THE BIOLOGY OF THE GREY MULLET, *MUGIL TADE* FORSKÅL, WITH NOTES ON ITS FISHERY IN BENGAL

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Contents

Introduction

The Grey Mullets belonging to the family Mugilidae (Order Percesoces) are of major economic importance in the coastal and estuarine fisheries of India. Out of the total of twenty-six species described by Day (1878) from India, only five, viz., *Mugil cephalus* Linn., *M. tade* Forsk., *M. corsula* Ham., *M. parsia* Ham. and *M. speigleri* Blkr. have so far been recorded from Bengal (Pillay, 1951). Very little detailed work has been reported on the biology of these species in Indian waters. This paper is an attempt to contribute to the knowledge of the general biology of

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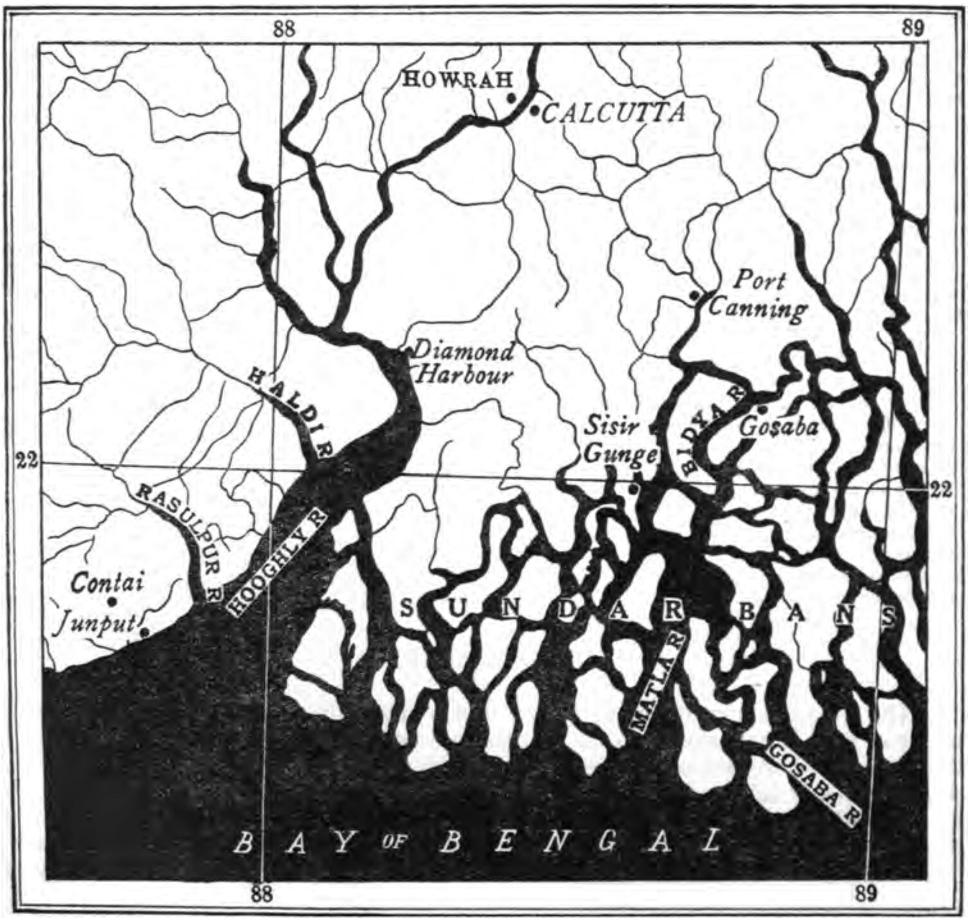
M. tade, which is one of the common species in Bengal. The report of investigations on its food and feeding habits and culture have been dealt with in detail in two separate papers (Pillay, 1953*a* and 1953*b*).

Material and Methods.

Regular collection of material for the purpose of this study was started in the month of January, 1949. Being a species that occurs both in marine and estuarine environments, as also in 'bheris' (embanked brackish water areas), sampling was done from all these representative localities (Text-fig. 1). But the data collected from the sea (Junput on the Contai Coast, Midnapore district) and the estuary (Port Canning on the River Matla, 24-Parganas) only are discussed in this paper. Though most of the mullet fishing and assembly centres in W. Bengal were visited for the collection of material, due to the distance of these localities from the laboratory, lack of proper transport facilities and the total absence of any organization to help in the collection of material, regular sampling work had to be restricted to the nearby centres. The sampling was done once every month at regular intervals. Several difficulties were experienced in obtaining regular representative samples.



TEXT-FIG. 1. Map of lower Bengal showing the centres where observations were made during the investigations.

Both at Junput and at Port Canning, where the catches are landed just in time to be rushed to the market—in the former case to Contai, a distance of six miles by road and in the latter to Calcutta, a distance of twenty-eight miles by rail—the fishermen seldom allow anybody to handle the fish. As mullets are sold only in whole lots mixed with other species, it was not always possible to purchase enough fish for the studies. In the local markets catches from these localities are mixed with fish from other sources, including farms, and so no reliable data could possibly be obtained from there. In spite of these serious handicaps, every effort was made to get fairly representative samples of mullets from the landing places, the actual fishing centres or, as in Port Canning, from the local markets where a small part of the catches are sold in retail. Only samples, the original sources of which could be reliably determined, were collected, and even so the disinclination of the fishermen to sell the fish at the landing places greatly restricted the size of the samples obtained.

All collections were personally made and, in every case, all available field information was gathered. The samples came from catches of the hand seine (*Katti jal*) and the barrier net (*Bher jal*) in Junput, and mostly the bag net (*Behundi jal*) in Port Canning. Short descriptions of these nets are given on pages 27-28. The total length, weight, sex, and condition of gonads of all the specimens in the samples were recorded. During the first year of investigation, the various body measurements referred to on page 7, vertebral count, and scale and fin ray counts, were also made. Scales and stomach contents were examined from all the specimens in the smaller samples or, in the case of larger samples, from smaller sub-samples. The details of techniques employed in the investigation are described in the appropriate sections.

Description of the species.

As observed by Schultz (1946), the family Mugilidae 'is remarkably constant in anatomical structures', and the identification of a species becomes extremely difficult when the descriptions available are inadequate. During the present study it was found that the species had neither been adequately described nor the full range of characters recorded. A fuller description of the species, including the characters of the mouth parts considered useful in the identification of mullets by Schultz (*op. cit.*) and Smith (1948), based on the study of a large series of samples, is given below:

Mugil tade Forskål.

Mugil crenilabris tade: Forskål, *Descr. Anim.*, 1775, p. 74.
Mugil tade: Cuvier and Valenciennes, *Hist. Nat. Poiss.*, **11**, 1836, 114.
Klunziger, *Abhandl. Zool. Bot. Ges. Wien.*, **20**, 1870, 828.
Sitzungsb. Akad. Wien., 1880, 394.
Fische des rothen Meeres, 1884, 133.
Macleay, *Proc. Linn. Soc., N.S. Wales*, **11**, 1884, 40.
Day, *Fauna Brit. India—Fishes*, **2**, 1889, 344.
Weber and de Beaufort, *Fish. Indo-Austr. Arch.*, **4**, 1922, 236.
Fowler, *Mem. Bernice P. Bishop Mus.*, **10**, 1928, 122.
Herre, *Mem. Indian Mus.*, **13**, 1941, 348.
Kulkarni, *Journ. Bombay Nat. Hist. Soc.*, **47**, 1947, 3.
Devanesan and Chidambaram, *Common Food Fishes Madr. Pres.*, 1948, 30.
Jacob and Krishnamurthy, *Journ. Bombay Nat. Hist. Soc.*, **47**, 1948, 663.
John, *Progr. Rep. Fish. Dev. Scheme, Centr. Res. Inst. Trav. Univ.*, 1948, 7.
Devasundaram, *J. Zool. Soc. India*, **3**, 1951, 21-22.
Mugil planiceps: Bleeker, *Verb. Bat. Gen.*, **25**, 1853, 101.
Günther, *Cat. Brit. Mus.*, **3**, 1859–61, 428.

Kner, *Fische Novara Exp.*, 1865–67, 225.
Day, *Fishes of India*, 1878, 350.
Seale, *Occ. Pap., Bernice P. Bishop Mus.*, **1**, 3, 1901, 66.
Evermann and Seale, *Bull. U.S. Bur. Fish.*, **26**, 1906, 59.
Max Weber, *Nova Guinea*, **9**, 4, 1913, 569.
Whitehouse, *Madr. Fish. Bull.*, **15**, 1922, 82–84.

Mugil belanak: Bleeker, *Nat. Tijdschr. Ned. Indie*, **13**, 1857, 356.
Günther, *Cat. Brit. Mus.*, **3**, 1859–61, 427.
Day, *Fishes of India*, 1878, 350.
Day, *Fauna Brit. India—Fishes*, **2**, 1889, 345.
Vinciguerra, *Annal. Mus. Civ. Genova* (2), **9**, 1890, 180.
Fowler, *Proc. Acad. Nat. Sci.*, **57**, 1905, 455.
Max Weber, *Nova Guinea*, **5**, 2, 1908, 244.

Mugil bontah: Bleeker, *Verh. Bat. Gen.*, **25**, 1853, 48.
Bleeker, *Nat. Tijdschr, Ned. Ind.*, **13**, 1857, 336; **16**, 1858-59, 278; **18**, 1859, 367.
Bleeker, *Act. Soc. Sci. Indo-Neerl.*, **8**, 1860, 49.

Mugil cephalotus: Cantor (not Cuvier and Valenciennes), *Cat. Malayan Fish, Journ. Asiatic Soc. Bengal*, **18**, 2, 1850, 1077.

Mugil kandavensis: Günther, *Fische d. südsee*, **2**, 1876–1881, 215.

D. 4 1/8; P.17; V. 1/5; A. 3/9; C.14-15; Ll. 30–35; Ltr.11; Pyl. Caec. 5; Br. 4.

The rostro-dorsal profile is nearly straight, and from the crown of the head to the snout it is strongly declivous. The height of the body is contained 4 to 6·3 times in the total length, the proportion being 4–4·5 in young specimens below 3 cm. in length. The head is nearly conical in shape and its anterior portion is depressed and pointed. The least height of caudal peduncle is contained 1·4–1·8 times in its own length and 1·5 to 2·4 times in the length of head. The head is contained 4·4 to 4·9 times in the total length in adults, but is relatively larger in juveniles (up to about 5 cm. in length) being only 3·9–4·2 times in the total length. The eyes are provided with gelatinous eyelids in adults. There are adipose thickenings both in front and behind the eyes and there are distinct anterior and posterior eyelids. The anterior lid is narrow and covers only about 1/6 of the eye, whereas the posterior one is broader and covers about ¼ of it. The adipose eyelids are absent in young individuals. In 9 cm. long fish, the anterior adipose eyelid is absent, but the posterior one is developed as a narrow flap. Specimens 15 cm. in length show the adult character of the eyelids fully developed. The relative size of the eye varies with the size of the fish. Up to a size of about 5 cm. it is contained 2·2 to 3·5 times in the length of the head and in full grown specimens, 4·7 to 6·7 times. The snout, which is pointed, is nearly equal in length to the diameter of the eye. The preorbital bone is emarginate, strongly curved, and lies over the maxillary reaching far beyond the corner of the mouth posteriorly, in the adults. The posterior end of the preorbital is rounded and the front edge is not notched. The anterior margin of the bone is denticulate. In juveniles, this bone is nearly straight. The end of the maxillary is visible when the mouth is closed and reaches beyond the posterior end of the preorbital. The premaxilla and maxilla are bent downwards. The anterior margin of the premaxilla bordering the mouth is nearly straight. The mouth is slightly inferior in position. The upper lip forms the tip of the snout and is thick, and its breadth is contained 3 to 3·6 times in the orbit. The upper jaw bears numerous minute ciliform teeth with simple undivided truncate tips. The lower lip is thin, the edges of which are sharp and straight. The upper lip overhangs the lower lip. There are no teeth on the lower jaw. The symphysial knob is single. The uncovered chin space is long and cuneiform anteriorly, but is pointed behind. The interorbital space is distinctly flat and is 1·3–2·5 times the diameter of the eye in adults. In juveniles up to a length of about 5 cm., it is equal to the diameter of the eye. The two nostrils on either side, are situated close together, the distance between the two being contained 1·1 to 1·2 times in the interorbital space.

