SOME ASPECTS OF THE BIOLOGY OF THE RIBBON FISH *TRICHIURUS HAUMELA* (Forskål)*

BY M. S. PRABHU

(Central Marine Fisheries Research Station, Mandapam Camp)

CONTENTS

I. INTRODUCTION

RIBBON fishes of the genus *Trichiurus* occupy an important place among Indian marine fishes judged by the magnitude of the fishery they support. Delsman (1926) gave an account of six kinds of eggs and larvæ of this genus from Java Sea. Chacko (1950) reported the occurrence of eggs and larvæ of *T.* (?) *savala* from waters around Krusadai Island. Tang and Wu (1936) published a preliminary note on the spawning ground of *T. japonicus* in Poi-hai, Gulf of Chihli. Prabhu (1950) gave a short account of the breeding habits of *T. haumela.* Venkataraman (1944) and Chidambaram and Venkatraman (1946) dealt with the feeding habits and natural history respectively. Jacob (1949) published some notes on their bionomics. In a detailed work on the food and feeding relationships of the fishes of Singapore,

* This paper formed part of a thesis submitted to the University of Madras for the degree of Master of Science.

Tham Ah Kow (1950) has described the feeding habits of *T. haumela*. Recently, Vijayaraghavan (1951) has published the results of a quantitative and qualitative analysis of the stomach contents of *T. haumela* and *T. savala* at Madras. Mahadevan (1950) has described the histology of the alimentary tract of *T. haumela*. Devanesan and Chidambaram (1948) have enumerated in a brief account, certain points of fisheries interest in these species in the Madras State. With a view to obtaining accurate information on the fishery biology of *T. haumela*, the most common Madras species, a detailed investigation on this species was taken up at Madras during 1947–49 and the results obtained were supplemented by further observations during subsequent years.

II. Material and Methods

A representative sample of 15–20 fish was collected each time at regular intervals, often from the fish-landing places or, when this was not possible, from fish markets at Madras, Calicut, Quilandy and Mangalore during the years 1947 to 1949. As soon as the specimens were brought to the laboratory, they were measured and sorted into different size groups. The gonads were dissected out and examined in detail to study the different stages of maturity. The guts were removed and fixed in 5% formalin and later examined for the gut-contents, the volume of which was determined by the displacement method. Ova, teased out from fresh ovaries or in prepared sections of ovaries, were measured with the help of an ocular micrometer giving a magnification of $16 \cdot 7\mu$ to each micrometer division. In studying the otoliths, the method suggested by Nair (1949) was employed. In determining the number of ova in each ovary, weighed portions of ovaries were teased in water or boiled in water for 2–3 minutes and then the ova separated to count the number of maturing ova. Hickling's (1940) method of fixing weighed portions of ovaries and then teasing them and counting was found to be more time-consuming and hence that method was not followed. From the number of ova in the known weight of the ovary, the total number of ova in the whole ovary was calculated.

III. The Genus *Trichiurus* in Indian Waters

The family *Trichiuridæ* consists only of the single genus *Trichiurus* which can be easily identified by its elongated, ribbon-shaped and laterally compressed body tapering towards the posterior end (Plate III, *a*). There is no caudal fin. The dorsal fin extends from the hind edge of the preopercle along the whole of the back and is many-rayed. Ventrals are in the form of scales and anal spines are minute and sometimes concealed under the skin. The entire body is scaleless and is coated with a shining silvery substance. The cleft of the mouth is deep with teeth in jaws and palatines, those on the premaxillaries being arched and strong. The lateral teeth are lancet-shaped. Lateral line is just below the middle of the body and is very clear.

The genus *Trichiurus* is represented in the Indian seas by three species *T. haumela*, *T. savala* and *T. muticus*. The chief characters by which the three species can be identified quickly in the field are given in Table I. In Madras the three species, *T. haumela*, *T. savala* and *T. muticus*, are popularly called 'Olai valai', 'Kartigai valai' and 'Savalai' respectively. Ribbon fishes in general are known as 'Savallu' in Telugu, 'Pambole' in Canarese, 'Pituirkti' or 'Pitiwagti' and 'Bala' in Marathi and 'Thalayan' or 'Pambada' in Malayalam.

IV. Distribution

The ribbon fishes have a wide range of distribution throughout the warm seas. Besides being landed at several places along the eastern and western coasts of peninsular India, *T. haumela* has been known to be the most common species occurring in the Indian Ocean, around the Archipelago and in various parts of the Pacific.

As stated by Goode (1884), some writers believe *T. haumela* of the Indo-Pacific region to be identical with *T. lepturus* found in the tropical Atlantic, on the coast of Brazil, in the Gulf of California, the West Indies, the Gulf of Mexico and north of Woods Hole, Massachusetts, and he states that this species occurs also on the coast of Europe as also in Southern England where they occur abundantly, but they do not however enter the Mediterranean. Various foreign authors such as Fowler (1903–43), Higgins (1921), Cornish (1867–72), Clogg (1871), Gatcombe (1871 and 1876) and Herre (1940) have recorded the occurrence of ribbon fishes in the Indo-Pacific and Atlantic regions. *T. lepturus* (Linnæus) which is very common along the American coasts, described by Fowler (1904), does not vary much from *T. haumela* (Forsk.) described by Day (1889). Fowler (1904) while describing *T. haumela* collected from Sumatra says that this species is closely related to *T. lepturus* (Linnæus) differing apparently in the less numerous dorsal rays and the deeper body. He further states that *T. haumela* has been recorded a number of times from India although Day considered his *T. malabaricus* as identical.

In the Indian waters the three species shoal separately at different places. On the east coast *T. haumela* predominates in the catches at Madras and in north Andhra, *i.e.*, in the fishing centres north of Visakhapattinam. *T. savala* has been reported to be more common on the coast of central Andhra, *i.e.*, Visakhapattinam to Masulipattam; whereas in the south near Gulf of Mannar and Palk Bay, in addition to *T. haumela* and *T. savala* which occur in very small numbers, the third species *T. muticus* is also quite common. In the southern part of west coast consisting of Travancore-Cochin and Malabar and in the northern part comprising the Konkan, Bombay and Ratnagiri coasts, *T. haumela* and *T. savala* respectively are the common species caught.*

* This information is partly based on the reports of the fishery survey assistants of the C.M.F.R. Station working along the east and west coasts of India.

Table I

Showing the Chief Characters by which the Three Species can be Quickly Identified in the Field

	T. haumela	*T. savala*	*T. muticus*
1.	Lower jaw considerably longer than the upper jaw.	Lower jaw considerably longer than the upper jaw.	Lower jaw more prolonged than the upper jaw.
2.	Dorsal profile, between end of snout and eye, rather concave.	Interorbital space nearly flat.	Interorbital space with a keeled ridge.
3.	Medium number of dorsal rays. (127–33)	Smallest number of dorsal rays. (112–20)	Largest number of dorsal rays. (140–50).
4.	The longest rays in the middle of the dorsal fin equal to height of body.	Longest dorsal rays equal to height of body.	Longest dorsal rays equal to only half height of body.
5.	No rudiment of ventrals.	No rudiment of ventrals.	Ventrals indicated by two small rounded scale-like projections on the lower surface of the abdomen.
6.	Anal fin in the form of short spines, often concealed or blunted at their extremities.	Anal fin in the form of short spines, often distinct, especially the first which is twice as long as in *T. haumela*.	Anal fin almost or entirely concealed under the skin.
7.	Lateral line gradually descends until above the commencement of the anal fin where it is in the lower third of the body.	Lateral line passes downwards to the lower third of the side.	Lateral line almost straight and a little below the middle of the body especially in the last part of the course.
8.	Upper half of the body rendered dark by numerous black dots. Fins pale yellow.	Silvery. Fins yellow-white.	Burnished silver. Fins yellowish.

Delsman (1929) states that out of the nine species enumerated by Bleeker, only six occur in the Indo-Australian seas, and of these the best known is *T. haumela*. From the observations made during the present investigation, it has been found that *T. haumela* is the most common species occurring along the coasts of Madras State, although occasionally *T. savala* and *T. muticus* are also caught from certain restricted regions.

V. Maturation of Gonads and Size at First Maturity

Structure of ovary.—The ovary in *T. haumela* is located just above the alimentary canal in the abdominal cavity and is bilobed. The two lobes are asymmetrical in length as well as in girth (Figs. 1 and 2) and they appear

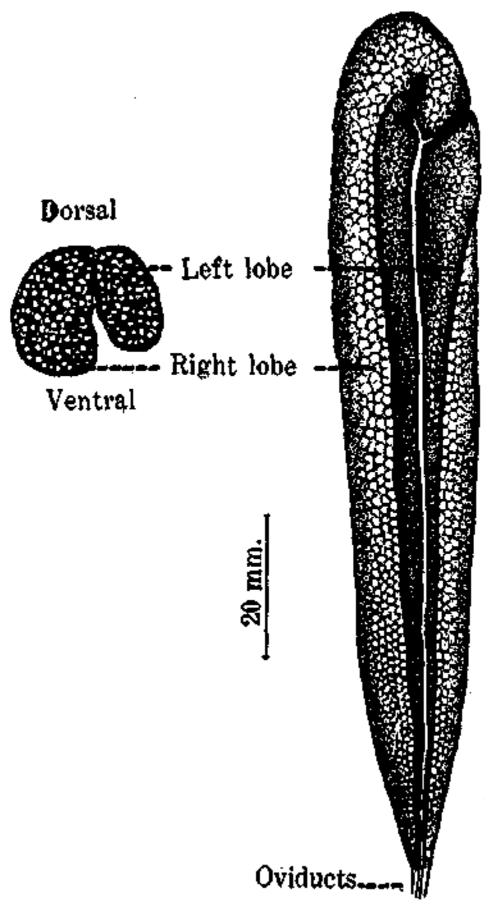


Fig. 1. A cross section of the ovary.

Fig. 2. Ventral view of the asymmetrical lobes of the ovary of *T. haumela*.

to be in the form of a U-shaped loop of which the left forms a part of one limb and is nearly two-thirds the length of the right one. The two lobes are fused together along the dorsal edges of their adjacent sides and are suspended from the dorsal wall of the abdominal cavity by a thin mesovarium. The ovary is of the cystoarian type and the internal structure is of the pattern found in the ovaries of most teleostean fishes. In the ovigerous lamellæ, the mature ova are usually located away from the ovarian wall and towards the centre of the ovarian cavity. During the spawning season, the ovaries get distended and ova burst out from the follicles and lie in the lumen of the ovary, to be subsequently shed during the spawning season.

