A CONTRIBUTION TO THE BIOLOGY OF INDIAN SAND WHITING—*SILLAGO SIHAMA* (FORSKÅL)

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CONTENTS

		PAGE
I.	INTRODUCTION	254
II.	MATERIAL AND METHODS	255
III.	DISTRIBUTION	255
IV.	RELATIONSHIP OF BODY MEASUREMENTS TO TOTAL LENGTH	256
V.	WEIGHT-LENGTH RELATIONSHIP	258
VI.	PONDERAL INDEX OR CONDITION FACTOR ..	261
VII.	FOOD AND FEEDING HABITS	262
VIII.	MATURATION AND SPAWNING	266
IX.	SEX RATIO AND FECUNDITY	270
X.	AGE AND RATE OF GROWTH	272
XI.	FISHERY AND FISHING METHODS	279
XII.	SUMMARY	280
XIII.	ACKNOWLEDGEMENTS	281
XIV.	REFERENCES	281

INTRODUCTION

THE Indian Sand Whiting, belonging to the family Sillaginidæ (Order Percomorphoidea), is of some importance to the coastal and estuarine fisheries of India. Very little detailed study of this fish seems to have been made, except for a short account of its food and feeding habits by Chacko (1949), notes on the larval and post-larval stages by Gopinath (1942, 1946), general notes by Devanesan and Chidambaram (1948), and observations on the eggs and larvæ by Chacko (1950). Cleland (1947) has given an account of the

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economic biology of the Sand Whiting, *Sillago ciliata*, the best known species in Australian waters. The post-larval stages of this species were described by Munro (1945) and eggs and early larvæ by Tosh (1903).

Although there are three Indian species, *Sillago sihama*, *Sillago panijus* and *Sillago maculata*, the first constitutes by far the largest element in the commercial catches around Mandapam and Rameswaram Island in the Gulf of Mannar and Palk Bay. A detailed study of the biology of the commonest species was therefore taken up in September 1953 at the suggestion of Dr. N. K. Panikkar, the Chief Research Officer, Central Marine Fisheries Research Station, Mandapam Camp, and a note, forming part of the work, has already been published (Radhakrishnan, 1954).

Material and Methods

Regular collection of material for the investigation was started in September, 1953. The samples were obtained from shore-seine and bag-net catches, operated around Mandapam and Rameswaram Island in the Gulf of Mannar and Palk Bay. The sampling was done twice a week and during each visit the total length of at least 80 specimens, selected at random, were noted on the spot. The data were then arranged in a frequency table, and were also represented graphically (*vide* Text-Fig. 16). All collections were made personally.

For a detailed study, a random sample was brought to the laboratory on each day and the total and standard lengths in centimeters, weight in grams, sex, condition of gonads, average maximum size of ova, stages of maturity, length and breadth of gonads, volume of gut-contents and the various components thereof, were recorded. The Peterson method (analysis of length-frequency distribution) and the scale- and otolith-methods (recognition of periodic structures in the discrete hard parts of the fish), usually utilized in studies on the age of fishes, have been employed in the present investigation. The various body measurements, referred to in Text-Fig. 1 were also noted. The details of the various techniques employed in the investigation are described in the respective sections.

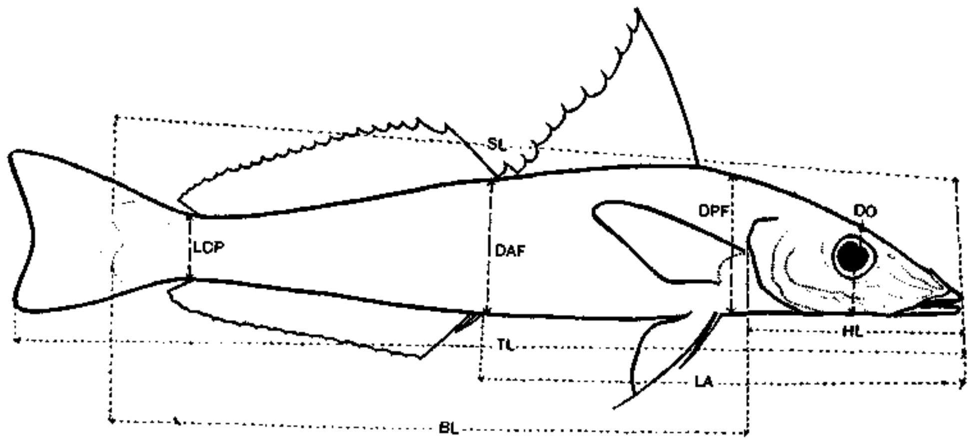
Distribution

Day (1889) mentioned the Red Sea, the seas of India to Malaya Archipelago, and Australia as the area of distribution of this species. According to Weber and De Beaufort (1931) it occurs in the western part of the Indo-Pacific region, from Red Sea, east coast of Africa, Madagascar through India to coasts of India, China, Japan, Philippines, Indo-Australian Archipelago, Australia to Bougainville Islands.

In India, this species appears to occur all along the coast. Devanesan and Chidambaram (1948) mentioned its occurrence in Ganjam (Ganjam District), Pukkilipeta, Bimilipatnam, Uppada (Godavari), Madras, Tranquebar and Sethubavachathram (Tanjore), Mukkur, Pamban (Ramnad), and Tuticorin on the east coast, and Hosdurg (South Canara), Cannanore, Valapad, Calicut and Tannur on the west coast of the Madras Presidency.

Relationship of Body Measurements to Total Length

The relation between the dimensions of the external parts of the fish and its total length was determined from the measurements of over 300 specimens ranging from 5 to 24 cm. in length. The measurements taken are represented diagrammatically in Text-Fig. 1.



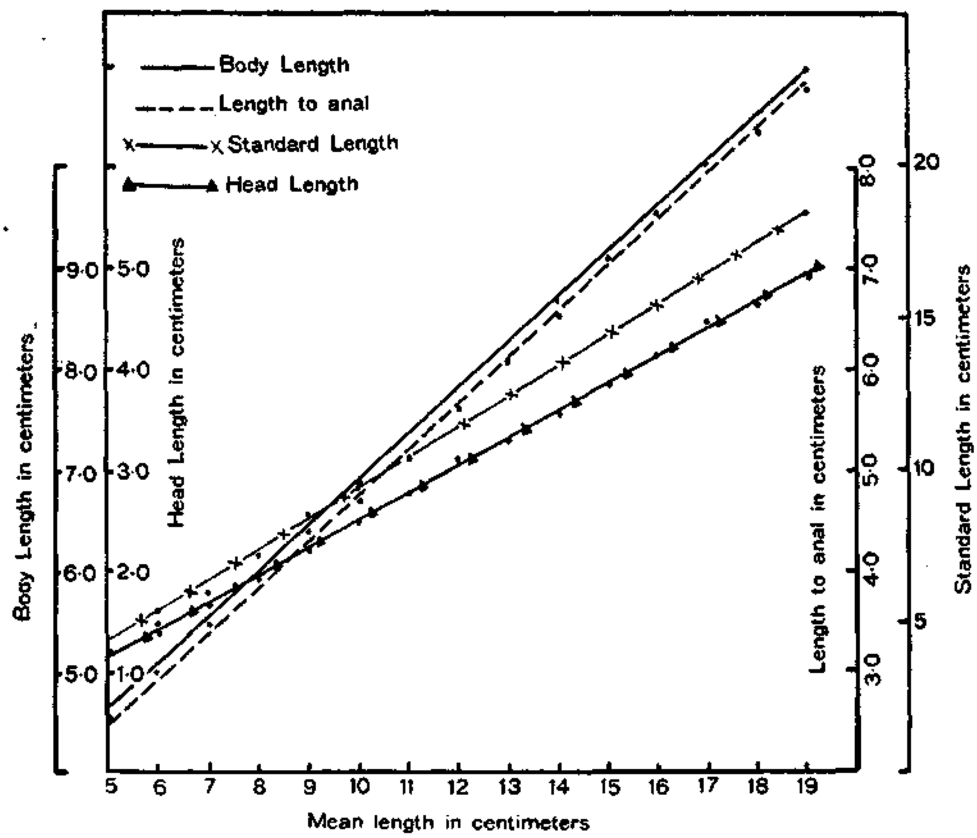
Text-Fig. 1. Measurements used to establish relationships of various body measurements to total length in *Sillago sihama* (Forskål). DO, Depth through orbit; DPF, Depth through pectoral fin base; DAF, Depth through anal fin base; LCP, Least depth of caudal peduncle; SL, Standard length; TL, Total length; BL, Body length; LA, Length to anal; HL, Head length.

