STUDIES ON THE MATURATION AND SPAWNING OF THE INDIAN WHITING (*SILLAGO SIHAMA* FORSKAL) FROM KARWAR WATERS

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1. Introduction

The progress of fisheries research in India during the last decade has revealed new techniques and methods of approach to specific problems in this field. The aspect of maturation studies, in particular, on a number of marine, estuarine and inland fishes has been receiving considerable attention from different workers. From among the estuarine and semi-estuarine fishes, however, the Indian Whiting (*Sillago sihama*) has been known to be a delicious food fish in the estuarine and semi-estuarine waters of the Bombay State and little is known about its bionomics. Only recently, Radhakrishnan

(1957) studied some aspects of biology of this fish from Rameshwaram Island. The present paper deals mainly with the study of ova and their maturation, and the spawning behaviour of *S. sihama* in the Kali River Estuary, Karwar.

2. Material and Method

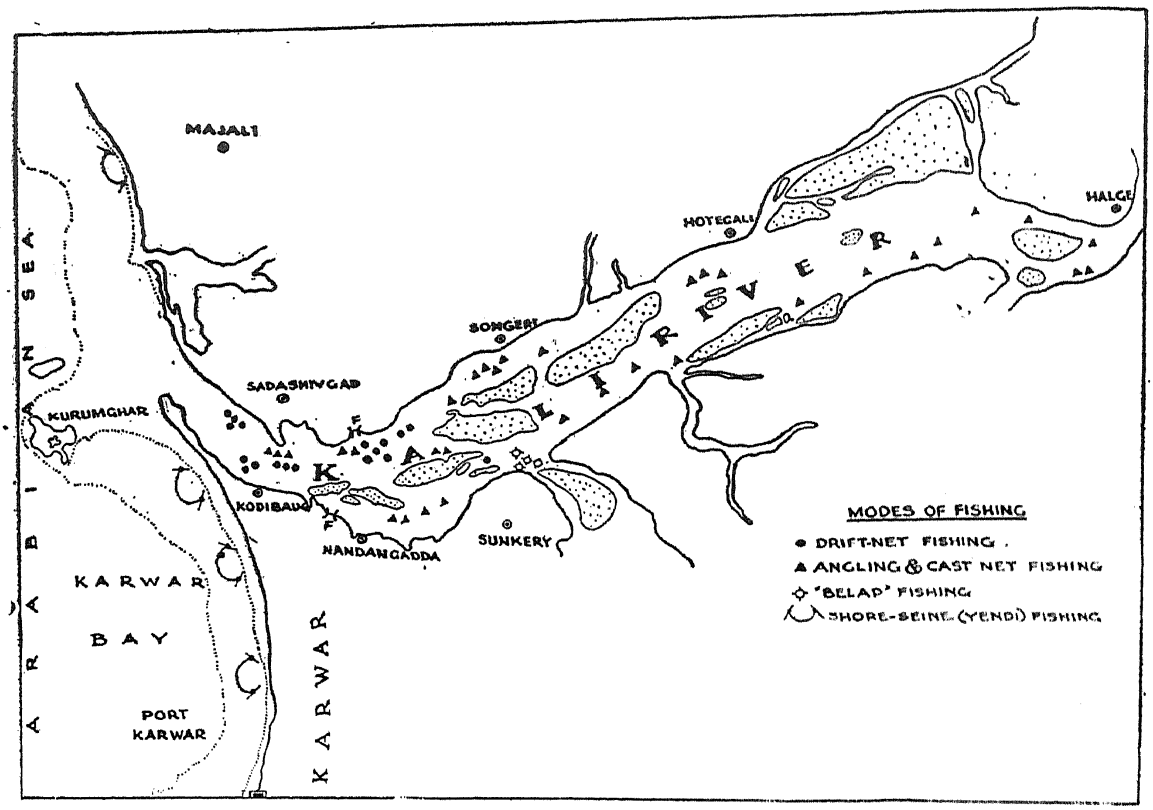
In order to study the process of maturation and the spawning activity of the species under investigation, over a thousand specimens were examined for their general condition during a period of nearly one and half years. Detailed observations in respect of the length and weight of the fish, extension of the ovary in the abdominal cavity, weight of the ovary and microscopic study of the ova in each ovary were made from about 500 specimens collected from the Kali River estuary, during different months of the year. The fish was obtained from the Karwar fish market, where it is brought from Kodibaug, Nandangadda, Sunkeri, Hotegali and other places on the bank of the Kali River (*see* Map). On some occasions, it was also taken from the actual landing places or from anglers along the estuary. Marine specimens obtained from inshore catches were also examined several times, but were generally found to be in the early stages of maturation only.

Measurement of the ova.—On account of the ease in handling the material, ovaries preserved in 5 per cent. formaldehyde were used for measuring the ova-diameters, especially as shrinkage was almost negligible. The method adopted by Clark (1939), in her studies on the maturity of *California sardine*, was followed in the present investigation also. The ova were measured by means of a micrometer eye-piece, which gave a value of 0·019 mm. to each micrometer unit.

In order to eliminate any error due to irregular sampling of ova, the fraction from the middle portion of each ovary was considered to give satisfactory readings in ova-diameter measurements from ovaries in different stages of maturity.