Stages of maturity.—The ovaries of *T. haumela* in various stages of maturity show a gradation which is found to be characteristic of this species. A scale of only five stages of maturity is found practicable for *T. haumela* as against the seven stages followed by the International Council for the Exploration of the Sea. These may be labelled as 'immature', 'maturing', 'mature', 'spawning' and 'spent'. A comparison, as is made below, will show that the third 'mature' stage of gonads in the fishes studied was equivalent to the III, IV and V stages of the International Council.

Stage			Stages followed by the I.C.E.S.
I.	Immature	Testes slender and transparent, ovaries slender, transparent, eggs not visible to naked eye	I
II.	Maturing	Testes slightly enlarged, opaque, ovary slightly enlarged, eggs having granular appearance (includes gonads in rematuring condition after spawning)	II
III.	Mature	Testes greatly enlarged, pale-white, ovaries greatly enlarged, yellowish, eggs visible to naked eye	III, IV and V
IV.	Spawning	Not observed	VI
V.	Spent	Testes loose, opaque, few sperms, either motile or non-motile, ovary flabby, contracted, showing traces of hæmorrhage, eggs granular in appearance, few yolky eggs	VII

By a comparison of fishes classified according to the condition of gonads, it was found that specimens with gonads immature enough to be considered as of Stage I averaged round 42 cm., while those with gonads more mature and fit to be placed in Stage II averaged round 46 cm., and those with still more mature gonads and deemed to fit into Stage III measured 48 cm. However, fishes with gonads in fully spawning condition (Stage IV) have not been observed among the 976 ripe specimens examined, whereas those with gonads showing all the characteristic features of being in a spent condition were found to be measuring more than 48 cm. An examination of the maturity groups obtained by such a classification on the basis of size showed also clear and well marked differences in the sizes of the ova.

TABLE II

Showing the Average Size of the Largest Eggs and the Range in Size of Specimens in Different Stages of Maturity

Stages of maturity	Range in size of specimens	Average size of the largest eggs
I	up to 42 cm.	0·22 mm.
II	„ 46 cm.	0·4 mm.
III	„ 48 cm.	1·1 mm.
IV	..	Ovaries in this stage have not been observed
V	above 48 cm.	0·56 mm. (in spent ovaries)

In Table II the diameters of the intra-ovarian eggs are also given in order to assess the maturity of the gonads more correctly than by mere description. As will be seen from the table, the eggs increase in size markedly in Stage III, when they are of maximum diameter.

Minimum size at first maturity.—To determine the size at which *T. haumela* mature, the data collected on the condition of gonads of 976 specimens studied during a continuous period of 12 months were analysed and tabulated (see Table III).

It is obvious from Table III that individuals up to a length of 37 cm. are immature and that in the next size group also, *i.e.*, 37–41 cm., the majority of the fishes are in Stage I. In the following size group, *i.e.*, 41–45 cm., the percentage of maturing individuals has increased to 91, whereas in the next

TABLE III

Showing the Percentages of Gonads of T. haumela *in Different Stages of Maturity*

Size groups (cm.)	Percentages of gonads in each stage of maturity				
	I	II	III	IV	V
17–21	100	..	..	..	..
21–25	100	..	..	..	..
25–29	100	..	..	..	..
29–33	100	..	..	..	..
33–37	100	..	..	..	..
37–41	74	26	..	..	..
41–45	9	91	..	..	..
45–49	..	51	43	..	6
49–53	..	..	78	..	22
53–57	..	..	59	..	41
57–61	..	..	75	..	25

size group individuals with gonads in Stages II (including those in rematuring condition—Plate III, *b*), III and V also occur. The occurrence of specimens with gonads in Stage V (spent) for the first time in this size group clearly indicates that *T. haumela* begin to spawn when they attain a length somewhere between 45·1 and 49 cm. From Table II it could be seen that the large intra-ovarian eggs of 1·1 mm. are first found in the ovaries of individuals of 47–48 cm. in length. As the smallest specimens with spent ovaries measured 47–48 cm., it is clear that the minimum size at which *T. haumela* mature is 47–48 cm.

VI. Spawning Period, Its Duration and Occurrence of Young Ones

The conspicuous absence of ribbon fishes with fully ripe gonads (Stage IV) along the coastal waters and the reappearance of these fish with spent gonads, suggest that they spawn in the offshore waters. The conclusion is supported by the fact that so far neither developing eggs nor larvæ of *T. haumela* have been collected from the coastal plankton samples except the two post-larvæ obtained by Nair (1952). He says that though this fish occurs in huge swarms, the post-larval stages are extremely rare in the Madras plankton and that so far only two specimens have been obtained, one in September and the other in December 1944. Further, he states that the extreme rarity of the post-larval forms may be due to their oceanic habitat. The occurrence of gravid specimens measuring 48 cm. and above during the months of April and May and their reappearance in large numbers in spent condition in July, lead to the conclusion that the spawning should have taken place in the interval. Systematic data gathered on the condition of gonads in mature specimens for a continuous period of 12 months show that fishes with gonads in spent condition (Stage V) begin to appear from the month of July thereby indicating that the spawning must have taken place towards the end of June and that the spawning is probably restricted to a definite and short period.

The above inference is confirmed by a study of the diameters of the intra-ovarian eggs carried out on the lines suggested by Hickling and Rutenberg (1936) and De Jong (1940). From each ovary nearly 1,000 ova in all stages of development were measured, and another set of measurements were made from random samples of ova collected from 8 different ovaries. Thus about 1,000 ova each were measured from mature ovaries of specimens 48·0, 50·7, 53·3 and 54·0 cm. in length and other measurements were made from ovaries of 8 different individuals ranging in size from 48 to 55 cm. Altogether about 5,000 ova were measured. The entire range in size of the ova was then divided into several 5 m.d.* size groups and the percentage number of ova in each size group was calculated. The data thus derived are shown in Fig. 3. Similarly, more than 1,000 intra-ovarian eggs each from two spent ovaries of individuals 55·7 and 57·5 cm. in length were also measured and the data are shown in Fig. 4 to enable easy comparison of the frequencies of ova in spent and mature ovaries. The degree of formation of yolk in maturing and mature ova was taken as a reliable guide in judging the stages of maturity of the intra-ovarian eggs. The diameters of ova varied from 5 to 75 m.d. A microscopical examination of the intra-ovarian eggs in mature ovaries (Plate III, *c*) revealed that all ova measuring 30 m.d. and above were fully yolked and mature and those measuring less than 30 m.d. immature. From Fig. 3 it could be seen that there are at least 2 distinct modes, mode '*a*' representing the mature stock of ova and mode '*b*' the immature ova and that the mature ova are more or less sharply differentiated from the immature ones. The fact that the maturing eggs are sharply differentiated from the immature stock of ova makes it probable that the spawning is restricted to a definite and short period. Jacob (1949) suggests the possible occurrence of two spawning seasons or a single prolonged one. The present observations do not support this suggestion. Moreover studies on the spawning habits indicate that not only is the spawning period restricted to a short and definite period but also that spawning takes place only once a year probably at the end of June. Young ones of this species measuring 7–9 cm. in length have been observed in large numbers only once a year towards the end of

* (m.d. represents micrometer division. In the graphs, a scale is also given for easy conversion of m.d. into mm. With a view to avoid giving diameters of ova in fractions of mm. the measurement of ova are given in m.d.)

July in the fish-landing places along the Madras coast as well as at Attankarai and Thangachimadam along the Ramnad coast. Thus it is quite probable that the post-larvæ of *T. haumela* grow to a size of 7 to 9 cm. in length within a period of a month and a half. This observation agrees with that of Tang and Wu (1936)

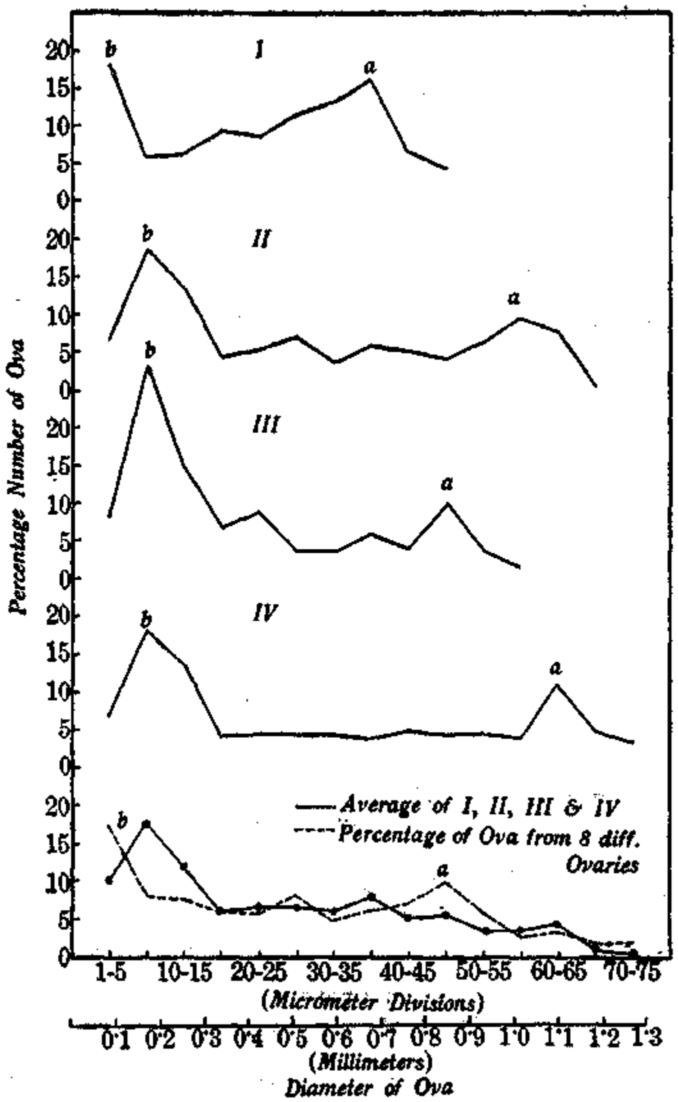


FIG. 3. Frequencies of ova in mature ovaries of *T. haumela* in different size groups.