In Text-Figs. 2 and 3 the various measurements are plotted against the total length. A straight line relationship in all cases suggests that, after the 5 cm.-stage, there is no allometric growth in the species. The rate of growth of the different parts of the body in relation to the increase in total length (not in relation to time) was determined by the tangent method (Crozien and Hechts, 1913). The tangent of each curve was calculated by dividing the vertical distance between two points on each curve by the horizontal distance. The data obtained by this analysis are given in Table I.

As can be seen from Table I, the standard length has the maximum rate of growth. Amongst the other measurements, the body length and the depth of the body through pectoral fin base have the maximum and minimum

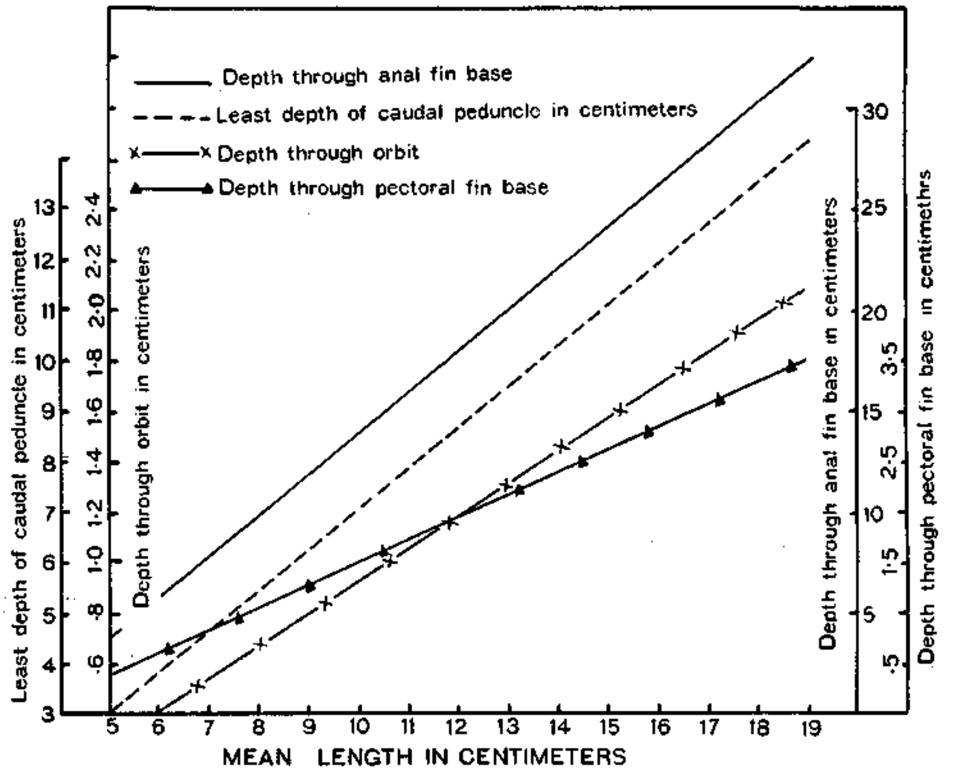
TABLE I

Standard length	0·9325
Body length	0·9115
Length to anal	0·9004
Least depth of Caudal peduncle ..	0·8391
Depth through anal fin base ..	0·8200
Depth through orbit	0·5856
Head length	0·5543
Depth through pectoral fin base ..	0·4663



TEXT-FIG. 2. The relationship of body measurements to total length in *Sillago sihama* (Forskål).

rates of growth. The body length and length to anal increase nearly at the same rate.

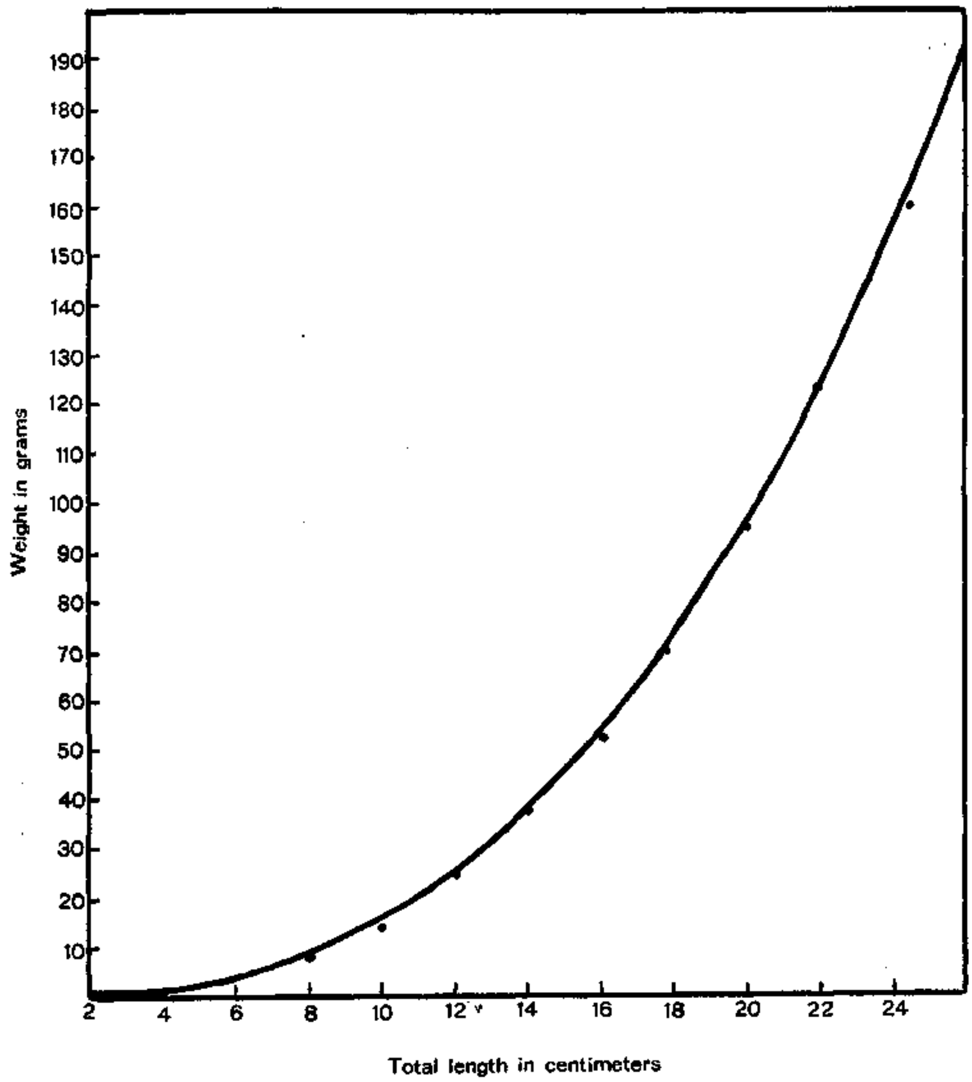


TEXT-FIG. 3. The relationship of body measurements to total length in *Sillago sihama* (Forskål).

An analysis of the relationship between the total length and the standard length of the Indian Sand Whiting, was made to determine the degree of association of these two characters, and to establish an equation for the determination of one measurement from the other. When the standard length Y is plotted against the total length X, the points as would be expected are found to be closely clustered around the linear regression line as shown in Text-Fig. 3. To express the relationship between the two variables X and Y, the equation for the regression line $Y = a + bX$ was used (a and b are the constants). The equation for the regression line was found to be $Y = 0{\cdot}98X - 0{\cdot}70$.

