342-0.4843); no ova beyond 54 m.d. (0.9018 mm).

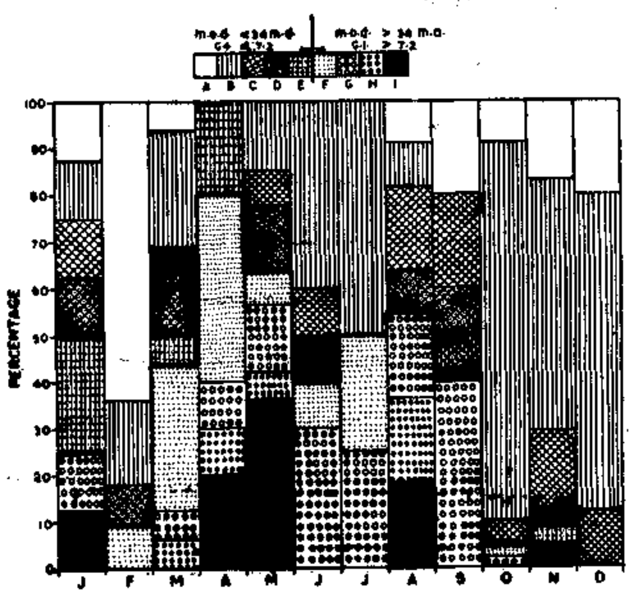

FIG. 5. Percentages of maturity stages A to I in the samples for successive months based on the pooled data for the period July, 1967 through July, 1969.

Stage K: Mode of the most mature group of ova very prominent and rather sharp, between 49 and 53 m.d. (0.8183 & 0.8851 mm) and separated from the small preceding mode at 32-39 m.d. (0.5344-0.6513 mm) by a long, distinct trough; another insignificant mode at 27-30 m.d. (0.4509-0.5010 mm); no ova beyond 60 m.d. (1.0020 mm).

Stage L: Mode of the most mature group of ova between 54 and 59 m.d. (0.9018 & 0.9853 mm), less sharp and with a gradually descending limb; preceding mode at 37-42 m.d. 0.6179-0.7014 mm) sharp, prominent and separated from the former by a deep trough; another insignificant mode at 31-33 m.d. (0.5177-0.5511 mm); no ova beyond 67 m.d. (1.1189 mm).

Gonad index

During the quarter October-December (Fig. 6D), 94% of the fish were in immature or resting stages. The bottom line in Fig. 6D is a regression line of gonad index (G.I.) on fish length (L),

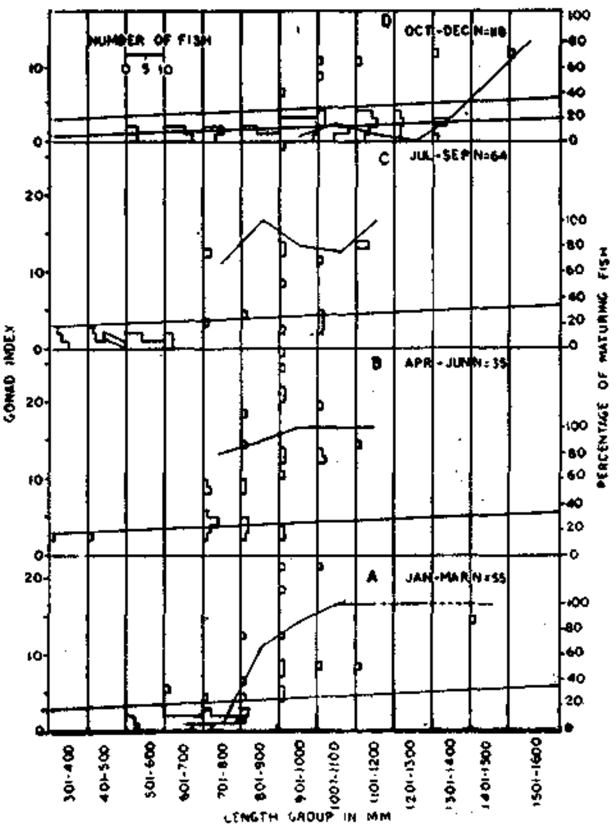

FIG. 6. Relation between total length of fish and gonad index for the four annual quarters based on the pooled data for the period July, 1967 through July, 1969.

$$G.I. = -0.195 + 0.002046\ L \qquad \ldots. \qquad \ldots. \qquad (10)$$

based on the data for 112 females which were in immature and resting stages of maturity (this excludes the 6 indices above 7). The upper line is 3 standard errors (2.444 index units) above this regression line, and the gonad indices below this line are considered to correspond to immature or resting ovaries and those above this line to maturing ovaries (Orange 1961, Raju 1964). This line is reproduced in Panels A, B and C of Fig. 6, to separate the gonad indices of the spawning fish from those of the nonspawning fish.