Curve I.	Percentages of ova from a fish	50·7 cm.	in length
Curve II.	,, ,, ,,	53·3 cm.	,,
Curve III.	,, ,, ,,	54·0 cm.	,,
Curve IV.	,, ,, ,,	48·0 cm.	,,

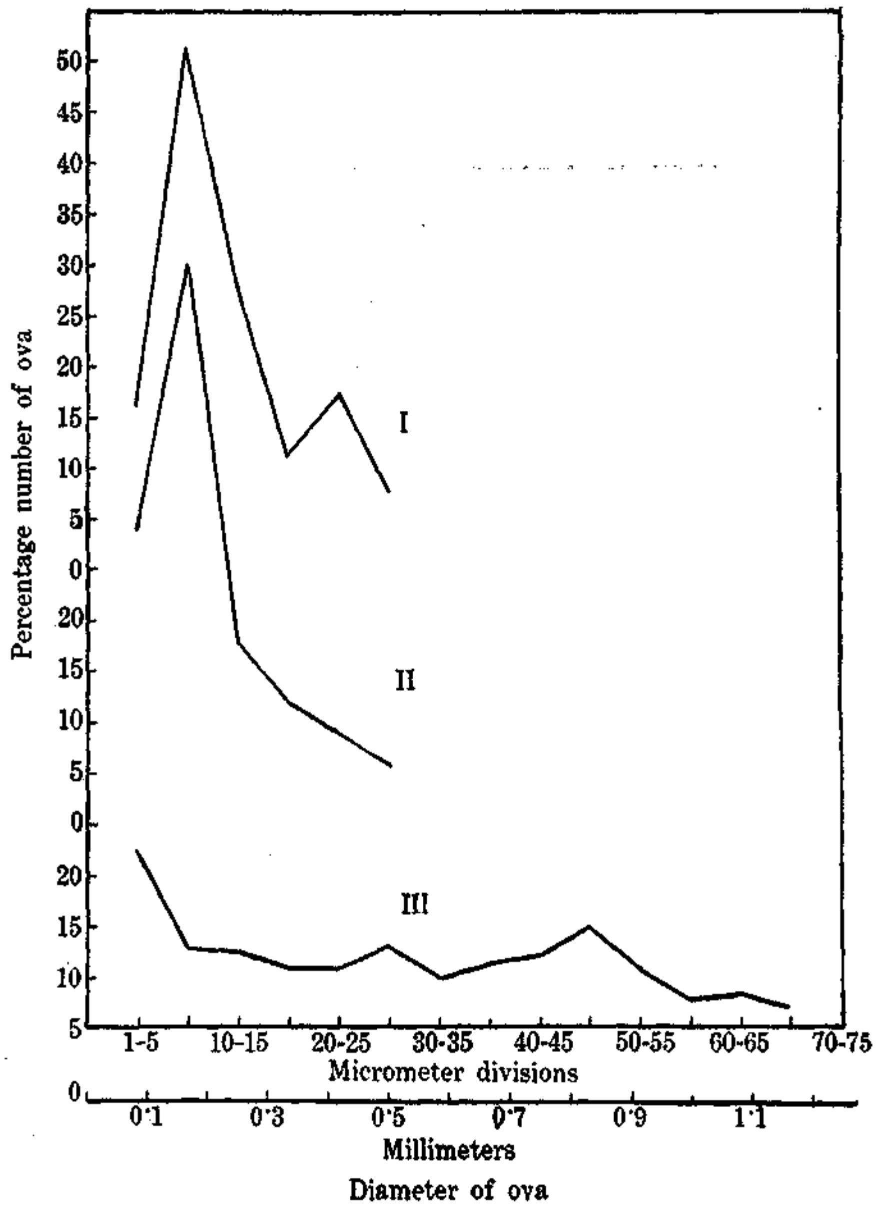


FIG. 4. Frequencies of ova in two spent ovaries of fishes 55·7 cm. (curve I) and 57·5 cm. (curve II) in size and mature ovaries (curve III) of 8 different fishes ranging in size from 48–55 cm.

who have reported that eggs of *T. japonicus* give rise to post-larvæ of 5·4 to 9·5 cm. in length within a period of a month and a half from the time of spawning.

From a comparison of the curves I and II with that of curve III (Fig. 4), it is evident that in spent ovaries, eggs above 30 m.d. are not at all represented, thereby indicating that the entire stock of ova above 30 m.d. are shed during spawning. It can be concluded that the range in size of ova shed during spawning season is from 30 to 75 m.d.

VII. Age and Growth

Ribbon fishes being scaleless, age determination has been attempted only by studying the otoliths and length frequencies.

Otolith studies.—Nearly 126 otoliths of *T. haumela* of different sizes (10·1–63·5 cm.) were studied. It was, however, interesting to note that growth rings were absent in almost all the otolithis. An examination of a few otoliths from fishes belonging to the other two species, namely, *T. savala* and *T. muticus*, indicated that they also had otolithis of the same character. In almost all the otoliths of *T. haumela*, a narrow strip of area along the periphery alone was found to be translucent and this area is probably the zone where fresh calcification is taking place. Even by employing the method of clearing and mounting the otoliths suggested by Nair (1949), it was not possible to make out any growth checks.

Though growth rings are absent in the otoliths, the length, width and thickness of otoliths show a gradation which corresponds with the length of the fishes. The otoliths dissected out from each individual was measured and the entire range in size of the individuals was divided into several 10 cm. size groups and the size of the otoliths in each size group was calculated (Table IV).

Table IV

Showing the Number of Otoliths Examined and Their Average Size in Different Size Groups

Size groups of specimens (cm.)	Number of otoliths examined	Average size of the otoliths (mm.)
10–20	11	1·64
20–30	11	2·35
30–40	28	3·13
40–50	37	4·00
50–60	31	4·67
60–70	8	5·90

It may be seen from Table IV that the rate of increase in length of otoliths in the various size groups is more or less gradual and somewhat proportional to the length of the fish.

Size frequency distribution.—1,054 specimens of *T. haumela* were examined between March and July 1952. Every week during this period, about 100 fish were taken from the fish haul and sorted into 12 different size groups, each having a length-range of 4 cm. and the number of fish belonging to each size-group was noted and the percentage also calculated. The data collected during the weeks of each month were averaged and taken as typical for the month (Fig. 5).

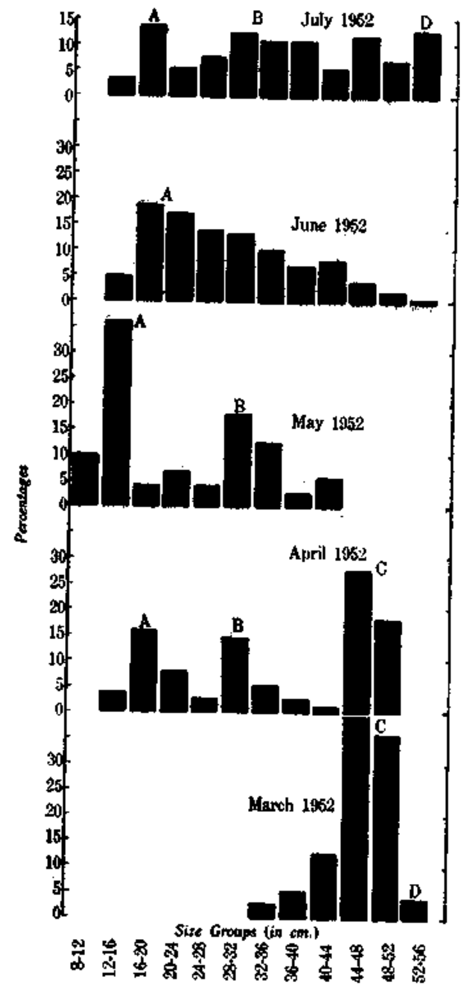


FIG. 5. Showing the size frequency distribution in *T. haumela* from March to July 1952.

In March it was found that the first six size groups ranging from 8–32 cm. were not at all represented whereas the last size group, *i.e.*, 52–56 cm. formed 3·85% and the two size groups 44–48 cm. and 48–52 cm., formed 39·74% and 35·9% respectively. In April, the three size groups, namely, 16–20 cm., 28–32 cm. and 44–48 cm. forming 15·79%, 14·47% and 27·63% respectively, were found to show three definite peaks while the lowest and the largest size groups, namely, 8–12 cm. and 52–56 cm., were absent. In May, the size groups ranging from 44–56 cm. were absent but two size groups, 12–16 cm. and 28–32 cm., constituted two definite peaks. The lowest size group, 8–12 cm., also formed about 9·27 %. In June, the lowest size group was not present and the longest size group formed only 0·16%. One size group, *i.e.*, 16–20 cm., formed a definite peak, whereas all the other size groups ranging from 20–52 cm. appeared to be gradually decreasing in number. In July, excepting the lowest size group, i.*e*., 8–12 cm., all the others were found to be well represented. Four size groups, 16–20 cm., 28–32 cm., 44–48 cm. and 52–56 cm., were found to constitute four definite peaks.

From Fig. 5 it could be seen that there are at least four distinct modes '*a*', '*b*', '*c*' and '*d*' representing probably four year-classes. The first one, *i.e.*, mode '*a*', is in the 16–20 cm. size group in the months of April, June and July and in the 12–16 cm. size group in May alone. As the mode '*a*' has been found to be between 12–16 cm. only in one month, its occurrence in 16–20 cm. for a longer period has been given consideration. The second mode is in the 28–32 cm. size group, the third in the 44–48 cm. size group and the fourth in the 52–56 cm. size group. Considering that the mid-point measurements of these four size groups are the average sizes attained by individuals from their first to fourth year of life, it could be seen that the first-year class specimens attain a length of 18 cm., the second-year class 30 cm., the third-year class 46 cm. and the fourth-year class 54 cm. Therefore the individuals represented by mode '*a*' may be those hatched from the eggs shed during the previous spawning season, *i.e.*, June 1951, and the individuals represented by modes '*b*', '*c*' and '*d*' hatched out from eggs shed during 1950, 1949 and 1948 respectively. As the spawning in *T. haumela* seems to take place at the end of June and because the first-year class with an average length of 18 cm. is found in large numbers in the month of April, a growth of nearly 18 cm. during the first year seems to be indicated. Following the same principle it could be seen that the growth during the second year is about 12 cm. and during the third and fourth years 16 and 8 cm. respectively. It is evident that the growth rate in *T. haumela* is fairly high during the first year, and slightly less during the second year. The growth rate of about 16 cm. during the third year (which is more than the growth during the second year), is probably due to some bias in the samples brought about by the inshore migration of the different size groups. The mode '*c*' has been found to be quite prominent in the same size group, *i.e.*, 44–48 cm., during March, April, June and July. The rate of growth in length during the fourth year was found to be only 8 cm., which is much less than during the first, second and third years. Hence the findings of Baranov (1916) and Ford (1933) that the fishes in general have an accelerated growth during the first year and a lesser rate during the subsequent years, seem to hold good in the case of *T. haumela* also. *T. haumela* has been found to attain sexual maturity and commence spawning at a length of 47–48 cm. which corresponds to the size attained by the third-year class individuals. During the fourth year the rate of growth has been found to be on the decrease. It is also obvious from Fig. 5 that the mature individuals in the 52–56 cm. size group and in all the size groups ranging from 44–56 cm. disappear from the coastal waters in the months of April and May respectively. Such an off-shore migration of mature individuals in April and May and their appearance in small numbers in June and in larger shoals in July in the inshore waters, seem to indicate that the mature individuals move away from the coastal waters probably for the purposes of spawning.