Fins: The origin of the first dorsal is slightly nearer to the end of the snout than to the base of the caudal in adults, but in young ones it is nearly in the middle. It is situated opposite 10th–12th scale of the lateral line, separated from the snout by about 19 predorsal scales, and is nearly as high as the second dorsal (1·1–2·0 times in the depth of body). The origin of the second dorsal is opposite 20th–23rd lateral scale, and is about $\frac{1}{3}$ of the length of the base of the anal behind its origin. Both the second dorsal and anal are slightly concave and covered with fine scales on their bases. The anal fin has three spines in adults, but in juveniles there are only two. In 2 cm. long specimens, there are only 2 spines, but the first soft rays have articulations only on the distal ends. This ray gradually becomes thicker as the fish grows and the number of articulations on it decreases. In 47 mm. specimens this ray is developed into a spine. The length of the pelvic fin is contained 1·4–1·7 times in the length of the head. The length of the pectoral fin is contained 1·1–1·6 times in the length of head and it reaches the 8th lateral scale. The caudal is slightly emarginate.

Scales: The scales are ctenoid in adults but are cycloid in juveniles. They become ctenoid when the fish is about 3·4 cm. long. The scales of adults are longer than broad with apicad nuclei, undulate basal margins and basal radii arranged fanwise. The dorsal scales also have only single grooves as the scales on the sides. The axillary scale is small and the enlarged scale at the base of the pelvic is slightly less than half the length of that fin. The bases of all the fins except the spinous dorsal are covered with fine scales which are cycloid.

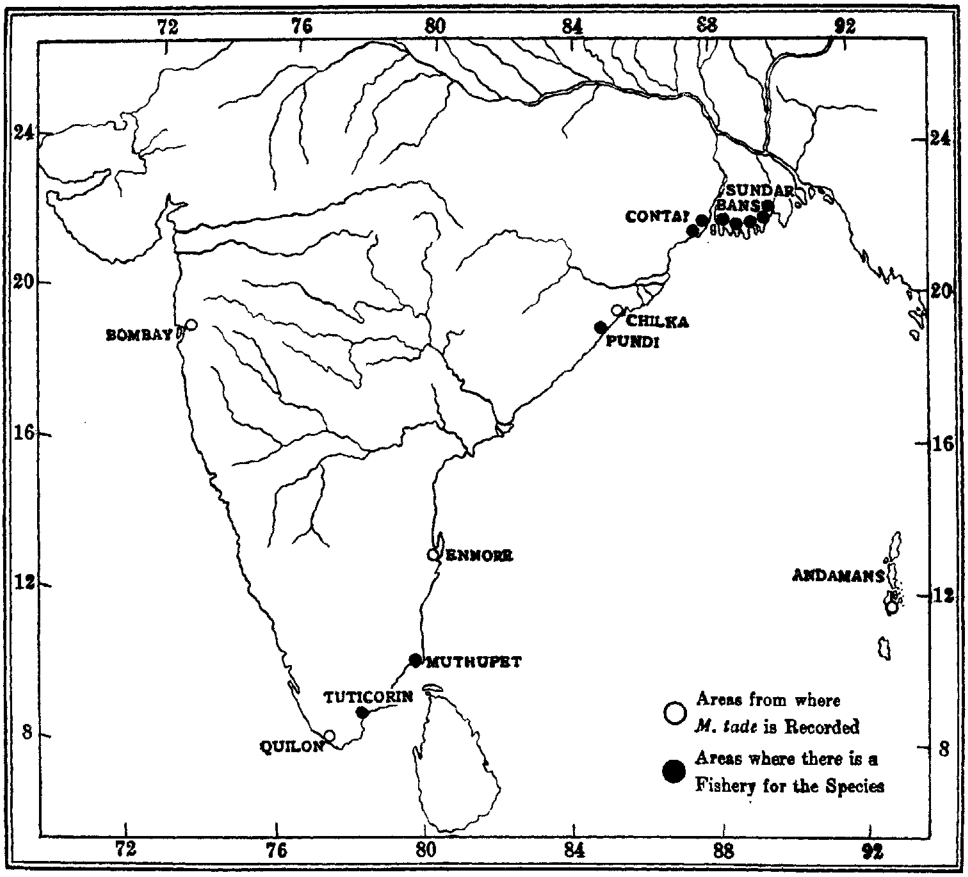
Colour: Specimens from the natural habitats are olivaceous above and silvery below, with 5–7 indistinct dark longitudinal lines on the sides. The edges of the pectoral, soft dorsal and anal are also olivaceous. The caudal is edged with black. Specimens from enclosed brackishwater farms are dark brown above and the dark longitudinal lines on their sides are very prominent. The edges of pectoral, soft dorsal, anal and caudal are also dark brown. The juveniles have the same coloration as adults, but the longitudinal lines appear only when they are about 5 cm. long. Preserved specimens of juveniles show a thick dark line along the middle of the sides. Other parts of the body are covered with scattered pigment spots.

According to Day (1889) *M. tade* grows to at least 18″ (45·7 cm.) in length. Specimens measuring up to 67·9 cm. have been collected by the author from the Sundarbans.

Distribution

Day (1878) mentioned the 'seas, estuaries and tidal rivers of India to the Malay Archipelago and China' as the habitat of this species. According to Weber and de Beaufort (1922), it occurs in the seas of South East Asia, Red Sea, Sokotra, Bay of Bengal, British India, Ceylon, Andamans, Penang, Malacca, China, Philippines, Marianas, Guam and Australia.

In India, *M. tade* appears to occur all along the coasts, though definite records exist only for certain localities (Text-fig. 2). Kulkarni (1947) recorded it in the Vehar and Borivli streams near Bombay. Dr. S. B. Setna, Director of Fisheries, Bombay, kindly informs me that it is a rare species on the Bombay Coast. John (1948) has included *M. tade* in the list of the ten species of mullets identified from Travancore waters. Mr. K. Gopinath, Marine Biologist, Trivandrum (now Director of Fisheries, Travancore-Cochin), in a private communication has informed me that this species locally known as 'Karincha' is common in Kayamkulam and Quilon backwaters. According to Devanesan and Chidambaram (1948), *M. tade* occurs on the coast of the Madras State, but they do not mention the precise range of its distribution. Mr. K. Chidambaram, Asst. Director of Fisheries (Marine Biology)



TEXT-FIG 2. Map of India showing the distribution of *Mugil tade*.

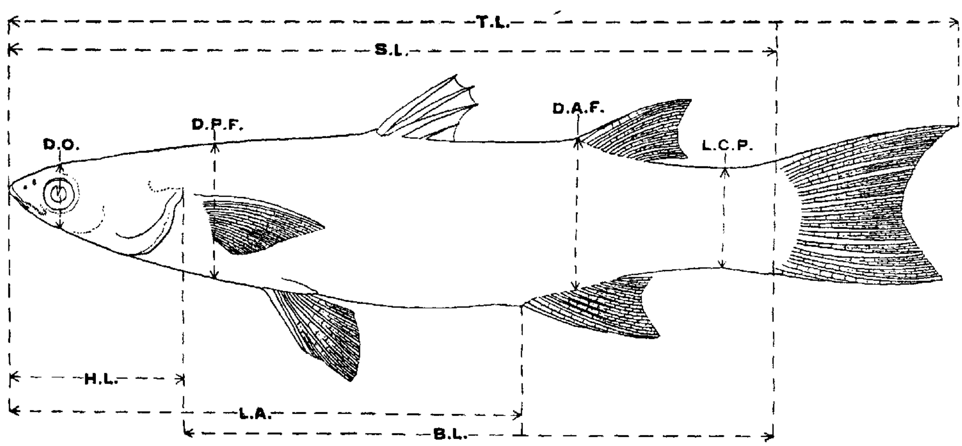
West Hill (now Asst. Fisheries Development Adviser to the Government of India), has, however, kindly informed me that the fishery of this species is not important on the West Coast of the Madras State, but on the East Coast they are caught in appreciable numbers in Pundi (Vizagapatam), Mangodu (Tanjore), Muthupet and Arcothurai (Tuticorin). According to Mr. P. I. Chacko, Asst. Director of Fisheries (Freshwater Research), Madras (private communication), this species, locally known as 'Karattukendai', forms only about 5% of the mullet catches. Whitehouse (1922) has described *M. planiceps* (= *tade*) as one of the economically important mullets occurring in the Silavathurai lagoon in Tuticorin (Coromandel Coast). Jacob and Krishnamurthy (1948) have observed the occurrence of *Mugil tade* in the Ennore Creek near Madras. Devasundaram (1951) has recently identified *M. tade* from the Chilka Lake, but it is reported that they are found only in very small quantities there. As will be evident from the above, though the species is widely distributed in India, it does not rank high in production in these localities. Its main commercial fishery is mostly restricted to the estuarine and coastal regions of Bengal. The species has been observed along the coast of Midnapore district to the mouth of the Gangetic system ascending to a distance of about 80 to 90 miles from the sea. In the estuarine area it is being cultured on a large scale in 'bheri' (Hora and Nair, 1944) and on the Contai Coast, in freshwater tanks (Pillay, 1949). They have also been observed to ascend freshwater channels, where they live and grow well. In Bengal, the fish is known as 'Bhangon' in Calcutta and nearby places, and 'Dhoka' on the Midnapore Coast.

Raciation

Distinction is often made between the 'sea mullet' and the 'river mullet'. Even though there were very few easily recognizable differences between them, the possibility of the existence of separate races had to be considered, especially since very little was known definitely about their migrations. Due to the limitations of the present investigation which was confined to Bengal, it was not possible to study specimens of mullets from other parts of India. However, the chief aim of the study was to ascertain whether homogeneous populations were being handled in the present investigation of the biology of the fish. For the purpose of this work, samples were collected from the sea coast at Junput (Contai, Midnapore district) and the estuary at Port Canning (Matlah River, 24-Parganas).

Examination of a large number of specimens showed that the meristic characters were very stable in the species. The range of fin ray and scale counts was the same for samples from both localities. Similarly the number of vertebrae was 24 (11 plus 13) for samples from the two localities. Morphometric data were analysed to determine whether the body proportions showed any significant variations in the specimens from the two localities. Text-fig. 3 shows the measurements concerned in this study. As shown on page 194, there is a straight line relationship between these measurements and the total length, in fish above 5 cm. in size. The measurements of specimens above that size only were utilized for the analysis.

In racial studies, generally, the method of indices (the various proportional measurements expressed as fractions of total length) is made use of. In the present study this method was employed, the indices used being the values of the various measurements, shown in Text-fig. 3 * in relation to total length. From the



Text-fig. 3. The measurements of *Mugil tade* used in racial study.

D.O. .. Depth through orbit.
D.P.F. .. Depth through pectoral fin base.
D.A.F. .. Depth through anal fin base.
L.C.P. .. Least depth of caudal peduncle.
S.L. .. Standard length.
T.L. .. Total length.