The relationship between gonad indices (x) and maximum ova diameter (y) could be used for computing maximum ova diameter (and hence, the stage of maturity) from G.I. alone (Orange 1961). The scatter values for the two variables conform to a parabola (Fig. 7) to which the following equation has been fitted,

$$y = -0.1501\ x^2 + 5.0198\ x + 2.1065 \qquad \ldots. \qquad \ldots. \qquad (11)$$

The curve ascends to a peak at the coordinates of 44 m.d. maximum ova diameter (m.o.d.) and 16.5 G.I. units, and then descends steeply towards the coordinates of m.o.d. of 28 m.d. and 27 G.I. units. Normally, the relation is linear with m.o.d. increasing with G.I. over the entire range. A straight line fitted to the entire data in Fig. 7,

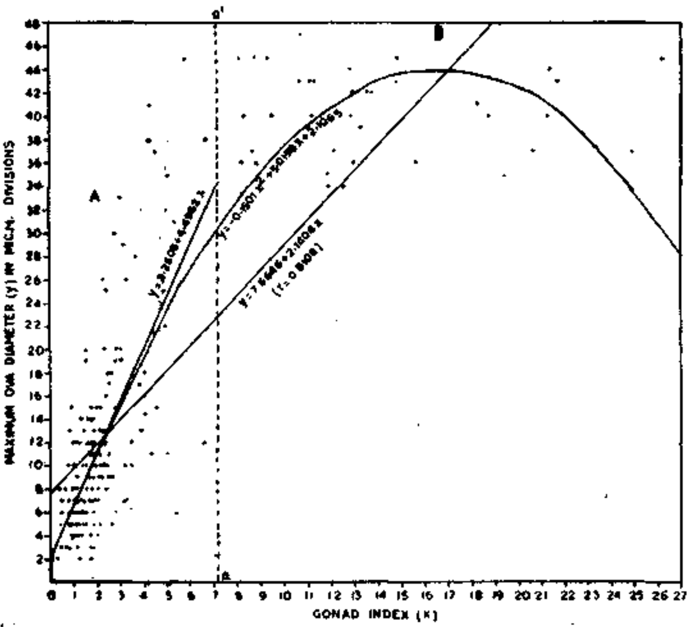

FIG. 7. Relation between gonad index and maximum ova diameter.

$$y = 7.6646 + 2.1404\ x \qquad \ldots. \qquad \ldots. \qquad (12)$$

despite the high correlation between the variables ($r = 0.8108$), is of no value for realistic estimates of m.o.d. as evident from the position of the fitted line in relation to the distribution of the scatter values. In order to resolve this problem, a vertical line a-a' has been drawn in Fig. 7 along the 7.2 G.I. unit to denote the fact that (with a single exception) in no G.I. unit beyond 7.2 is there any m.o.d. less than 34 m.d. It may be noted that stages F and above are characterised by G.I. > 7.2 and m.o.d > 34 m.d. Two definite patterns are now discernible in the distribution of the scatter values in Fig. 7—one ascending pattern in the area marked A left of the a-a' line, and the other horizontal pattern in the area B right of the a-a' line. To the scatter values in section A, is fitted the straight line,

$$y = 2.2608 + 4.4962\ x \qquad \ldots. \qquad \ldots. \qquad (13)$$

If a straight line is fitted to the data in section B, the slope of the line may not be significantly different from zero and therefore, for any G.I. between 7.2 and 26.4, the m.o.d. could be any value between 34 and 47 m.d. Thus, only an approximate estimate of the m.o.d. may be gained by using Eq. (11) for any value of G.I., but fairly accurate estimate is possible by using Eq. (13) for G.I. up to 7.2, in which case, m.o.d. should be taken to be between 34 and 47 m.d. for any value of G.I. beyond 7.2.

2. *Size at first maturity*

It may be seen in Fig. 6 that, with the exception of only 5.5% maturing fish in the 601-700 mm group in the first quarter, all fish below the 701-800 mm group have gonad indices much below the line separating the spawning from the nonspawning fish. The length group at which the king seer first attains maturity may, therefore, be taken as 701-800 mm or 750 mm. By inserting $y = 0$ in the equation $y = -4790 + 6.4612\ L$ expressing the relationship between fecundity in thousands (y) and total length of fish in mm (x) for the 46 fecundity observations on F to I stage ovaries, the length at first maturity is found to be 741 mm. The king seer from east African waters is reported to attain first maturity between 550 mm and 640 mm fork length (= 634 mm and 734 mm total length; Williams 1964). According to Lewis et al (1974), the minimum size at first maturity in Papua New Guinea is 654 mm fork length (= 749 mm total length). The similarity in the size at first maturity from these three widely separated areas is thus quite remarkable.

II. *SPAWNING*

1. *Frequency of spawning*

a) *Multiplicity of modes*: The trimodal distribution of ova at stages J to L (Figs 3 & 4) seems to indicate that the king seer may spawn more than once each represented in the study, the mean ratio recorded 0.82, 1.14 and 1.41, respectively, and for stages H, J, K and L, represented only by 5, 1, 3 and 1 specimens, respectively, the mean ratios were high and fluctuated widely (H = 1.80, J = 2.80, K = 1.67 and L = 3.2). Since the variation in the mean ratios between most of the length groups is within narrow limits (Table 2), the wide fluctuations of the mean ratios when grouped for the different maturity stages, may be attributed to the meagre samples in some of the stages. Therefore, the mean ratio 1.27 for the 51 females may be considered to be characteristic of the population in the study areas. The mean ratio of 1.27 to 1 reveals that, on the average, 2.27 batches of eggs would be spawned in a spawning season if all the yolked ova develop to maturity.

