STUDIES ON THE AGE AND GROWTH OF *CIRRHINA MRIGALA* (HAMILTON) FROM THE RIVER YAMUNA AT ALLAHABAD

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The study of the marginal rings on the scales of *C. mrigala* indicated their annual nature. These annual rings are carved out grooves. From a critical study thereof it was observed that age could be determined accurately. The occurrence of confusing rings in smaller specimens has been explained. The results obtained by the present method agreed highly with those obtained by Petersen's method. von Bertalanffy's growth equation describes adequately the growth pattern in mrigal. The theoretical growth equation derived for mrigal is:

$$l_t = 1060(1-e^{0{\cdot}290649(t-0{\cdot}03964)})$$

C. mrigala attains an average maximum length of 1060 mm. The rate of increase in length was found to be maximum in the first four years of its life.

Introduction

Cirrhina mrigala, commonly called mrigal, is an indigenous major carp which is widely distributed in the inland waters of India. It forms a capture fishery of great value in the Ganga river system, apart from being one of the important species on which a valuable culture fishery of the country is based.

An authentic method of age estimation of mrigal is useful in solving basic life-history problems of the species and is an essential prerequisite for understanding the population dynamics of the fish. The use of scales for estimation of age has met with varying degrees of success in India (Seshappa and Bhimachar 1954; Pillay 1958; Pillay and Rao 1962; Pantulu 1956; Jhingran 1957 and 1959; Natarajan and Jhingran 1963).

Jhingran (1959) established the validity of scales as suitable age indicators in *C. mrigala* from the river Ganga at Buxar (Bihar). This paper presents the results of further studies on the age determination of mrigal by means of scales, establishing their utility as age indicators in a population of the species of river Yamuna at Allahabad. The validity of scales of mrigal as age indicators of the fish is established by correlation of lengths at different ages derived from scales and from length-frequency data analysis; further refined by dissecting polymodal length-frequency distributions adopted by Harding (1949) and Cassie (1954) and used by Pantulu (1961 and 1962). The growth equation has been derived and parameters worked out to fit the equation of yield/recruit on the lines developed by Beverton and Holt (1957).

MATERIAL AND METHODS

The material for the present study was drawn from the commercial catches landed at Sadiapur fish assembly centre, Allahabad. This assembly centre, situated on the bank of river Yamuna, is mainly fed by the catches of the same river. While collecting the scales of the fish and recording length measurements, particular care was taken to avoid specimens from other sources. These investigations were commenced in September 1962 and continued through December 1964. In this study while 16,439 specimens of mrigal representing all size-age-groups were measured for length-frequency studies, 850 scales from 278 specimens, ranging from 83–965 mm in total length, were used for ageing by scales. The scales taken for this study were picked up from the region directly below the dorsal fin and above the lateral line. They were first washed in tap-water for about an hour and then scrubbed between the thumb and fingers in water, taking care not to damage the delicate margins. They were dried on a neat blotting paper. The scales at this stage became quite clean and translucent and were immediately mounted in between two-glass slides with both the remote ends of the slides fastened with a sticking tape.

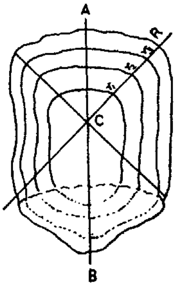


FIG. 1. Diagrammatic representation of a scale showing annuli and the axis of measurements (*CR*).
(*AB*—line of bilateral symmetry; *C*—focal point; r_1, r_2, r_3—annuli).

The examination of the scales then followed under a photographic enlarger magnifying the scales to 6·3 times its actual size. The distances from scale focal points to different rings on the scale surface were measured and recorded by placing millimeter graph paper strips directly over the scale images under the enlarger after sharply focusing the same thereon.

For determining the focal point of the scale, its image was first projected as stated above and the point of intersection of two straight lines, at right angles to each other, extending from the two shoulders of the scale to their diagonally posterior ends was ascertained. This is illustrated diagrammatically in Fig. 1. On all scales of regular shape this angle was always found to be 45°. While plotting the magnified dimensions of the scales, against the body lengths, they were reduced to the exact size by dividing the measured values with the magnification.

The length-frequency analysis was done by seriating the data into 20 mm class intervals and the multimodal polygons were dissected using arithmetical probability paper by the method described by Harding (1949) and Cassie (1954). Lengths attained by the fish at the time of formation of the various annuli were back calculated for each specimen individually using the formula:

$$Y = b_1X+c$$

(where Y is the scale radius and X is the length of the fish, b_1 and c being the constants).

The logarithmic transformation was also attempted but as the above stated direct algebraic formula gave better results (*vide* Table I) it was adopted.

AGE AND GROWTH

Age determination from scales.—Elucidation of growth history of a fish from the measurements of a skeletal part depends upon the existence of a high correlation between growth of the part concerned and the growth of the entire body. The coefficient of correlation between scale length and fish length was found to be +0·99.

The nature of growth rings on mrigal scales and the time of annulus formation.—As found by Jhingran (1959), the present study also shows the presence of varying number of rings on scales of different sizes, their number proportionally increasing in large fish and vice versa (Plates I, II and III). The distance between adjacent rings also progressively decreases as the fish size increases. The nature or type of rings was, however, not described by Jhingran (1959), though their annual nature was established by him. Certain rings on the scales of mrigal from the Yamuna were found to be annuli, as is established later in this paper, and they may be described as consisting of relatively broad grooves or depressions lying between adjacent circuli running all round the scale (except at the posterior end) preceded by closely packed circuli and followed by relatively more widely spaced ones. The significance of closely packed circuli preceding and widely spaced ones following the annulus has been pointed out by Robertson (1933). According to him, there are concentric folds on the scale surface corresponding to the position of the rings, and owing to perspective the circuli appear to lend or kink when crossing these folds. This happens in such a way that they seem to become first relatively closely approximated and then relatively widely separated, giving

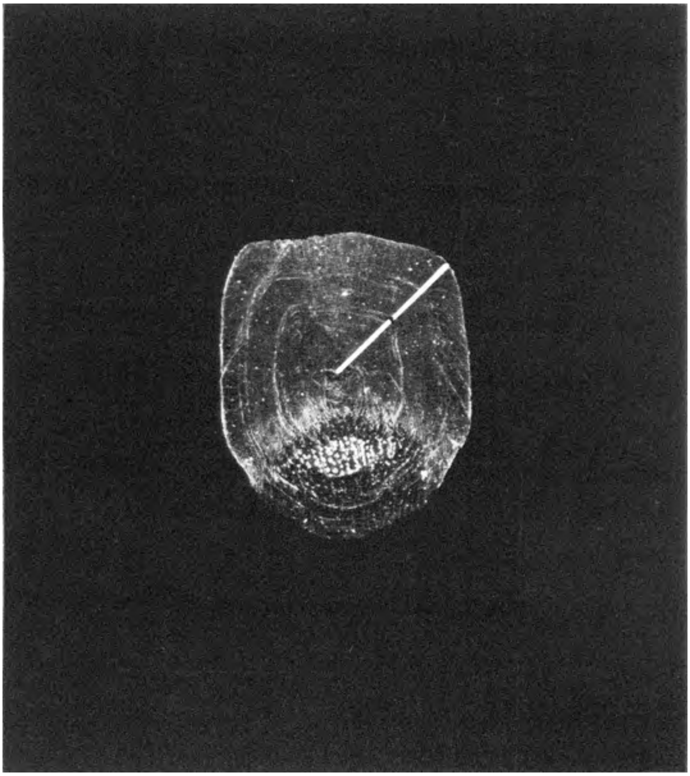
TABLE I

Size-frequency distribution of stunted specimens of mrigal up to three years of age as revealed by scale study