VIII. Length-Weight Relationship

The length-weight relationship in *T. haumela* was determined by measurements on 174 specimens ranging in size from 12 to 56 cm. The total range in size was divided into 11 size groups with a class interval of 4 cm. and the mean length ('L') and weight ('W') in each size group were calculated. It has been found that the length-weight relationship of most fish can adequately be described by a formula $W = AL^B$ where 'W' = weight, 'L' = length, 'A', a constant and 'B', an exponent usually lying between 2·5 and 4 (Hile, 1936; and Martin, 1949). For all ideal fish which maintain the same shape, the value for 'B' has been found to be 3 (Allen, 1938).

The observed and the calculated values for 'W', when plotted against their respective values for 'L' (Fig. 6) indicate that there is close agreement between the observed and the calculated sets of values. Applying the formula $W = AL^B$, the length-weight relationship formula was calculated to be $W = 0{\cdot}0004935\, L^{3{\cdot}0819}$ Hence it is to be inferred that in *T. haumela* the weight increases in proportion to its length showing the normal pattern.

As can be seen from Fig. 6, fishes up to 32 cm. in length increase in weight at a lesser rate than the subsequent size groups. This is further

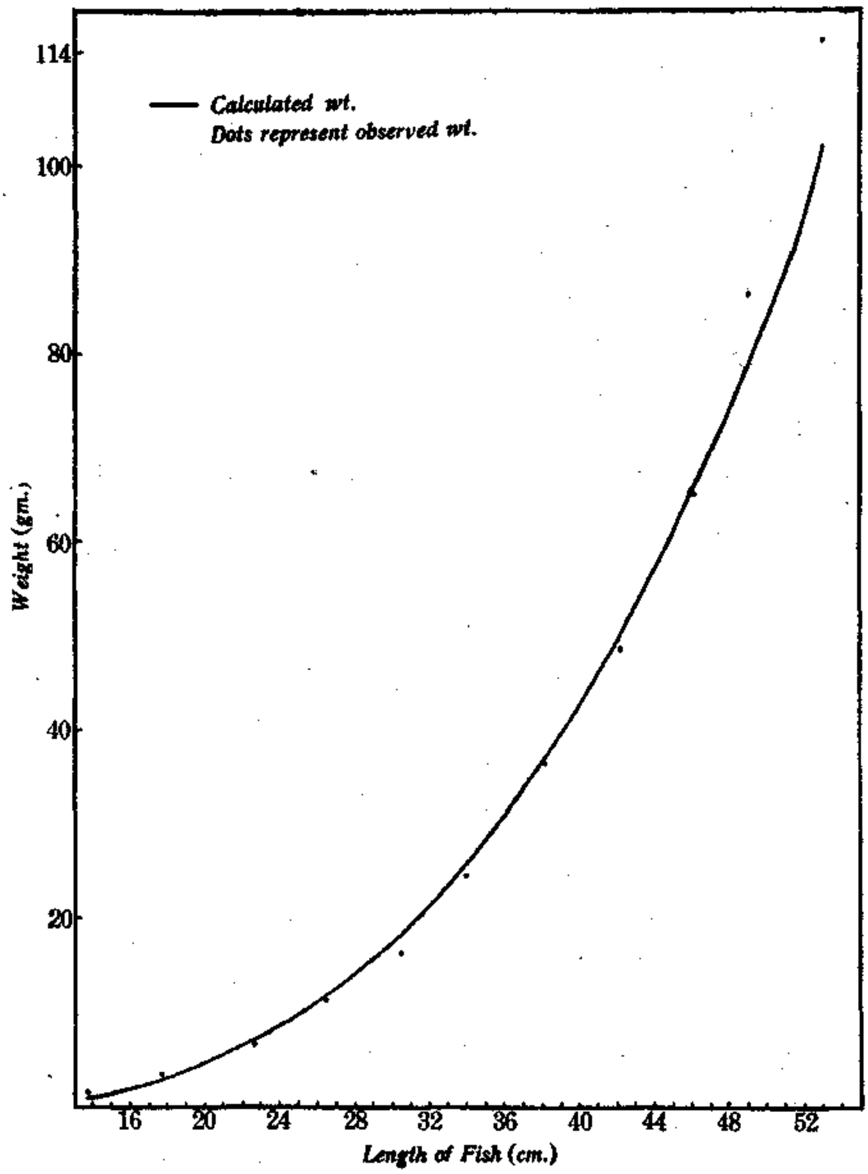


FIG. 6. Calculated length-weight curve fitted to the average observed length-weight values for *T. haumela*.

borne out by the observations on feeding (*vide infra*) that the maturing fishes ranging in size between 42 and 48 cm. feed ravenously and increase in weight out of all proportions to the increase in length.

IX. CORRELATION BETWEEN SIZE OF FISH, WEIGHT OF OVARY AND FECUNDITY

Size of fish and fecundity.—The fecundity of any species of fish is usually determined from the total number of ova forming a season's crop. While studying the fecundity of the herring of the Southern North Sea, Hickling (1940) stated that in the herring, the large yolky eggs found in the maturing ovary were the whole of the season's crop of eggs and a count of them gave the absolute fecundity of the fish. Since the individuals of *T. haumela* measuring more than 47–48 cm. seem to breed once a year and since all individuals ranging in length from 47–62 cm. are capable of producing eggs, an attempt was made to find out the relation that exsits between the rate of increase in length of a fish and numbers of ripe ova in its ovary. The values obtained from 18 sets of observations on the number of eggs from fishes of different lengths with ovaries in maturing and mature conditions were utilised.

The theoretical values for the number of eggs produced by individuals in different size groups were calculated (Fig. 7). By the method of least squares, the formula which best expresses the relation between length and fecundity was calculated to be $F = 0{\cdot}0004119\ L^{4{\cdot}3475}$ where 'F' and 'L' represent fecundity and length respectively. Hence the fecundity was found to increase with length at a rate substantially greater than the fourth power of the length. Smith (1947) found a straight line relationship between logarithms of number of eggs and lengths of fish in a study of their relationships for the eastern trout. Hickling (1940) found in the herring of the Southern North Sea the rate of increase to be greater than the third power of the length, and Farran (1938) found in the Irish herring the fecundity increasing at the order of 4·5 power of the length. Thus the rate of increase in the fecundity of *T. haumela* could be compared to that in Irish herring.

Weight of ovary and number of ova produced.—If the weights of the gonads of different mature fishes are correlated with the total number of ova they contain and a graph be drawn, it will show a relationship either identical to that found between the length of fish and fecundity, or if the rate of growth in length of gonads in relation to the length of the fish is not directly correlated (*vide infra*) the graph will show an entirely different type of relationship from that observed in the previous section.

As in the previous case, employing the method of least squares, the formula which best expresses the relation between the weight of the ovary and fecundity was calculated to be $F = 2526\ W^{1{\cdot}0808}$, where 'F' and 'W'

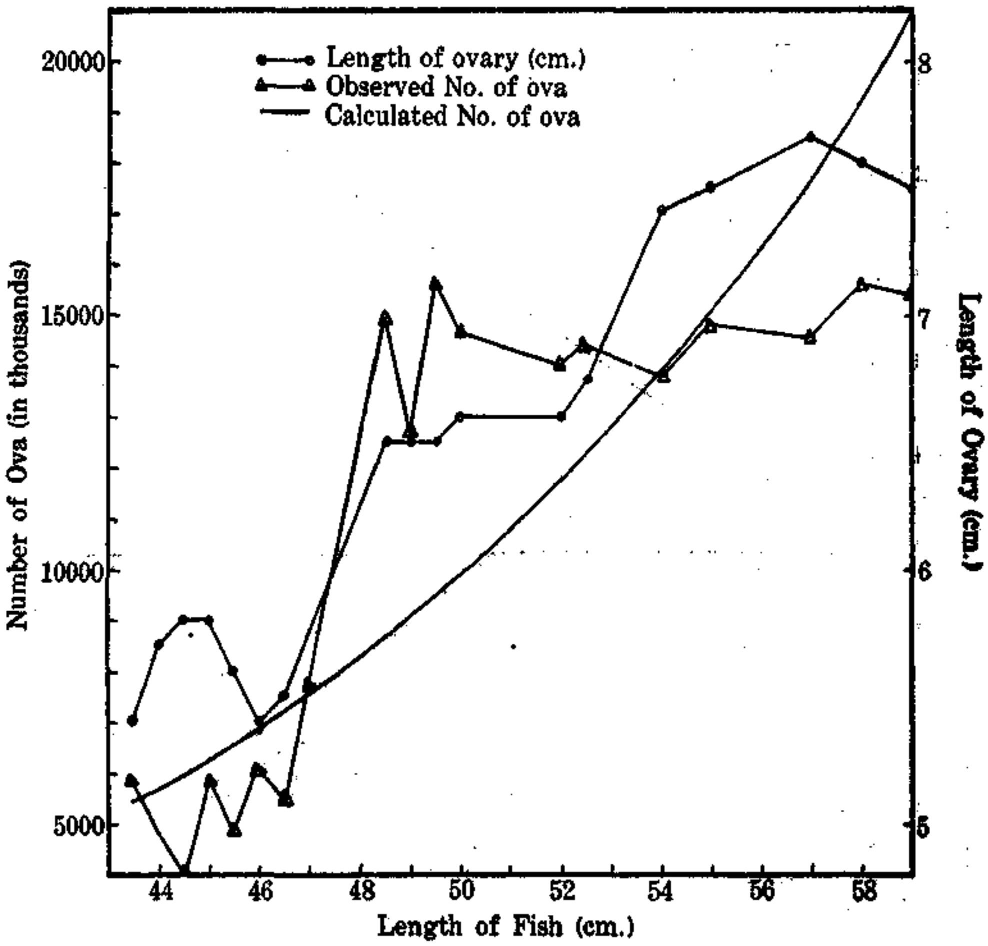


FIG. 7. Showing the relation between the length of fish and number of ova produced.

represent fecundity and weight respectively. The observed and the theoretical values for 'F' in relation to weight of ovary are shown in Fig. 8, from which it could be seen that the theoretical values are more or less in close agreement with the observed values. This formula expressing the relation between the number of ova and weight of ovary clearly shows that the number of eggs produced has a very close correlation to the mean weight of the ovary. Thus the observations on *T. haumela* are in agreement with the remarks of Hickling (1940) who has stated that, since the production of eggs is the dominant function of the ovary, a close correlation should be expected between the weight of the ovary and the number of eggs produced.