* The body length was not examined separately as the standard length and head length were being considered.

standard errors of the samples, the standard error of the difference between means of the two sets of samples was estimated using the formula

$$\sigma_d = \sqrt{\frac{N_1}{N_2}\sigma^2_{M_1} + \frac{N_2}{N_1}\sigma^2_{M_2}}$$

where σ is the standard deviation, σ_{M_1} the standard error of the 1st sample, σ_{M_2} the standard error of the second sample, and N_1 and N_2, the number of individuals in the first and second samples respectively (Rounsefell and Dahlgren, 1935 and Simpson and Roe, 1939). From this the t value which is an index of the significance of the difference between the samples was calculated by employing the formula $t = \frac{d}{\sigma_d}$ where d is the difference between the means of the two samples. The data obtained by this analysis are given in the following table:

TABLE I

Index.	N_1	N_2	σ_1	σ_2	SE_1	SE_2	σ_d	t	Significance
Total length/Standard length	200	200	0·173	0·013	0·024	0·002	0·024	0·083	Nil.
Total length/Head length ..	200	200	0·308	0·162	0·043	0·023	0·049	2·041	,,
Total length/Length to anal	200	200	0·060	0·011	0·008	0·002	0·008	2·500	,,
Total length/Depth through eye	200	200	1·656	1·453	0·234	0·206	0·224	0·446	,,
Total length/Depth through pectoral fin base ..	200	200	0·384	0·247	0·054	0·035	0·064	0·167	,,
Total length/Depth through anal fin base ..	200	200	0·366	0·242	0·052	0·034	0·062	1·000	,,
Total length/Least depth of caudal peduncle ..	200	200	0·557	0·544	0·079	0·077	0·110	0·239	,,

As will be evident from the above table, the morphological differences between *Mugil tade* in the sea off Junput and in the river Matlah are not statistically significant, and the populations in these localities do not constitute separate races. But at present we have no evidence to decide whether the two stocks remain distinct or whether they intermingle.

RELATIONSHIP OF BODY MEASUREMENTS TO TOTAL LENGTH

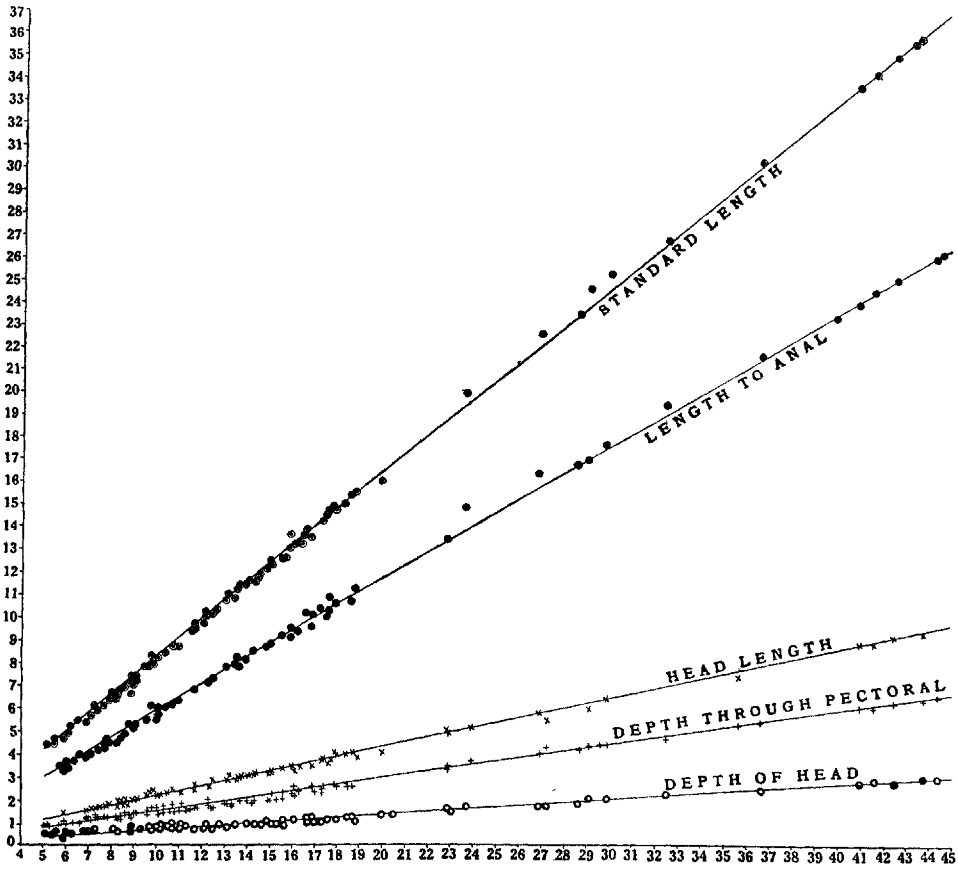
The relation between the dimensions of the external parts of the fish and its total length was determined from the measurements of over 400 specimens ranging from 5·0 cm. to 45·0 cm. in length. The measurements were (*vide* Text-fig. 3):

1. Standard length, from tip of snout to the end of hypurals.
2. Head length, from tip of snout to the end of opercle.
3. Body length from the end of opercle to the end of the hypurals.
4. Length to anal, from the tip of snout to the anterior end of anal fin base.
5. Depth of body through the pectoral fin base.
6. Depth of body through the anal fin base.
7. Depth of head at the region of the orbit.
8. Least height of caudal peduncle.

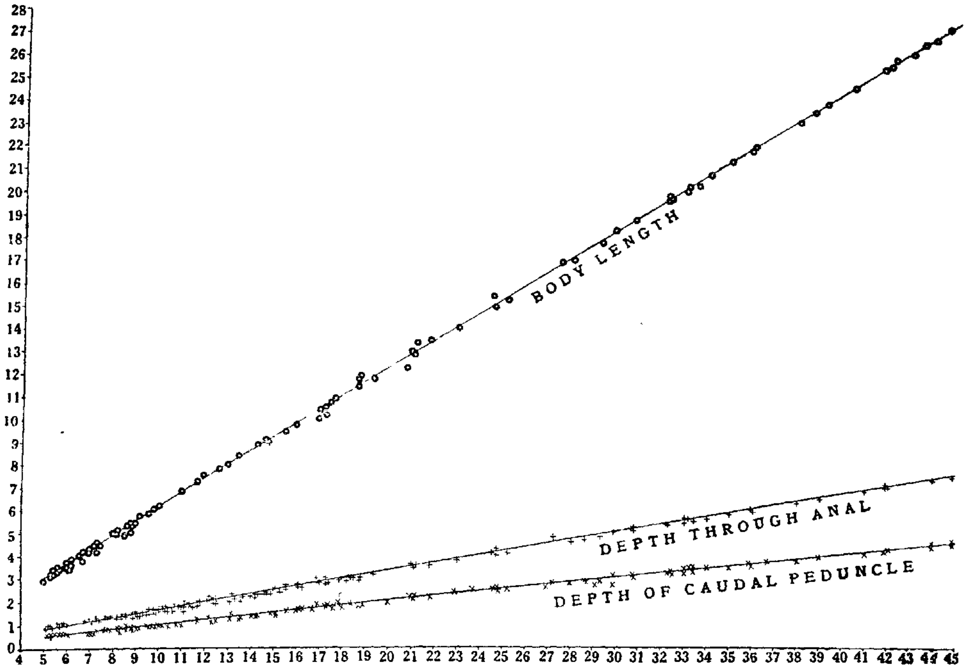
In Text-figs. 4 and 5, the various measurements are plotted against the total length. In each case it is a straight line relationship and suggests that after the 5 cm. stage there is no allometric growth in the species. The rate of growth of the different parts of the body in relation to the increase in total length (not in relation to time) was determined by the tangent method (Crozier and Hecht, 1913). The tangent of each curve was calculated by dividing the vertical distance between two points on each curve, by the horizontal distance. These tangents are as follows:

Standard length	0·815
Body length	0·619
Length to anal fin	0·581
Head length	0·212
Depth of body through anal fin base	0·163
Depth of body through pectoral fin base	0·131
Least-depth of caudal peduncle	0·105
Depth of head through orbit	0·068

As is evident from the above, the standard length has the maximum rate of growth. Among the other measurements, the body length from opercle to hypurals has the maximum rate of growth, and the depth through orbit, the minimum. The growth rate of the head is approximately ⅓ that of the body. The depths of the body at the anterior end of anal fin base and at the pectoral fin base increase nearly at the



TEXT-FIG. 4. Graph showing the relationship of body measurements to total length.



TEXT-FIG. 5. Graph showing the relationship of body measurements to total length.

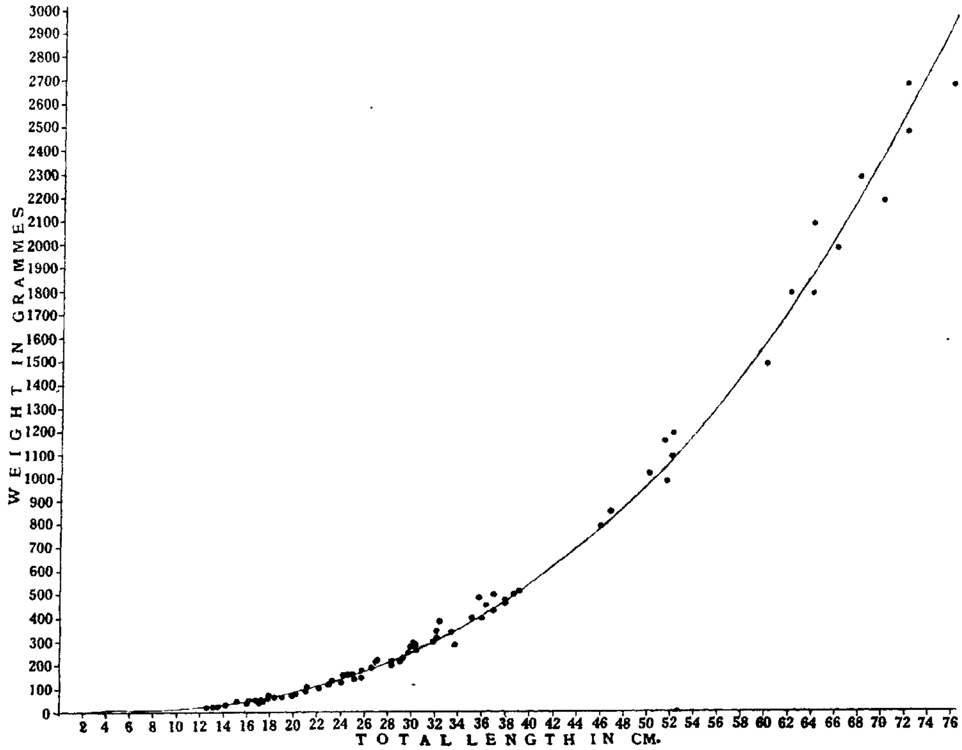
same rate. The rate of increase of the depth through orbit is about half that of the depth through pectoral fin base.

Research workers very often use the standard lengths of fishes in their studies, though total lengths are more readily accepted and understood by the fishermen and the fish traders. Moreover, there is a likelihood of some confusion in measuring standard length, as the base of the caudal fin in mullets is covered by scales and the end of the lateral line series or the tip of the hypurals cannot be located easily. However, to facilitate the comparison of data, the mathematical relationship between the total length and the standard length was determined from a series of 200 measurements. The linear regression line is shown in Text-fig. 4. The coefficient of correlation r, was found to be 0·998. The equation for the regression line, $Y = a+bX$, was used to express the relationship between the two variates, X (= total length) and Y (= standard length). The equation was found to be $Y = 0{\cdot}81125\,X - 0{\cdot}025$.

WEIGHT-LENGTH RELATIONSHIP

A knowledge of the weight-length relationship of a fish is of great value both to the fishery operatives and the fishery biologist. Besides serving as the basis for the calculation of weights of fishes of known lengths or lengths of fishes of known weights, the coefficients of this relationship have been used as measures of individual or average seasonal and regional differences in the condition or 'degree of well being' of fishes. The average weight-length relationship was determined from measurements of 400 specimens from 4 cm. to 67·9 cm. in total length, collected from the estuarine and coastal waters. The fish were weighed with a spring balance graduated to the nearest gramme. Preliminary analysis of the available data did not show any significant differences in the weight-length relationship of the two sexes and so the average has been calculated for the two sexes combined.