Preliminary observations having brought out definite trends in the growth of the ovaries examined during different months, only representative samples of ovaries were selected for taking ova-diameter counts, so as to indicate the structure of the ovaries in each month. This involved measurements of over 18,625 ova from 70 ovaries, during the period June 1950 to May 1951. As the number of ova measured from each ovary varied from month to month, percentages of ova against each size-group were calculated, to facilitate comparison between the ova from each of the size-groups month by month. At least 250 ova were measured from a single ovary. For the

sake of convenience in taking diameter counts, all ova below 0·095 mm. were left out, as they were innumerable in most of the maturing and mature ovaries at all times of the year.



Map of Kali River, Karwar, showing the modes of fishing of *Sillago sihama*.

3. Definition of Terms

In the present study, greater emphasis is laid on the state of maturity and hence all fish with their ovaries in 'immature' state are termed as 'immature', those with 'maturing or intermediate' state of their ovaries as 'maturing', and those with 'mature' or 'ripe' ovaries have been termed 'mature'. The 'spent' females are those with 'immature and early maturing ova' some of which may be degenerating and being resorbed.

4. Limitation of Study

Sillago forms a minor fishery in India and, as such, fishing is generally poor except during June to October, when representative samples from the market landings could be conveniently obtained. During the rest of the year, specimens obtained either from the market, or from anglers or castnet fishermen, plying within the estuary up to about eight miles, were used for

the study. This is likely to bring in certain amount of error in obtaining representative samples and the data had to be judged and interpreted on the assumption that whatever specimens obtained during this period were representative of the fish in the locality under investigation.

Since the study on maturity of female fish could be greatly facilitated with the help of ova-diameter measurements, the methods used in this study could be aptly applied to females only. However, preliminary observations on the maturity of males are also made.

5. The Ovaries

The paired ovaries are generally symmetrical, though instances of some degree of asymmetry are not uncommon. In many specimens the right ovary was found to be slightly longer than the left, by about 2 to 5 mm. in length.

In a female fish measuring 184 mm. in total length and having well-developed gonads, the right ovary showed very extensive growth occupying a major portion of the abdomen, while the left was poorly developed in size extending over half the abdominal length. In another female, measuring 293 mm. in total length, the left ovary, which was slightly smaller than the right one, was found to be distinctly bilobed, the anterior $\frac{1}{4}$ portion being constricted from the rest of the ovary. An extreme instance of asymmetry was observed in a specimen 201 mm. in total length where the left ovary was very feebly developed and measured 13 mm. in length, as compared to the right one which measured 30 mm.

6. The Growth of the Ova to Maturity

The ovary starts its growth from the posterior region of the abdomen near the vent and grows anteriorly as maturity advances. The growth of the ovary to maturity involves a number of changes, chiefly in the appearance and size of the ovary and in the structure and the size of the ova at different stages of growth (Fig. 1).

Immature fish, their ovaries and ova.—The ovary makes its first appearance in young fish measuring about 100 to 110 mm. in total length, all fish below 100 mm. generally comprising juveniles or those with undifferentiated gonads. Generally, a number of specimens of varying lengths up to 220 mm. in total length were found to be in the immature state of their ovaries. The whitish tape-like ovaries, extending to about half the length in the abdominal cavity, range from 0·2 to 1·7 gm. in weight. The tiny transparent immature ova vary from 0·03 to 0·14 mm. in diameter.