WEIGHT-LENGTH RELATIONSHIP

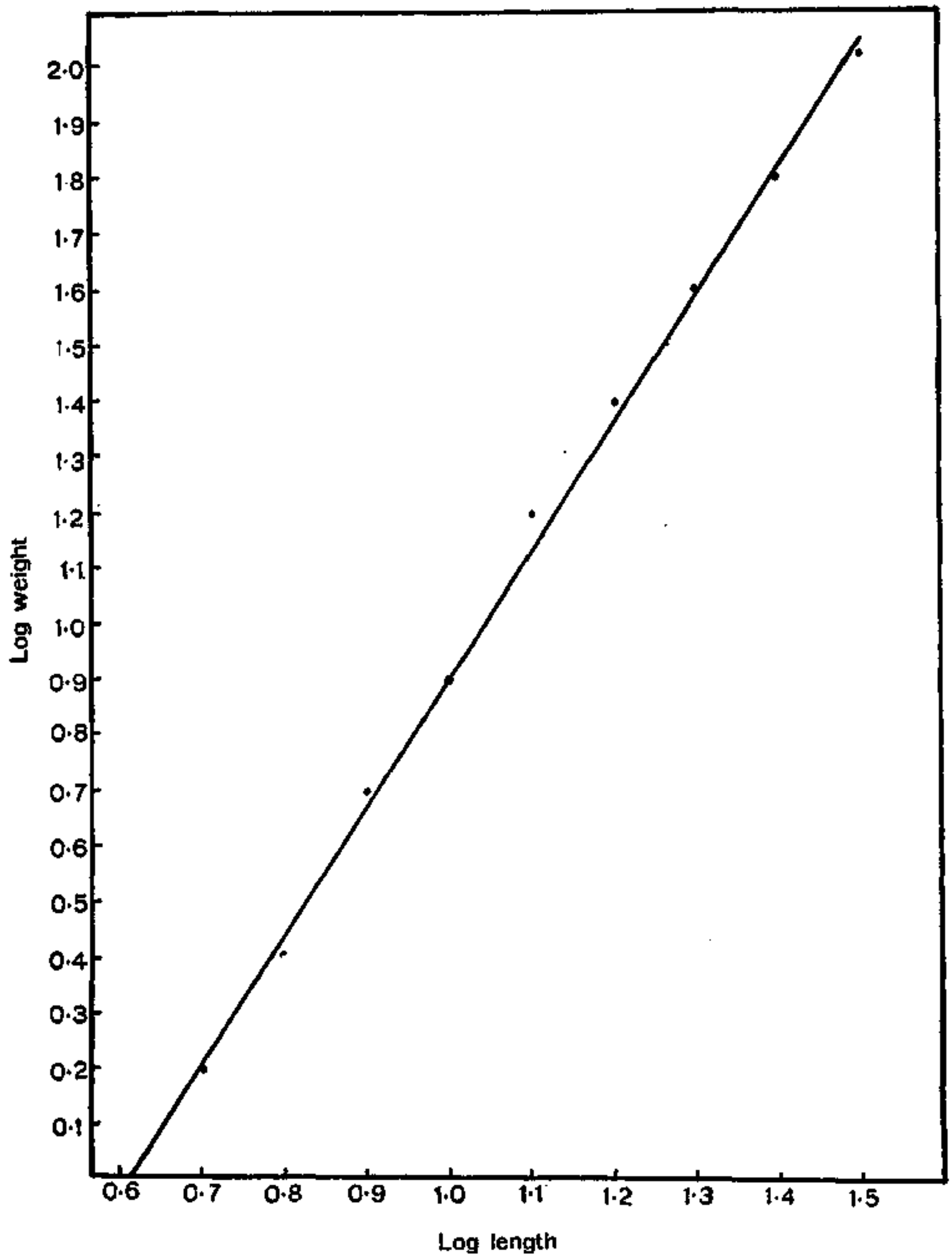
The relationship was calculated from measurements of 520 specimens ranging from 2 cm. to 28 cm. in total length. Earlier observations revealed no marked difference in the length-weight relationship of the males and females, and so calculations were made for the two sexes combined.



TEXT-FIG. 4. The weight-length relationship of *Sillago sihama* (Forskål).

Text-Fig. 4 represents the relationship of the average weight to the length. Since the weight-length ratio is a power relationship, the logarithms of the readings were used in the calculations. The logarithmic relation of weight and length is shown in Text-Fig. 5, which clearly shows a straight-line relationship.

The equation for the length-weight curve was found to be $W = 0{\cdot}01504\, L^{2{\cdot}8862}$ where the weight and length are in grams and centimeters

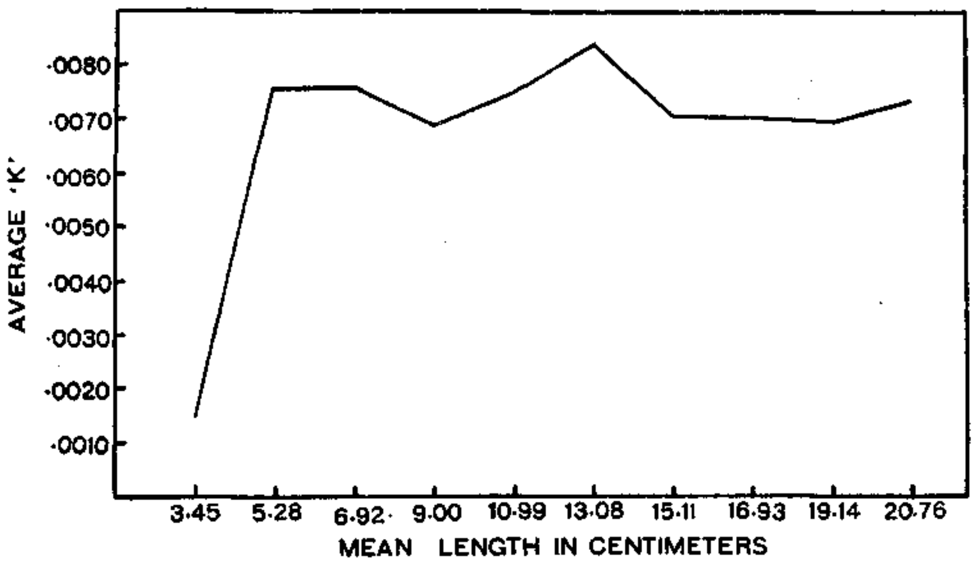


TEXT-FIG. 5. Logarithmic relation of weight and length of *Sillago sihama* (Forskål).

respectively. Allen (1938) recorded that for all ideal fish which maintain the same shape, the value for the exponent has been found to be 3. As can be seen from Text-Fig. 4, fishes up to 6 cm. in length increase in weight at a lesser rate than the subsequent size-groups. The data plotted in the text-figure show that the values are uniform up to 12 cm. length, above which there is a noticeable variation.

Ponderal Index or Condition Factor

Hickling (1930), Hart (1946) and Morrow (1951) have correlated fluctuations in the ponderal index with the attainment of maturity and spawning. The weight-length data, discussed in the previous section, were analysed separately for the various size-groups. Throughout the work, the weight-length coefficient 'K' was calculated by employing the formula used by Hickling (1930) and Hart (1946), *viz.*, $K = W/L^3 \times 100$ where W is the weight of the fish in grams, L the length of the fish in centimeters and K the ponderal index. As the data available for larger fishes were very limited, fishes up to the total length of 21 cm. only were taken into account, to ensure correctness of interpretation.



Text-Fig. 6. The average 'K' Ponderal index at the different lengths of *Sillago sihama* (Forskål).

Hart (1946), in the report on trawling surveys on the Patagonian continental shelf, has stated that the 'K' values may give a very good idea of the broad outline of the seasonal cycle for the species. He observed that "apart from the seasonal variation in condition there is a secondary variation related to the length of the fish. With increase in age there is a lower level of condition throughout the seasonal cycle consequent upon the increased metabolic strain of spawning. The point of inflexion on a curve showing this diminution of 'K' with increasing length is thus a good approximate indication of the length at which sexual maturity is attained."

The average values for 'K' for each size-group are plotted in Text-Fig. 6. If the point of inflexion of the curve is indicative of the length at first maturity, it may be said that the fish matures at an average length of 13 cm. This inference is further supported by the study of intra-ovarian eggs during the course of this investigation.

FOOD AND FEEDING HABITS

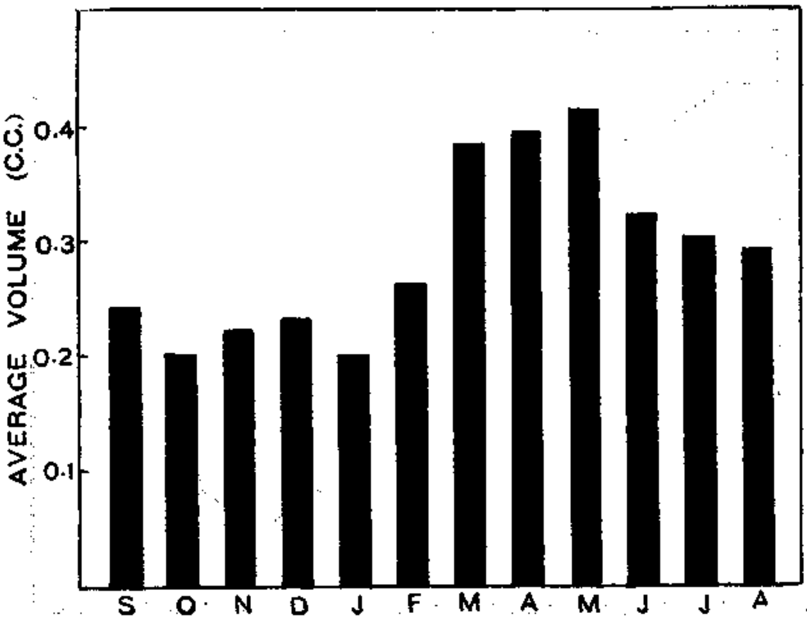
The specimens were fixed in 5% formaldehyde, and brought to the laboratory for detailed examination. The gut was then dissected and the contents removed into a petri dish, for qualitative and quantitative analysis. Very often the food matter in the gut, especially the crustaceans, was found in an advanced state of digestion, and so only the generic identification of the food components was possible. The quantitative analysis was carried out by the volumetric method in which the volume of each food item is expressed as a percentage of the volume of the total gut-contents (Hynes, 1950). The total volume of the gut-contents was determined by the displacement method in a measuring cylinder and its percentage calculated. The prevalence of each item of food in the diet during different months was calculated by the occurrence method (Hynes, 1950). In this method, the number of fish in which each food item occurs is expressed as a percentage of the total number of the fish examined.