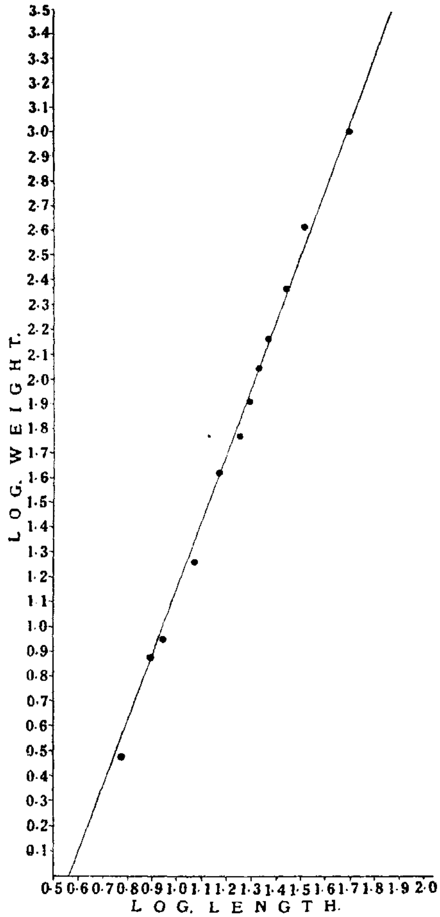
The relationship of the average weight to the length is represented in Text-fig. 6. As can be seen from this figure, the weight of the fish increases as an exponential function of its length. Since the weight-length ratio is a power relationship, the logarithms of the readings were used for calculations. The logarithmic relation of weight and length is illustrated in Text-fig. 7, which clearly shows a straight line relationship. The equation for the weight-length curve was found to be $W = 0{\cdot}3337\ L^{2.6198}$, where the weight is in grammes and the length is in cm. The weight-length data plotted in Text-fig. 6 show that the values are very uniform up to about 36 cm. length, above which there is noticeable variation. Kesteven (1942) and Morrow (1951) have shown that such variations are generally caused by the fluctuations in the weight of the visceral and somatic tissues. When compared with the increase in length, the proportional increase in weight is not marked up to about the 18 cm. stage, whereafter the increase in weight is quite rapid. From the commercial stand-point, it may not, therefore, be economical to catch fish below this size, thus foregoing the advantage of the rapid gain in weight.



TEXT-FIG. 6. Weight-length relationship of *Mugil tade*.

PONDERAL INDEX

Ponderal index or the coefficient of condition has been established to be of help in understanding some important features of the biology of fishes. Hickling (1930), Hart (1946), Menon (1950) and Morrow (1951) have correlated fluctuations in the ponderal index with the attainment of maturity and spawning. In the present study the weight-length data discussed in the previous section were analysed

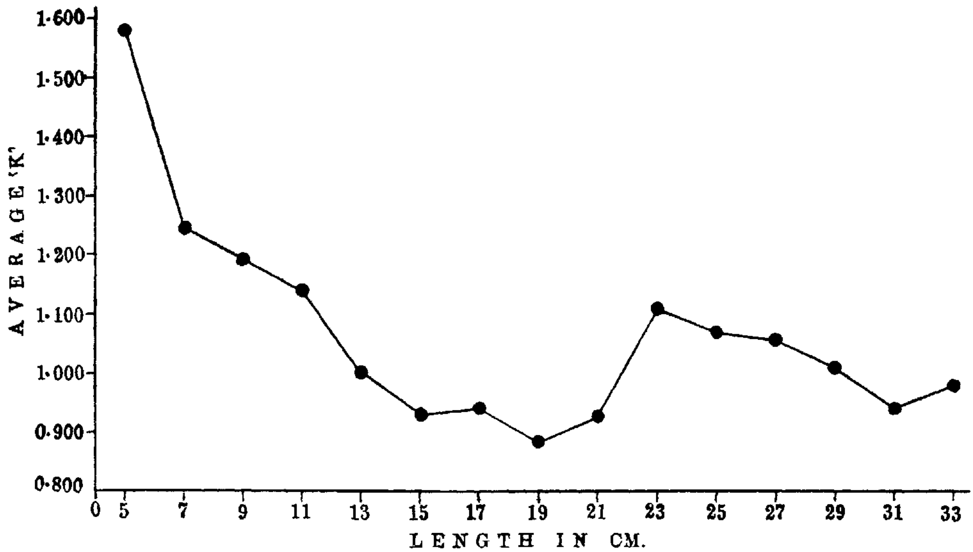


TEXT-FIG. 7. Logarithmic relation of weight and length of *Mugil tade*.

separately for the various size groups and for samples collected during different months. The ponderal index was calculated employing the formula

$$K = \frac{W}{L^3} \times 100$$

where W is the weight of fish in grammes, L is the length of fish in cm. and K is the ponderal index. The average ponderal index for each cm. length group and the average ponderal index for the whole sample in different months have been computed. Lengths up to 34 cm. alone were considered in this study, as the data available for larger fish were very limited for any correct interpretations. Hart (1946) and Menon (1950), have found that besides the seasonal fluctuations in the ponderal index or condition factor, there is a marked lowering of the value, associated with the increased metabolic strain of spawning. Table II gives the average values for K for each cm. length group, and these values are plotted in Text-fig. 8. The curve in this figure shows that the K value progressively decreases with increase in length up to about 21 cm., whereafter it shows a marked rise. If the point of inflection of the curve is indicative of the length at first maturity, it may be said that the fish matures at an average length of 23 cm. Some evidence in



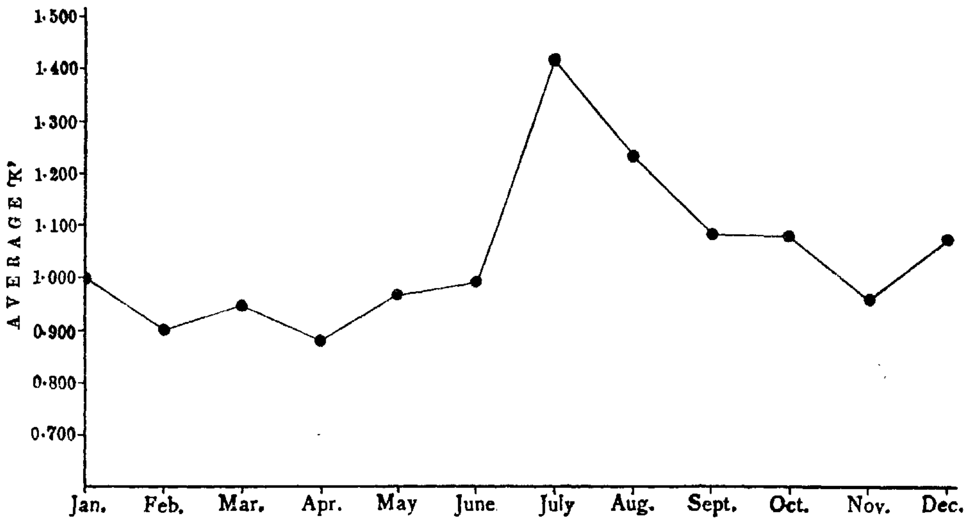
TEXT-FIG. 8. The average K at the different lengths of *Mugiltade.*

support of such a conclusion has also been afforded by the fact that the smallest females with maturing eggs in the ovary, examined during this investigation, were also of about this size.

TABLE II

Mean length in cm.	Number of specimens.	K.
5	22	1·581
7	46	1·247
9	76	1·199
11	98	1·092
13	48	1·004
15	52	0·932
17	40	0·941
19	16	0·884
21	6	0·928
23	12	1·103
25	4	1·069
27	10	1·057
29	20	0·989
31	4	0·937
33	4	0·979

The mean K values for the samples in successive months are presented in Table III, and these values are plotted in Text-fig. 9. The samples studied did not contain any spent fish and so a complete picture of the correlation between spawning and the fluctuations of K cannot be read from the data. Morrow (1951) has found that associated with the pre-spawning growth of the gonads in the Longhorn Sculpin, a peak of condition is reached at the beginning of the spawning season. It will be seen from Text-fig. 9 that the condition factor begins to increase steadily from about May and reaches the maximum in July, falling thereafter; but up to about October the values are maintained fairly high.



TEXT-FIG. 9. The monthly fluctuations in the *K* value of *Mugil tade*.

Maturing fish have been observed till about October. Though the actual spawning period cannot be inferred with certainty from these data, it is clear that May-June to September-October is the breeding period of the fish. Evidence in support of this conclusion has been obtained from the ova maturation studies and the seasonal occurrence of larvae and juveniles. The relatively higher values of *K* for December and January are probably to be correlated with the increase in the intensity of feeding noticed (Pillay, 1953*a*).

TABLE III

Month.	Number.	*K*.
January ..	70	1·000
February ..	60	0·900
March ..	30	0·950
April ..	30	0·884
May ..	30	0·969
June ..	34	0·994
July ..	32	1·444
August ..	30	1·236
September ..	62	1·087
October ..	28	1·080
November ..	45	0·953
December ..	66	1·071

FOOD AND FEEDING HABITS

The food and feeding habits of *M. tade* in varying environments during different seasons and in different stages of growth have been described in a separate paper (Pillay, 1953*a*). It is now definitely known that the adult mullet is iliophagous and feeds on algae, diatoms and decayed organic matter occurring in the benthic zones. While diatoms, algae and organic matter are consumed in about equal quantities in marine environments, algae are eaten in larger quantities in the estuarine habitats. The young ones up to a stage of about 2 cm. length feed on floating or attached algae, mostly Myxophyceae. An increase has been noticed in the feeding activity of the fish during the winter season, when there is a bloom of algal growth in its habitat.

Sex ratio and fecundity

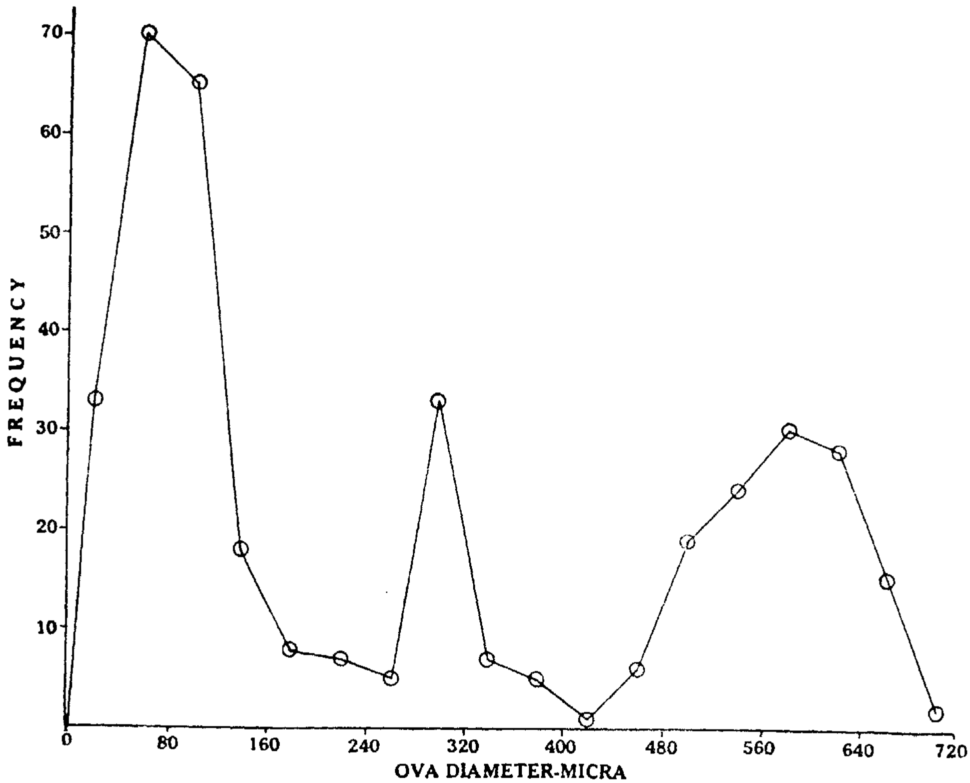
A knowledge of the sex ratio in populations is considered essential in the management of a fishery as it will be necessary to devise means of ensuring a proportional fishing of the two sexes. In adult specimens examined during the investigation, in which sex determination was possible 56·3% were females and 43·7% were males. Thus, the number of individuals in the two sexes appears to be more or less equal. Though the possibility of the sex ratio having been influenced by differential fishing exists, there is at present no evidence to show that this is actually the case in *M. tade*. Kesteven (1942) estimated that the gonads of mature *M. dobula* contained from 1,275,000 to 2,781,000 ova. Jacob and Krishnamurthy (1948) have estimated that a mature *M. oeur* (= *cephalus*), 20·6 inches in length, contained 1,32,00,000 eggs in the ovary. In the ovaries of mature *M. tade*, three groups of ova were found. The number of maturing and nearly ripe ova (*vide* the classification on page 203), which gives an indication of the reproductive capacity of the fish during a particular spawning season (see page 203), was estimated from four nearly ripe specimens ranging from 23 cm. to 50 cm. in length, by counting the ova in a small portion of the ovary of known weight and computing the total number of ova based on this count and the total weight of the ovary. The number ranged between 90,416 and 3,22,959. As was only to be expected, the number of ova in smaller individuals was proportionately less, since as a rule the size of ripe eggs is constant for each species.