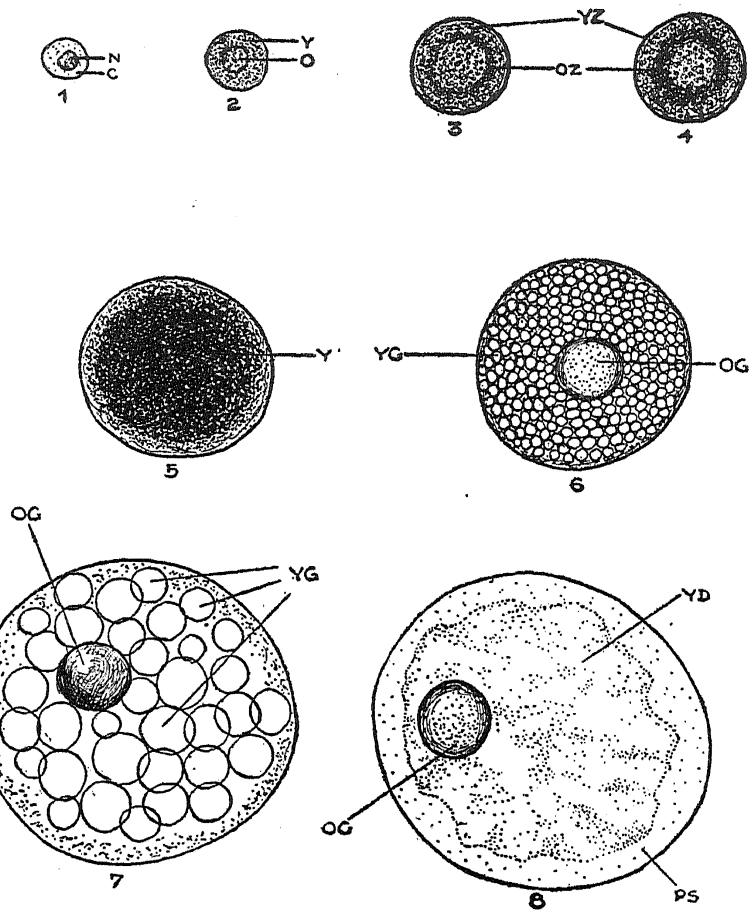


FIG. 1. Showing the growth of the ovum to complete maturity. 1. A yolkless, transparent immature ovum (0·095 mm.). N, Nucleus; C, Cytoplasm, × 10. 2. Young immature ovum (0·13 mm.) showing the initial traces of yolk and oil globule. *y*, Deposition of yolk particles; O, minute traces of oil globules, × 10. 3. Semi-transparent immature ovum (0·20 mm.), the zone of yolk and oil globules becoming distinguished; YZ, yolk zone; OZ, oil globule zone, × 10. 4. Immature ovum (0·23 mm.) showing further distinction between the two zones; central inner darker ring marks the zone of oil globules. YZ, zone of yolk granules; OZ, zone of oil globules, × 10. 5. Dark opaque maturing ovum (0·38 mm.) packed with yolk granules and oil globules, × 10. 6. Maturing ovum (0·51 mm.) showing yolk granules and oil globule (0·15 mm.) in the late state of maturation. YG, yolk granules; OG, oil globule. × 10. 7. Translucent mature ovum (0·68 mm.) with distinctly rounded yolk globules and single oil globule (0·15 mm.). YG, yolk globules; OG, oil globule, × 10. 8. Mature (Ripe) ovum (0·70 mm.) with yolk diffused into paste-like substance. YD, diffused yolk; OG, oil globule; PS, Perivitelline space, × 10.

Some ova, which appeared semi-transparent by virtue of slight deposition of yolk particles, varied from 0·15 to 0·22 mm. in diameter and are also considered immature.

Maturing fish, their ovaries and ova.—S. sihama showing the 'maturing' state of its ovaries was first observed as small as 129 mm. in total length.

Subsequently they were also noted in all sizes up to 354 mm., their number increasing appreciably in fish over 220 mm. in length. Majority of the specimens above 220 mm. length group may have once spawned as explained later and hence termed as 'second and subsequent maturing fish', in constrast to the 'first maturing' fish up to 220 mm. length group.

On the basis of this classification, the 'first maturing' fish were found to weigh from 15 gm. to about 90 gm. while the second and subsequent maturing fish generally varied in their body weights within a range of 90 gm. to 313·5 gm. The 'maturing' ovaries, extending over $\frac{1}{2}$ to $\frac{3}{4}$ of the abdominal length, were found to vary in weight over a wide range of 1 gm. to 13·7 gm.

The spherical dark opaque 'maturing' ovum contains, besides the yolk granules, a number of oil globules which can be seen as clear spaces in histological sections. The sizes of the maturing ova vary generally within a range of 0·23 mm. to 0·56 mm. in diameter.

Mature fish, their ovaries and ova.—Females measuring over 230 mm. in total length may generally be termed as 'mature' since the size of the smallest mature specimen was found to be 228 mm. in total length. Their weight varied within a wide range of 90 to 295 gm. in general, for the size range of 228 to 340 gm.

The mature ovaries extended over the entire length of the abdominal cavity and occupy a major portion of the abdodmen, squeezing aside the rest of the viscera. They appear generally creamy to orange-yellow in colour and weigh from 5 to 17·7 gm. according to the size of the individual.

The mature ovum is rounded and translucent in appearance by virtue of its colourless, transparent yolk globules. The numerous oil globules of the maturing ovum become fused into a large single oil globule which remains suspended in the perivitelline space of the mature ovum. The vacuolated condition of yolk is a characteristic feature of the mature ovum of *S. sihama*, though in some cases it is found to be broken down and diffused into a paste-like substance of semi-fluid consistency in the central region of the mature ovum. This may be termed as the 'ripening' condition in contrast to the 'fully mature' ovum. The sizes of the mature ova generally vary within a relatively small range of 0·57 to 0·70 mm., though occasionally they were also noted to be as large as 0·76 to 0·80 mm. in diameter. The presence of a single shining, translucent oil globule is also characteristic of the mature ovum of *S. sihama*, its size varying between 0·13 mm. and 0·15 mm. in most ova. On rare occasions, ova with one to three smaller

oil globules were observed which varied from 0·095 to 0·13 mm. in diameter.

Spent ovaries and ova.—The spent ovaries, as in many other fishes, appear flaccid, wrinkled and rather heavily vascularised, being reddish in colour. The presence of some empty follicles often gave a clue to identify the spent ovaries. The weight of the spent ovaries varies between 2·7 and 3·7 gm. The maturing opaque ova from spent ovaries generally measure from 0·38 mm. to 0·44 mm. in diameter. The larger resorbing ova appeared rather distorted and unhealthy.

7. MATURATION CYCLE IN *Sillago sihama* FROM THE KALI ESTUARY DURING THE COURSE OF THE YEAR

A routine study of the female maturity in the case of *S. sihama* is found to show a close sequence in the maturation of the fish, month by month. The representative stages of maturity attained by the fish have been presented in Fig. 1 by polygons for respective months.