TABLE 2. *Frequencies of ratios of number 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).*

Ratio	Fish length in millimeters												
	751-800	801-850	851-900	901-950	951-1000	1001-1050	1051-1100	1101-1150	1151-1200	1301-1350	1401-1450	1501-1550	Total
0.3	—	—	—	1	—	1	—	—	—	—	—	—	2
0.4	—	1	1	—	—	—	1	—	—	—	—	—	3
0.5	1	—	—	1	—	—	—	—	—	—	—	—	2
0.6	—	—	—	—	1	—	1	1	—	—	—	—	3
0.7	1	—	—	2	2	—	—	—	—	—	—	1	6
0.8	—	—	1	1	—	—	—	—	—	—	—	—	2
0.9	—	—	—	—	1	2	—	—	—	—	—	—	3
1.0	—	—	1	1	—	—	—	—	—	—	—	—	2
1.1	1	—	—	—	—	1	—	—	1	—	1	—	4
1.2	1	—	—	1	—	—	—	1	—	1	—	—	4
1.3	1	—	—	—	—	—	—	1	—	—	—	—	2
1.4	1	—	—	1	—	—	—	—	—	—	—	—	2
1.5	—	—	—	—	—	—	—	1	—	—	—	—	1
1.6	—	1	1	—	—	—	—	—	—	—	—	—	2
1.7	1	—	—	—	1	—	—	1	—	—	—	—	3
1.8	—	—	—	—	—	1	—	—	—	—	—	—	1
2.1	1	—	—	—	—	—	—	—	—	—	—	—	1
2.2	—	1	—	—	—	—	—	—	—	—	—	—	1
2.3	—	—	—	—	—	—	—	1	—	—	—	—	1
2.4	—	—	—	1	—	—	1	—	—	—	—	—	2
2.8	1	—	—	—	—	—	1	—	—	—	—	—	2
3.2	1	1	—	—	—	—	—	—	—	—	—	—	2
Number	10	14	4	9	5	5	4	6	1	1	1	1	51
Mean ratio	1.60	1.85	0.95	1.00	0.92	1.00	1.55	1.43	1.10	1.20	1.10	0.70	1.27

2. *Number of broods spawned each season*

That the king seer releases a strong brood (b) during the peak spawning in April-May was evident from the monthly length-frequency data, which also suggested the production of two minor brood—one (named a) at the commencement (January-February) and the other (named c) towards the culmination (July-August) of the spawning season (Devaraj 1981).

Since the ratio of the number of ova in the most mature group to all the smaller yolked ova is 1 : 1.27, it is inferred that the former would be released as the first full batch leaving a balance of 1.27 batches. The estimated number of ova in the first preceding mode (second batch) is found to be the same as that of the most advanced mode (first batch) (Table 6, Fig. 13). It is therefore inferred that the former is released as the next full batch, leaving the 0.27 batch to become mature and spawned from the second preceding mode (third batch). Apparently, in each of the first two acts of spawning, equal number of eggs are spawned, and, in the third, only 0.27 of the average number of eggs discharged in the first two are spawned. It would thus appear that the spawning of the three successive batches in the ratio of 1, 1 and 0.27 is not responsible for the origin of the broods a, b and c respectively, for, if it were so, the strength of the a and b broods must be the same and that of c nearly 0.27 of either of the first two, which is not the case (Devaraj 1981). This would also mean that the interval between two successive spawning acts is not as wide as that (about 3 months) between the origin of two successive broods indicated by the length-frequency analysis (Devaraj 1981). Contrarily, the interval must be very short, one spawning act following the other, probably in less than a month's time. At this rate, supposing a fish begins to spawn at the beginning of April, it would discharge at least the first two full batches of ova before the end of April, and the fractional batch probably in May if not earlier. Therefore, the fact that brood b is much stronger than either a or c is attributable only to the peak spawning activity in April-May and not to a particular batch of egg.

The percentage distribution of maturity stages A to I in the pooled monthly samples is shown in Figs. 5, in which a thick boundary line is drawn to separate stages F to I (characterised by maximum ova diameter of $>$ 34 m.d. and G.I. of $>$ 7.2) from earlier stages A to E. There are three modes in the monthly distribution of stages F to I: in January, April and August. The mode in April is the largest, the last mode (August) is smaller, and the first mode (January) smallest. Stage I, which is the last stage occurring in the drift-netting grounds, occurs in January (12.5%), April-May (56.0%) and August (18.3%), i.e., at an interval of two months within the spawning season. The occurrence of stage I in relatively large number during April-May is in excellent conformity with the relative abundance of stages F to I in the three modes already mentioned. The king seer disappear from the drift-netting grounds after attaining stage I, and begin to occupy the protected bays and coves quite close to the shore, where they become fully ripe and spawn. Therefore, the abundance of ripe running stages in the spawning grounds should be proportionate to the abundance of either the maturing stages F to I or I alone in the fishing ground. On this inference, the origin of the three broods of an year class may well be correlated with the relative abundance of spawners at the commencement, peak, and culmination of the spawning season—brood a originating in January-February, when only a small proportion of the population undergoes spawning, brood b originating in April-May, when a vast majority of fish spawn, and brood c in July-August, when there are only very few spawners.