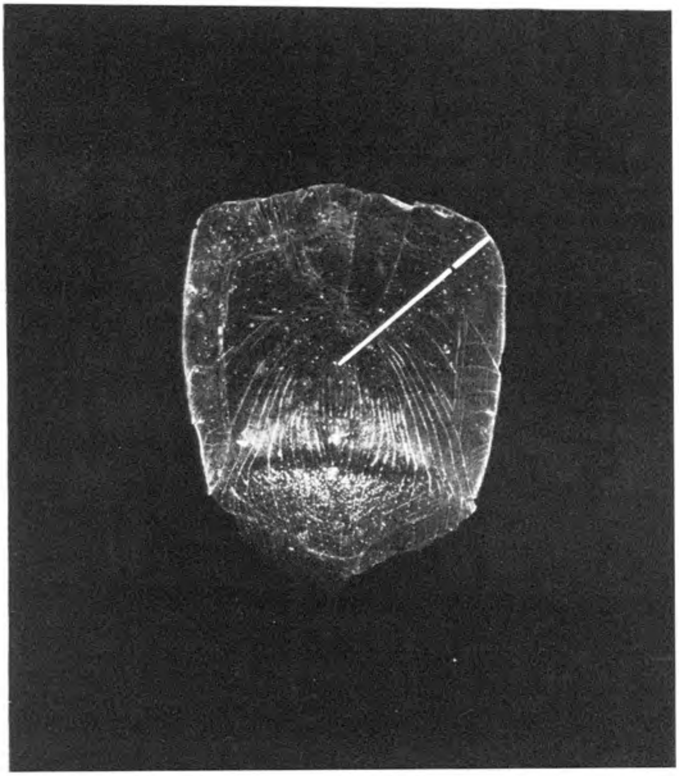
Class-range in mm	Number of completed annuli		
	I	II	III
101–120	15	—	—
121–140	22	—	—
141–160	21	—	—
161–180	20	—	—
181–200	21	—	—
201–220	5	—	—
221–240	1	—	—
241–260	—	—	—
261–280	—	—	—
281–300	—	—	—
301–320	—	2	—
321–340	—	10	—
341–360	—	25	—
361–380	—	16	—
381–400	—	19	—
401–420	—	5	—
421–440	—	—	—
441–460	—	—	—
461–480	—	—	—
481–500	—	—	—
501–520	—	—	3
521–540	—	—	5
541–560	—	—	13
561–580	—	—	12
581–600	—	—	11
Total	105	77	44
Average lengths in mm	156·3	367·2	559·6

by contrast the effect of a transparent zone. Molander (1946) has observed that transparent zones are preceded by concentric bands of closely approximated circuli. According to him, the transparent zones really represent the beginning of faster growth, whereas the zone of diminished growth is represented by the concentric band of closely packed circuli just inside the transparent zone. Annuli of similar nature have been observed by Fage (1913), Savage (1919), Tchougounova (1940), Blackburn (1949), Natarajan and Jhingran (1963) and Jhingran (unpublished).

Jhingran (1959) has mentioned about the presence in mrigal scales of accessory checks, which he found misleading in age estimation. The present paper traces their probable cause of formation and clears up the confusion caused by the presence of such false rings. Two types of rings, termed here as false rings, were met with in the present study, namely (1) those which were not continuous all round the scale (except at the posterior end) and (2) those which appeared like compactly deposited circuli. The false rings of the second type are encountered at various points in specimens up to 600 mm in total length. If these false rings, which were commonly encountered in specimens measuring up to 240 mm, are given the status of annuli, the average size of mrigal on completion of about a year's growth would be 156·3 mm only. For considerable time in these investigations, interpretation of these false rings baffled progress in work until it was discovered that the specimens showing such false rings were encountered only during the spring and early summer months, in relatively smaller numbers, and that they were actually

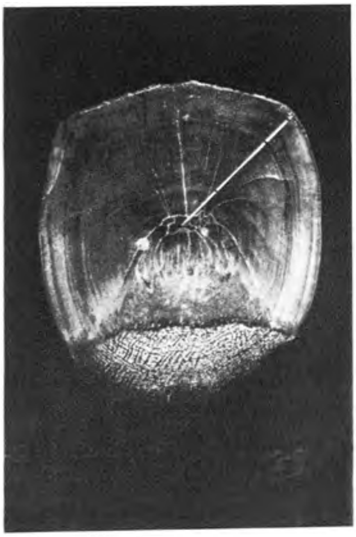


Scale radius: 4·0 mm.
Total length of fish: 217 mm. Date of collection: 2-3-64.
Shows one false ring.



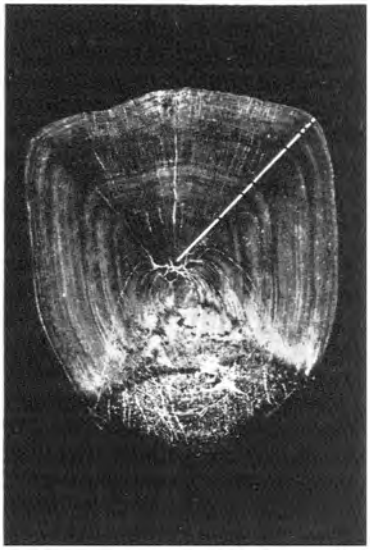
Scale radius: 7·1 mm.
Total length of fish: 372 mm. Date of collection: 20-11-63.
Shows one age-ring.

Scale radius: 8·2 mm.
Total length of fish: 493 mm.
Date of collection: 13-1-64.
Shows two age-rings.



Scale radius 17·1 mm.
Total length of fish: 760 mm.
Date of collection: 31-3-64.
Shows four age-rings.

Scale radius: 16·7 mm.
Total length of fish: 815 mm.
Date of collection: 2-5-64.
Shows five age-rings.



Scale radius: 19·7 mm.
Total length of fish: 903 mm.
Date of collection: 27-9-63.
Shows seven age-rings.