A close scrutiny of the polygons in Fig. 2 brings out the following main features with regard to maturation of this fish:

(i) The ovary attains its maximum growth during August, September and October, when it contains the immature and mature ova, with a negligible percentage of the larger maturing ova.

(ii) An abrupt fall in maturity condition during November marks the close of spawning and probably the disappearance of the spawning individuals.

(iii) December to March indicates a resting period, the ovarian growth remaining more or less constant.

(iv) The period from April to May, however, seems to lose the sequence due to improper sampling, especially as there is little or no fishing of *S. sihama* during these months.

(v) The fish remain in the early maturing state till June.

(vi) In the month of July, the peak of the early maturing group becomes conspicuous, suggesting active maturation during this month.

(vii) The growth rate of maturation appears to be much faster generally during the period July to October, when majority of the adults attain complete maturity. This may be seen from the monthly progression of the ova described later.

A closer study of the monthly progression in the ova diameters during each month of the year has been found to throw more light in tracing the

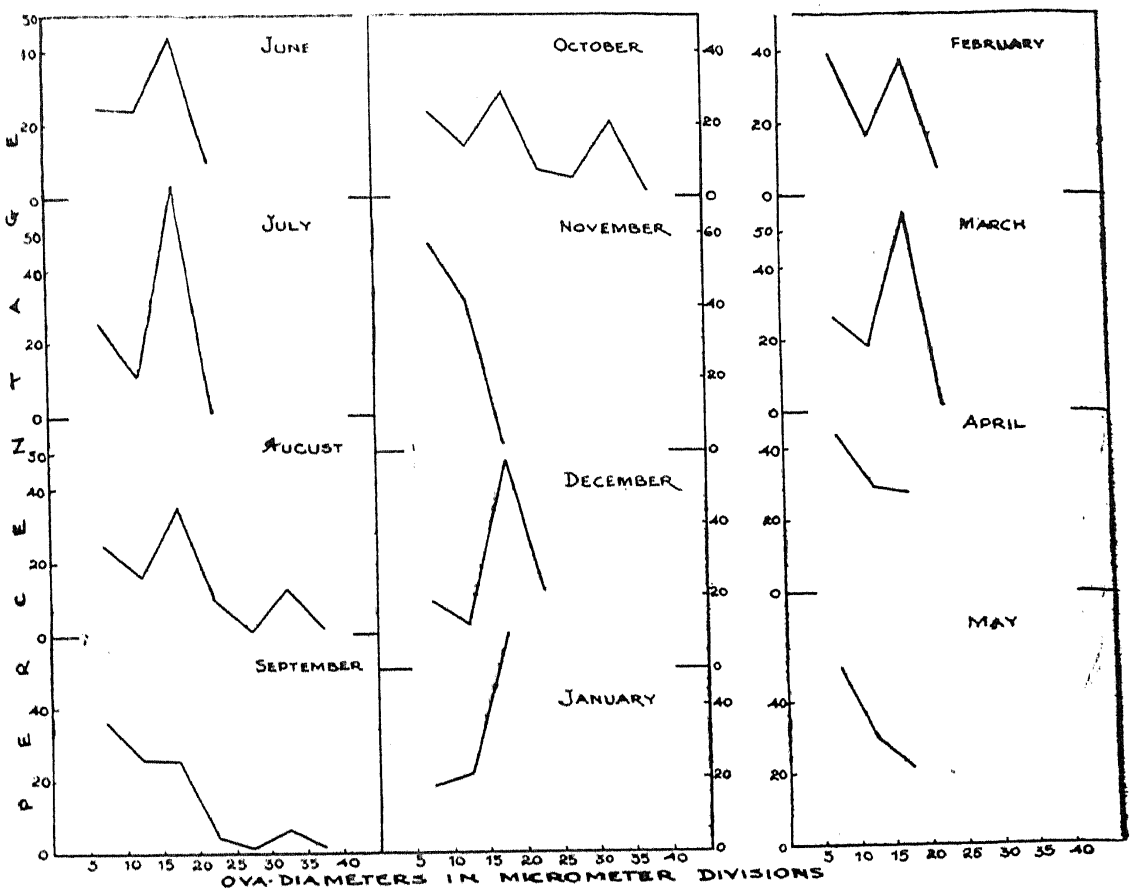


FIG. 2. Ova-diameter frequency polygons indicating the distribution of ova in the ovaries of *S. sihama*, in each month.

maturation cycle of *S. sihama*. The data obtained for this purpose are conveniently arranged as shown in Table I.

The following important points have been brought out from Table I :

(i) The ova attain maximum size at complete maturity during August to October, when spawning takes place.

(ii) Majority of the ova are in the 'D' group during the major part of the year.

(iii) The apparent majority of 'B' group ova (immature) during November coupled with the small range in size of ova due to abrupt fall in ova diameters, as a result of spawning, marks the end of the breeding activity of the fish.

(iv) From December to March 'D' group seems to maintain a constant majority, thus marking the 'Resting period' with respect to maturation.