Maturation and Spawning

Maturation.—The maturation of the female mullet was studied by the measurement of ova diameters.

The measurements of ova were taken from formalin-preserved material. These ova were in many cases somewhat distorted in shape due to preservation. With a view to avoid any possible selection or bias in taking the measurements, a procedure similar to that adopted by Clark (1925) and Arora (1951) was employed as follows. A piece of the ovary was teased out in formalin on a slide and the diameters measured by means of an eye-piece micrometer in a compound microscope. The scale of the micrometer was kept across the field of the microscope from left to right. The diameters of 100 ova, along whichever axes that lay parallel to the micrometer, were taken. This procedure ensured random nature of the readings and unbiased values. Preliminary studies showed that there are no significant differences in the development of the ova in the different regions of the ovary.

Text-fig. 10 represents the curve of the frequency distribution of 380 ova of 8 nearly ripe specimens obtained during the spawning season. From the modes of the curve three distinct stages can be recognized in the maturation of the ova. Stage I consists of eggs measuring up to 180 micra with the mode at about 60 micra. These ova are transparent and are devoid of any yolk accumulations. They have very prominent nuclei filling nearly half of the cell space. These form the immature ova, representing a resting stage between seasons. The next stage (Stage II) consists of an intermediate group of maturing ova with the mode at about 300 micra. The smaller ova of the group (160–280 micra in diameter) are semi-opaque and the larger ones are more heavily laden with yolk. Stage III is composed of nearly mature eggs with the mode at about 580 micra. The eggs of Stage III had their margins transparent but the major part of the ova remained opaque. The smallest female in roe examined during this investigation was 23·1 cm. in total length. This observation corroborates the inference drawn, from the fluctuation in the ponderal index, that the average size of the fish at first maturity is 23 cm. The samples examined did not contain any fully ripe and oozing fish. Fully ripe ova may probably be slightly larger than the size shown in Text-fig. 10.



TEXT-FIG. 10. Size distribution of ova from mature and maturing females of *Mugil tade*.

Spawning Season.—Just as the related species *M. parsia* Ham., *M. tade* was also generally believed to spawn during winter (Hora and Nair, 1944). As will be seen from the length-frequency distributions of catches from Junput and Port Canning (pages 208-210), the fry of *M. tade* have been obtained during this investigation only during the rainy season. Though the correct period of occurrence of fry is not known to the fishermen and the fish culturists in the Sundarban area, most of the fishermen on the Contai Coast are aware of this, and collect the fry of this fish for stocking tanks during this season (Pillay, 1950). The observation regarding the spawning season was verified by studying the size progression of ova during different months of the year. The data are presented in Text-fig. 11, and show that the immature eggs up to about 160 micra occur in every adult female during all the months of the year. A feeble increase in size of the ova noticed in the month of March becomes conspicuous by April, and as growth is quite rapid thereafter, nearly ripe ova are seen in the gonads by the end of May. Such ova have been found in the ovary from May to September with two peak periods in June and August. It is inferred from this that the spawning season of the fish extends from about May to September with the peak periods in June and August. Actual oozing specimens have not been examined and the nearly ripe ova may take some time to

Maturity	Diameter in micra	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Nearly ripe	681-720								○	●	○	●	○
	641-680								●	●	○	●	
	601-640								●	●	●	●	
	561-600								●	●	●	●	
	521-560								●	○	●	●	
	481-520								○	○	○	○	
	441-480								○	○			
Maturing	401-440												
	361-400									●			
	321-360									●			
	281-320									●			
	241-280								○	○			
	201-240							○	●	○	○		
	161-200						○	●	●	○	○		
Immature	121-160						○	●	○	●	○	○	
	20-120	●	●	●	●	●	●	●	●	●	●	●	●

TEXT-FIG. 11. Monthly size progression of ova of maturing *Mugil tade*. (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 range of solid circles).

become fully transparent and ready for spawning. So the period indicated gives only an approximate picture of the spawning season. Observations during the last three years have shown that the appearance of fry of *M. tade* is dependent on the onset of S.W. monsoons. So the actual beginning of the breeding season appears to fluctuate from year to year.

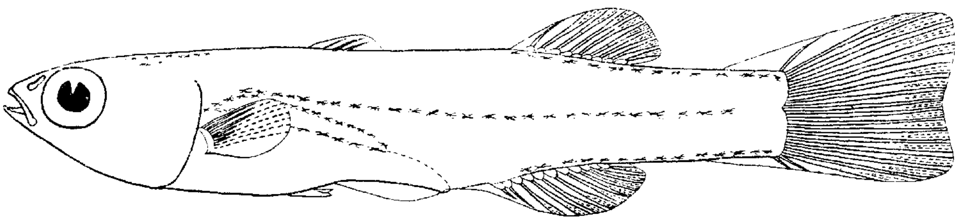
Frequency of spawning and the spawning grounds.—The ova measurement data discussed above suggest that the fish spawns more than once during each spawning season. The ovaries of nearly ripe females contained immature, maturing and nearly ripe ova at the same time. It appears that by the time the ova of Stage III become fully ripe, those of Stage II advance rapidly in maturity and become nearly ripe, and within a short interval the fish is able to spawn again. The two peak periods of spawning that are indicated in Text-fig. 11, also support such a conclusion. More extensive observations may, however, be necessary to establish this tentative inference.

The breeding season of the fish coincides with the off-season for fishing in both the estuarine and coastal waters where the prevailing rough weather prevents fishing with the gear and tackle used by the fishermen. For lack of a suitable sea-going vessel, it has not been possible to make any detailed investigations in these areas during this season. The limited samples examined were those taken by the fishermen in the hand seines from the onshore areas of the Contai Coast and in bag nets from the estuarine regions near Gosaba. The fishermen are of the opinion that the mullet spawns in the sea. The catches of the fishermen on the Contai Coast during this season have been carefully examined, but no fully ripe specimens were ever found among them. Maturing and nearly ripe specimens have been found in the catches from both the lower estuarine areas and the onshore regions of the sea. Several plankton collections were made from the onshore waters at Junput and on some occasions in the lower reaches of the Sundarbans. Neither eggs nor larvae were seen in the collections, except for a couple of larvae caught in the plankton from off Junput, which, in all probability, were brought in by the high tide. However, juveniles appear in large schools throughout the rainy season in the coastal areas and estuaries. These observations strongly suggest that the fish probably spawns in deeper waters away from the onshore areas. This inference is contrary to the opinions of several workers (*vide* Sarojini, 1951), who believe that the mullets breed in the onshore or inland waters. It is interesting to note that the fish virtually enjoys the benefits of a closed season during its spawning period, since fishing is almost non-existent at this time.

Description of Larvae

Two larvae referrable to *M. tade*, 8·6 mm. and 9·0 mm. long respectively, were obtained in the plankton collected from Junput on 18th July, 1950. These are the earliest stages obtained during the investigation.

In the 8·6 mm. larva (Text-fig. 12) all the fins are well marked out. There are three spines evident on the first dorsal, and nine rays on the second dorsal. The caudal fin possesses 15 well-developed rays. The anal has two spines and eight rays of which two are in advance of the vertical from the second dorsal. The rays have not been differentiated on the pelvic fins. There are indications of rays on the dorsal aspect of the pectoral fins. The pre-anal fin-fold is present at this stage. There are 11 pre-anal and 13 post-anal vertebrae.



TEXT-FIG. 12. Larva of *Mugil tade*, 8·6 mm. in length ×16$\frac{3}{5}$.

There is a row of chromatophores along the lateral line, one row from the base of the anal fin to the caudal and another row from the base of the second dorsal to the caudal fin, on either side of the body. There are several chromatophores on the dorsal aspect of the head, extending posteriorly up to the nape.

The eye measures about 2·9 times in length of head. The head is about 4·5 times, and the height of body about 6·0 times, in total length. The scales have not yet been formed.

The 9 mm. larva does not show any advance in development beyond what is seen in the one 8·6 mm. long.

Age and Growth

Scales as indicative of age and growth

Scale characters.—The scale of the adult *M. tade* and its development have been described in detail by the author in a separate paper (Pillay, 1951). The examination of scales from individual fish has shown that while the scale size is variable on different parts of the body, there is a high degree of constancy in size in the scales of the linear series on the sides. Kesteven (1942) has demonstrated that the scales of *M. dobula* on the flanks show very little variation in size, and has observed a remarkable uniformity in the calculated intermediate lengths and the growth increments, based on many scales from each of a number of fish. He has concluded that there are different coefficients of regression of scale size on fish size, and that these coefficients are real and operative over the whole life of the fish for each scale. The examination of scales of *M. tade* also revealed a similar condition which indicated that any of them from the flank could be utilized for reading. However, it was noted that, as in the case of *M. dobula* (Kesteven, *loc. cit.*, p. 39), there was a minimum of variation in scale size at the region behind the tip of the pectoral fin, and so scales from this region alone were used in the present study of age determination. The assumption that the scale size holds a constant relation to the length of the fish was demonstrated to be correct.

Annulus formation.—Typical growth rings such as are observed on the scales of fishes in temperate regions are not noticeable on the scales of the mullet. Regular markings in the form of 'breaks', are, however, observed in *M. cephalus*, as recorded by Jacot (1920). These breaks generally appear as wide, clear spaces between circulii in the basal sector, formed either by the cutting off of circulii and a difference in their disposition, or by their excessive splitting. Kesteven (1942) and Thomson (1951) have also observed the same type of rings on the scales of *M. dobula*. Kesteven has explained the formation of the rings as follows:

"The appearance of the complete 'break' suggests quite convincingly, that feeding has ceased for a period during which resorption may have occurred; at any rate at this time the circulii were differentially shortened, at the end of the period, with the resumption of feeding, scale accretion was resumed, but in such a manner as to produce complete circulii lying at a different angle to those of the previous annulus. This assumes no more than is normally assumed in interpreting scales, and is sufficient explanation of the origin of 'breaks'."

After a consideration of the probable causes for the formation of such 'breaks' on the scales of *M. dobula*, he inferred that the migrations of the fish in autumn and the consequent cessation of feeding, which are at or near the anniversary of spawning, is the annual event recorded on the scale. He had not sufficient data to say whether the cessation of feeding in the sea alone can give rise to such 'breaks'. Thomson (*op. cit.*) has observed that the annulii are formed on the scales of *M. dobula* in Western Australian waters at the end of September or the beginning of October, when growth re-commences after the winter cessation.