An exploratory examination of the gut-contents showed that *Sillago sihama* is an omnivorous feeder, as stated by Chacko (1949). In order to see if there was any difference in the composition of the diet in fishes of different sizes, a detailed analysis of the gut-contents of 900 specimens of different sizes was made for a period of one year.

In the analysis of the stomach contents of whiting, it was found that polychætes and crustaceans form the greater part of the food consumed. Polychætes, crustaceans and fishes constitute the principal food material of this fish in the area investigated, besides sea weeds and bivalves in small proportion.

The average volume of food per stomach for the period of investigation was 0·29 c.c.; the values for individual months are shown in Text-Fig. 7.

The fish were collected at about the same time of the day throughout the investigation. The volume of food in the stomach does not represent



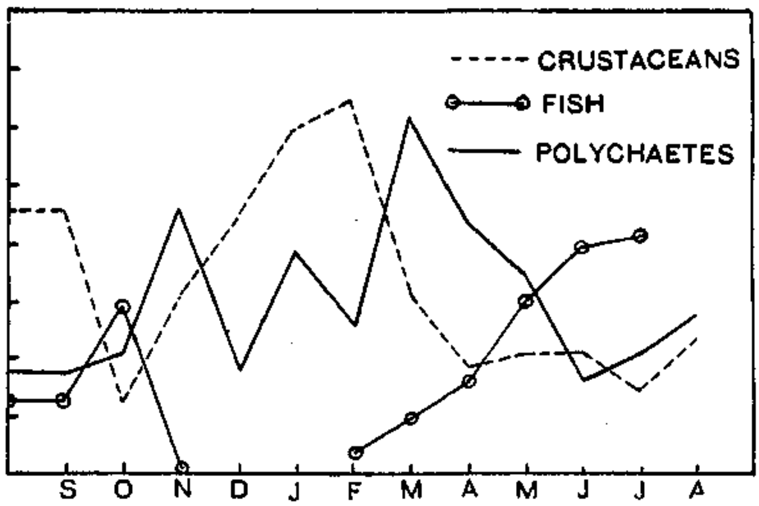
TEXT-FIG. 7. The average volume per stomach during the successive months in *Sillago sihama* (Forskål).

the volume consumed during feeding, because different food organisms will be digested at different rates. But, on the general assumption that the food in most stomachs has reached the same state of digestion, the results can roughly be treated as a fair guide to the feeding activity of the fish. On this basis three definite stages of feeding activity, *viz.*, average, active and reduced, could be noticed.

It is clear from Text-Fig. 7 that the feeding becomes active from March to May, the months immediately following the spawning time, when the fish are recovering from the strain. This is followed by a period of reduced feeding activity, from June to August, which are the months just prior to spawning. During the spawning months the feeding activity is average. That the feeding activity increases soon after spawning and decreases prior to spawning is further borne out by the greater number of empty stomachs observed just prior to and during the spawning period. The percentage of empty stomachs that occurred in the respective months is shown in Text-Fig. 8.

Considering the part that each of the principal food organisms plays in the food and feeding of whiting, we find that polychætes (*Nereis* and *Perinereis*) are the commonest organisms, forming a very large proportion

TEXT-FIG. 8. The percentage of empty stomachs that occurred in the respective months in *Sillago sihama* (Forskål).



TEXT-FIG. 9. Frequency of occurrence of the three groups of organisms in *Sillago sihama* stomachs during each month, expressed as percentage of the total number of stomachs examined.

of the food throughout the year. Polychætes have presented considerable difficulty in identification, as most of them were in an advanced state of digestion. They were predominant in the months following spawning. Among the curstaceans, prawns and crabs were commonly observed. Among the amphipods, *Ampelisca* spp. were found in the stomachs, more often in the months of June, July and August than in the other months. It is said that *Ampelisca* spp. are burrowers, usually lying buried under the surface layer of sand or gravel. The occurrence of these amphipods in such large numbers in the stomachs of whiting, suggests a deliberate search on the part of the fish for these forms, and it further emphasizes the bottom-feeding nature of the fish. Fishes do not constitute an important portion of the diet of the whiting, but from May to July fish fragments were found in the stomachs examined. It was not possible to identify all of them, owing to their advanced state of digestion, but *Zonogobius* sp. and *Leiognathus* sp. at least could be made out.

For the study of the food of the 0-year group, comparatively very few specimens were obtained, those too only in september 1953. The stomach contents showed amphipods of the genus *Ampelisca*, calanoid copepods, and also decapods and their larvæ. Mysids were often found in the stomachs examined.

The monthly variations in the proportions of the three chief food-components are given in Text-Fig. 9.

A scattering of empty broken frustules of planktonic diatoms such as *Bacteriastrum*, *Nitzschia* and *Coscinodiscus* was seen with a few Peridiniæ in a few specimens during the course of the present investigation. Probably these might have been taken in quite accidentally. The fish swallows sand along with the food taken, as their intestines were always found to be filled with sand particles. To get polychætes, the fishes probably have to dig into the sand with their snout. Devanesan and Chacko (1942) observed 12 specimens of *Balanoglossus* in a sample of 125 fishes examined around Krusadai Island. Varadarajan, as quoted by Devanesan and Chacko (1942), also has referred to the occurrence of *Balanoglossus* in the stomachs of *Sillago sihama*. During the detailed analysis of the gut contents of fish of different sizes for a period of one year, the author did not observe a single specimen of *Balanoglossus*, even in the stomachs of fishes collected from near Krusadai Island.

The various food-components of *Sillago sihama* occurring in the Gulf of Mannar and Palk Bay are given in Table II.

TABLE II

Fishes	Polychætes	Crustaceans	Miscellaneous
Zonogobius sp., *Leiognathus* sp., Packets of cycloid scales	*Nereis*, *Marphysa*, *Perinereis*, *Armandia* and indistinguishable moults of others	*Penæus indicus*, *Gonodactylus*, *Ocypoda*, *Alpheus*, Shrimps, Mysids, Amphipod of the genus *Ampelisca*, Calanoid copepods, Decapods, and their larvæ, Appendages of crustaceans were often found	Sea weeds—*Sargassum*, *Enhalus*, Remains of bivalve shells, Gastropod shells occurred rarely

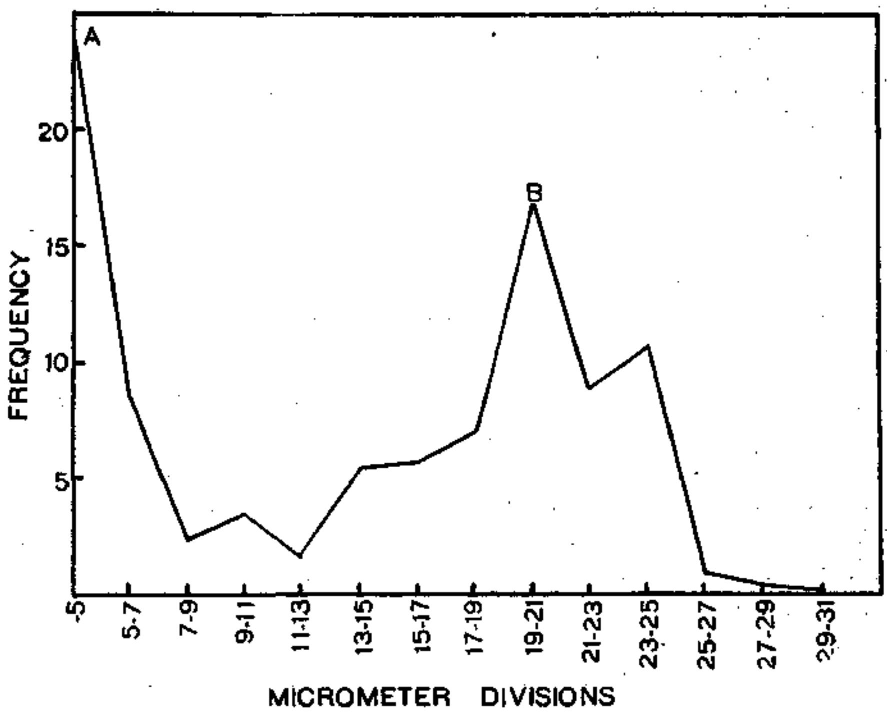
MATURATION AND SPAWNING

Maturation.—The study of the intra-ovarian eggs in the ripe ovaries of penultimate stages of maturity is the basis of the present investigation which was initiated with a view to determining the duration of spawning period. The procedure, similar to that adopted by Clark (1925), Arora (1951) and Prabhu (1952 *a* and *b*) was employed with a view to avoiding any deliberate selection or bias in taking the measurements.