Scale radius: 21·9 mm.
Total length of fish: 955 mm. Date of collection: 9-7-63.
Shows eight age-rings.

collected from isolated river pools, which are generally intensively fished during the above period. There is little doubt that the isolated pools, on sandy river-bed, are deficient in fish food and that the specimens in question were actually the stunted progeny of the previous year's brood. These specimens, in contrast with those dwelling in the main stream, are really insignificant numerically. In support of this contention it may be stated that it is a well-known fact in knowledgeable fishery circles in India that the fingerling collections, made in autumn months practically throughout the country, overwhelmingly represent the fish of the year, the breeding season being May–August. Further, the stunted specimens referred to above are probably the late brood of the year-class concerned. The formation of isolated pools on river-bed and their getting fished in spring and early summer is an annually recurring feature of the riverine fishery. The fish contained therein may belong to different year-classes and this explains the occurrence of false rings showing the sizes of one-, two- and three-year-old specimens to average at 156·3, 367·2 and 559·6 mm as shown in Table I. The subsequent occurrence of these specimens, stunted in growth during the first year of life was, however, not traceable beyond the third-year class, due to their progressive decrease in number to the extent of becoming negligible. By the removal of these specimens from the main body of the data on growth, the rest of the growth picture is easily elucidated and is presented in the following section of this paper.

For ascertaining the time when the rings are laid down on the scales of mrigal, the scales showing rings at the margin or very close to it were studied and their percentage of frequency calculated during different months. It was observed that maximum number of scales with marginal rings were found in the early summer months (March to April) (Fig. 2) indicating thereby that the

FIG. 2. Histogram showing the percentage of scales with marginal rings during different months.

rings are mainly laid down during this period. Jhingran (1959) found starvation as the main causative factor for the appearance of annuli on the scales of mrigal from river Ganga at Buxar, and mentioned March to June as the period of ring formation. If these were true, then the sizeable percentage of mrigal scales with marginal rings in the month of July (Fig. 2) may well be explained by the fact that during this month the plankton population in the river declines considerably (Chakrabarty *et al.* 1959 and Pahwa and Mehrotra 1966), thus causing a retardation in growth of the fish for want of required nutrition in the environment.

Relationship between scale radius and fish lengths.—Scale measurements of fish are often used to calculate the growth over periods of time previous to the time of capture. Most fishes show a high correlation between the growth of the body and the growth of the scales, and the relationship is usually linear. In some fishes, though the relationship appears to be non-linear, it is usually regarded as sufficiently nearer to linearity to be treated as such. Such an assumption of a linear relationship between body length and scale length makes it fairly simple to back calculate the growth of the fish. Thompson (1923) found for North Sea haddock a proportional relation which yielded a straight-line fit. Those who have noted the existence of a curvilinear relationship, often found that the scale growth decreased as the fish became larger. Wise (1957), while studying the growth rate of Browns Bank haddock, found a straight-line relation from smallest scale length up to about 3·5 mm scale length or about 510 mm fish length and there was strong evidence that the scale growth increased with increasing fish size after a certain critical size was reached. Jhingran (1959) did not find a rectilinear relationship between scale radii and body lengths in mrigal from Ganga at Buxar, but observed that two or more straight lines or a curve fitted to the points would better describe scale-body relationship. Natarajan and Jhingran (1963) observed in catla that the fish lengths are not in direct proportion, but their increments are.

Fig. 3 presents the scatter diagram on an arithmetic plot of observations on the total lengths of mrigal from Yamuna at Allahabad ranging from 83 mm to 965 mm plotted against corresponding scale radii ranging between 1·7 and 24·0 mm. The relationship between the fish lengths and scale radii in this case can be best explained by fitting a straight line to the points. The relationship could be expressed by the regression formula:

$$Y = 0{\cdot}02108\,X + 0{\cdot}0387$$

where Y is the scale radius and X is the total length of the fish. The correlation coefficient (r) for this regression is calculated to be $+0{\cdot}99$. Thus a direct proportion has been accepted from the practical fisheries point of view which is justified by the occurrence of a high coefficient of correlation ($+0{\cdot}99$) between the scale radii and fish lengths found in Yamuna mrigal at Allahabad.

In a similar study on Ganga mrigal from Buxar, Jhingran (1959) found the value of r to be $+0{\cdot}96$ whereas in the case of catla the value of r was found to be $+0{\cdot}99$ by Natarajan and Jhingran (1963).

When the establishment of proportional relationship between the scale radii and fish lengths has been accomplished and the annual nature of the rings found to be definite in the case of true rings, each of these 'checks' was taken to indicate a year's growth. The intermediate lengths were back calculated, in all cases, by the application of the formula mentioned above and the mean values were taken to represent the lengths at different ages and shown in Table II and in column 2 of Table III. Other characters stated in the table are described later in this paper.

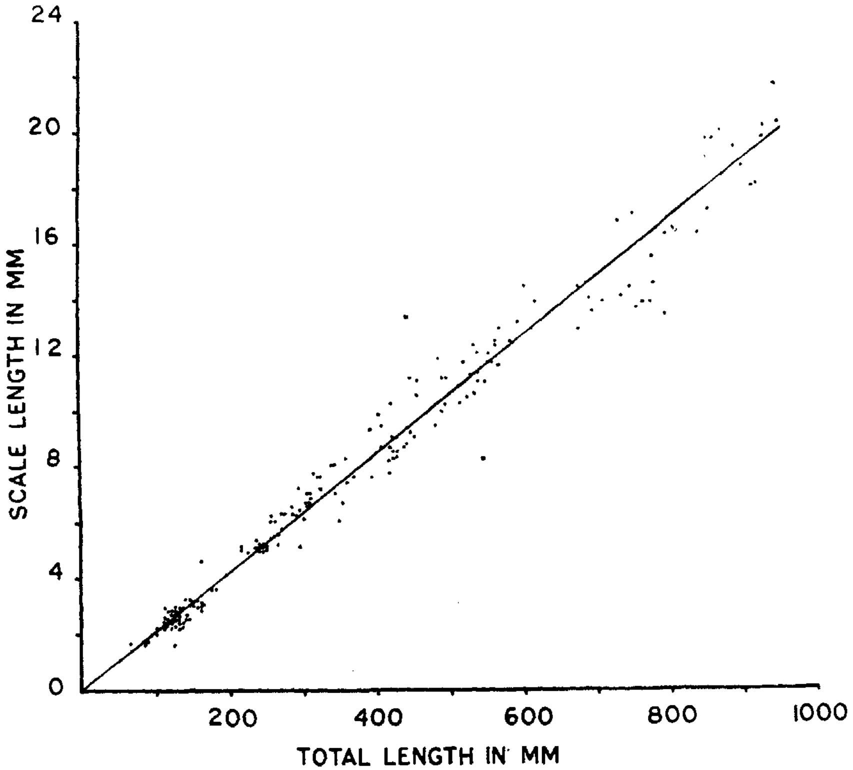


FIG. 3. Relationship between scale radius and total length. Points represent the scatter of observed values.