TABLE I

Monthly size progression of ova as indicated by ova-diameter measurements from maturing ovaries of S. sihama *from Kali River Estuary, Karwar,* 1950–51

Maturity	Ova-diameter classes	Group	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Mature	0·685–0·779	H	..	..	0	0	0	..	..	..	..	..	..	..
	0·690–0·684	G	..	..	0	0	0	..	..	..	..	..	..	..
Maturing	0·495–0·589	F	..	..	0	0	0	..	..	..	..	..	..	..
	0·400–0·494	E	0	0	0	0	0	..	0	..	0	0	..	..
	0·305–0·399	D	*	*	*	0	*	0	*	*	*	*	0	0
	0·210–0·304	C	0	0	0	0	0	0	0	0	0	0	0	0
Immature	0·114–0·209	B	0	0	0	*	0	*	0	0	*	0	*	*

The extreme range in size of ova found in each month is represented by the columns of circles.

The asterisks indicate the group forming major percentages of ova from advancing ovaries in respective months. (Ova of A group have not been taken into account.)

(v) Abrupt fall in proportion of 'D' group and major percentages of ova in 'B' group during April and May, seem to suggest that complete resorption of ova of the 'D' group occurs during the late resting period. This further suggests the beginning of fresh maturation during April and May.

(vi) Persistence of majority of 'D' group again during June to August suggests active growth of immature ova from April onwards.

(vii) Only during the breeding season, *i.e.*, August to October, the ova of 'D' group contribute to the larger groups which ultimately make the spawning crop.

(viii) The apparent majority of young immature ova of 'A' and 'B' groups during September indicates further addition to the larger groups (through 'D' group) consequently lowering their percentages in general.

(ix) Majority of ova of 'D' group, again during October, may be attributed to slight retardation of the growth of ova beyond 'D' group and also

in the general development of the immature stock, with the close of spawning period.

Casual observations made during two subsequent years (1952 and 1953) have also shown that *S. sihama* closely follows this course of maturation and spawning in locality under investigation. Three periods thus seem to be generally significant in the maturation cycle of *S. sihama*. They are:

(*a*) Period of active maturation .. From April to July.
(*b*) Spawning period .. .. From August to October.
(*c*) Resting period .. .. From November to following March.

8. Spawning

Having established the different stages of maturity in general, it has been possible to ascertain the conditions of the ovaries examined during each month of the year. The data relating to the percentages of maturity states in each month reveal some interesting features with regard to spawning of this species. Of the females examined during August, 18·32 per cent. were in the VI stage of maturity and 2·29 per cent. spent. During September, 31·50 per cent. were observed to be in stage V, 4·72 per cent. in stage VI and 1·57 per cent. spent. In October 2·5 per cent. of the females examined were in stage V, 25·83 per cent. in stage VI and 7·50 per cent. spent. The above figures indicate that most *S. sihama* attain complete maturity and spawn during September and October. Their time of spawning coincides more or less with the rainy season at Karwar.

It is further observed from Fig. 3 that during the rest of the year all the females remain in the immature or maturing state of the ovaries, their growth being confined to II or III stage of maturity. In fact, III stage of maturation appears to be highly significant with respect to spawning activity of the fish. A close examination of the data, relating to stage III, brings out the following:

(i) Total absence of III stage fish during April, May and June.

(ii) Fairly high proportion of the same during the pre-spawning and spawning periods.

(iii) Abrupt fall in their percentages during the post-spawning period, *i.e.*, November onwards.

The above points offer adequate evidence to believe that majority of the fish in stage III observed during the pre-spawning and spawning months take part in the spawning activity during the season.