Prabhu (1952 *b*) considered that measurements of at least 1,000 eggs were necessary to mitigate the probable error in the representation of various groups of eggs in different stages of maturity. So the diameters of nearly 1,000 ova were taken, irrespective of which axis lay parallel to the micrometer. This procedure ensures the random nature of the readings and represents, with fair accuracy, the numerical ratio of eggs in different size-groups.

Text-Fig. 10 represents the size-frequency distribution of ova in six nearly ripe specimens obtained during the spawning period. The total range in size of the intra-ovarian eggs was 0·0501 mm. to 0·517 mm. From the modes of the curve in Fig. 10 two distinct stages can be recognized in the maturation of the ova. Stage I (mode 'A') consists of eggs, which are purely immature ones. Another mode 'B' (Stage II) at 19–21 micrometer division represents mainly the mature and ripe eggs. Moreover, the eggs under the mode 'B' seem to be sharply differentiated from the immature ones.

As the numerical ratio between the eggs in fully ripe condition and the next group of eggs in mature condition indicates that the former are comparatively less in number, it may be inferred that the individuals examined were already in the spawning condition. As the difference in diameter between the fully ripe ova and the mature ova is not much, it is also possible that, by the time the fully mature ova are shed, the latter batch of eggs would have attained full maturity, to be spawned subsequently. From these observations it could be concluded that this species spawns only once in a year, and that its spawning season is not restricted to a short period but is a prolonged one.



TEXT-FIG. 10. Frequency of ova in different size-groups from ovaries of six different individuals of *Sillago sihama* (Forskål).

The smallest female in roe examined during this investigation was 13–14 cm. in total length. This observation corroborates the inference drawn from the fluctuations in the ponderal index that the average size of the fish at first maturity is 13 cm.

The ovaries were yellowish in colour, containing ova of all the four stages of maturity. Various workers have adopted different types of classification for the intra-ovarian eggs, but the following convenient method was followed for the present study.

Stage I.—Immature ova: Transparent ones which could be distinctly recognized as possessing a prominent central nucleus and a protoplasmic layer devoid of any yolk accumulations. The size varies from 0·0334–0·167 mm.

Stage II.—Maturing ova: Small, opaque ova in which the yolk formation has just commenced, but which are not fully yolked. The diameters vary from 0·183–0·217 mm.

Stage III.—Mature ova: Opaque and yolky with distinct yolk spherules but still contained within the follicles. The size ranges from 0·233–0·400 mm.

Stage IV.—Ripe ova: fully mature, large, free, fully or partly transparent eggs which have burst from the follicles, the diameter range being 0·417–0·517 mm.

The samples examined did not contain any fish in spent condition (Stage V). Probably fully ripe ova may be slightly larger than the size described above. Chacko (1950) observed eggs and larvæ of *Sillago sihama* from the plankton around Krusadai Island. Gopinath (1946) has described the advanced post-larvæ of *Sillago sihama* which begin to appear along the Travancore Coast by the end of December.

Spawning Season.—It is believed that this fish spawns during the colder months. As could be seen from the length-frequency distribution of catches, the small ones of 2–4 cm. have been obtained during this investigation only during the rainy season. The observation regarding the spawning season was verified by studying the size progression of ova during the different months of the year. The immature eggs occur in every adult female during all the months of the year. The largest eggs examined in September showed the nearly ripe condition. Such ova have been found in the ovary up to February. It is inferred that the spawning season of the fish extends from about August to February with a peak period in October. Specimens with actual oozing of ova have not been examined and the nearly ripe ova may take some time to become fully transparent, and ready for spawning. So the period indicated gives only an approximate picture of the spawning season. The data of the monthly size progression of the ova is given in Table III.

Spawning ground and occurrence of larvæ.—It is likely that spawning takes place in the mouths of rivers as suggested by Chaudhuri (1923). According to him, this fish is a permanent inhabitant of the Chilka lake, and goes out to the sea or the mouth of the lake for breeding. During this investigation larger whitings were very scarce. The absence of eggs and larval forms of this fish in inshore waters indicates that the spawning takes place somewhere beyond this region. It is probable that an intensive study of the fish taken from deeper waters may throw more light on the spawning habits. For lack of a suitable sea-going vessel it has not been possible to make any detailed investigation in these areas.

TABLE III

Monthly size progression of ova in Sillago sihama (*Forskål*)

(The range in size of ova found in any particular month is represented by the columns of circles: The majority of females had ova of the sizes indicated by the solid circles) 1 micrometer division = 0·0167 mm.

Maturity	Diameter in micrometer divisions	S	O	N	D	J	F	M	A	M	J	J	A
Fully ripe ..	31—33	○	●	○			●						
	28—30	○	●	●		○						○	
	25—27	●	●	○	○	○	○			○		●	●
Mature ..	22—24	●	●	○	●	●		○		○	○	●	
	19—21	●	●	●	○	●	●	○	○	●	○		
	16—18	○	●			○		○	○				
Maturing ..	13—15		●			○		○			●	●	
	10—12			○					●	●			
Immature ..	7—9	○		○	○			○					
	4—6	●	○	○	●	●	●	○	●	○	○	●	○
	1—3	●	●	●	●	●	●	●	●	●	●	●	●

Gopinath (1946) has described the advanced post-larvæ of *Sillago sihama* which begin to appear along the Travancore Coast from the end of December.

Growth-rate of gonads.—With a view to knowing how the size of gonads in the fish is actually related to their lengths and how the gonads in male and female are related to the length of the fish even in immature forms the entire range in size of the specimens available in the usual commercial landings was conveniently divided, with a class interval of 2 cm. The average size of the ovary and testis in each size-group was determined from the total of 330 observations. In calculating the theoretical values of the sizes of ovaries and testes, the midpoints of each size-group were taken into consideration. To express the relation between the two variables X and Y (X being the length of the fish in cm.; Y the length of ovary or testis in cm.) the equation for the regression line $Y = a + bX$, where a and b are the constants, was used. The equation for the regression line in the case of ovary and testis were found to be $Y = -1\cdot5677 + 0\cdot2533\ X$ and $Y = -1\cdot893 + 0\cdot2489\ X$ respectively. When these observed values for Y were plotted against their respective calculated values it was seen that the points were more or less closely located near the linear regression line. The data are plotted in Text-Figs. 11 and 12. It could be inferred that for every 10 cm. increase in the length of the fish the lengths of the ovary and testis increase approximately 2·53 cm. and 2·48 cm. respectively.

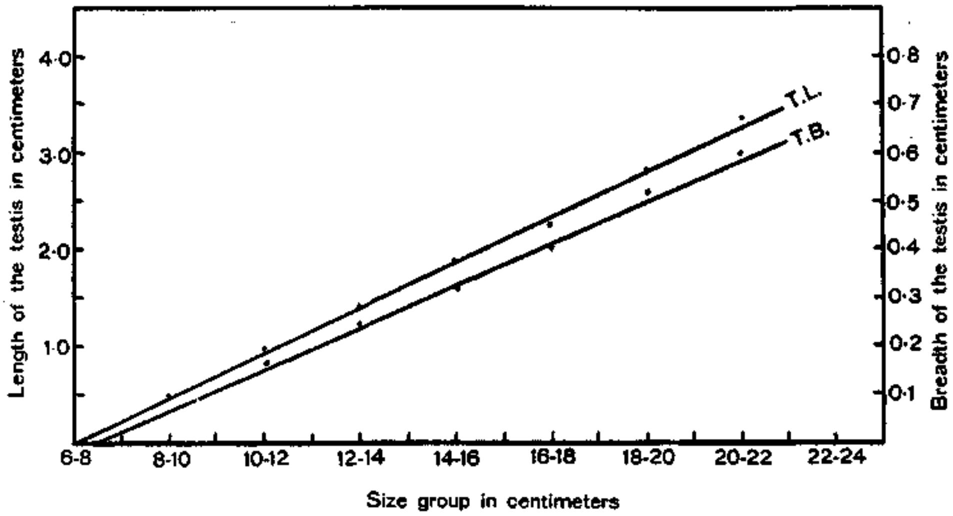
Similarly the average breadth of the ovary and testis, was calculated from the total of 330 observations. The equations for the regression line in the case of ovary and testis were found to be $Y = -0\cdot3037 + 0\cdot0449\ X$ and $Y = -0\cdot3003 + 0\cdot0424\ X$ respectively. It could be inferred that every 10 cm. increase in the length of the fish the breadths of the ovary and testis increase approximately by 0·44 cm. and 0·42 cm. respectively.