The mean lengths as back calculated at ages from I to VIII years were estimated to be 268·0, 458·4, 644·2, 736·1, 816·7, 867·1, 924·0 and 958·6 mm respectively.

Empirical growth curve.—On the basis of the results obtained by the scale studies and the length-frequency methods (Table III), it is observed that the growth in mrigal is most rapid during the first four years of its life; first year

TABLE II

Size-frequency distribution of mrigal of various ages as revealed by scale study

Class-range in mm	Number of completed annuli							
	I	II	III	IV	V	VI	VII	VIII
201–220	11	—	—	—	—	—	—	—
221–240	17	—	—	—	—	—	—	—
241–260	18	—	—	—	—	—	—	—
261–280	11	—	—	—	—	—	—	—
281–300	29	—	—	—	—	—	—	—
301–320	17	—	—	—	—	—	—	—
321–340	4	—	—	—	—	—	—	—
341–360	—	—	—	—	—	—	—	—
361–380	—	—	—	—	—	—	—	—
381–400	—	—	—	—	—	—	—	—
401–420	—	5	—	—	—	—	—	—
421–440	—	13	—	—	—	—	—	—
441–460	—	17	—	—	—	—	—	—
461–480	—	13	—	—	—	—	—	—
481–500	—	14	—	—	—	—	—	—
501–520	—	2	—	—	—	—	—	—
521–540	—	1	—	—	—	—	—	—
541–560	—	—	—	—	—	—	—	—
561–580	—	—	—	—	—	—	—	—
581–600	—	—	—	—	—	—	—	—
601–620	—	—	4	—	—	—	—	—
621–640	—	—	4	—	—	—	—	—
641–660	—	—	11	—	—	—	—	—
661–680	—	—	2	—	—	—	—	—
681–700	—	—	1	3	—	—	—	—
701–720	—	—	—	2	—	—	—	—
721–740	—	—	—	7	—	—	—	—
741–760	—	—	—	5	—	—	—	—
761–780	—	—	—	4	2	—	—	—
781–800	—	—	—	—	3	—	—	—
801–820	—	—	—	—	2	—	—	—
821–840	—	—	—	—	2	1	—	—
841–860	—	—	—	—	3	3	—	—
861–880	—	—	—	—	1	2	—	—
881–900	—	—	—	—	—	3	—	—
901–920	—	—	—	—	—	—	3	—
921–940	—	—	—	—	—	—	2	1
941–960	—	—	—	—	—	—	2	—
961–980	—	—	—	—	—	—	—	4
Total	107	65	22	21	13	9	7	5
Average lengths in mm	268·0	458·4	644·2	736·1	816·7	867·1	924·0	958·6

TABLE III

Comparison of mean lengths of C. mrigala *in mm at various ages as estimated by different methods*

Age in years	Length-at-age (scale method) (mm)	Length-at-age (Petersen's method) (mm)	Length-at-age (probability method) (mm)	von Bertalanffy's fit (mm)
I	268·0	260·0	240·0	276·4
II	458·4	470·0	471·0	473·9
III	644·2	600·0	620·0	622·8
IV	736·1	740·0	775·0	732·4
V	816·7	840·0	842·0	815·0
VI	867·1	890·0	898·0	876·8
VII	924·0	920·0	—	923·0
VIII	958·6	940·0	948·0	957·5
IX	—	960·0	—	—

having maximum growth, as also observed by Jhingran (1959) in mrigal from Ganga at Buxar. The gradual decrease in growth rate is observed during later years until a limiting value of total length (ultimate length) is approached. The increments in length and rate of increment in length per year, calculated individually for each of the eight years of life, are given in Table IV (Fig. 4).

TABLE IV

Annual growth increments and growth rate per year of mrigal in length

Duration between checks	Growth increment in mm	Growth per month in mm	Per cent of total growth (relative growth)
0–I	268	29·8	27·95
I–II	190	15·8	19·82
II–III	186	15·5	19·40
III–IV	92	7·7	9·60
IV–V	81	6·8	8·45
V–VI	50	4·2	5·22
VI–VII	57	4·8	5·95
VII–VIII	35	2·9	3·65

Fitting of the von Bertalanffy growth equation.—The use of mathematical expressions in fitting growth curves is particularly advantageous in interpolation and extrapolation, in addition to their utility in production computations (Pantulu 1962). von Bertalanffy's growth equation (1938, 1949 and 1957), based on the concept of growth as the net result of interaction of the process of anabolism and catabolism, gives a curve of growth in length which fits well the growth rates of many species of fish (Beverton 1954; Beverton and Holt 1957). The equation thus obtained gives a linear relation between length at time t and at time $t+x$ and is written as follows:

$$l_t = l\infty(1-e^{-k(t-t_0)})$$

where l_t = length at age t; $l\infty$ = asymptotic length; e = base of the Naperian logarithm; k = coefficient of catabolism; t = age of fish; t_0 = arbitrary origin of the growth curve.

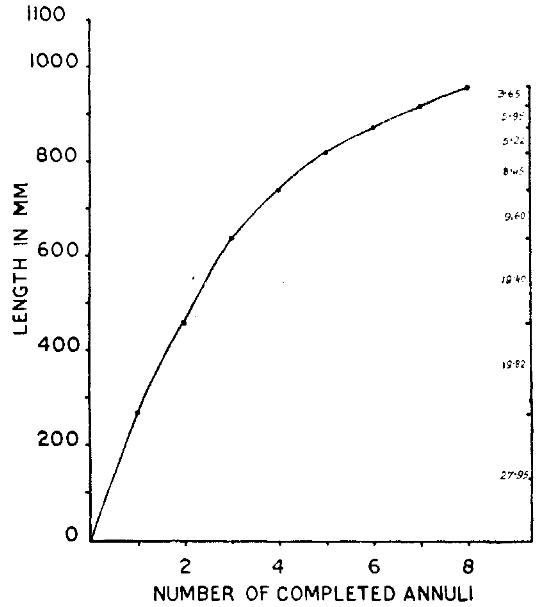


FIG. 4. The growth curve in length of mrigal in the first eight years of its life showing also the rate of growth and the percentage of the total of eight years' growth during each individual yaer.