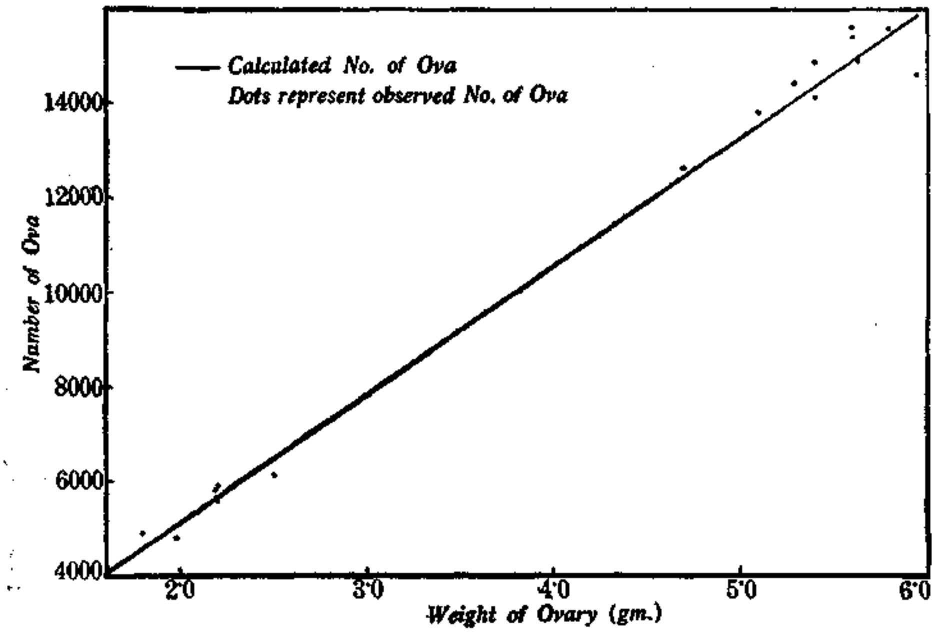


FIG. 8. Showing the relation between the weight of ovary and the number of eggs produced.

X. Growth Rate of Gonads

While it is probable that the size (or weight) of gonad is directly proportional to the size (or length) of fish during the maturing stages (as has been indirectly inferred in previous sections), it will be of interest to know how the size of the gonads in fishes is actually related to their length and how the gonads in male as well as female are related to the length of fish even in immature forms. A study of the graphs given for males and females, ranging in length from 18–62 cm., which includes specimens with gonads in all stages of maturity, will show that the relationship is simple and direct.

The entire range in size of the 976 available specimens was conveniently divided into 22 size groups with a class interval of 2 cm. in preparing Figs. 9 and 10. In calculating the theoretical values of the sizes of the ovaries as well as testes, the mid-points of each size group were taken into consideration.

Female.—To express the relation between two variates 'X' and 'Y' ('X' length of individual and 'Y' of ovary), the equation for the regression line $Y = a + bX$, where 'a' and 'b' are the constants (Pearson and Bennet, 1942) was used. In the case of ovary the equation was found to be $Y = -0\cdot6806 + 0\cdot1431\,X$. When the observed values for 'Y' were plotted against their respective 'X' values, it could be seen that the points are more or less closely located near the linear regression line (Fig. 9). From

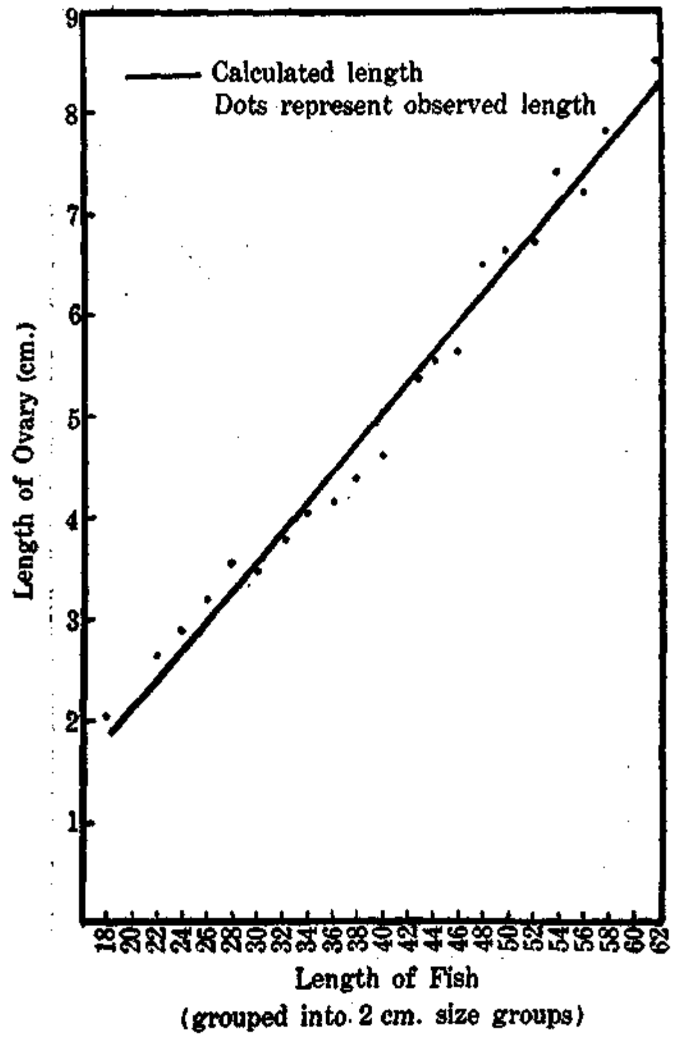


FIG. 9. Showing the relation between lengths of fish and ovary in *T. haumela*.

the equation calculated for the regression line, it could be inferred that for every 10 cm. increase in the length of the fish, the length of the ovary, increased approximately by 1·43 cm.

Male.—As in the case of female, when the observed values for 'Y' (length of testes) were plotted against their respective values for 'X' the points were found to be located close to a linear regression line (Fig. 10). Employing the same equation as before, it was found that $Y = -0\cdot3765 + 0\cdot1465\,X$, where 'X' is length of individual and 'Y' of testis. In other words, for every 10 cm. increase in the length of the individual, the length

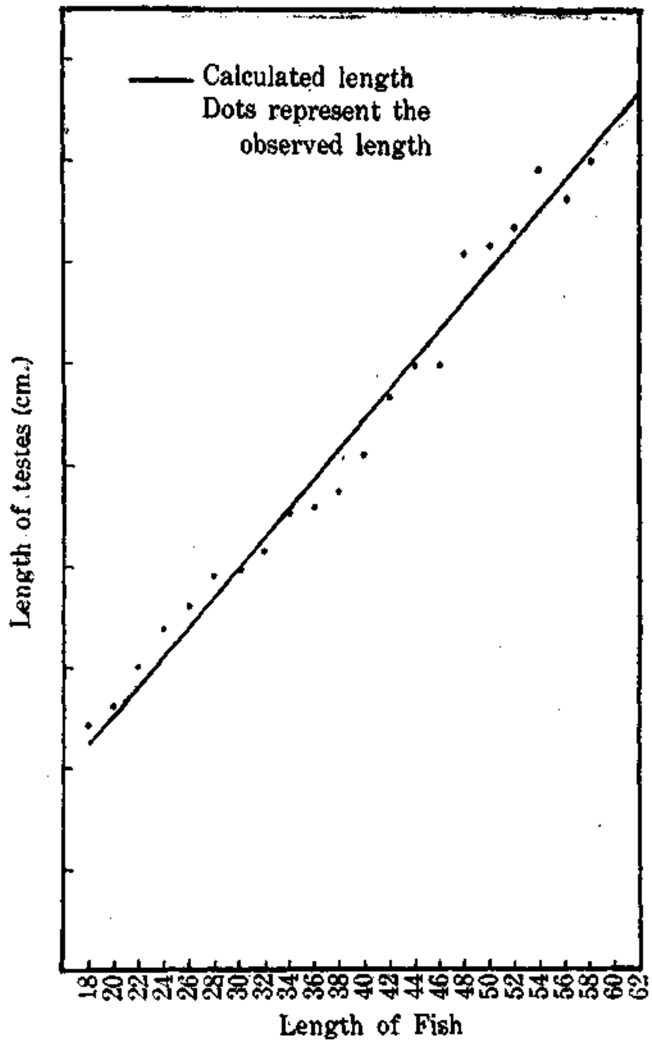


FIG. 10. Showing the relation between lengths of fish and testes in *T. haumela*.

of the testis was found to increase approximately by 1·47 cm., that is to say, at a slightly higher rate than the ovary. This is in conformity with the view of Hickling (1940) who found that the weight of testis increases with length at a slightly higher rate than the ovary in the herring of the Southern North Sea. It is interesting to note in this connection Hickling's obervation on the increase in weight of testis and ovary in the young and old herring. He found that while the mean weight of the testis is greater than that of the ovary among the younger fish, the ovary is heavier than the testis at any given length among the older fish. He ascribes this discrepancy as probably due to the simultaneous increase in weight of the permanent tissue of the ovary.