3. *Spawning season and spawning grounds*

The spawning season of the king seer seems varied in different areas within the geographical limits of its distribution. Protracted spawning from about January to August is obvious from Figs. 2, 5, 6 and 8. Fig. 8 traces the spawning season by extrapolating the age of young juveniles (Devaraj 1981) to the time axis. The occurrence of larvae and early juveniles (14.4-91.5 mm length)

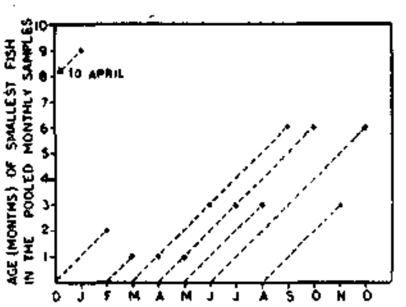

FIG. 8. Age in months of the smallest fish (dots) in the samples for successive months based on the pooled date for the period July, 1967 through July, 1969; dashed lines connect the dots with the months of birth.

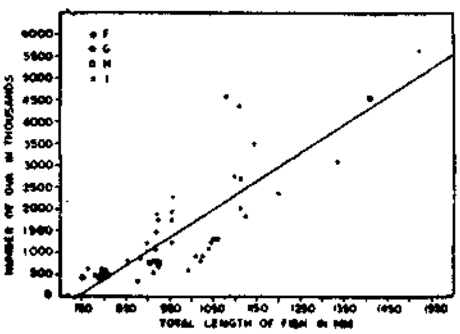

FIG. 9. Relation between fecundity and total length of fish for 46 fish in different stages of maturity

at Vizhinjam, in the southwest coast of India, during January-March (Jones 1961) and the capture of milting males and partly spent females in the trolling grounds off Tuticorin, in the Gulf of Mannar, during August (Silas 1967) also indicate the extended spawning season of the king seer in the Indian seas. In the east African waters, spawning extends from October to July, partly synchronizing with that in India. The occurrence of ripe fish in August and September in the east African region, however, suggests that the king seer may in fact breed at any time of the year, but with peaks at certain periods (Williams 1964). In the Australian region, the king seer spawn during summer (Whitely 1964), the peak spawning period in India, and October to December (Munro 1942), which is the postspawning period in the Indian region. In Papua New Guinea, maturing (stage III) king seer females were encountered during August to December with peak in October, ripe (stage IV) female was met with only once, i.e., in January, and spent (stage V) females during July to December (Lewis et al 1974). These observations denote an extended spawning season around Australia, with a winter peak. In Taiwan the fish spawn during the spring months (Kishinouye 1923).

The absence of ripe fish in the drift-net grounds at 15-80 m deep areas was somewhat puzzling until their discovery very close to the shore at Panaikulam, a protected cove in Palk Bay, on the morning of 6th March 1974, when about two dozen females in J to L stages of maturity were landed by the shore seines. About 100 king seer, 725-1425 mm in length, in advanced maturing stages (H and I) about to become ripe, were caught in shore seines operated on 25th and 26th March 1968 at the Pudumadam cove in the Gulf of Mannar. Jones (1961) collected the larvae of king seer from Vizhinjam, a typical cove, in the southwest coast of India. Lewis et al (1974) referred to the rarity of prespawning (= ripening) king seer in the catches, and reported that the only ripe female taken by them was from Port Morseby. Munro (1942) observed king seer spawning in the vicinity of certain coral reefs off north Queensland, and collected their eggs in tow nettings near Watt Reef. He collected fully ripe fish at Watt Reef and succeeded in their artificial fecundation. However, the larvae of *Scomberomorus* are found distributed both in the intermediate zone towards the coastal areas (Rao 1973), as well as the oceanic region (Peter 1973) of the Indian Ocean under the agency of the monsoon currents prevailing at the time of spawning.

4. *Sexual and lunar rhythms*

Ripening and ripe females (J, K and L stages) were met with only once in the present study, i.e., on the 6th March 1974, two days before the full-moon. The only ripe female that Lewis et al (1974) were able to collect from Papua New Guinea was on the 20th January 1972, four days after the new-moon and ten days before the full-moon. Therefore, there seems to be no lunar periodicity in the spawning of the king seer.