As can be seen from the above description the length and breadth were found to increase at a greater rate in the ovary than in the testis in *Sillago sihama*. It is quite probable that the weight of the ovary also increases at a slightly higher rate than the weight of the testis.

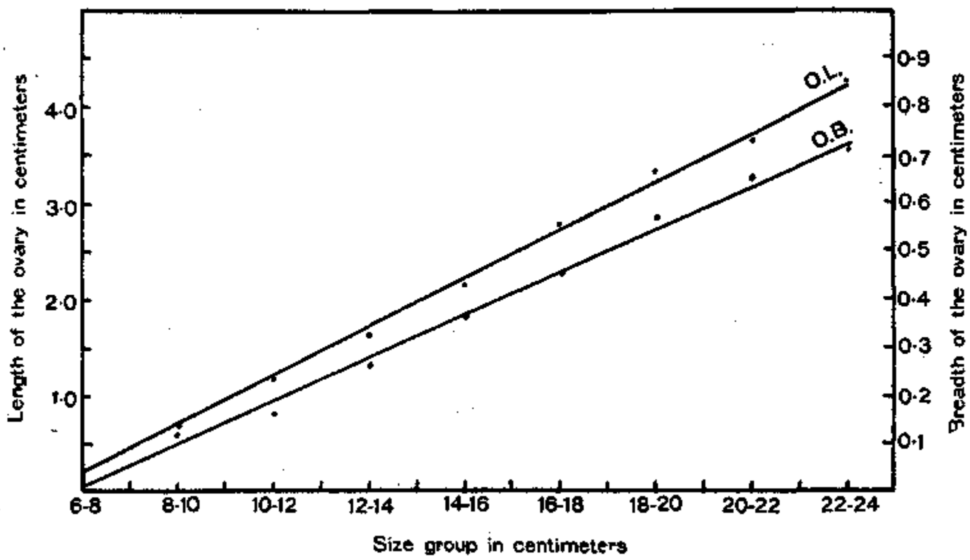
SEX RATIO AND FECUNDITY

The sex composition, of the random samples examined in 1953 and 1954, was 55·6% males and 44·4% females. Size-frequency of the males and females in 5 cm. range of total length is given in Text-Fig. 13. It was also noticed, that the males formed a higher percentage than the females in the size-groups up to 17 cm.

Fecundity was estimated by counting the ova in a small portion of the ovary of known weight and computing the total number of ova based on

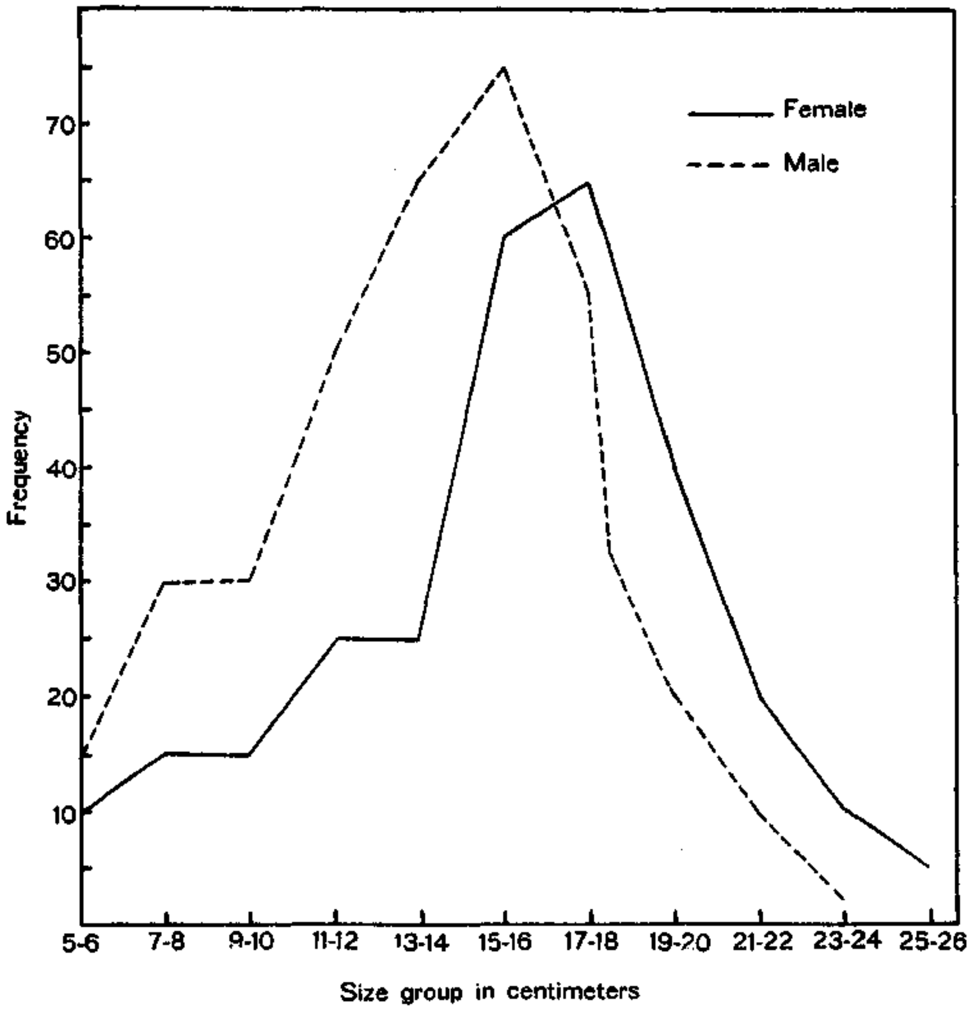


TEXT-FIG. 11. The observed and calculated (—) length and breadth of testis of *Sillago sihama* (Forskål). T.L., Length of the testis; T.B., Breadth of the testis.



TEXT-FIG. 12. The observed and calculated (—) length and breadth of ovary of *Sillago sihama* (Forskål). O.L., Length of the ovary; O.B., Breadth of the ovary.

this count and the total weight of the ovary. Two portions were taken from each ovary, one each from the anterior and posterior ends, and an estimate



TEXT-FIG. 13. The length-frequency polygons of males and females of *Sillago sihama* (Forskål).

was made of mean egg-weight of each ovary from the samples taken. It was found that the ovaries of the fully mature specimens of *Sillago sihama* contained on an average 14,000 eggs. As was also to be expected, the number of ova in smaller individuals was proportionately less since, as a rule the size of the ripe eggs is constant for each species.

AGE AND RATE OF GROWTH

There have been only a few individual attempts at the determination of the age and rate of growth of fishes in the tropical and sub-tropical waters.

The work of Rao (1935) on the otoliths of *Psettodes erumei*, of Hornell and Naidu (1923) and Devanesan (1943) on the scales of *Sardinella longiceps*, of Nair (1949) on the otoliths of *Sardinella longiceps*, of Chacko, Zobairi and Krishnamurthy (1948) on the scales of *Hilsa ilisha*, of Seshappa and Bhimachar (1951) on the scales of *Cynoglossus semifasciatus*, and of Prabhu (1953) on the scales and otoliths of *Chirocentrus dorab* may be mentioned in this connection.

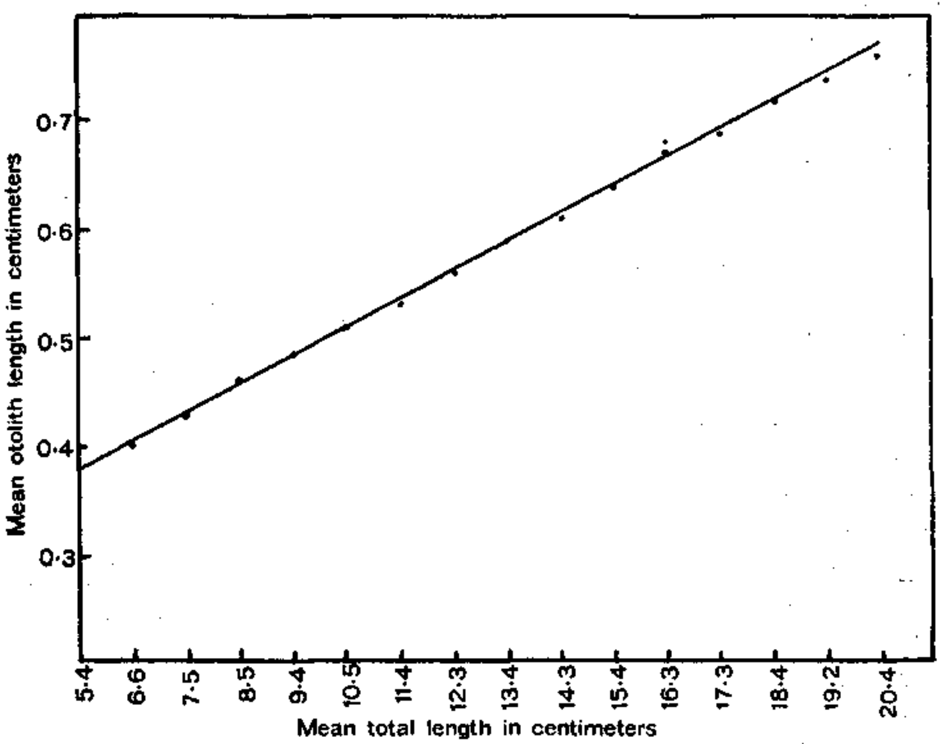
Since it was found, when this present study was started in September 1953, that there were distinct zones on the otoliths of Indian whiting an attempt was made to see whether these could be used in the same manner as Nair (1949) used them to age the Oil Sardine, *Sardinella longiceps*. A note, forming part of the work, has been published (1954) on the possibility of age determination of this species by the study of otoliths.