XI. Food and Feeding Habits

(*a*) *Important items of food*.—An exploratory examination of the gut contents of a few showed that *T. haumela* is a carnivore as stated by Venkataraman (1944) and Vijayaraghavan (1951). In order to see if there was any difference in the food of fishes of different sizes, detailed analyses were made of the gut contents of 976 fishes of different sizes caught during the course of a year. The food items were sorted out and identified from the mutilated bits. A regular record was also kept to indicate the fishes, prawns and others which occurred along with the ribbon fishes. A comparison was made between the food items represented in the stomach and those available in the vicinity to see if any selective feeding existed in the fishes of different sizes and ages (see table below).

During times of intensive feeding, mature and spent individuals of *T. haumela* have been found with young and mutilated individuals of the same species in their alimentary tract. This ' cannibalism ' does not correspond to a period when there is lack of other species of fish on which they feed, because, when shoals of ribbon fishes migrate to the coastal waters from the month of July, *Stolephorus* spp., forming a favourite food, have been found to occur in large numbers in the coastal waters. Similar case of ' cannibalism ' has been recorded in the Bombay duck (*Harpodon nehereus*) by Bapat, Banerji and Bal (1952) and Pillay (1952). On the other hand, it may be only due to overcrowding of the shoals. Venkataraman (1944) states that he found during September 1943, guts of ribbon fishes being literally clogged with macerated fish eggs and he further states that this feature might very greatly hit other fisheries; but during the course of the present study, no fish eggs have been observed among the gut contents of *T. haumela*. Young ones of *Sepia* were found to constitute only a rare item of food.

Cestode larvæ such as *Tetrarynchus* sp. and *Gymnorynchus* sp. were found in the gut in large numbers only during the times of intensive feeding in mature and spent individuals. No cestode larvæ have been found in the guts of immature specimens.

It will be seen from the following table that though *T. haumela* feed indiscriminately, the food items shown in the second column of the following list have never been found in the guts of any of the specimens of *T. haumela*.

Items found in the alimentary tract of *T. haumela*	Fishes and other animals caught along with *T. haumela*
Fishes:	
Hemiramphus spp.	*Therapon theraps*
Dussumieria spp.	*Therapon puta*
Kowala coval	*Pelates quadrilineatus*
Mugil spp.	*Parupeneus* spp.
Caranx spp.	*Upeneoides* spp.
Sardinella spp.	*Rastrelliger kanagurta*
Leiognathus spp.	*Sardinella longiceps*
Sciæna spp.	Young ones of *Chirocentrus dorab*
Trichiurus spp.	and *Cybium* spp.
Stolephorus spp.	
Crustaceans:	
Penæus spp.	
Metapenæus dobsonii	Nil
Acetes spp.	
Others:	
Sepia	
Silicoflagellatæ	Nil

The present observations, therefore, do not support the conclusions made by Venkatraman (1944) that the ribbon fishes do not exhibit any type of selective feeding. Further, as will be seen from Table V, fishes ranging in size from 17–45 cm. which are definitely not mature, show a tendency to feed on prawns and small-sized fishes such as *Stolephorus* spp. and *Leiognathus* spp. though the smaller sized individuals of other species like *Parupeneus* spp., *Upeneoides* spp., mackerel, dorab and oil sardine are available. It will also be seen that fishes of 46–62 cm. which are definitely adult forms, feed on fewer prawns and smaller fishes than the young ribbon fishes. Hence, though *T. haumela* is a complete carnivore, the species, to some extent, seems to be a selective feeder as is evident from a qualitative analysis of the gut contents.

(*b*) *Quantitative analysis and the seasonal variation of the gut contents.*—*T. haumela* die in the nets soon after capture and it is known that most fishes in the throes of death, vomit a good part of the gut contents. Volumetric estimations of the gut contents will not, therefore, have much value in judging the variations in the degrees of feeding. Moreover, as a large number of fishes had to be handled in a short time, the volumes of the different animal components could not be estimated separately. Owing to these reasons it was considered that a simple arbitrary assessment of the rate of feeding from the amount of food left in the gut would alone be satisfactory. The condition of stomach has been classified as shown below into four convenient categories depending on the quantity of food in the gut.

		Degrees of feeding activity
1. Empty ..	Nil	Nil
2. Almost empty..	When the gut contents were less than 4 c.c. in specimens of 30 cm. and above and when the gut contents were less than 2 c.c. in specimens up to 30 cm. in size..	Slack
3. Partly full ..	When the gut contents were above 4 c.c. and less than 8 c.c. in specimens above 30 cm. in size and when the gut contents were 2 c.c. and above and less than 4 c.c. in specimens up to 30 cm. in size..	Active
4. Full ..	When the gut contents were 8 c.c. and above in specimens above 30 cm. in size and when gut contents were 4 c.c. and above in specimens upto 39 cm. in size	Intense

A regular examination of the gut contents for a continuous period of one year has shown that the feeding activity increases soon after spawning.

The mean monthly averages for a period of 12 months are shown in Fig. 11, from which it could be seen that the feeding activity is very high from July to February. As the shoals of *T. haumela* begin to move out into offshore waters from the month of January or February, the stragglers left behind, mostly immature specimens measuring less than 47–48 cm., seem to avoid bigger forms of fishes on which they feed and thereafter a total change is noticed in the items of food. For a period of 4–5 months, from March to July, the important items of food have been observed to be composed of young ones of *Acetes* spp., *Stolephorus* spp. and *Leiognathus* spp.

The degree of feeding has been observed to be ' slack ' in individuals ranging in length up to a size of 31 cm. (Table V); ' slack ', ' active ' or

TABLE V

Showing the Sex Ratio, Average Size of Female and Male Gonads, Degrees of Feeding Activity and Important Items of Food in T. haumela *in Different Size Groups*

Size groups (cm.)	No. of specimens examined	Sex ratio Female: Male	Average size of gonads		Degree of feeding activity	Important items of food
			Female	Male		
17–19	52	1 : 1	2·03	2·4	Slack	*Acetes* spp., *Penæus* spp., young ones of teleosts
19–21	11	5 : 6	2·2	2·6	Slack	Young crustaceans and teleosteans
21–23	6	5 : 1	2·65	3·0	Slack	*Acetes* spp., *Penæus* spp., young ones of *Stolephorus* spp.
23–25	20	1 : 1	2·9	3·37	Slack	*Acetes* spp., *Penæus* spp., young ones of teleosts
25–27	9	4 : 5	3·2	3·6	Slack	*Acetes* spp., young ones of *Stolephorus* spp.
27–29	62	7 : 5	3·56	3·9	Slack	*Acetes* spp., *Penæus* spp., young teleosts
29–31	29	1 : 1	3·6	3·98	Slack	*Leiognathus* spp., *Stolephorus* spp.
31–33	28	4 : 3	3·8	4·15	Slack or Active	*Caranx* spp., *Therapon* spp., *Stolephorus* spp., *Acetes* spp., young ones of Sepia
33–35	67	1 : 1	4·03	4·52	Slack or Active	*Stolephorus* spp., *Leiognathus* spp., *Penæus* spp.
35–37	16	5 : 3	4·15	4·58	Slack or Active	*Stolephorus* spp., remains of other young teleosts, *Acetes* spp., *Penæus* spp.
37–39	80	4 : 3	4·37	4·74	Slack or Active	*Stolephorus* spp., *Dussumieria* spp., *Leiognathus* spp., *Penæus* spp.
39–41	29	2 : 1	4·57	5·07	Slack or Active	*Caranx* spp., *Kowala coval*, *Mugil* spp., *Therapon* spp., *Stolephorus* spp., *Penæus* spp.
41–43	36	2 : 1	5·35	5·69	Slack or Active	*Stolephorus* spp., *Dussumieria* spp., remains of other teleosts, *Acetes* spp., *Penæus* spp.
43–45	88	3 : 2	5·57	5·98	Slack or Active	*Trichiurus* spp., *Dussumieria* spp., *Stolephorus* spp., *Leiognathus* spp., *Acetes* spp., *Penæus* spp., Sepia
45–47	74	8 : 7	5·64	5·98	Slack, Active or Intense	*Trichiurus* spp., *Therapon* spp., *Sciæna* spp., *Caranx* spp., *Stolephorus* spp., *Acetes* spp., *Penæus* spp., Silicoflagellatæ
47–49	77	3 : 2	6·5	7·08	Slack, Active or Intense	*Trichiurus* spp., *Hemiramphus* spp., *Mugil* spp., *Caranx* spp., *Stolephorus* spp.

TABLE V—(*Continued*)

Size groups (cm.)	No. of specimens examined	Sex ratio Female: Male	Average size of gonads		Degree of feeding activity	Important items of food
			Female	Male		
49–51	78	5:3	6·63	7·16	Slack, Active or Intense	*Trichiurus* spp., *Sciæna* spp., *Mugil* spp., *Therapon* spp., *Sardinella* spp., *Kowala coval*, *Caranx* spp., *Stolephorus* spp., *Penæus* spp., Silicoflagellatæ
51–53	77	3:2	6·74	7·35	Slack, Active or Intense	*Trichiurus* spp., *Mugil* spp., *Sciæna* spp., *Caranx* spp., *Leiognathus* spp., *Acetes* spp., *Penæus* spp.
53–55	75	2:1	7·41	7·92	Slack, Active or Intense	*Trichiurus* spp., *Sardinella* spp., *Sciæna* spp., *Caranx* spp., *Stolephorus* spp., *Metapenæus* spp., other crustacean remains
55–57	31	5:3	7·2	7·63	Active or Intense	*Trichiurus* spp., *Sciæna* spp., *Therapon* spp., *Mugil* spp., *Stolephorus* spp., Silicoflagellatæ
57–59	25	3:2	7·53	8·0	Active or Intense	*Trichiurus* spp., *Sciæna* spp., remains of young teleosts
59–61	..	..	..	..	..	..
61–63	6	1:1	8·5	9·0	Active	*Trichiurus* spp., *Sardinella* spp., *Kowala coval*, remains of young teleosts

'intense' in individuals ranging from 45·1–55 cm., 'active' or 'intense' in those ranging from 55·1–61 cm. and only 'active' in those above 61 cm. Comparing these with the stages of maturity, it could be seen that in immature specimens, the degree of feeding is 'slack', and in maturing ones 'slack', 'active' or 'intense'. Certain notable features in these observations are that *T. haumela* has been found to feed intensely when they attain a size of 47–48 cm. (size at maturity) and that this type of feeding activity continues until they attain a size of 61 cm. after which the feeding activity decreases from 'intense' to only 'active'. Thus it could be seen that the degree of feeding activity is more or less closely associated with the attainment of maturity.