5. *Sex ratio of the spawning population*

All fish below 301 mm were indeterminate. Within the size range studied, there were 52.3% males and 43.2% females, besides 4.5% indeterminates (Table 3). In the size groups up to 1201-1300 mm, males were dominant except for a negligible decline at 601-700 mm and 801-900 groups (males = 49.1%; females = 50.9%). Females were dominant (73.7%) in the 1301-1400 mm group. Both sexes were in equal proportion in the next group (1401-1500 mm). The only fish in the largest group, 1501-1600 mm, was a female. In Papua New Guinea, Lewis et al (1974) found that the males and females were in the ratio

TABLE 3. *Sex ratio according to length groups.*

Length group (mm)	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300	1301-1400	1401-1500	1501-1600	Total
Male (%)	40.5	48.3	57.5	49.1	57.5	49.1	54.9	58.9	55.1	52.9	26.9	50.0	—	52.3
Female (%)	15.9	41.1	41.0	50.9	42.5	50.9	45.1	41.1	44.9	47.1	73.7	50.0	100	43.2
Indeterminate (%)	43.6	10.6	1.5	—	—	—	—	—	—	—	—	—	—	4.5
N	69	265	266	175	134	108	144	95	69	17	19	2	1	1364

of 53:45 for the size groups less than 900 mm fork length, but 4:38 for the size groups beyond 900 mm fork length (900 mm fork length = 1022 mm total length). There is thus a reversal of dominance to females in the length groups > 1301 mm in the Indian region and > 1022 mm in New Guinea. The number of females was nearly double that of males in the 169 king seer from east African waters sexed by Williams (1964).

III *FECUNDITY*

The long ascending limbs of the modes at stages F, G and H begin on the positive side of the mean at about an ova size of 15 m.d. and at stage I at which the king seer begin to migrate to the spawning grounds, the size distribution on either side of the mode is nearly symmetrical, as a result of the quicker growth of the smaller yolked ova > 15 m.d. (Fig. 4). Therefore, an ova diameter of 15 m.d. is considered to be the lower limit of the range of ova to be included in fecundity estimation. In herrings, the number of eggs to be spawned in the ensuing season is already determined in the middle stages of maturity (Baxter 1963). In the case of the king seer, however, only a fraction of ova of the second preceding batch seems to be matured and spawned, and, hence, absolute fecundity should be less than estimated fecundity.

1. *Relation between fecundity and length*

a) *Maturing ovaries* (F to I)

Except for the two high values of fecundity at stage F for fish lengths 1082 mm and 1111 mm, the dispersion of egg numbers over the length classes considered is quite linear (Fig. 9). There appears to exist significant differences in the egg number estimated by the different formulae (Fig. 10; Table 4) only at the first two length groups, i.e., 750 mm and 800 mm, and probably the last three length groups (1500 mm, 1550 mm and 1600 mm) also, but not at any

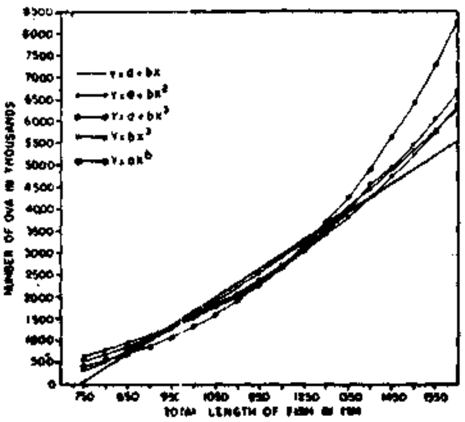

FIG. 10. Comparison of different fecundity-length regression lines for maturing fish (stages F to I)

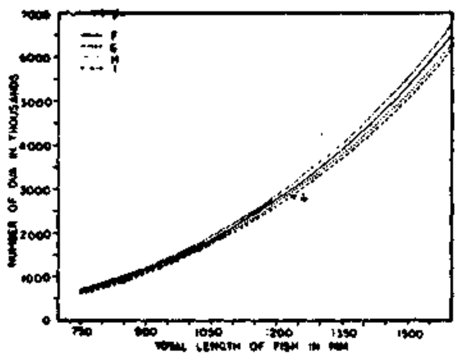

FIG. 11. Fecundity-length regression of the form: y = bx3 for each of the stages F, G, H and I.

TABLE 4. *Comparison of some possible fecundity (y) - length (x) relationships for maturity stages F to L.*

Stage	Fecundity	Parameter	$y = a + bx$	$y = a + bx^2$	$y = a + bx^3$	$y = bx^3$	$y = ax^b$
F (N = 15)	Total	a	−4921	−1516	−383	0	0.0000000003898
		b	6.560	0.00309	0.000001897	0.000001586	4.1663
		Sy	1069	1079	1099	1112	5.727
		r	0.6732	0.6656	0.6496	0.6389	0.7558
C (N = 15)	Total	a	−3599	−1136	−314	0	0.00000002389
		b	5.1662	0.002654	0.000001784	0.000001505	3.5887
		Sy	461	449	442	462	7.7800
		r	0.8522	0.8609	0.8655	0.8525	0.9081
H (N = 5)	Total	a	−4940	−1496	−471	0	0.000000003415
		b	6.6471	0.003004	0.000001802	0.000001537	3.8475
		Sy	383	428	141	414	9.3170
		r	0.9821	0.9777	0.9976	0.9792	0.9977
I (N = 11)	Total	a	−5279	−1340	−27	0	0.000000003621
		b	7.0555	0.003034	0.000001659	0.000001643	3.8646
		Sy	1500	625	642	643	5.9700
		r	0.9128	0.9169	0.9120	0.9120	0.8050
F to I (N = 46)	Total	a	−4790	−1421	−160	0	0.000000002693
		b	6.4612	0.003004	0.000001669	0.000001555	3.8974
		Sy	1761	1759	1782	728	6.6076
		r	0.8361	0.8391	0.9081	0.8271	0.8368