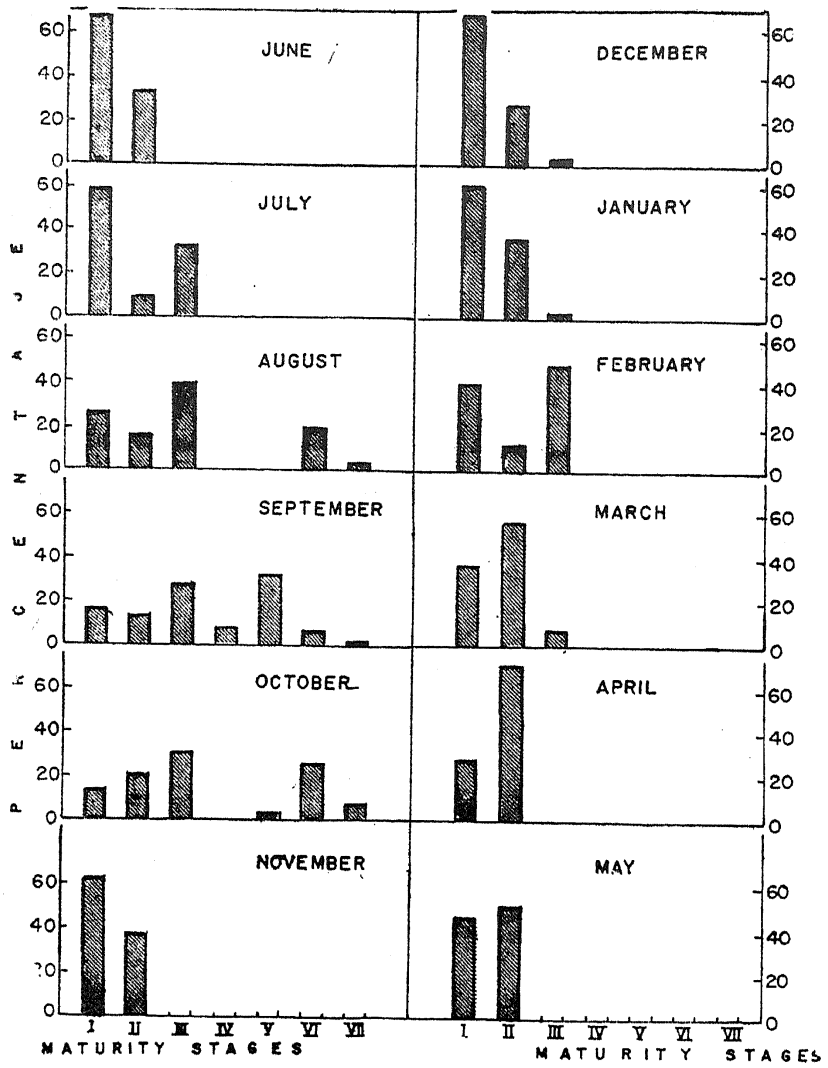


FIG. 3. Percentage distribution of adult *S. sihama* in each stage of maturity month by month.

Frequency and duration of spawning.—A close study of the completely mature ovaries was made from the data relating to the percentage frequencies of ova from mature ovaries obtained during August, September and October (Fig. 3). The first observation that strikes one from Fig. 4 is the complete separation of the mature class of ova from the general egg stock, in all the polygons. On the basis of the hypothesis stated by Hickling and Rutenberg (1936) it appears that *S. sihama* must be having a short spawning period. Further, the simultaneous occurrence of mature and spent individuals during the spawning period indicates that spawning takes place only once during the season (Walford, 1932).

9. SIZE AT FIRST MATURITY

For determining the size of first maturity, observations made on fish collected only during the pre-spawning and spawning months, *i.e.*, July to

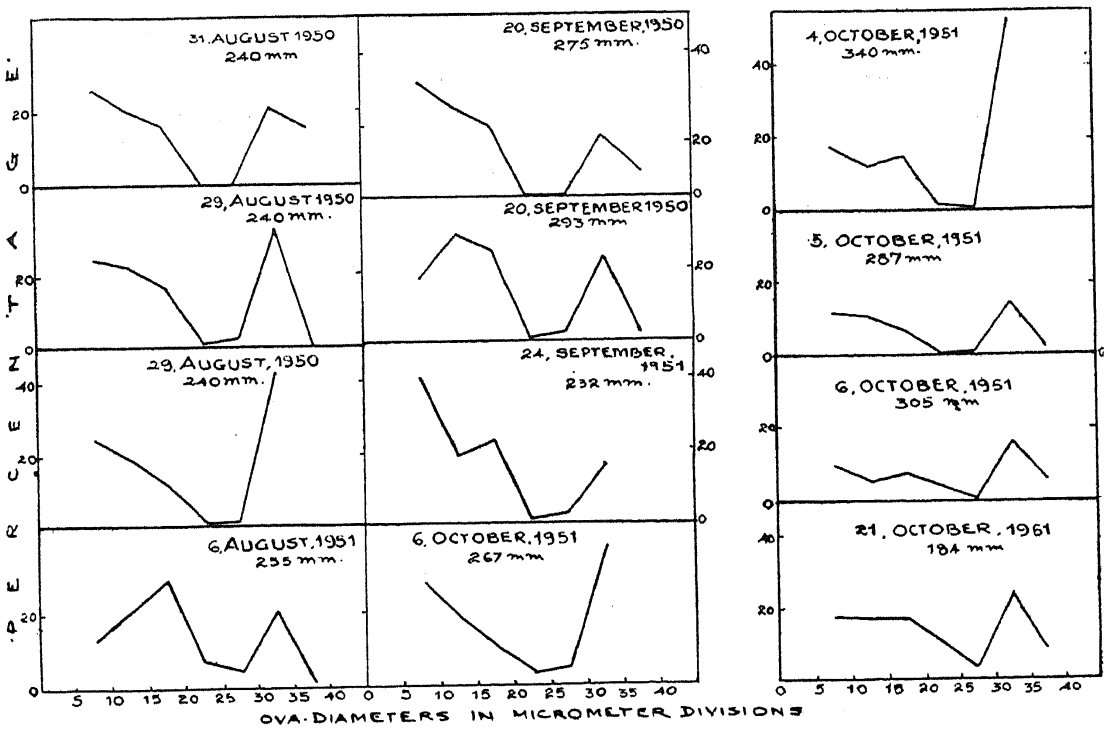


FIG. 4. Ova-diameter frequency polygons showing the distribution of ova in mature females during the seasons, August–October (1950 and 1951).

October, were considered to give consistent results. As will be seen from Table II percentages of females above 170 mm. are only indicated, as all females below 180 mm. were generally observed to be immature. Besides, only the mature, spent and III stage maturing females (which were expected to mature and spawn in the same season) were taken into account and collectively termed as 'maturing spawners'.