To fit this growth equation to the length at age data it is written in the following form:

$$l_t+1 = l\infty(1-e^{-k})+l_te^{-k}$$

when l_t+1 is plotted against l_t a graph well represented by a straight line is obtained. A straight line is drawn which passes through most of the points, from the resultant slope, $k(=e^{-k})$, has been estimated, whereas the point of intersection of this straight line with the bisector drawn through the origin (Fig. 5) gave the value of $l\infty$ (Walford, 1946). The estimated value of these parameters is as under:

$$l\infty = 1060\,;\; k = -0{\cdot}290649$$

t_0 was estimated by plotting $\log_e(l\infty-l_t)$ against age (Fig. 6). The value of t,

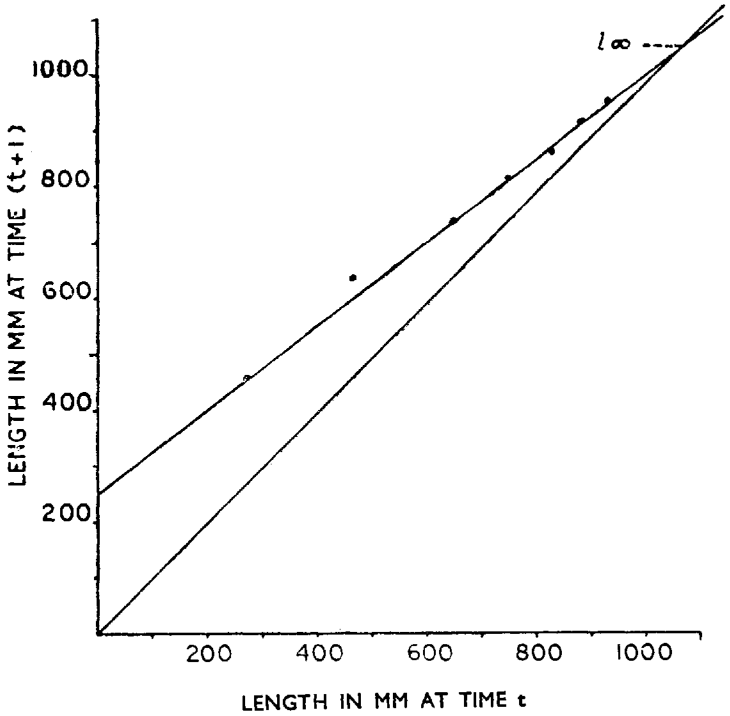


FIG. 5. Ford-Walford plot of growth of mrigal; sizes at age t plotted against sizes at age $t+1$ showing the ultimate length attained by the fish.

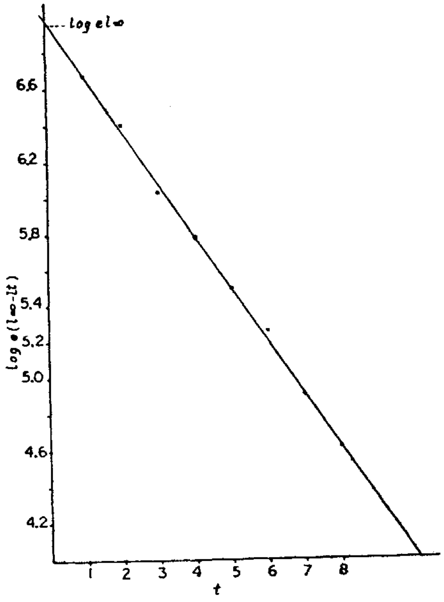


FIG. 6. $\log_e (l_\infty - lt)$ plotted against age to determine t_0.

where it has an ordinate of 1, gave the estimate of t_0 (Beverton 1954). Thus t_0 was calculated to be

$$t_0 = 0{\cdot}03964.$$

Substituting the values of $l\infty$, k and t_0 in the above equation the von Bertalanffy growth equation for mrigal can be expressed as

$$l_t = 1060(1 - e^{0{\cdot}29065(t - 0{\cdot}03964)}).$$

The theoretical lengths at different ages as calculated by this growth equation (Table V) showed a high degree of agreement with lengths at ages calculated both by scale studies and length-frequency studies (Table III, Fig. 7).

Table V

Lengths (mm) at different ages of mrigal as calculated by von Bertalanffy growth equation

Age in years	Length	Increments in length
I	276·4	276·4
II	473·9	197·5
III	622·8	148·9
IV	732·4	109·6
V	815·0	82·6
VI	876·8	61·8
VII	923·0	46·2
VIII	957·5	34·5

Comparison of calculated and empirical scale radii.—Comparison between calculated values of scale radii of mrigal with their observed values shows a very high degree of agreement (Table VI). The value of the scale radii is represented by Y in this manuscript. The percentage difference between the actual and calculated Y amounted to a minimum of 1·16 per cent and a maximum of 19·11 per cent. Scale radii from 80 fishes (42·11 per cent) showed a difference up to five per cent, another 80 fishes (42·11 per cent) had a difference of 5–10 per cent, scale radii from 10 fishes (5·26 per cent) differed 10–15 per cent and those of the remaining 19 fishes (10·23 per cent) differed from over 15–20 per cent. Thus, out of 189 fishes whose scales were examined, 160 fishes (84·22 per cent) showed a very negligible difference of 5–10 per cent between their observed and calculated values of scale radii and only 29 fishes (15·79 per cent) revealed a difference of over 10–20 per cent, thus showing a very good amount of agreement between the two values of scale radii of mrigal.

Agreement with Petersen's method.—Petersen's method is based on length-frequency distributions of fish. It assumes that each age class is distributed normally and that in a total length-frequency curve of distribution of all ages of fish contained in the population, the various year classes will appear as individual modes. In practice, Petersen's method must be used cautiously (Perlmutter 1954). He further mentions that, in actual practice, most of the length-frequency curves for an age-group that he examined are not normal in distribution, but have slight tendency towards negative skewness. This method has been inadequate in animals with prolonged or discontinuous breeding because of the resultant overlapping or multiplicity of modes.

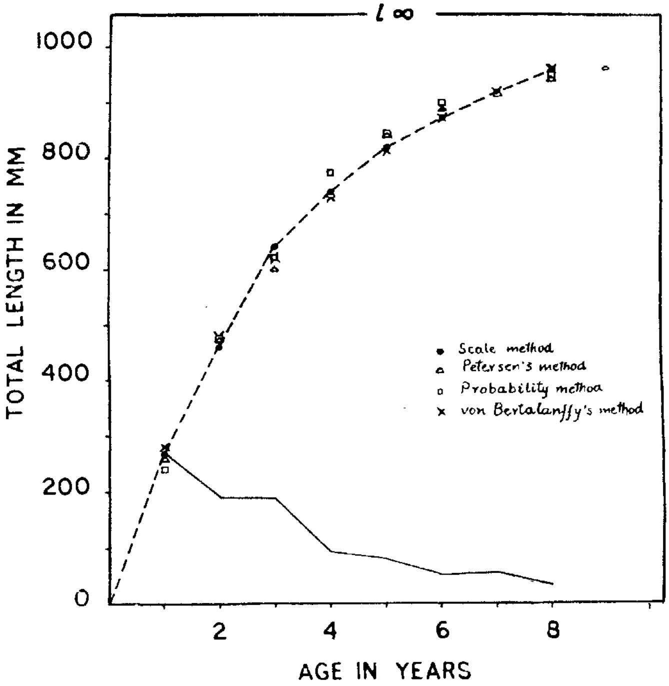


FIG. 7. A comparative depiction of lengths at ages of mrigal as computed by different methods. The solid line represents the length increments.