J to L (N = 5)	Total	a	−3769	−1323	−514	0	0.00000000004714
		b	5.6240	0.003211	0.000002437	0.000001703	4.5429
		Sy	53	56	69	172	9.286
		r	0.9948	0.9940	0.9945	0.9439	0.9869
J to L (N = 5)	Advanced mode (first batch)	a	−1044	−341	−108	0	0.0000000008208
		b	1.6170	0.0009229	0.0000007007	0.0000005462	3.9524
		Sy	109	109	109	114	7.551
		r	0.8074	0.8068	0.8059	0.7851	0.8300
J to L (N = 5)	Preceding mode - 1 (second batch)	a	−960	−292	−71	0	0.0000000007039
		b	1.5375	0.0008786	0.0000006675	0.0000005648	3.9810
		Sy	82	82	81	85	7.079
		r	0.8643	0.8647	0.8647	0.8537	0.7693
J to L (N = 5)	Preceding mode - 2 (third batch)	a	−1177	−493	−266	0	0.00000000000000000000127
		b	1.5748	0.0009002	0.0000006841	0.0000003033	7.5175
		Sy	84	84	84	118	7.674
		r	0.8659	0.8662	0.8665	0.7100	0.9446
J to L (N = 5)	Smaller yolked eggs (15-25 m.d.)	a	−591	−199	−70	0	0.00000000001306
		b	0.8984	0.0005114	0.0000003871	0.0000002867	4.4698
		Sy	24	25	26	34	8.414
		r	0.9553	0.9566	.9534	0.9200	0.9387

of the other groups. Therefore, convenience, rather than theoretical considerations, should be the deciding factor in selecting one of the regression equations to describe the data (MacGregor 1957). Eq. (5) makes the curves much easier to compare, since the y intercept is taken as zero for all the stages, and the slopes may be compared directly. It shows that, with the exception of stage F, there is only a slight increase in the fecundity with the progression of stages from G through I (Fig. 11). More or less a similar trend is seen from Eq. (2) also (Fig. 12), except that the line for stage G is further down the lines for the other stages beyond the 950 mm length category. Six possible combinations of pairs of b's for Eqs. (2) and (5) for the different stages, compared by t test indicate that there are no pairs of regression slopes that are significantly different, when Eq. (5) is taken into consideration. In the case of Eq. (2), all the pairs

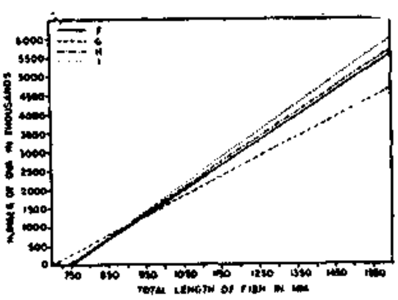

FIG. 12. Fecundity-length regression of the form: $y = a + bx$ for each of stages F, G, H and I.

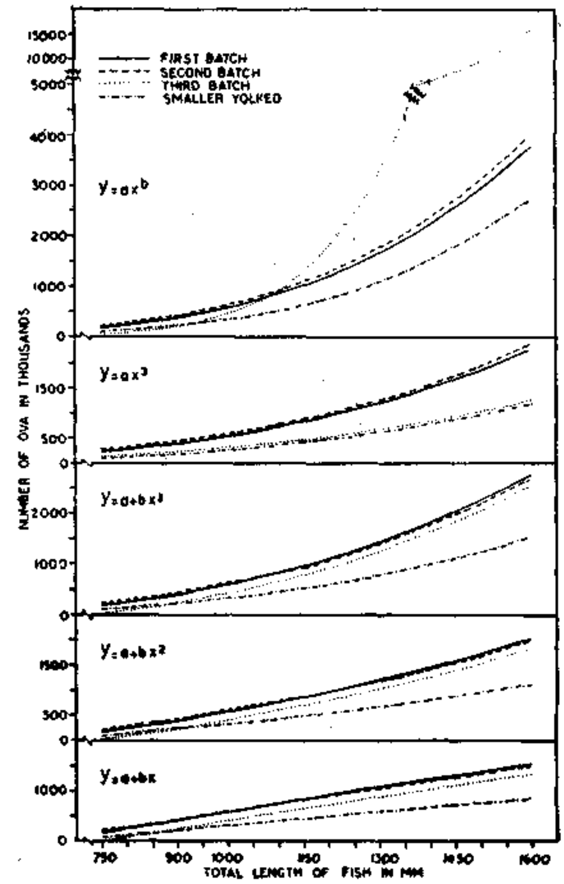

FIG. 13. Relation between total length of fish and number of yolked ova in different batches.