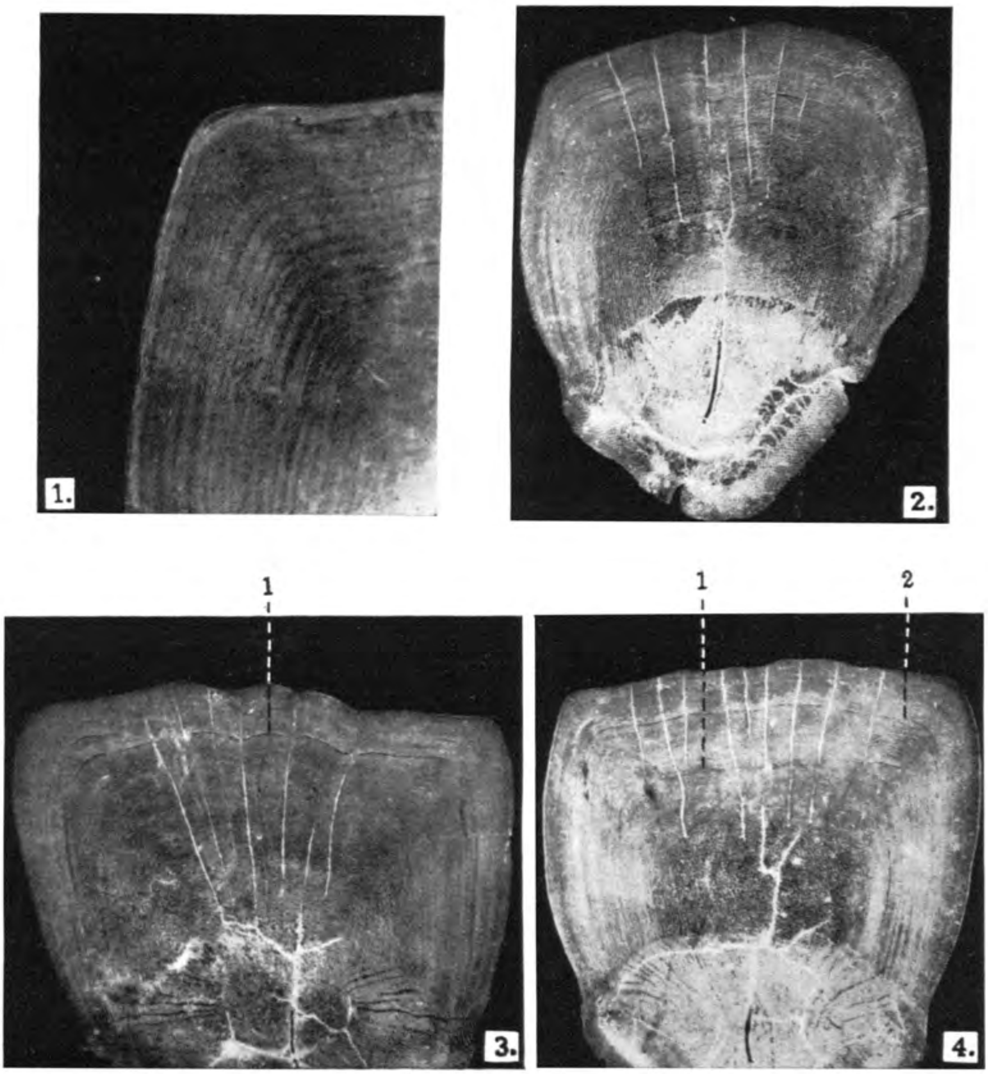
From an examination of the scales of *M. tade* collected during different months of the year it is found that most of the scales obtained during May-July period had recorded wide clear spaces or the excessive cutting off of circulii at the margin. Example of this is shown in Plate V (Fig. 1).

During other parts of the year, the marginal regions did not show any such features, though in a few cases during August and September also such formations have been noticed. The study of the food and feeding habits of the fish (Pillay, 1953*a*) has not offered any proof to show a specific period of fasting and even mature specimens contained food materials in the gut. From the study of the maturation of ova it has been inferred that the fish attains maturity only when about 23 cm. in length. Smaller specimens of about 16 cm. length had one annulus mark on their scales (Plate V, Fig. 3). So it appears unlikely that the spawning migration is primarily the annual event that is recorded on the scales. Further support for such an inference is afforded by the fact that the scales of fish reared in enclosed farms also had regular formations of 'breaks', just as the fish in the wild. These fish undoubtedly would have had no opportunity of migrating into the sea for spawning. Kesteven (*loc. cit.*, p. 37) has hinted at the possibility of a cessation of feeding in land-locked fish due to an internal rhythm (Dakin, 1939) and the consequent formation of 'breaks'. The study of the gut contents of *M. tade* has afforded some evidence of a real lowering of the feeding intensity during certain periods of the year due to more clearly understood reasons. Though a complete cessation of feeding is not discernible, Tables I, IV and VII of the paper dealing with the food and feeding habits of the fish (Pillay, 1953*a*) show that during the rainy season (S.W. monsoon), generally extending from about May-June to August-September, a distinct period of low feeding activity can be noticed. As has already been elucidated, the fish feeds on fresh or decayed bottom flora. During floods consequent upon the heavy rainfall in the area, the benthic flora gets very much disturbed and dislodged due to the strength of the currents, and the normal feeding of the fish is frequently interrupted. A similar condition has been observed by Seshappa and Bhimachar (1951) in the bottom feeding fishes of the West Coast. It therefore appears that the disturbances lowering the intensity of feeding is the prime cause of the formation of 'breaks' on the circulii. This inference also fully explains the formation of more than one 'break' seen quite close together on some of the scales. Whenever there is a serious lack of the abundance of food at the bottom for an appreciably long period due to flood and consequent churning up of the benthic flora, such 'breaks' are likely to be formed on the scales. In the case of mature *M. tade*, this period coincides with the spawning season when they are believed to migrate to the sea. In view of this fact, these 'breaks' can, as will be proved by other methods later, be considered as indicative of a full biological year's growth.

Age and growth determination.—In estimating the age and growth, only regular scales from the region below the tip of the pectoral fin, were utilized. Regenerated scales were often met with (Plate V, Fig. 2); but they lacked most of the earlier markings and so they were always rejected. The scales were washed in a very dilute solution of Potassium hydroxide to remove skin, dirt and adhering pigments and then was cleaned in water. They were mounted dry between two glass slides, the ends of the slides being secured together by means of adhesive paper or in the case of large scales by means of narrow rubber bands. The mounted scales were examined with the aid of a microscope. In the absence of a scale projection apparatus, the smaller scales were measured with the aid of a camera lucida. The larger scales were projected on to a white glossy surface on a photographic enlarger, using the scales as negatives. For the measurement of the scales, paper rulers prepared from mm. graph paper were employed. The zero of the ruler was placed at the nucleus of the projected image and the ruler placed along the most median basal radius. The ruler was then marked at each annulus and the basal margin. For each scale a separate ruler was used. On these were recorded all relevant data regarding date of collection, locality, total length, sex and the magnification of the image. The back calculation of the length of the fish at the end of each year was done employing the formula

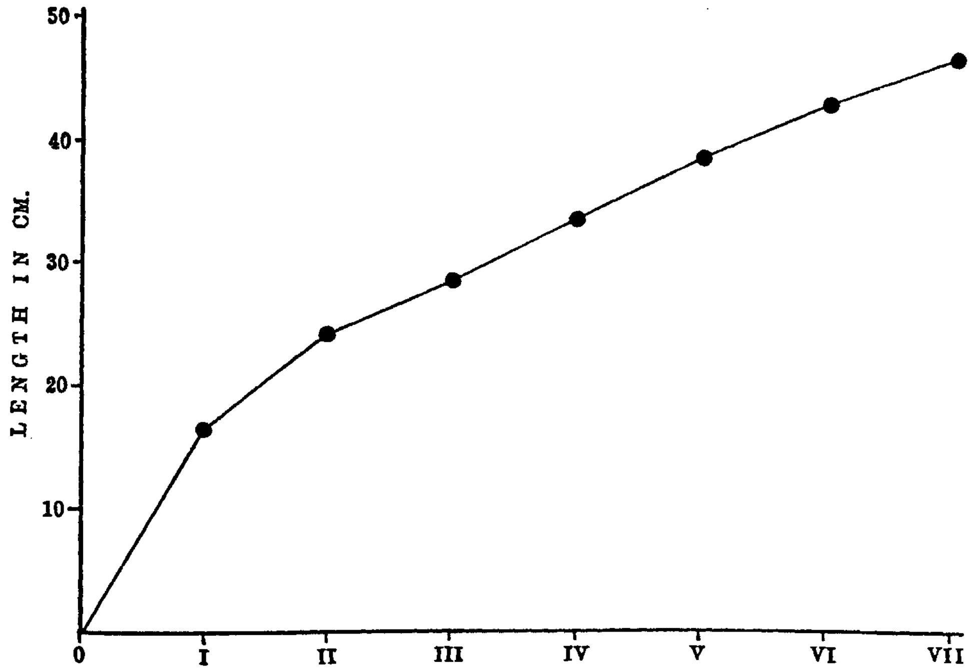
$$L_x = \frac{S_x}{S_t} \times L_t$$

where L_x is the total length of the fish at the time annulus X was formed, S_x is the distance from the nucleus of the scale to the particular annulus X; S_t is the distance from the nucleus to the basal margin of the scale and L_t is the total length of the fish at the time of observation. From the calculated lengths the mean length for each year was estimated. Certain difficulties were experienced in reading the scales especially of the large-sized fish. In some scales more than one 'break' were found close together. This is apparently due to more than one period of low feeding activity. Untimely showers and flooding of rivers is not uncommon in the Gangetic delta and when this happens additional breaks can appear on the scales. However, such additional annulii have generally been observed on the scales of fishes above the size of about 23 cm. when they are known to attain maturity and probably migrate to the sea for spawning. There is therefore some probability that these additional rings are spawning marks; but these rings are usually not very clearly marked out. The converse, *viz.*, the omission of one or two 'breaks' has also


1.
2.
1
3.
1
2
4.

been observed, though only rarely. This is probably due to the favourable feeding conditions that existed during the season as a result of the paucity of heavy rains and the consequent absence of floods. Kesteven (*op. cit.*) has also noticed these features on the scales of *M. dobula*. When there are excessive numbers of breaks, he, like Thompson (1923), rejected the intermediate lengths calculated from these, which are not in conformity with the remainder of the sample and the general indication of the length frequency data. When 'breaks' were omitted or had disappeared, they were placed in the appropriate group following the indication of the remainder of the sample and the length frequency data. This procedure was also adopted in the present work.

The measurements of 69 scales were taken and the lengths for each year were calculated. The results are given in Table IV. As can be seen from this Table, the numbers of observations of l_8, l_9 and l_{10} are too meagre, though these may serve to give a rough idea of the growth rate. The data do not show any evidence of Lea's phenomenon of a progressive decrease in the calculated intermediate lengths. The mean growth curve up to the seventh year of life is shown in Text-fig. 13. In Text-fig. 14 this growth curve has been transformed into a straight line, employing Walford's (1946) method. l_8, l_9 and l_{10} have also been plotted in the figure. The limiting length L has been located graphically as the point where the length at age n equals the length at age n_1. From the growth characteristics it can be inferred that the fish can attain a size of about 85 cm. The largest fish observed during this investigation was about 70 cm. in length.