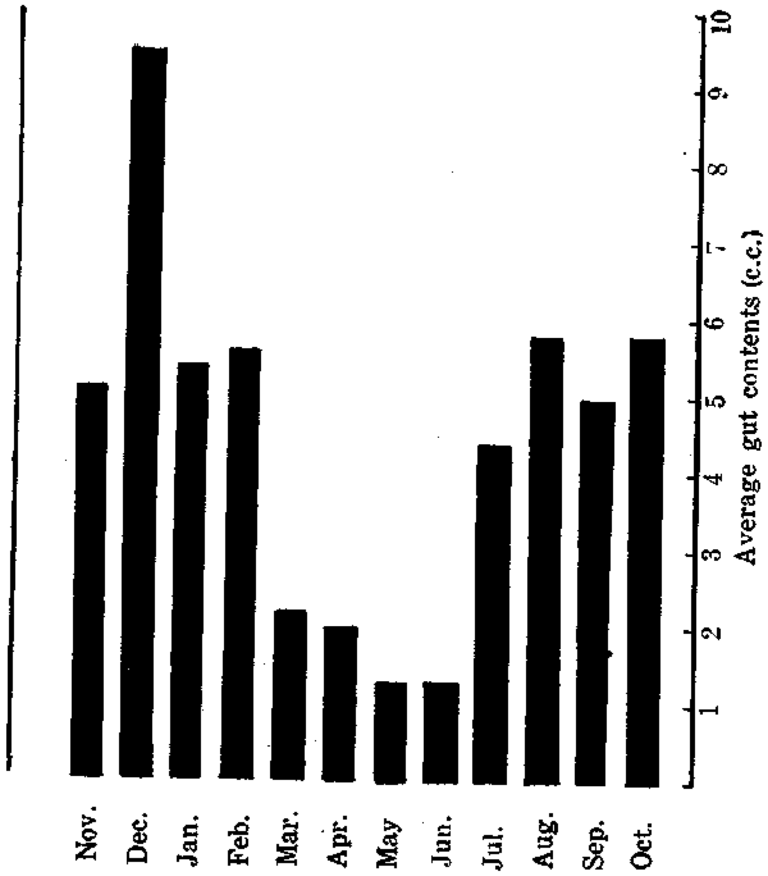


FIG. 11. Average monthly gut contents for a period of twelve months.

XII. DISCUSSION

The spawning period of *T. haumela* is largely a matter for inference from circumstantial evidence though its duration is indicated to some extent by the studies on intra-ovarian eggs and occurrence of post-larvæ. This species undoubtedly migrates from inshore to offshore areas for spawning.

Devanesan and Chidambaram (1948) and Jacob (1949) recorded from plankton of October 1939, eggs believed to be those of ribbon fishes, but as no details have been given by them, the eggs could not be referred to any particular species. Chacko (1950) claims to have observed eggs and larvæ of *T. savala* from the plankton around the Krusadai Island. As stated by Delsman (1926) the eggs of ribbon fishes are so remarkably alike that it is difficult to ascribe them to their respective species until their development is followed to the stage at which specific characters can be noted. In the absence of such developmental details, and as the present investigations have shown that *T. muticus* and *T. haumela* occur, the former in larger numbers, in the Gulf of Mannar, it is equally possible that the eggs referred to by Chacko belong to *T. muticus* or *T. haumela*.

Tang and Wu (1936) in a preliminary note on the spawning ground of *T. japonicus* (Schlegel) in Poi-hai (Gulf of Chihli) have stated that the depth of the sea where they found great quantities of the eggs of *T. japonicus* was 13·5 metres. This observation throws light on the fact that the ribbon fishes probably do not spawn in the disturbed shallow waters. The authors also observed eggs of *T. japonicus* floating on the surface waters over an area of more than 10 nautical miles in diameter, giving the water a pink appearance. Delsman (1926) has only stated that the eggs of ribbon fishes have a fairly large diameter and contain a considerably large oil globule but no details on the exact range in size of either the eggs or the oil globules are given. It has been found from this work that though freshly spawned eggs of the common Madras species *T. haumela* have not been observed, the average size of the largest intra-ovarian eggs from mature ovaries in Stage III is 1·1 mm. It must be concluded therefore that the eggs of *T. haumela* are definitely larger than those of *T. japonicus*.

Closely associated with the fact that no freshly spawned eggs of *T. haumela* were encountered by a large number of observers, is the absence of records of its post-larvæ. However, from Tang and Wu's account of *T. japonicus*, it would appear that the post-larvæ (which measure 57–95 mm. a month after hatching) do not swim away from the area where the eggs were spawned. The absence of eggs as well as larvæ in the inshore areas (Nair, 1952) may be explained on the basis of the offshore spawning habits of the fish. It is inferred that *T. haumela* spawns in offshore waters by June and that the young ones of 7–8 cm. in size migrate into the coastal waters by the end of July. It has also been observed that the migration of the young ones of *T. haumela* to the coastal waters takes place along with the shoals of adult individuals and not independently.

Regarding the duration of spawning, there have been different views (*vide supra*). For *T. savala*, Chacko (1950) observed that the spawning period extends from September to October in the Gulf of Mannar. A study of the gonads and ova does not lend support to the views that the spawning season is either a prolonged one or that there are two distinct spawning seasons. Observations reported earlier in this paper clearly suggest that the spawning is restricted to a definite and short period and that it takes place only once a year. Such abundant occurrence of eggs of *Trichiurus* spp.

extending over an area of 10 nautical miles as reported by Tang and Wu also suggests that the spawning takes place within a short period. If it were to be a continuous process, there ought to have been at least a few larvæ hatched out from the first stock of eggs shed during the commencement of the spawning period.

Venkataraman (1944), Devanesan and Chidambaram (1948), Jacob (1949), Prabhu (1950), Tham Ah Kow (1950) and Vijayaraghavan (1951) have dealt with the feeding habits of ribbon fishes. The observations of all the earlier authors show that the ribbon fishes are mainly piscivorous. Venkataraman says that coupled with the voracity for eating, these carnivorous fishes exhibit a total lack of choice in their food. Devanesan and Chidambaram (1948) say that the diet of ribbon fishes is remarkable because it consists mostly of economically important food fishes though this wide range in fish diet does not include oil sardine or mackerel. However, the present observations agree with those of Tham Ah Kow in that the main items of food have been found to consist of white-baits and prawns.

Vijayaraghavan (1951) found in general an increased feeding activity in *T. haumela* extending only from September to November, but no information has been given regarding the variation in the degree of feeding in the pre- and post-mature size groups. It may be mentioned in this connection that his observations were based on only 37 specimens in 10 inches size group and 107 specimens in the 20 inches size group. All the specimens in the former size group would have been immature and it is not clear whether there were any mature ones at all in the specimens examined in the 20 inches size group. Those observations, therefore, cannot be related to the present investigations which have shown that there is a wide range in the items of diet and the degree of feeding among the immature, mature and spent specimens. The immature individuals have been found to feed mainly on young prawns and clupeids without any seasonal variation. The mature and spent specimens have been found to be voracious feeders, even resorting to cannibalism, whereas individuals just prior to spawning show a definite slackness in feeding. However, from the quantitative analyses made during this study it has been inferred that the active feeding in *T. haumela* is evident soon after spawning in July and continues up to February.

XIII. Summary

Among the three species of the genus *Trichiurus*, namely, *T. haumela*, *T. savala* and *T. muticus*, inhabiting the Indian waters, *T. haumela* has been found to predominate in the landings at Madras. The distribution of the

three species along the east and west coasts of India and certain chief characters by which they could be identified in the field are given.

The structure of the ovary in *T. haumela* and the stages of maturity based on the condition of the gonads are described. Adult size is reached when the fishes are about 47–48 cm. in length.

It is inferred from observations detailed that this species migrates to offshore waters in June probably for spawning which appears to be restricted to a definite short period. This inference is supported by the studies on the diameters of intra-ovarian eggs from sections of spent and mature ovaries. *T. haumela* appears to spawn only once a year, as post-larvæ of 7–8 cm. in length occur by the end of July. From length frequency studies it is found that this species spawns first during its third year of life.

The otoliths do not show any growth rings and the calcification appears to be continuous.

From a study of the size frequency distributions, it is shown that *T. haumela* attains a size of 18 cm. in the first year and 30 cm. in the second year. The large fish of 54 cm. have been inferred to belong to the fourth year class.

T. haumela is a voracious carnivore. The seasonal variations in the feeding activity of specimens of *T. haumela* at different stages of maturity are discussed.

XIV. Acknowldgements

The author is grateful to Dr. N. K. Panikkar, Chief Research Officer, Central Marine Fisheries Research Station, Mandapam Camp. for his encouragement throughout the period of the present investigation and to Dr. C. P. Gnanamuthu, Director, Madras University Zoology Research Laboratory, for his very helpful criticism.

XV. References

Allen, K. R. 1938 .. Some observations on the biology of the trout (*Salmo trutta*) in Windemere. *J. Anim. Ecol.*, **7**, 333–49.

Baranov, F. 1916 .. On the question of the biological foundations of fisheries. Moscow, February 1916.

Bapat, S. V. Banerji, S. K. and Bal, D. V. 1952 Observations on the biology of *Harpodon nehereus* (Hamilton). *J. Zool. Soc. India*, **3** (2), 341–56.

Cornish, Thomas. 1867 .. The silvery hairtail (*Trichiurus lepturus*) in Mount's Bay. *Zoologist*, **2**, 793–94.

——————. 1871 .. More specimens of the silvery hairtail (*Trichiurus lepturus*) at Penzance. *Ibid.*, **6**, 25–29

——————. 1872 .. Silvery hairtail in the Whitesand Bay. *Ibid.*, **7**, 3274–276.

Clogg, Stephen. 1871 .. Silvery hairtail (*Trichiurus lepturus*) at Looe Polperro, etc. *Ibid.*, **6**, 2444–45.

Chidambaram, K. and Venkatraman, R. S. 1946 — Tabular statements on the natural history of certain marine food fishes of the Madras Presidency-West Coast. A Madras Government Publication, 15.

Chacko, P. I. 1950 .. Marine plankton from waters around the Krusadai Island. *Proc. Ind. Acad. Sci.*, **31 B**, 162–74.

Day, F. 1889 .. *Fauna of British India*, II, 133–36.