At first it was assumed that the zones on the otoliths were annual, and the age determined from the number of zones was compared with the estimates of growth obtained from the other method, namely, Peterson's method of tracing the length-frequency modes. To test the assumption that the zones were annual, a study of the growth at the edge of the otolith, according to the season, was made.

Detailed examination of the scales taken from the axillary region, just behind the pectoral fin, revealed that only some of them show the formation of clear annuli, particularly in the advanced size-groups, while in the earlier stages these annuli are not very clear. Since the occurrence of rings on the scales were of a very small percentage it was not helpful for the study of the rate of growth.

Age estimates from otolith studies.—An attempt was made to discover if there is a relationship between the selected otolith length and the total length of the fish expressible as an equation involving one or more constants. For this part of the study, there were measurements available of all the otoliths examined. To express the relationship between the two variables X and Y (X = length of the fish in cm., Y = length of the otolith in cm.) the equation for the regression line $Y = a + bX$ was used (a and b are the constants). The equation was found to be $Y = 0{\cdot}23 + 0{\cdot}027\,X$. When the observed values of Y were plotted against the respective X values, it could be seen that the points were more or less closely located near the linear regression line as shown in Fig. 14.

The methods employed throughout the investigation were similar to those of Nair (1949). The procedure often gives an unevenly ground surface, with liability to frequent fractures. This was minimised by carefulness in grinding, and in examination of the otolith frequently with a magnifying glass. Instead of mounting the otoliths in canada balsam, as suggested by Nair, keeping the otoliths in small air-tight specimen tubes, with a drop of xylol in it was



TEXT-FIG. 14. The relationship between total length of the fish and otolith size in *Sillago sihama* (Forskål).

found to give better results. The best method for the examination of an otolith is by placing it in a watch glass with xylol, and orientating it until a uniform field of light struck the convex surface at right angles. All age assessments were made after such examination. The two otoliths from the same fish were always found to have identical markings. Age estimates were made in a manner similar to that adopted by Bowers (1954) in *Gadus merlangus* L., from the number of bands and zones on the otolith as follows:—

1.	Otolith with no translucent band	Age group 0
2.	Otolith showing centre and translucent edge	,, 1
	Otolith showing centre, translucent band and opaque edge	,, 1

3. Otolith showing centre, translucent band, opaque zone, and translucent edge .. .. Age group 2

   Otolith showing centre, two translucent bands, with opaque zone in between and opaque edge .. .. „ 2

and so on up to age 4. In short the fish was allotted to the age-group corresponding to the number of translucent bands seen on the otolith, irrespective of whether the outermost translucent band was at the edge or within an opaque edge.

The age determinations from otolith readings were based on the assumption that growth rings on the otoliths are laid down annually. There is no absolute proof available that this is true (Graham, 1929) as the seasonal records of the state of the edge of the otoliths were incomplete. Age determination made by means of otolith readings showed that the fish in all age-groups up to 4 were present in the area investigated; age-groups 1–3 were well represented, but the older fish were scarce. A migration might account for the scarcity of 3-year old fish in the samples examined. Lack of evidence on this point may be owing to the fact that this investigation was limited to depths of 8–10 fathoms.

The range in length and the mean length in each age-group are shown in Table IV. The mean length at age-group 4 may probably be not very reliable, because the number ot fishes examined in this group was small.

TABLE IV

Mean lengths and length range of whiting at each age-group in 1953–54. Age determined by otolith readings

Age-group	Range in length (cm.)	Mean length (cm.)	Increase per year (cm.)
1	10–16	14·79	..
2	16–20	19·03	4·24
3	20–24	22·41	3·38
4	24–28	24·02	1·61

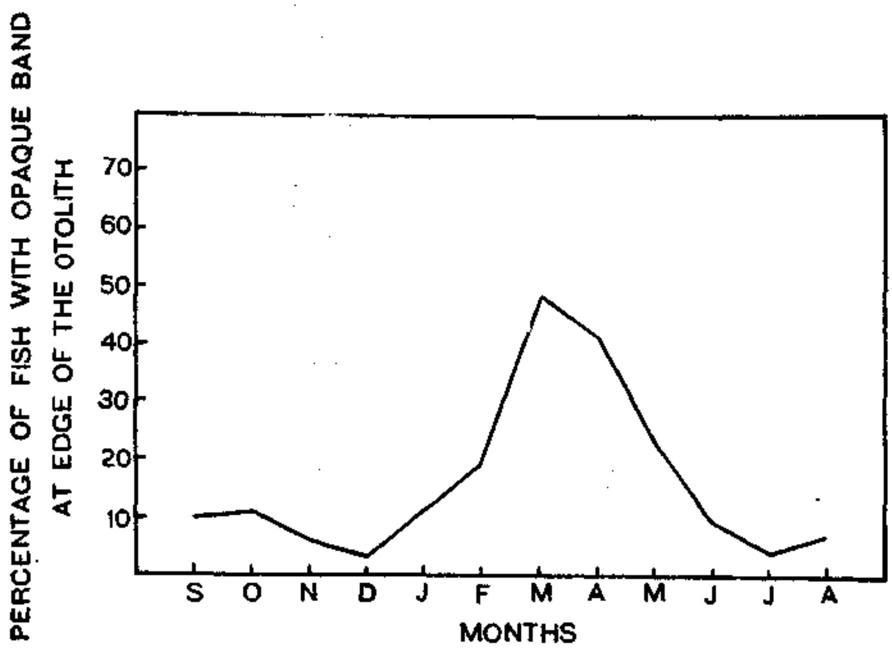
Errors in otolith readings could have arisen where secondary bands and true year bands were confused. Such errors do not appear to be numerous, and probably have little effect on the calculated mean lengths of each age-group.

Hickling (1933), on otoliths of hake, and Dannevig (1933), on scales and otoliths of Norwegian cod, have examined the validity of the annual nature of the zones. An effort was made to fix the validity of the annual nature of the rings found on the scales of Malabar sole, *Cynoglossus semifasciatus*, by Seshappa and Bhimachar (1951), probably for the first time in the tropical fisheries research.

The present investigation of *Sillago sihama* covers only a period of 12 months, and it was not possible to examine the validity of the method of age determination using all the methods described by Graham (1929). However, the two methods, namely, agreement with Peterson method and seasonal record of the ring or zone formation, were employed to fix the validity of the annual nature of the zones.

To find out whether these zones on the otoliths, though countable only in about 20–30% of cases, were put on in a regular annual sequence the structure of the edges of the otoliths of specimens in different size-groups was examined carefully, throughout the investigation. The periphery may be formed of an opaque or a translucent band, depending largely on the season of capture. Since the edge is very thin, it is sometimes difficult to distinguish whether the edge is opaque or translucent (Wallace, 1907; Jones and Hynes, 1950); but with practice it becomes possible. The relative width of the translucent bands and opaque zones varies considerably in otoliths of different fish, but when there are more than three bands on an otolith these bands are narrower and more crowded towards the edge. Text-Fig. 15 shows the condition of margin of otolith throughout the year. It was found that a particularly definite zone appeared on most otoliths about February-March, probably owing to intensive feeding during that period. More intensive work is needed to find out whether the opaque band would end abruptly as a ring or fade out gradually as a zone. It is however often hard to defferentiate between 'Zones' or 'Rings', especially in the older fish where the bands are close together. This type of study must therefore be used with great care and only where there are other means of checking the rate of growth. The possibility that two transparent bands are laid down in one year cannot be completely excluded, although it appears unlikely.