Mrigal, as in other major carps, has a specific breeding season conditioned by the South-West monsoon. The validity for the use of hard parts for age determination can be ascertained by the agreement with Petersen's method. In mrigal, as in other fishes with a single spawning season, the individual lengths of each age-group are approximately normally distributed and the modes of successive age-groups in the length-frequency distributions in the samples are separated along the length axis.

An over-all picture of growth of mrigal has been obtained by the study of its scales. The analysis of the length-frequency data for the years 1962, 1963 and 1964, comprising of the measurements of 16,439 specimens, corroborates the results of growth of this species delineated by scales. Figs. 8 and 9 show the histograms of the length-frequency distribution for different months and quarters, during the period January 1962 to December 1964, which enabled the tracing of modes and elucidation of growth picture.

Analysis of data for the year 1962.—7,833 specimens were examined for length-frequency studies from January to December. The modes at 100 mm in October, 120 mm in November and 240 mm in April represent the fish of the year (zero group). The peaks at 260 mm in June-July, approximately 300 mm in September–November, 380 mm in December and 420 mm in March and May are interpreted to be representing the first-year group and at 480 mm in June, 500 mm in July, 540 mm in September, 560 mm in October-November as representing the second-year group. The modes at 620 mm in June, about 640 mm in July, 660 mm in August–October, 680 mm in December, 700 mm and 720 mm in March and April respectively represent the third-year group and at 800 mm in February-March, 780 mm in October and 760 mm in June are caused by the fourth-year group.

TABLE VI

Differences between the empirical and calculated radii of scales of mrigal

Scale No. N	Fish length X	Scale radius Y	Calculated $\bar{\bar{Y}}$	Per cent difference between Y and $\bar{\bar{Y}}$
5	101	1·9886	2·1679	9·02
15	116	2·5455	2·4841	2·41
25	124	2·8636	2·6527	7·36
35	133	2·3864	2·8425	19·11
45	151	3·1023	3·2219	3·86
55	184	3·5796	3·9176	9·44
65	245	4·9318	5·2035	5·51
75	262	5·4886	5·5619	1·34
85	305	6·6818	6·4684	3·19
95	344	7·0000	7·2906	4·15
105	395	9·3068	8·3657	10·11
115	427	8·5909	9·0403	5·23
125	460	10·5796	9·7360	7·97
135	529	10·6591	11·1905	4·99
145	564	11·7727	11·9284	1·32
155	626	14·0000	13·2354	5·46
165	765	13·8409	16·1657	16·80
175	848	16·5455	17·9154	8·28
185	938	20·0455	19·8127	1·16

$b_1 = 0{\cdot}021081;\ c = 0{\cdot}0387.$

Probably due to the indiscriminate exploitation of younger age-groups many fishes are not allowed to attain bigger sizes, resulting in a very scanty representation of those higher age-groups in the commercial landings. This

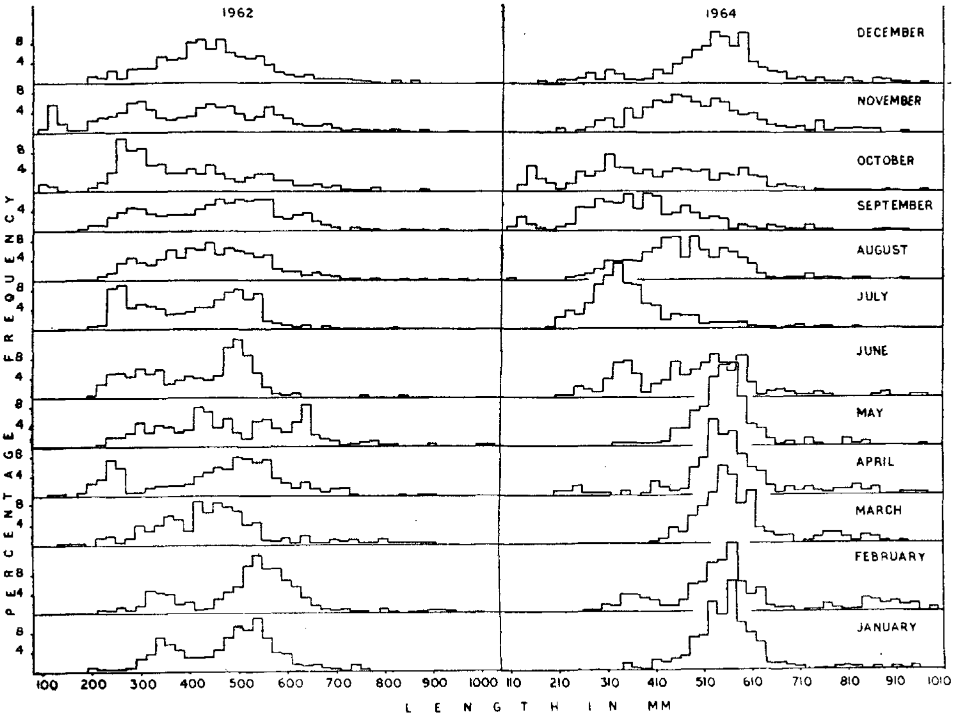


FIG. 8. Histograms of the length-frequency distribution of mrigal, pooled for corresponding months of the years 1962 and 1964.

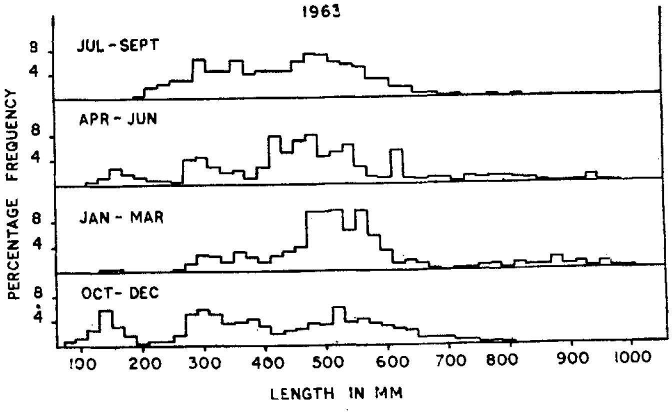


FIG. 9. Histograms of the length-frequency distribution of mrigal, pooled for the corresponding quarters of the year 1963.

leads to error in sampling, hence the progression of modes in older age-class became extremely poor.