with G as one of the components exhibited significant difference in their slopes (Table 5). But for this, it could be concluded that the fecundity of king seer could be reliably estimated from any one or any combination or all of these stages. The increase of the egg number (y) per 10 mm body length (x) revealed directly by Eq. (2) ($y = -4790 + 6.4612$) is 64,612. By inserting $y = 0$ in this equation the length at first maturity was found to be 741 mm.

b) *Nearly-ripe ovaries* (J to L)

Test of significance (Table 5) to regression of egg number on fish length (Table 4) shows that the variance for the estimated egg number between stages F to I and J to L is insignificant for the two models tested (for Eq. 2 : $t = 0.819$, $P < 0.4$; for Eq. 5 : $t = 0.075$, $p < 0.9$). This indicates that the number of yolked ova present in the spawn ripe ovaries is already determined at the maturing stages, and there seems to be little increase in number, but only the size after that. Therefore, fairly accurate estimates of fecundity is possible based on any of the stages F to L. However, the number of ova released in each of the three spawning acts could be estimated only after the ovaries have attained a nearly-ripe stage, but before shedding any of the ova, for, it is at the onset of the ripe condition the ova destined to be spawned in the successive batches group themselves into three definite modes (a, b and c), besides the smaller yolked ova between 15 m.d. and 25 m.d. The observed number of ova within each of the three groups at J, K and L stages (Table 6) and the estimated egg number in the different groups for each of the length classes (Fig. 13) indicates that the difference in the egg number between the first (a) and second (b) batches is quite negligible. Therefore, assuming that all the ova within the first and second batches are spawned, the mean of the two values would represent the number of ova spawned in each of the first two spawning acts (Fig. 14). The relation of this mean number in thousands with fish length in mm is found to be,

$$y = -1001 + 1.577\,x \qquad \ldots\ldots \qquad \ldots\ldots \qquad (14)$$

The number of ova spawned from the third group (c) in the third spawning act (0.27 batch) is evidently 0.27 times the mean number of ova spawned in the first two spawning acts (Fig. 14) and the relation of this number in thousands with fish length in mm may be expressed as,

$$y = -270 + 0.4255\,x \qquad \ldots\ldots \qquad \ldots\ldots \qquad (15)$$

Thus, the absolute fecundity or the total number of ova spawned in one spawning season would be the sum of ova spawned in the first two full batches and the third 0.27 batch (Fig. 14). The relation between absolute fecundity in thousands and fish length in mm is therefore,

$$y = 2\,(-1001 + 1.577\,x) + (-270 + 0.4255\,x) \qquad \ldots\ldots \qquad (16), \text{ or}$$
$$y = -2273 + 3.5793\,x \qquad \ldots\ldots \qquad \ldots\ldots \qquad (17)$$

TABLE 5. *Comparison of regression coefficients between various pair combinations of maturity stages.*

Stage	$y = a + bx$			$y = bx^3$	
	n	t	p	t	p
Stage - F) Stage - G)	30	3.698	> 0.01	0.861	< 0.8
Stage - F) Stage - H)	20	0.190	< 0.8	0.106	< 0.9
Stage - F) Stage - I)	26	1.209	< 0.2	0.221	< 0.8
Stage - G) Stage - H)	20	3.232	> 0.01	0.060	< 0.9
Stage - G) Stage - I)	26	4.587	> 0.01	0.235	< 0.8
Stage - H) Stage - I)	16	0.764	< 0.4	0.192	< 0.8
Stage - I) Stage - L)	51	0.819	< 0.4	0.075	< 0.9

The number of ova likely to be resorbed at the end of the spawning season is: number of ova in the third group (c) minus the number of ova spawned in 0.27 batch plus the smaller yolked ova of size 15-25 m.d. (Fig. 14). The relation between the number in thousands of ova resorbed and fish length in mm may be expressed as,

$$y = -1498 + 2.0477\, x \qquad \ldots . \qquad \ldots . \qquad (18)$$

The regression of the total number of yolked ova or estimated fecundity in thousands which includes both the spawned and resorbed ova on fish length in mm could be expressed as (Fig. 14),

$$y = -3769 + 5.6240\, x \qquad \ldots . \qquad \ldots . \qquad (19)$$

2. *Relation between fecundity and weight*

The 46 fecundity observations for F to I stages of maturity considered for the fecundity-length relationship were also utilised for fecundity-weight relationship. Three regression equations were fitted to these observations (Table 7; Fig. 15) and the high correlation between the variables ($r = 0.81$) is brought out by all these equations. The parameters b, Sy and r are nearly similar for Eqs. (7) and (8), (Table 7), and, hence, for practical purposes, the y-inter-

TABLE 6. *Number of ova in the different batches at maturity stages J, K, and L sampled on 6-3-1974 at Panaikulam, Palk Bay (figures in paranthesis indicate the size range of ova in m.d.).*