De Beaufort, L. F. and Chapman, W. M. 1951 — The fishes of the Indo-Australian Archipelago, 9, Leiden, Holland, 194.

Delsman, H. C. 1926 .. Fish eggs and larvæ from Java Sea. *Treubia*, **9**, 338–51.

——————. 1929 .. The study of pelagic fish eggs. *Proc. 4th Pac. Sci. Congr.*, Java.

De Jong, J. K. 1940 .. A preliminary investigation of the spawning habits of some fishes of Java Sea. *Treubia*, **17**, 307.

Devanesan, D. W. and Chidambaram, K. 1948 — The common food fishes of the Madras Presidency, *A Madras Government Publication*, 38.

Farran, G. P. 1938 .. On the size and number of the ova of Irish herrings. *Jour. Cons. Int. Explor. Mer.*, **13** (1), 91–100.

Fowler, H. W. 1903 .. The fishes of Nautucket. *Proc. Acad. Nat. Sci.*, Philadelphia, **55**, 108.

——————. 1904 .. Some fishes from Borneo. *Ibid.*, **56**, 494.

——————. 1904 *a* .. New or rare or little known Scomberoides. *Ibid.*, **56**, 770.

——————. 1906 .. Some cold blooded vertebrates of the Florida Keys. *Ibid.*, **58**, 96.

——————. 1909 .. A new species of fish of the genus *Atopichthys* with notes on New Jersey fishes. *Ibid.*, **61**, 408.

——————. 1927 .. Notes on some shore fishes from Bombay. *J. Bombay Nat. Hist. Soc.*, **32**, 253.

——————. 1937 .. A collection of Haytian fishes obtained by Mr. Stanley Woodward. *Proc. Acad. Nat. Sci.*, Philadelphia, **89**, 310.

——————. 1943 .. Notes and descriptions of new or little known fishes from Uruguay. *Ibid.*, **95**, 332.

Fulton, T. W. 1891 .. The comparative fecundity of sea fishes. 9th annual report, Fish. Bd., Scotland, for the year 1890, Pt. III, 243–68.

Ford, E. 1933 .. An account of the herring investigations conducted at Plymouth during the years from 1923 to 1933. *Jour. Mar. Biol. Assoc. U.K.*, **19**, 305–84.

Gatcombe, J. 1871 .. Silvery hairtail (*Trichiurus lepturus*) on the coast of Devon. *Zoologist*, **2**, 2529.

——————. 1876 .. Silvery hairtail (*Trichiurus lepturus*). *Ibid.*, **11**, 4806.

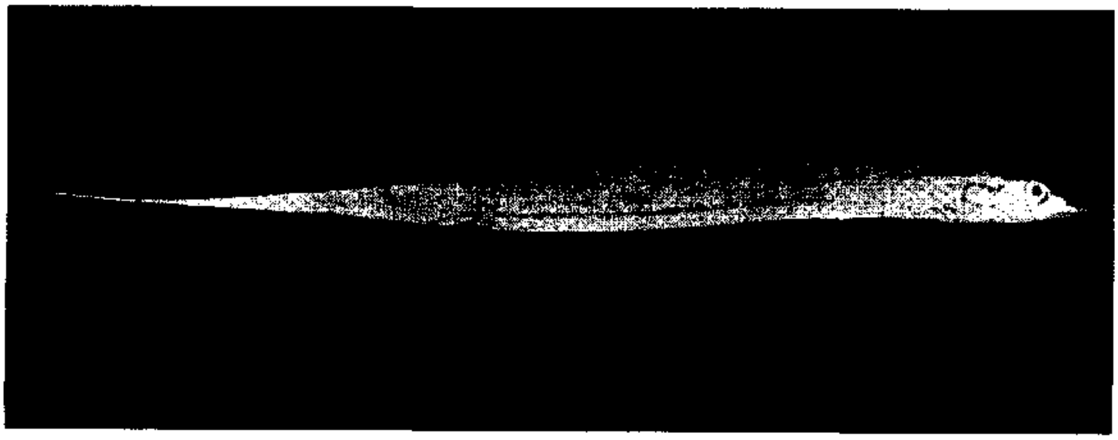
Goode, G. B. 1884 .. Natural history of useful aquatic animals. *U. S. Commn. Fish and Fisheries*, Sec. **1**, 335.

Higgins, E. 1921 .. Cutlass fish taken off Long Beach. *Calif. Fish and Game*, **7**, 179.

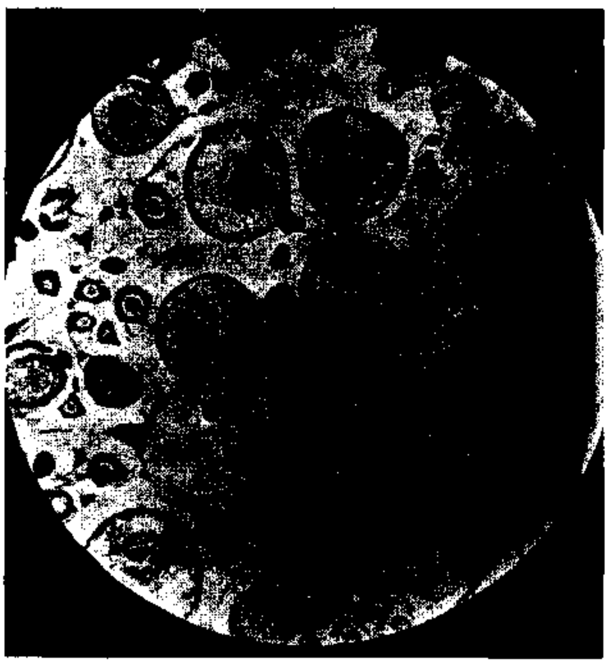
Hickling, C. F. 1940 .. The fecundity of the herring of the Southern North Sea. *Jour. Mar. Biol. Assoc.*, N. S. **24** (2), 619–32.

—— and Rutenberg, E. 1936 .. The ovary as an indicator of spawning period in fishes. *Ibid.*, **21**, 331.

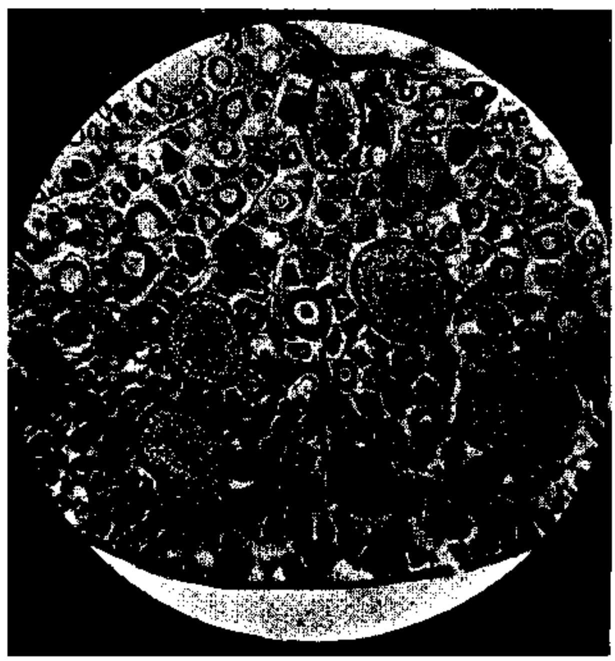
Hile, R. 1936 .. Age and growth of the cisco *Leucichthys artedi* (Le Sueur) in the lakes of the north-eastern highlands, Wisconsin. *Bull. U.S. Bur. Fish.*, **48**, 211–317.



a



c



b

Herre, A. W. C. T. 1940 .. Distribution of the mackerel-like fishes in the western Pacific north of the equator. *Proc. 6th Pac. Sci. Congr.*, 3, 211–15.

Jacob, P. K. 1949 .. The bionomics of ribbon fishes (*Trichiurus spp.*) and their fishery on the west coast of Madras Province. *Jour. Bombay Nat. Hist. Soc.*, **48** (2), 261.

Le Cren, C. D. 1951 .. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatalis*). *J. Anim. Ecol.*, **20**, 201–19.

Martin, W. R. 1949 .. The mechanics of environmental control of body form in fishes. *Univ. Toronto stud. Biol.*, **58**, *Publ. Ont. Fish. Res. Lab.*, **70**, 1–91.

Mahadevan, S. 1950 .. The digestive system of *Caranx djedaba* (Forsk.) and *Trichiurus haumela* (Forsk.). *J. Madras Univ.*, **20**, 25–48.

Nair, R. V. 1949 .. The growth rings on the otoliths of the oil sardine *Sardinella longiceps* Cuv. and Val. *Cur. Sci.*, **18** (1), 9–11.

————. 1952 .. Studies on some post-larval fishes of the Madras plankton. *Proc. Indian Acad. Sci.*, **35 B** (6), 225–44.

Pearson, F. A. and Bennet, K. R. 1942 Statistical Methods Applied to Agricultural Economics. New York and London, p. 147.

Pillay, T. V. R. 1952 .. A preliminary note on the food and feeding habits of the Bombay duck, *Harpodon nehereus* (Ham.) in the river Matlah. *Sci. and Cul.*, **17** (6), 261–62.

Prabhu, M. S. 1950 .. On the breeding habits of the ribbon fish *Trichiurus haumela* (Forsk.). *Cur. Sci.*, **19** (7), 213–14.

Raitt, R. S. 1933 .. The fecundity of the haddock. *Fisheries Scotland Sci. Invest.*, 1932, **1** (42), 82.

Smith, O. R. 1947 .. Return from natural spawning of cut-throat trout and eastern brook-trout. *Trans. Amer. Fish. Soc.*, **74**, 281–96.

Tang, S. F. and Wu, H. W. .. A preliminary note on the spawning ground of *Trichiurus japonicus* (Schlegel) in Poi-hai. *Ling. Sci. Jour.*, **15** (4), 651.

Tham Ah Kow, 1950 .. The food and feeding relationships of the fishes of Singapore Straits. *Colonial Office, Fishery Publications*, **1** (1), 1–35.

Venkataraman, R. S. 1944 The food of ribbon fishes *Trichiurus spp. Cur. Sci.*, **13** (9), 239.

Vijayaraghavan, P. 1951 .. Food of the ribbon fishes of Madras. *J. Madras Univ.*, **21**, 81–95.

Wynne Edwards, V. C. 1929 .. The reproductive organs of the herring in relation to growth. *Jour. Mar. Biol. Assoc.*, **16**, 49–65.