Analysis of data for the year 1963.—4,306 specimens formed the basis of length studies during 1963. In quarterly pooled data the prominent modes at 140 mm in October–December and 180 mm in April–June represent the zero group. The first-year group appears in July–September in 300 mm and 360 mm, at 320 and 380 mm in October–December, at 300 and 360 mm in January–March and at 320, 380 and 440 mm in April–June. The peaks at 480 mm in July-August, 480, 520 and 560 mm in October–March, 500 and 560 mm in April–June are caused by the second-year group. The modes in 640 mm class in January–June are caused by group three. The peaks in 720 and 780 mm class in July-August, 780 mm class in January–March and 760 mm in April–June represent group four. Representation of still higher groups became scanty and groups five, six and eight are represented by peaks in 880, 920 and 960 mm class during January–March whereas during April–June only group six is shown by a mode at 960 mm.

Analysis of data for 1964.—4,300 specimens were measured during the year and the monthly progression of modes was studied for all the 12 months. Fish of the year consistently show up in a series of peaks at the extreme left of the histograms for August, September, October and December. Fish of the first-year group appear in modes of histograms in January-February, April and June–December, whereas group II peaks are found all the year round. Fish in group III are prominent in modes during February–July and October–December. Group IV is represented by modes of histograms during February–June, September and November-December. Group V is traceable in January–May and then again during December, whereas the sixth group can be located only during February and June. The fifth- and sixth-year classes are detectable by modes of a lower magnitude and were not encountered so frequently. Beyond this the continuity of the data is completely broken.

Putting together the results obtained by length-frequency analysis of these 16,439 specimens during the three years, the growth picture of mrigal emerges clearly as shown in Table III. Table VII presents a pooled length-frequency distribution for the corresponding months of all the three years.

The probability paper method (Harding 1949 and Cassie 1954) was also utilized for separating the various age-groups from the polymodal-frequency distributions and the results obtained by this analysis are expressed in Table III. It has been revealed beyond doubt that there is a high degree of agreement between the age and growth calculations from the scales by the application of von Bertalanffy growth equation and with the help of length-frequency studies.

TABLE VII

Pooled length-frequency of mrigal (in percentages) for the years 1962, 1963 and 1964. (N = 16439)

Class-range (mm)	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
71–90	—	—	—	—	—	—	—	—	—	0·56	—	—
* 91–110	—	—	—	—	—	—	—	—	0·07	1·53	0·42	0·07
111–130	—	—	—	0·26	—	0·24	—	0·06	0·78	3·34	3·57	0·59
131–150	0·16	0·26	0·16	0·26	—	0·56	0·09	—	0·99	2·36	1·63	3·62
151–170	0·16	—	0·16	—	0·13	1·11	0·05	—	0·14	1·34	0·54	1·64
171–190	—	—	0·16	0·51	—	1·98	0·09	0·11	0·35	1·11	0·54	0·59
191–210	0·31	—	—	1·79	—	1·11	1·18	0·06	0·64	0·74	1·57	0·20
211–230	0·23	0·32	0·63	2·04	0·38	2·14	1·67	1·06	0·92	1·67	1·94	1·12
231–250	0·31	0·32	0·78	4·98	1·01	3·57	5·83	1·28	1·70	2·74	2·30	0·59
251–270	0·39	0·85	0·16	3·45	0·89	3·97	6·51	2·85	3·11	5·66	2·66	1·58
271–290	1·17	0·43	0·63	0·64	1·27	3·33	5·24	3·96	3·11	7·42	4·72	1·45
291–310	2·49	1·28	1·72	0·64	3·67	5·16	6·71	4·69	5·51	8·07	5·63	2·50
311–330	2·80	3·31	1·10	0·89	2·53	5·56	6·37	3·80	4·24	5·29	4·48	2·30
331–350	3·35	2·99	1·25	1·28	2·66	5·56	6·37	4·80	4·31	4·73	3·03	2·37
351–370	4·13	3·42	1·56	1·28	2·15	3·81	5·70	5·97	5·09	3·80	2·97	3·62
371–390	2·88	1·71	1·25	1·28	2·15	3·17	4·66	4·91	4·45	3·57	3·75	3·88
391–410	2·18	2·35	1·88	2·30	1·77	3·17	4·20	6·20	4·59	3·99	3·45	3·88
411–430	2·41	1·39	3·44	2·94	4·43	3·81	3·30	6·76	4·45	3·01	4·66	5·33
431–450	3·27	1·07	3·44	3·32	7·47	3·97	3·84	7·15	6·15	4·08	4·78	5·53
451–470	4·13	2·88	2·35	4·85	4·81	4·84	5·24	5·75	5·37	3·11	4·84	5·07
471–490	7·01	5·45	6·73	4·21	6·08	8·97	6·74	5·53	4·59	3·20	5·15	6·84
491–510	8·10	6·09	7·98	7·66	4·68	10·64	6·56	6·36	5·58	2·64	3·81	6·32
511–530	10·28	9·19	8·92	8·81	5·70	7·06	3·62	5·86	4·66	3·89	3·93	7·11
531–550	10·67	10·26	9·70	9·32	9·40	4·84	4·79	5·47	5·30	2·83	4·36	6·38
551–570	11·84	10·58	8·61	8·68	10·25	2·78	3·16	4·63	6·15	3·71	5·33	6·25
571–590	6·85	8·76	7·36	5·87	5·82	2·38	2·71	2·79	2·61	2·74	3·99	5·00
591–610	5·14	6·09	5·63	3·70	3·29	1·43	1·58	2·29	3·18	2·64	3·09	4·28
611–630	2·65	4·38	3·44	3·32	3·16	1·03	0·63	1·95	1·98	2·04	2·66	2·76
631–650	2·02	2·78	1·56	3·70	5·32	0·71	0·90	1·00	1·98	1·58	1·63	1·45
651–670	1·09	1·39	2·35	1·40	1·52	0·48	0·36	1·17	1·34	1·39	1·45	1·64
671–690	0·78	0·75	1·25	0·77	1·01	0·40	0·45	0·73	0·92	1·34	1·15	0·72
691–710	0·55	0·32	1·10	1·79	0·63	0·32	0·23	0·61	0·85	1·11	1·09	0·59
711–730	0·23	0·53	0·47	1·53	0·76	—	0·27	0·28	0·49	0·46	0·54	0·72
731–750	0·62	0·32	0·78	0·64	0·89	0·24	0·14	0·33	0·71	0·51	0·85	0·53
751–770	0·23	0·64	2·03	0·51	0·89	0·32	—	0·11	0·49	0·28	0·61	0·46
771–790	0·16	0·32	1·41	0·38	1·01	0·08	0·18	0·22	0·78	0·56	0·24	0·66
791–810	0·31	0·53	1·41	0·64	0·76	0·16	0·09	0·18	0·28	0·23	0·30	0·33
811–830	0·23	0·43	1·56	1·02	0·76	0·16	0·05	0·11	0·42	0·19	0·54	0·07
831–850	0·23	0·53	1·25	1·28	0·38	0·24	0·14	0·11	0·25	—	0·36	0·39
851–870	0·08	1·28	1·10	0·64	0·25	—	0·18	0·11	0·28	—	0·30	0·13
871–890	0·08	2·03	1·41	0·38	0·13	0·32	—	0·11	0·14	0·23	0·42	0·59
891–910	—	0·96	0·94	0·13	0·38	—	—	0·06	0·28	0·09	0·18	0·46
911–930	0·16	1·60	0·47	—	0·13	0·08	0·05	0·18	0·07	0·05	0·12	0·13
931–950	0·31	0·85	0·31	0·26	0·25	0·08	0·08	0·11	0·21	0·09	0·12	0·13
951–970	—	0·96	0·94	0·64	0·63	0·16	0·05	0·22	0·14	0·09	0·24	—
971–990	—	0·32	0·47	—	0·13	0·08	—	0·06	0·14	—	—	0·07
991–1010	—	0·32	0·16	—	0·25	—	—	—	0·07	—	—	0·07
1011–1030	—	—	—	—	0·13	—	—	—	—	—	—	—
Number sampled	1284	936	639	783	790	1260	2212	1791	1415	2157	1652	1520