Fish length (mm)	Numbeŕ of ova in thousands					Stage
	First batch (advanced mode)	Second batch (first preceding mode)	Third batch (second prceding mode)	Smaller yolked ova	Total	
790	183 (42-54)	336 (30-41)	71 (26-29)	107 (15-25)	697 (15-54)	J
800	307 (44-56)	157 (31-43)	87 (26-30)	111 (15-25)	662 (15-56)	K
830	294 (44-60)	346 (31-43)	121 (26-30)	189 (15-25)	950 (15-60)	K
950	613 (44-58)	492 (31-43)	218 (26-40)	265 (15-25)	1588 (15-58)	K
950	369 (50-67)	507 (35-49)	423 (26-34)	251 (15-25)	1550 (15-67)	L

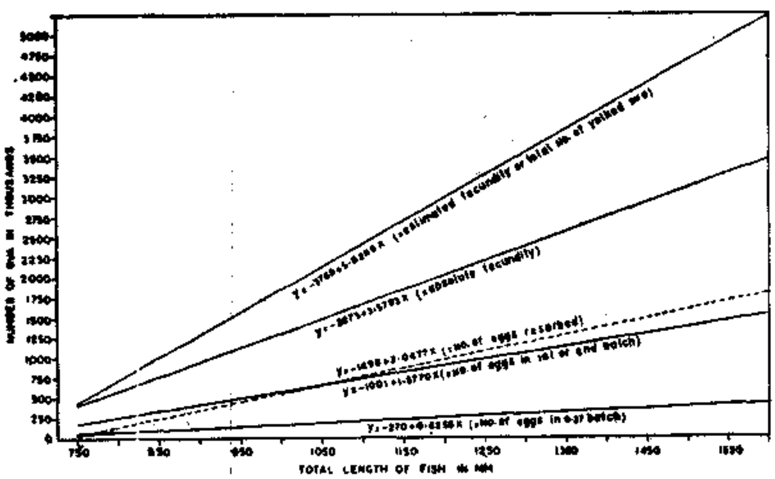

FIG. 14. Regression lines for the relation between total length of fish and (1) number of ova spawned in different batches, (2) total fecundity, (3) number of ova resorbed and (4) total number of yolked ova, based on ripe ovaries (stages J to L).

TABLE 7. *Comparison of fecundity-weight regressions.*

Item	$y = a + bx$	$y = bx$	$y = ax^b$
a	56.0	0.0	0.1016
b	0.2847	0.2919	1.1148
Sy	759.3	760.0	1.558
r	0.8096	0.8098	0.81

cept could be taken as zero in the fecundity-weight regression without any significant loss of accuracy. MacGregor (1957) also made similar observations in the case of the Pacific sardine *Sardinops caerulea*. If an estimation of the number of ova present on the spawning grounds for any one season is available, the total weight of spawning females required to produce the above number can easily be estimated by Eq. (8), i.e., on the basis of 291.9 ova per gram or 291.9 million ova per ton of spawning female king seer.

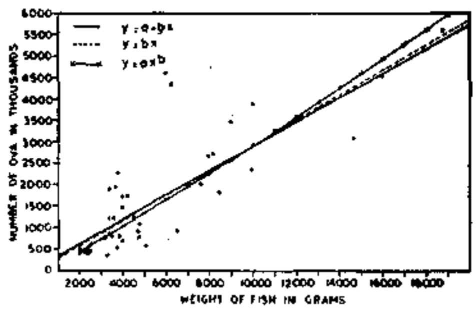

FIG. 15. Relation between fecundity and fish weight for maturing fish (stages F to I).

3. *Egg size* (E) *and egg mass* (M)

The egg size (E)-fish length (L) relationship exhibited negative correlation at all stages of maturity except for a very low positive correlation at stage H, as shown below,

Stage F : $\log E = 1.8598 - 0.3197 \log L$ .... (20)

$(E = 72.4\ L^{-0.3197})$

$r = -0.1306$

Stage G : $\log E = 2.2187 - 0.4225 \log L$ .... (21)

$(E = 165.5\ L^{-0.4225})$

$r = -0.2279$

Stage H : $\log E = 0.8058 + 0.0643 \log L$ .... (22)

$(E = 6.4\ L^{0.0643})$

$r = 0.0801$

Stage I : $\log E = 2.2670 - 0.4285 \log L$ .... (23)

$(E = 184.9\ L^{-0.4285})$

$r = -0.2466$

The equation describing the relationship between egg mass (M) and fish length (L) within the population is obtained by the multiplication of the egg number-length exponential equation (Table 4) by the corresponding egg size-length equation given above. The egg mass-length relationship derived thus for each of the maturity stages F, G, H and I is:

Stage F : $M = 3898 \times 72.4 \times 10^{-9} \times L^{3.7466}$ .... (24)

Stage G : $M = 2389 \times 165.5 \times 10^{-7} \times L^{3.1762}$ .... (25)

Stage H : $M = 3415 \times 6.4 \times 10^{-8} \times L^{3.9118}$ .... (26)

Stage I : $M = 3621 \times 184.9 \times 10^{-8} \times L^{3.4361}$ .... (27)

Studies concerning egg mass of fish and its relation to body growth are very scarce. Observations on *Tilapia, Clupea harengus* and *Gadus morhua* reveal that the relation between egg mass and body weight is not constant, but changes in a regular manner with body weight (Peters 1963, Schopha 1971).

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