The possible causes of zones and interzonal rings on the otoliths.—The causative factor in the formation of these growth-checks is neither clear nor conclusive. The works of Hickling (1933) on hake, Dannevig (1933) on cod, and Menon (1950) on poor cod may be mentioned in this connection. Nair (1949) concluded that the scarcity of planktonic food is the main reason for the occurrence of growth-rings on the otoliths of *Sardinella longiceps*. Seshappa and Bhimachar (1951), working on the scales of *Cynoglossus semifasciatus*, concluded that the rings were formed under the influence of the south-west monsoon season and thought it appropriate to call the rings as monsoon rings. Prabhu (1953) working on *Chirocentrus dorab* indicated that in the immature specimens the change in environment, from the deep

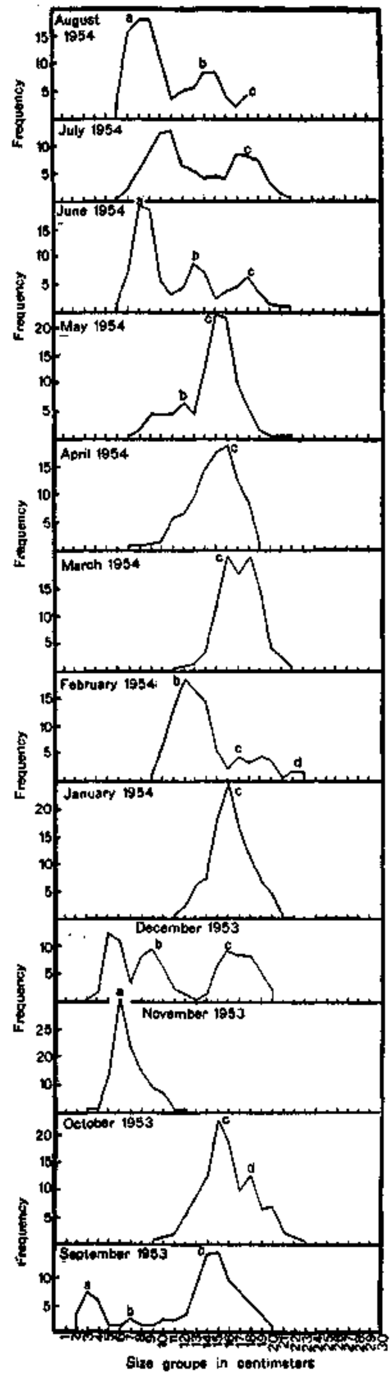


TEXT-FIG. 15. Condition of the margin of the otolith throughout the year, in *Sillago sihama* (Forskål).

and off-shore waters to the coastal waters, may have some effect on the formation of annuli on the scales.

During the course of the present investigation it has been noticed that there is a decrease in the rate of feeding and the amount of food consumed, with the maturation of gonads. The reduced feeding and the maturation of gonads occur simultaneously. Therefore, the suggestion is put forward now that the probable cause for the periodic formation of the rings on the otoliths of the Indian whiting is the reduction in the feeding of the fish which occurs simultaneously with the maturation of gonads.

Length-frequency studies.—Length-frequency studies are based on random samples of whiting collected regularly from September 1953 to August 1954. The samples were taken from the commercial catches around Mandapam and Rameswaram Island. The catches have been analysed irrespective of the gear employed for the purpose, since it was thought that this would give a clear picture of the population of Indian whiting in this area. However, mention may be made that the majority of the analysed catches were made from the shore-seine, which constitutes an important gear used along



TEXT-FIG. 16. Length-frequency graphs of the samples of *Sillago sihama* (Forskål) collected from Mandapam and Rameswaram Island.

the coast for the capture of pelagic fishes. Length-frequency data presented in Text-Fig. 16 are based on total length measurements of almost all the specimens in the catches. For the analysis of size-frequencies 1 cm.-groups have been employed (*e.g.*, 10 cm.-size-group includes specimens measuring 10·0–10·9 cm. in total length). For more accurate information the frequencies have been converted into percentages.

Considering the graph for September 1953 (Text-Fig. 16) three modes are clearly seen, *viz.*, *a* at 3 cm., *b* at 7 cm. and *c* at 13 cm. Young ones up to 5 cm. *a* in length appear in this month, and they are probably the progeny of fish that spawned in August 1953. The other groups *b* and *c* represent those spawned in 1952 and 1951 respectively. In October 1953 graph the mode *c* and a new group *d* appeared to be prominent. The latter mode represents the 1950 brood. As mentioned earlier, larger fish were very scarce, and it was difficult to obtain bigger specimens. But in January 1954 a small proportion of bigger specimens were obtained from the catches. A slight indication of a mode *e* can be spotted at 23 cm., which represents the one that spawned in 1949. In February 1954 graph there is another indication of a small mode *f* at 29 cm. representing probably the 1948 brood.

The groups represented by the modes *a*, *b*, *c*, *d*, *e* and *f* go on increasing in size every month. Considering the graphs of June 1954 three modes *a*, *b* and *c* representing 1953, 1952 and 1951 groups at 8 cm., 13 cm. and 18 cm. respectively, are seen. The mode *d* representing the 1950 group appeared in February 1954 at 23 cm. and later it goes out of the picture. In certain months the modes show slight retrograde movements which may probably be due to sampling error.

Viewing the graph as a whole, we can recognise four year-classes, *viz.*, the first year group having an average length of 15·5 cm., the second year 20·5 cm., the third year 24·5 cm. and the fourth year 27·5 cm. The growth rates during first, second and third years are thus approximately 5 cm., 4 cm. and 3 cm. respectively. Now comparing with the age estimates obtained by the study of otoliths, it can be said that there is slight agreement up to 1- and 2-year classes. This limit corresponds to the size at which the fish starts to breed, and after which the growth evidently slows down.

Fishery and Fishing Methods

The whiting supports a moderate fishery along the east coast, and the fishing season in this area extends approximately from May to December. Very heavy catches, constituted mainly by fish ranging from 15 to 24 cm., frequently occur during the period mentioned above.

On the east coast, whitings are caught by *kantivala, alivivala, iragavala, maravala, karavalai, kalamkattivalai, sippivalai* and *veechuvalai*. Most of the whiting catches in this area are by bag-nets and shore-seine operations. The bag-net is of conical shape and with mesh of ½ inch. The net varies in length from 36 to 42 feet, with a mouth opening of about the same diameter. The net is operated from two catamarans and at a depth of 3 to 6 fathoms. Fishes are caught by stake nets also, which are 1½ feet high, planted within the shore during the low tide, especially during the new moon and full moon days. During high tide sea-water flows above and over the net, carrying the fish along, but when the tide recedes most of the fishes are trapped in the net. The operation of *sippivalai* was found to be the most successful method for the capture of whiting, since the fish bury themselves in mud when they feel the shore-seine over them and leave the mud and swim off when it is removed. On the west coast, the main types of nets which are being operated for the capture of whiting are *periavala, kattuvala* and *veechuvala*. Hooks and lines are also used with prawns and bristle worms as baits.

SUMMARY

1. The extent of distribution of *Sillago sihama* in India is given.

2. The study of the growth-rate of the different parts of the fish has shown that the standard length and the depth of the body through pectoral fin base have the maximum and minimum rates of growth.

3. The relationship between total length and the standard length was found to be $Y = 0{\cdot}98\,X - 0{\cdot}70$.

4. The weight of the fish was found to increase as an exponential function of its length, and the equation for the curve was calculated to be $W = 0{\cdot}01504\,L^{2{\cdot}8862}$.

5. From the fluctuations in the ponderal index it has been inferred that the fish matures for the first time when it attains an average length of 13 cm.

6. Analysis of the stomach contents showed that polychætes formed by far the greater part of the food consumed. The four principal groups of organisms and their proportion in the total volume of food during the period under survey are given. A list of organisms found in the gut contents and the monthly variation in the proportion of the three chief food components are given. An increased feeding activity after spawning and a low feeding activity before spawning were noticed.

7. By the study of frequency distribution of intra-ovarian eggs, it was concluded that the fish has a single but prolonged spawning period in the course of a year. It was also inferred that the spawning season extends from August to February with the peak period in October.

8. From the study of the rate of growth of gonads, the length and breadth of ovary have been found to increase at a greater rate than the testis.

9. It was noticed that the males form a slightly higher percentage of the catches than the females, the ratio being 55·6 : 44·4.

10. The ovaries of a fully mature individual of *Sillago sihama* were found to contain about 14,000 eggs.

11. The relationship between otolith length and length of the fish was determined. The rate of growth computed from a study of otoliths indicated an increase of 4·24 cm., 3·38 cm. and 1·61 cm. for the first, second and third years respectively. It was concluded that the reduced rate of feeding, at the time of the maturation of the gonads, may probably be the cause of the periodic formation of the rings in the otoliths of Indian sand whiting.

12. The length-frequency distribution of *Sillago sihama* collected from the Gulf of Mannar and Palk Bay for the period of one year are presented and discussed. A slight agreement was noticed up to 1 and 2 year classes, on comparison with the age estimates obtained by the study of otoliths.

13. A brief account of the fishery of the sand whiting and the fishing methods of the east and west coasts are given.

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