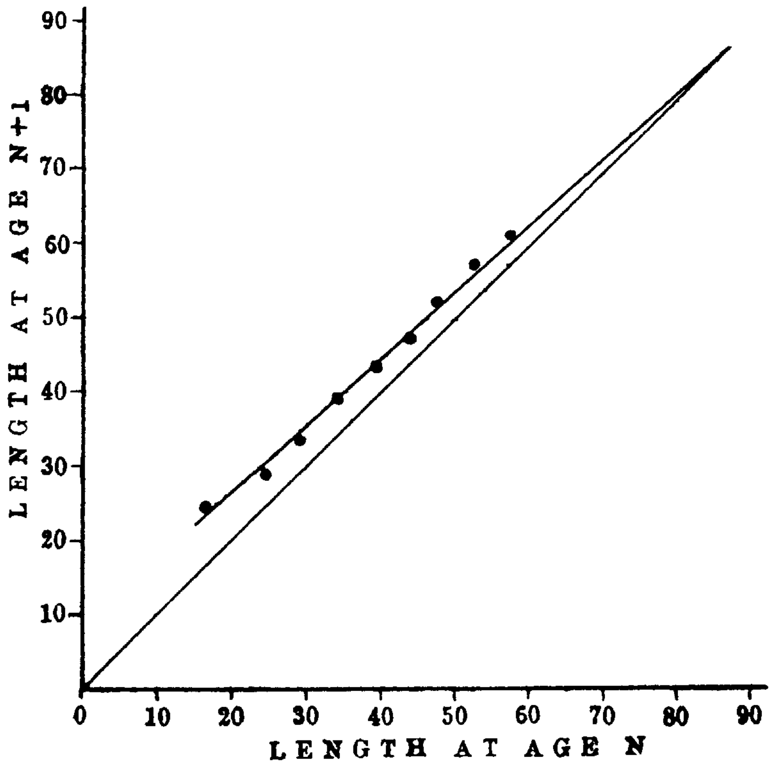


TEXT-FIG. 13. Growth curve of *Mugil tade* (lengths calculated from scale measurements).

TABLE IV

Calculated total lengths of Mugil tade *at the end of each year of life, as determined from measurements of scales*

Age Group.	l_1		l_2		l_3		l_4		l_5		l_6		l_7		l_8		l_9		l_{10}	
	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.	No.	Mean cm.
I ..	21	12·7																		
II ..	24	15·8	20	21·1																
III ..	6	18·9	6	26·3	5	29·4														
IV ..	6	18·7	4	25·3	6	29·1	6	32·0												
VII ..	5	16·0	3	24·0	4	30·0	6	33·8	6	38·8	6	44·3	6	47·7						
VIII ..	2	17·0	2	25·8	2	28·5	3	35·0	3	39·4	3	43·4	3	47·8	3	52·0				
IX ..	2	16·5	1	24·0	1	28·5	1	35·2	2	39·0	2	43·6	2	46·9	2	52·8	2	59·8		
X ..	..	..	1	25·8	1	28·5	1	34·0	1	39·9	1	43·9	1	47·3	1	52·6	1	55·7	1	61·3
All groups	68	16·5	37	24·6	19	29·0	17	34·0	12	39·3	12	43·8	12	47·4	6	52·5	3	57·8	1	61·3



TEXT-FIG. 14. Transformation of the growth curve of *Mugil tade* to show the limiting length.

Length frequency distribution.

Collections suitable for the study of growth trends of *M. tade* from length frequency distributions were available from Junput for a period of twelve months in 1949-50. Samples were available in Port Canning only for a period of six months during the year. The distributions for the two localities are presented in Tables V and VI respectively. The data for each month for Junput are presented graphically in the form of histograms in Text-fig. 15. The average lengths that the fish attains in the first three years of its life, calculated from the scales, are shown as vertical dotted lines. As is evident from the graph, the samples consisted of only the 0 group fish and I group fish with a few of the II group. Selectivity of the fishing gear is thus evident. Distinct modes are noticeable only for the 0 group fish.

Young ones up to 4 cm. in length appear from June to October. These are probably the progeny of fishes that spawned from May to September. The smallest group of the month of June, with its mode at about 2 cm., can be traced to form a distinct mode at about 14 cm. in December, after which it is not quite prominent. This is probably the group 16–20 cm. found in May. The smallest group found in October (those hatched out in about September) can be observed to form a mode at about 6 cm. in January. This group is not clearly seen during other months, but appears in the 12–16 cm. category in May. As can be seen from the range of calculated lengths for the first year's growth, it has a wide range from 12 to 18·9 cm. This is to be expected when the fish has a very extended spawning period as in the present case. The II group fish appears in the graph in December and forms a mode in May when it reaches a size of 24–28 cm. The data available are not sufficient to render possible any inferences on Group III or bigger fish.

TABLE V

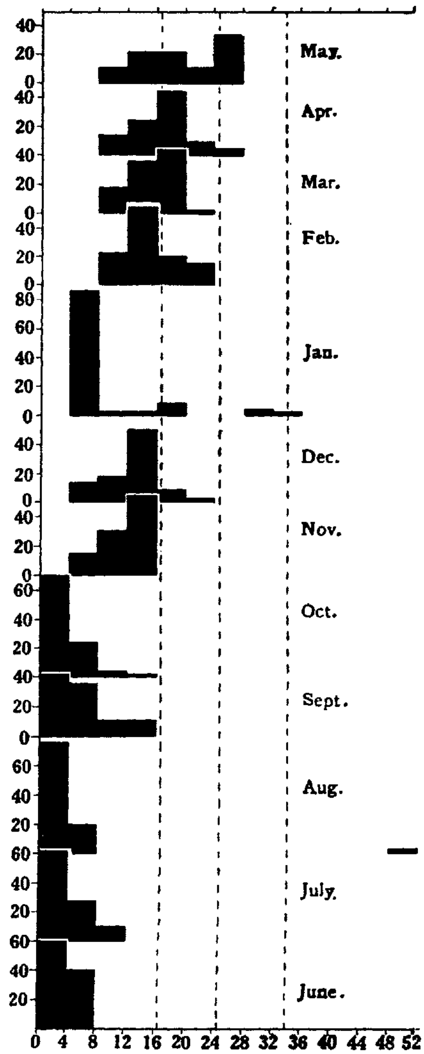
The length frequency distribution (in cm.) of the samples from Junput (expressed as percentages)

Month.	No. in sample.	0·1–4·0	4·1–8·0	8·1–12·0	12·1–16·0	16·1–20·0	20·1–24·0	24·1–28·0	28·1–32·0	32·1–36·0	36·1–40·0	48·1–52·0
(1949) June	68	60·0	40·0	..	..	..	..	..	..	..	..	..
July	45	62·0	28·0	10·0	..	..	..	..	..	..	..	..
August	58	77·0	20·0	..	..	..	..	..	..	..	..	3·0
September ..	45	42·0	36·0	11·0	11·0	..	..	..	..	..	..	..
October	80	70·0	24·0	4·0	2·0	..	..	..	..	..	..	..
November.. ..	60	..	15·0	30·0	55·0	..	..	..	..	..	..	..
December ..	85	..	14·0	18·0	51·0	9·0	2·0	..	4·0	2·0	..	..
(1950) January	64	..	86·0	3·0	3·0	8·0	..	..	..	..	..	..
February	35	..	..	22·0	55·0	18·0	5·0	..	..	..	..	..
March	15	..	..	18·0	36·0	44·0	2·0	..	..	..	..	..
April	20	..	..	15·0	25·0	45·0	10·0	5·0	..	..	..	..
May	25	..	..	11·0	22·0	22·0	11·0	34·0	..	..	..	..

TABLE VI.

The length frequency distribution (in cm.) of samples from Port Canning (expressed as percentages)

Month.	No. in sample.	0·1–4·0	4·1–8·0	8·1–12·0	12·1–16·0	16·1–20·0	20·1–24·0	24·1–28·0	28·1–32·0	32·1–36·0	36·1–40·0	48·1–52·0
(1949) June	35	87·0	..	..	..	1·0	5·0	4·0	3·0	..	..	..
July	25	..	100·0	..	..	..	..	..	..	..	..	..
August	140	21·0	24·0	55·0	..	..	..	..	..	..	..	..
September ..	120	11·0	22·0	42·0	25·0	..	..	..	..	..	..	..
October.. ..	40	9·0	27·0	46·0	9·0	..	..	9·0	..	..	..	..
November ..	75	20·0	60·0	20·0	..	..	..	..	..	..	..	..



TEXT-FIG. 15. Length frequency histograms of the samples of *Mugil tade* collected from Junput.

The modes of the distribution for May, which is considered as the beginning of the biological year of the fish, show a fair amount of agreement with the averages of the calculated lengths. The data for Port Canning show that the smallest group that appears in June attains a size of about 4–8 cm. by about November.

MIGRATIONS.

Sarojini (1951) has drawn attention to the contradictory theories held by workers on the migrations of the mullets, especially the spawning migrations. While Panikkar and Nair (1945) and John (1948) observe that mullets ascend rivers for spawning purposes, Kesteven (1942) and Jacob and Krishnamurthy (1949) believe that they migrate into the inshore waters for spawning. There appear to be no definite records about the migrations of *M. tade*. As has been shown on page 204, the evidence so far available indicates that they migrate into the sea for spawning purposes. This spawning migration appears to start when the fish are about two years old and about 23 cm. in length, when they attain maturity for the first time. There are not sufficient data to prove that the spawned fish immediately return to the estuaries after spawning, but there is some proof to show that the same fish spawns more than once in one spawning season, and that they are likely to remain in the spawning grounds till the second spawning is over. Spent fish have not been obtained during the investigation from catches in any of the localities. However, the fact that fish up to about ten years of age are caught in the estuarine waters indicates that a large part of the stock returns to the estuaries after spawning. The reports of the fishermen are also in favour of this assumption.

From the early part of June, juveniles and fry begin to appear along the coasts entering the tidal springs and creeks, and migrating in large schools into the estuaries. But the observations made on the Contai Coast and the evidence afforded by the length frequency data show that immature fish are found in the coastal waters throughout the year. It therefore appears probable that a good part of the stock remains in the coastal waters. Evidently the estuaries and the inshore areas of the sea form the natural habitat of the species, which they leave only during the spawning season.

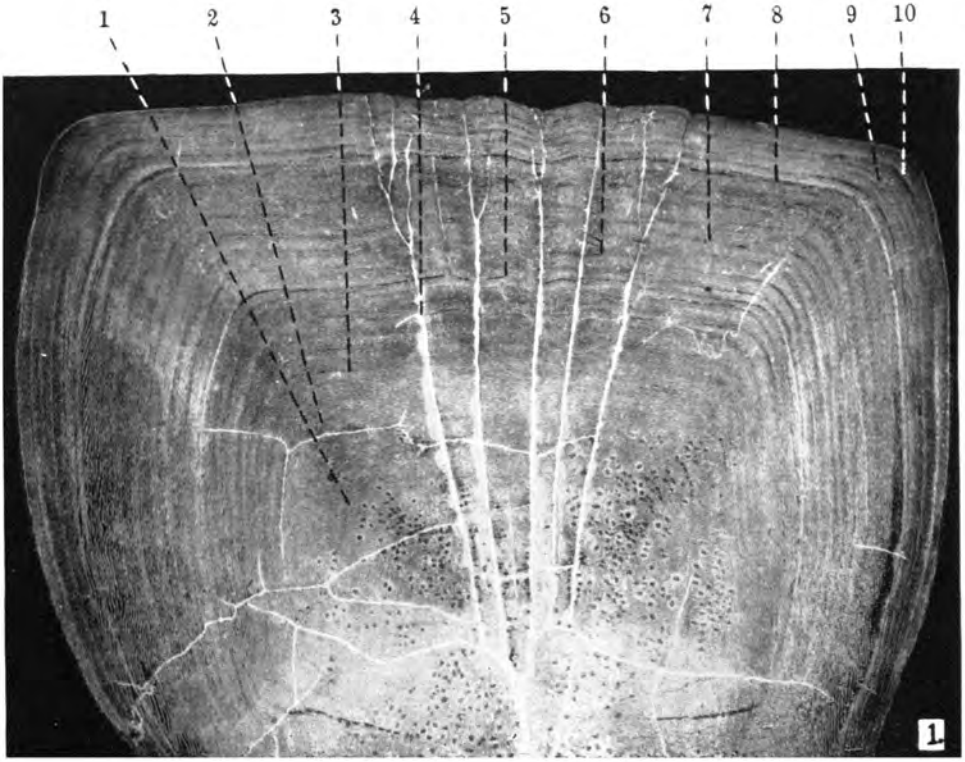
Chacko (1949*a* and 1949*b*) states that *M. olivaceus* Day and *M. borneensis* Blkr. ascend the rivers beyond the tidal limit for feeding. *M. tade* have never been observed by the author beyond the tidal limit in the main river. In areas where there are freshwater channels emptying into the estuary or the sea, the fry can be seen to collect together in schools and in several localities they have been observed to enter these channels and establish themselves there. Spurgeon (1947) has observed a similar habit in *M. dussumieri* (C.V.) and *M. oeur* (= *cephalus*) (Forsk.).