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REFERENCES

Beverton, R. J. H. (1954). Notes on the use of theoretical models in the study of the dynamics of exploited fish populations. *Misc. Contr. biol. Lab., Beaufort,* No. **2**, 181 pp. Mimeo.

Beverton, R. J. H., and Holt, S. J. (1957). On the dynamics of exploited fish populations. *Fishery Invest. Lond.,* Ser. II, **29**, 32.

Blackburn, M. (1949). The age, rate of growth and general life-history of the Australian pilchard (*Sardinops neopilchardus*) in New South Wales waters. *Commonw. Sci. Industr. Res. Aust., Bull.,* No. **242**, 9–86.

Cassie, R. M. (1954). Some uses of probability paper in the analysis of size-frequency distributions. *Aust. J. mar. Freshw. Res.,* **5**, 515–22.

Chakrabarty, R. D., Roy, P., and Singh, S. B. (1959). A quantitative study of the plankton and the physico-chemical conditions of the river Jumna at Allahabad in 1954-55. *Indian J. Fish.,* **6**, 186–203.

Fage, L. (1913). Resherches Sur la biologie de la sardine sur la eroissance et l'age des individus, principalement en Mediterrance. *Arch Zool. exp. gén.,* **52**, 305–41.

Harding, J. P. (1949). The use of probability paper for the graphical analysis of polymodal-frequency distributions. *J. mar. biol. Ass. U.K.,* **28**, 141–53.

Jhingran, A. G. (Unpublished, 1966). Studies on the biology and fisheries of the clupeoids, *Setipinna phasa* (Hamilton) and *Gudusia chapra* (Hamilton) in the Ganga river system. (D. Phil. Thesis, University of Allahabad.)

Jhingran, V. G. (1957). Age determination of the Indian major carp *Cirrhina mrigala* (Ham.) by means of scales. *Nature, Lond.,* **179**, 468-69.

———— (1959). Studies on the age and growth of *Cirrhina mrigala* (Ham.) from the River Ganga. *Proc. natn. Inst. Sci. India,* B **25**, 107–37.

Molander, A. R. (1946). The winter rings in the scale of the sprat. *Svensk. Hydrog.-biol. Komm. Skr.,* **6**, 1–16.

Natarajan, A. V., and Jhingran, A. G. (1963). On the biology of *Catla catla* (Ham.) from the River Jumna. *Proc. natn. Inst. Sci. India,* B **29**, 326–55.

Pahwa, D. V., and Mehrotra, S. N. (1966). Observations on fluctuations in the abundance of plankton in relation to certain hydrological conditions of river Ganga. *Proc. natn. Acad. Sci. India,* Sec. B, **36**, 157–89.

Pantulu, V. R. (1956). Studies on the biology of Indian freshwater eel, *Anguilla bengalensis* Gray. *Proc. natn. Inst. Sci. India,* B **22**, 259–80.

———— (1961). Determination of age and growth of *Mystus gulio* (Ham.) by the use of pectoral spine, with observations on its biology and fishery in Hooghly estuary. *Proc. natn. Inst. Sci. India,* B **22**, 198–235.

———— (1962). On the use of pectoral spines for the determination of age and growth of *Pangasius pangasius* (Hamilton Buch). *J. Cons. perm. int. Explor. Mer.,* **27**, 192–216.

Perlmutter, A. (1954). Age determination of fish. *Trans. N.Y. Acad. Sci.,* **16** (6), 305–11.

Pillay, T. V. R. (1958). Biology of the Hilsa, *Hilsa ilisha* (Hamilton) of the River Hooghly. *Indian J. Fish.,* **5**, 201–57.

Pillay, S. R., and Rao, K. V. (1962). Observations on the biology and fishery of the Hilsa, *Hilsa ilisha* (Hamilton) of the River Godavari. *Proc. Indo-Pacif. Fish. Coun.,* 10th Session, Section II, 37–61.

Robertson, J. A. (1933). Notes on the optical appearance of winter rings in some clupeoid scales. *J. Cons. perm. int. Explor. Mer.*, **8**, 357–70.

Savage, R. E. (1919). Report on the age determination from scales of young herrings, with special reference to the use of polarized light. *Fishery Invest., Lond.*, (2), **4** (1), 1–31.

Seshappa, G., and Bhimachar, B. S. (1954). Studies on the age and growth of the Malabar sole, *Cynoglossus semifasciatus* Day. *Indian J. Fish.*, **1**, 145–62.

Tchougounova, N. I. (1940). Methods of growth studies of *Caspialosa saposhnikovi* (Grimm). *Trans. Inst. mar. Fish. Oceanogr., U.S.S.R.*, **14**, 21–46 (*in Russian*, English summary).

Thompson, H. (1923). Problems of haddock biology, with special reference to the validity and utilization of the scale theory. *Scient. Invest. Fishery Bd. Scotl.* 1922, No. **5**.

von Bertalanffy, L. (1938). A quantitative theory of growth (Inquiries on growth laws II). *Hum. Biol.*, **10** (2), 181–213.

——— (1949). Problems of organic growth. *Nature, Lond.*, **163**, 156–58.

——— (1957). Quantitative laws in metabolism and growth. *Q. Rev. Biol.*, **32**, 217–31.

Walford, L. A. (1946). A new graphic method of describing the growth of animals. *Biol. Bull. mar. biol. Lab., Woods Hole*, **90**, 141–47.

Wise, John P. (1957). Growth rate of Browns Bank haddock. *Fish. Wildl. Serv. U.S.*, **32**, 1–20.