A general trend showing a consistent increase in the percentage of spawners at advancing length groups, beyond 230 mm., has been noticed in Fig. 5. The figures in Table II point out that, 50 per cent. of the females

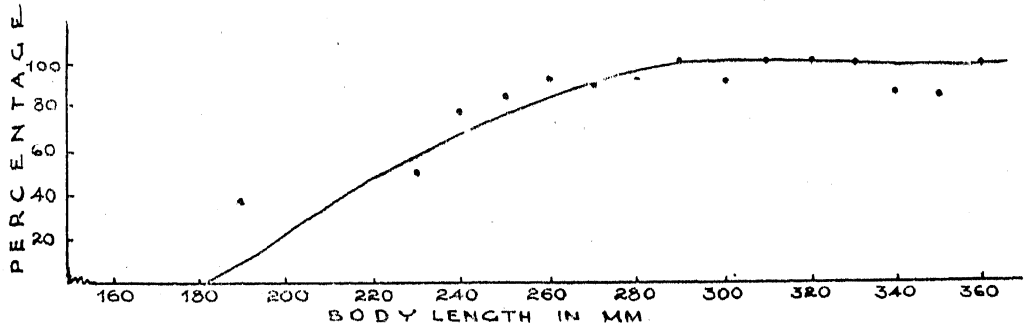


FIG. 5. Size at first maturity of *S. sihama* as indicated by the percentage of females maturing in each 20 mm. of length.

TABLE II

Percentage of 'maturing spawners' in each 10 mm. length group of S. sihama *from Kali River, Karwar, during the period July to October*

Length group	Total number of fish examined	Maturing spawners	
		No.	%
171–180	4	..	..
181–190	3	1	33·3
191–200	8	..	..
201–210	4	..	..
211–220	6	..	..
221–230	4	2	50·0
231–240	17	13	76·5
241–250	25	21	84·0
251–260	28	26	92·6
261–270	40	36	90·0
271–280	22	20	90·9
281–290	23	23	100·0
291–300	24	22	91·6
301–310	22	22	100·0
311–320	17	17	100·0
321–330	12	12	100·0
331–340	8	7	87·5
341–350	7	6	85·7
351–360	3	3	100·0

may mature and spawn at 221–230 mm., 76·5 per cent. in 231–240 mm. group; 84 per cent. in 241–250 mm. group and above 90–100 per cent. in majority

of the larger size classes. Evidently, 235 mm. may conveniently be taken as the size at first maturity.

Mention may be made here of the observations of Radhakrishnan (1957), on sexual maturity of *S. sihama* from the coast of Rameshwaram Island. According to him *S. sihama* has been found to attain maturity in the coastal waters, at a small size of 130–140 mm. when they are perhaps one year old, as indicated by the rings on otoliths. This observation differs from that made at Karwar, where the spawning is restricted to the estuary and to fishes of an average size of about 235 mm. and more. This aspect, however, seems to need further critical study.

10. Fecundity

In the present investigation, the usual procedure of calculating the number of mature eggs was followed. The observations were made from 19 females of *S. sihama*, ranging between 184 mm. and 340 mm. in total length. This revealed that the number of eggs produced by individual fish varied between 16,682 and 166,130 (Table III).

These observations were statistically treated to find out the relation between the number of ova produced and the length of the fish by applying the method of least squares. The formula which best expresses this relation was found to be as

$$F = (0{\cdot}000001817)\ (L)^{4.3100}$$

where 'F' is the total number of mature ova, and 'L' the length of the fish. The calculated numbers of eggs against each length shown in Table III are computed from this formula (Fig. 6).

11. The Testes and Their Maturation

The testes are in the form of flattened strips of tissue, which grow anteriorly with the advance in maturation of the fish. Both the tetses are generally found to be symmetrical in size and shape.

The (newly developed) immature testes appear as very small, thin threads which become flattened and ribbon-like after a little growth. In the absence of any definite criteria to distinguish the different stages in the growth of the testes, their extension in the abdominal cavity during growth, and their general appearance were found to be the only reasonable criteria for distinguishing the three main states of maturity, *viz.*, Immature, Maturing and Mature.

TABLE III

Showing the approximate number of mature ova, destined to be liberated by females of varying lengths during a season

Length of fish (L) mm.	Weight of fish (W) gm.	Total number of ova (F)	
		Observed	Calculated
184	44·0	17179	10190
228	90·0	16682	26360
240	102·0	34692	33060
248	112·0	42682	37090
255	137·0	40702	42580
260	131·0	53014	46680
262	111·0	34020	47770
268	103·5	22018	53590
270	147·5	64260	54860
270	138·0	111586	54860
275	178·0	44417	60150
287	182·6	104011	70660
288	196·5	66607	72300
293	182·0	67767	77490
293	140·5	98358	77490
301	192·5	77060	86920
303	131·0	53333	88960
305	217·5	166130	93130
340	295·0	153370	147700

$F = aL^b$; which is same as $y = A + B_x$; where $y = \log F$; $x = \log L$, $A = \log a$ and $b = B$.

$\Sigma x = 46{\cdot}1943$; $\Sigma y = 90{\cdot}0241$.