Predators and Parasites

Predators.—The main predators of the mullet in its estuarine habitats in Bengal are believed to be Bhekti (*Lates calcarifer* (Bloch)), Indian Salmon (*Eleutheronema tetradactylum* (Shaw)) and the Bombay duck (*Harpodon nehereus* Ham.). According to Menon (1948) more than 65% of the food of Bhekti consists of fishes, of which mullets have been listed as a predominant group. Though the proportion of *M. tade* consumed is not known, the examination of gut contents of several specimens has shown that *M. tade* forms a common item of food of Bhekti. Usually only fry and fingerlings are eaten. Mr. J. C. Malhotra who has studied the food and feeding habits of *E. tetradactylum*, informs me (private communication) that mullets form only a negligible percentage of the food of this fish, and that its main food consists of prawns. Pillay (1953*c*) has shown that though occasionally the mullet forms the food of the Bombay duck, the quantities eaten are very small. Kesteven (1942) found sharks to be predators of mullets. Though it has not been possible to collect any data on this aspect, it is most likely that sharks are highly destructive to mullet stocks in the coastal waters.

Parasites.—The material examined during this investigation shows that the mullet is relatively less prone to parasitic attacks. Mortality due to parasitism has not been reported even from farms. The only external parasite observed was *Rosinella latesi* Southwell (1915) found on the fins of a 55·9 cm. long fish collected from Port Canning on 29th July, 1951. They had attached themselves to the soft dorsal, caudal and ventral fins. A 30 cm. long fish obtained from Junput in April 1949 had its palates and pharyngeal cushions covered with parasitic copepods

2.



1.

belonging to a new family.* Other internal parasites collected were all from the intestines and consisted of a new species of Acanthocephala of the genus *Neoechinorhynchus* and a species of nematode.* These forms were very commonly found in adult fish, but were rare in young ones. In no case did the fish show any apparent signs of ill health or loss of weight. The association of a new species of *Zoothamnium* with the fish has been described elsewhere by Khajuria and Pillay (1950).

Five abnormally lean specimens of *Mugil tade* were collected from an enclosed brackishwater farm in Ghutiari Sharif (24-Parganas, W. Bengal, in the month of January, 1950). The relevant measurements of four of these specimens are given below:—

Measurements in cm.

Total length	19·8	17·1	18·4	18·9
Standard length	16·2	13·5	15·4	15·0
Depth of head through orbit ..	1·9	1·6	1·9	1·5
Depth through pectoral fin base ..	2·5	2·3	2·5	2·6
Depth through anal fin base ..	2·8	2·3	2·6	2·5
Width through pectoral fin base ..	2·3	2·0	2·0	2·3
Width through anal fin base ..	0·9	0·9	0·9	0·9
Length of caudal peduncle ..	3·1	2·5	3·0	2·8
Least height of caudal peduncle ..	1·7	1·4	1·6	1·5

The fin ray, scale and branchiostegal counts, dimensions of fins, etc., were the same as for normal specimens. The main difference was noticed in the relative depth of body and in the height of caudal peduncle. The width of body was also very much less than that of normal specimens.

At first these specimens were suspected to be only starved ones, but it was found on examination that the alimentary canal contained freshly consumed and partly digested food materials. Normal specimens were also obtained from the same locality in the same collections and so it was considered unlikely that the abnormality was due to the influence of hydrological factors. No parasites were found in the viscera, gills, etc., of the specimens. Dr. K. K. Nair informs me that he has noticed specimens of *Cirrhina mrigala* infested with leeches becoming extremely lean as in the present case. As the specimens of *M. tade* were not examined in fresh condition, it was not possible to detect any marks of attack by leeches. The brackishwater leech *Placobdella emydae* is known to occur in these localities (Sewell, 1934) and it is probable that these fish have become lean due to infestation by leeches.

Fishery in Bengal

Fishing methods

The main gears employed for mullet fishing in Bengal are: (1) Stake nets, (2) Hand Seines, (3) Cast Nets, and (4) Traps.

Stake nets.—The Stake nets generally operated are the *Bher jal*, *Charpatta jal*, *Khalpatta jal* and *Komar jal*. The *Bher jal* or the *Kutti bher jal* as it is known on the Midnapore Coast, is a very long net enclosing considerable portions of the foreshore areas. It consists of 200–300 rectangular pieces of netting, each measuring 30′ × 8′ (mesh ½″-1″), joined end to end and tied in the form of a wall on stakes fixed in the littoral regions, with about a foot of the net tucked in the mud (Plate VI, Fig. 2). Before high tide the net is untied and allowed to lie low on the bottom. At the turn of the tide, the wall of net is raised and fastened to the stakes. When the tide has fully receded, the stranded fish are either removed by hand, or by means of cast nets, if they are stranded in pools. *Charpatta*, a fence made of split bamboo

* Detailed accounts of these parasites will be published elsewhere by Mr. Y. R. Tripathi of the Central Inland Fisheries Research Station, Barrackpore.

is also operated in the same manner as the *Bher jal* in Bagerhat and Bakarganj. *Kalpatta jal* is a smaller rectangular net 40′–50′ × 12′ (mesh 1″) operated in canals in Sundarban area. The net is tied across the canals by fastening the head rope to strong posts fixed near the banks. It is kept stretched and upright by means of wooden stakes, hooked at the top. The *modus operandi* is the same as for *Bher jal.* Naidu (1939) has described the operation of *Komar jal.* It is operated on the margins of rivers and big canals. Fish are attracted by the decaying twigs and leaves of trees anchored in the area, and the fish arriving with the high tide are enclosed by means of the net. They are then removed towards the shore and the catches hauled up.

Hand seine and drag nets.—A hand seine known as *Katti jal* is operated by the fishermen on the Midnapore Coast. It resembles the *Kattuvalai* (Hornell, 1924) and *Khadi jal* (Chauhan, 1947) and consists of a long shallow bag of netting (¼″-½″ mesh) the mouth of which is kept open by means of sticks 8″-9″ long. The bag is subdivided into pockets at the bottom. The net is operated both at high and low tides mainly during the rainy season. The net, after being paid out in a direction at right angles to the shoreline, is dragged along the shore for some distance and then hauled up. A large number of prawns, crabs and other small fishes are also caught in the net along with mullets. The catches usually consist of small-sized fish not more than 9″-10″ in length. Large drag nets (*Tana jal*) are generally operated in enclosed fisheries. Cast nets (*Khapla jal*) of varying size and mesh are used for fishing mainly in shallow canals, estuaries and enclosed brackishwater farms. *Tras* (Atols) (Hora and Nair, 1944) are designed to capture the fish when it swims against the current and are suitable for operation in farms.

Composition of catches

Unfortunately there are no statistics available regarding the mullet catches in any of the fishing centres of the State. Though *M. tade* grows to a large size, they are relatively less abundant in numbers. This does not, however, prove that they are really less abundant in occurrence as the efficiency of the nets operated has also to be taken into consideration. Though mullets as a group form an important item in the Calcutta fish markets throughout the year, the peak period of supplies is the winter season when the lower reaches of the Sundarbans are exploited by the camping fishermen.

In Port Canning, fishing is done locally throughout the year. Young ones of *M. tade* are abundant during June and July and larger fish are caught from August onwards. In Junput also young ones are caught from June to about October. Larger fish are caught by the fishermen only during the winter season which is the regular fishing season on the coast. The analysis of the size composition (vide Tables V and VI) in both these centres very clearly shows that smaller size groups predominate in the catches. These fish seldom reach the stage of rapid increase in weight (vide page 197) or spawn even once before they are caught. The redeeming feature, however, is that there is a closure of fishing during the spawning season owing to the heavy monsoons prevalent at the time. In coastal areas the fishermen catch mullets by means of hand seines even during this season, but it is very seldom that a fish in roe is caught. This fact must be contributing greatly to the maintenance of population levels.

SUMMARY

Description of the species, distribution, raciation and body measurements.—A detailed description of *M. tade* is presented and the extent of distribution of the species in India is recorded. Statistical analysis of the morphometric data of samples from the sea and the estuary has failed to show any significant differences between them, and it is inferred that the stocks on the Contai Coast and in the estuary of the Matlah River form a homogeneous population. From a study of the growth rate of the different parts of the body, it is inferred that the standard

length, and the body length (from opercle to hypurals) have the maximum rates of growth and depth through orbit, the minimum. The relationship between the total length and the standard length can be expressed by the equation $Y = 0{\cdot}81125\,X - 0{\cdot}025$, where Y is the standard length.

Weight-length relationship and ponderal index.—The weight of the fish is found to increase as an exponential function of its length and the equation for the curve is $W = 0{\cdot}0337L^{2{\cdot}6198}$. From the fluctuations in the ponderal index it has been inferred that the fish attains maturity for the first time when it is about 23·0 cm. in length. The ponderal index of the fish shows seasonal fluctuations and from this it is inferred that the fish spawns during the S.W. Monsoons.

Food and feeding habits.—The juvenile fish feed on unicellular floating or attached algae and the adults feed at the bottom on the benthic flora and decayed organic matter. A marked increase in feeding activity is noticed during the winter season, and a low feeding activity during the rainy season.

Sex ratio, fecundity, maturation and spawning.—The sex ratio of *M. tade* appears to be nearly 1 : 1. The ovaries of nearly ripe specimens contained over ninety thousand to 3 lakhs mature and maturing ova at a time. From the frequency distribution of ova in the gonads of mature females it is seen that there are three distinct groups of ova, *viz.*, immature, maturing and mature. Maturing ova have been observed to appear for the first time in the ovaries of specimens of about 23 cm. length and this is considered to be the size at which first maturity is attained. This inference is also supported by data relating to the fluctuations in the ponderal index. The fish probably spawns more than once during one spawning season, and the spawning season which may start in May-June, depending on the onset of the monsoons, lasts till about September. It appears to breed in the sea away from the inshore regions. The description of larval forms obtained is given.

Age and Growth.—The scales of *M. tade* show annual rings which are most probably the recordings of low feeding activity apparent during the rainy season. From the back-calculated lengths it is inferred that on an average, lengths of 16·5, 24·6, 29·0, 34·0, 39·3, 43·8, 47·4, 52·5, 57·8 and 61·3 cm. are attained by the species in the respective ages attained during the 10 years of its life. The maximum limiting length is estimated to be 85·0 cm.

Length frequency distribution.—The length frequency distributions of *M. tade* collected from Junput and Port Canning for a period of one biological year have been presented and discussed. The trend of the progression of modes is in agreement with the growth rate estimated from scale studies.

Migrations.—The two main migrations of the fish appear to be the seaward migration of the mature fish for spawning and the movements of the fry and fingerlings into estuaries. The presence of large schools of immature fish in the coastal waters throughout the year indicates that all the young ones do not ascend the estuaries and that both the estuary and coastal waters form the natural habitats of the fish.

Predators and parasites.—*Lates calcarifer* forms a major enemy of the fish in estuarine waters. The parasites collected from the fish are listed. It is found that the mullet is relatively free from any large scale infection by parasites. The larger fish are more prone to parasitic attacks. In enclosed fisheries leeches probably infest the mullets.

Fishery.—The fishing methods for the mullet in the estuary and the sea in Bengal are briefly described. Analysis of the catches shows that large quantities of immature fish are caught by the fishermen.

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EXPLANATION OF PLATES.

PLATE V, FIG. 1. The margin of the scale of a specimen of *Mugil tade* caught in May, 1949.
,, 2. A regenerated scale.
,, 3. Scale showing one annulus.
,, 4. Scale showing two annulii.
PLATE VI, FIG. 1. Scale of *Mugil tade* showing ten annulii.
,, 2. A portion of the Barrier net (*Bher jal*) operated on the Contai Coast (Photograph taken at low tide).

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