$\Sigma x^2 = 112{\cdot}3686$; $\bar{y} = 4{\cdot}7381$; $\Sigma xy = 219{\cdot}1148$. $\bar{x} = 2{\cdot}4313$.

$y = 4{\cdot}31\,x - 5{\cdot}7408$, *i.e.*, $F = (0{\cdot}000001817)\,(L)^{4{\cdot}31}$.

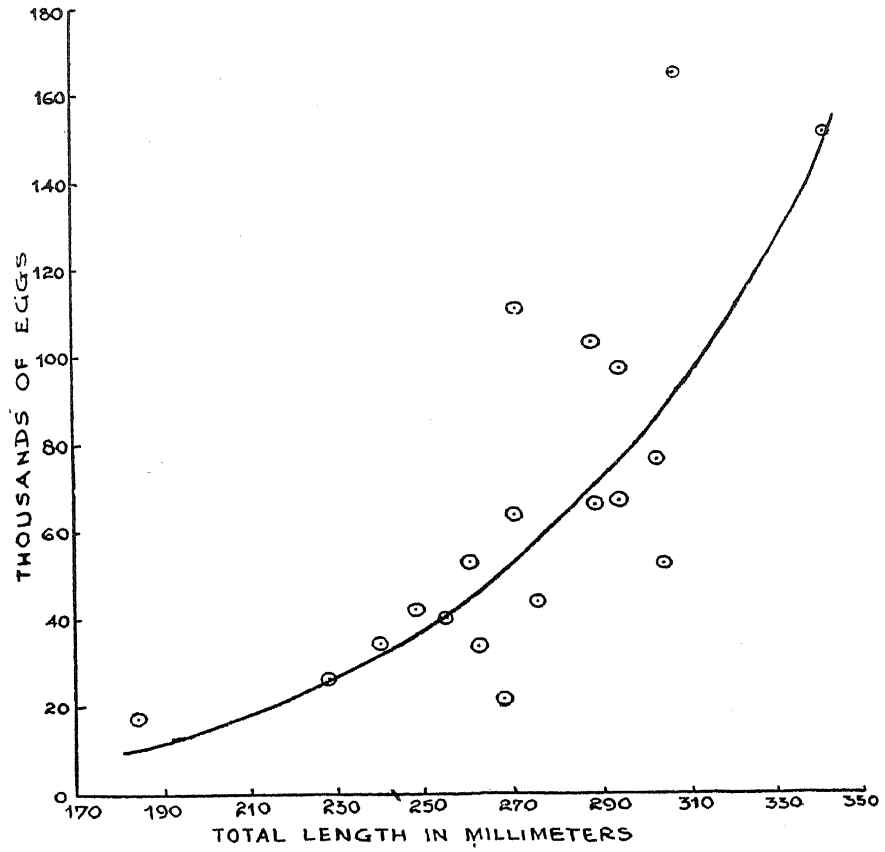


FIG. 6. Scatter diagram showing the approximate number of mature eggs produced by *S. sihama* at various legnths.

A general study of the male individuals, examined for gonad condition, showed the following ranges in length and weight, when broadly classified according to the main states of maturation:

	Immature	Maturing	Mature
Size range of fish mm. ..	121–180	181–224	224–273
Range of weight of fish gm. ..	12·5–53	49·9–86	74·9–116·7

A closer observation of the three states of maturation has further indicated the following 5 stages of maturity, based on the growth and appearance of the testes:

I. Thin thread-like organs whitish in appearance, often pigmented with minute greyish specks; extending less than ½ abdominal length } Immature

II.	Thin strips of tissue slightly greyish in appearance, extending over $\frac{1}{2}$ abdominal length	Maturing
III.	Whitish organs extending from $\frac{1}{2}$ to $\frac{2}{3}$ abdominal length; slightly creamy in appearance in later stages of maturation	
IV.	Creamy white, well-developed organs about $\frac{2}{3}$ length of abdomen	
V.	Organs creamy in appearance; extending over the entire abdomen, soft in texture, full of milt and sperm material; milt oozing with little pressure	Mature

12. SUMMARY

1. A study of maturity and spawnings of *Sillago sihama* based on the detailed examination of 500 specimens of fish and their ovaries and also on casual observations of over a thousand females has been attempted in this paper. Preliminary observations on the condition of testes have also been made from 135 specimens.

2. The female fish have been classified as Immature, Maturing, Mature and Spent, with reference to the condition of their ovaries. The mature ovum contains a single oil globule generally measuring between 0·13 mm. and 0·15 mm. in diameter.

3. A study of the maturation cycle brought out three phases in the life of the fish:

(*a*) Period of active maturation .. April to July.

(*b*) Spawning period .. August to October

(*c*) Resting period .. November to (following) March

4. The spawning period in *S. sihama* is of short duration and spawning takes place only once during the season.

5. The size of the female *Sillago* at first maturity has been approximately fixed at 235 mm. in total length. The females were found to attain a maximum size of 354 mm. in total length.

6. The smallest male specimen with 'mature' testes measured 224 mm. The males attain a relatively smaller size, the maximum size noted being 273 mm.

7. The number of mature eggs liberated in a single spawning has been found to vary from 16,682 to 166,130 in sizes of fish ranging between 184 mm. and 340 mm. in total length.

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