STUDIES ON THE BIOLOGY OF *CIRRHINUS MRIGALA* (HAMILTON) OF THE RIVER GODAVARI

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ABSTRACT

Some aspects of biology of *Cirrhinus mrigala* (Hamilton) from the river Godavari were studied. The markings on the scales were used as indices of age, after ascertaining the annual nature of formation of growth checks. The relationship between total length of the fish and scale radius was found to be linear. It was shown that the rings were laid during the period May-August. The probable causative factors in the formation of rings are discussed. Von Bertalanffy's growth equation was used for fitting the growth data obtained by scale study and it was found to adequately describe the actual growth of the fish. A close agreement was observed in the lengths calculated from scale study, Petersen's method, Probability paper and empirical growth equation. The length-weight relationship of the species was found to be $W = 10^{-9} \times 6853\ L^{3.0830}$. Relative condition of the species in various months and lengths was studied. The fecundity of *C. mrigala* for different age groups was estimated.

INTRODUCTION

In the total fish landings of a stretch of 189 km of the river Godavari, between two anicuts across the river located at Dowlaiswaram and Dummagudem, a trend of continuous decline through the years 1963-1969 was observed, affecting almost all the fish populations (Table 1). Among these, however, the landings of one species, *Cirrhinus mrigala* (Ham.) were unusually well balanced. This was so, when compared not only with rest of the major carps, such as *Labeo fimbriatus* and *Labeo calbasu*, but also with other fishes, such as catfishes, prawns etc. In 1967 and 1969, however, the landings of even this species have declined, despite increase in fishing effort. This could be an indication that a change in population size was taking place in this species as well, or it might be a simple fluctuation in the landings. The trend of general decline in the fishery necessitated investigations on the biological parameters of the major fish popu-

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lations. In this paper are presented the results of investigations conducted on *C. mrigala*. such as determination of age and growth of the fish by means of scales, size|age composition of the landings of each year, length-weight relationship, relative condition, maturity and fecundity at each age, during the years 1963-1969.

TABLE 1. *The annual fish landings from the river Godavari during the years* 1963-69.

Years	Total fish landed (in t)	Total effort in thousand man hours	Landings of *C. mrigala* in t	Percentage of *C. mrigala* in total landings
1963	329.9	614.5	19.3	5.86
1964	321.6	458.0	18.6	5.78
1965	245.5	465.0	18.5	7.71
1966	231.4	554.1	18.6	8.08
1967	261.7	968.0	12.7	4.90
1968	233.5	960.5	16.4	7.00
1969	218.0	1077.7	11.8	5.40

Cirrhinus mrigala was transplanted in the river Godavari (Ailkunhi, 1949). The success of its adaptation to the river's environment is shown by its proportion in the landings.

Chacko and Ganapathi (1951) have reported the growth rate of the species in some tanks in South India. Various aspects of biology of the species from river Ganga have been investigated in detail by Jhingran (1952 ,1957 and 1959). He has shown that the annular markings on the scales of the fish can be taken as reliable indicators of age. Yusuf Kamal (1969) has made a detailed study on the age and growth of *C. mrigala* from the river Yamuna and ascertained the validity of use of scales in age determination.

MATERIAL AND METHODS

Material for the present study was collected from the commercial gear, such as nylon gill nets, seines (Alivivala and Jaruguvala), castnets and long lines, at fortnightly intervals, from 11 sampling centres located on either side of the 189-km long stretch of the river Godavari, between two anicuts, Dowlaiswaram and Dummagudem (Fig.1).

Samples of scales from 600 specimens of total-length range 100-915 mm were examined for estimation of age and growth of *C. mrigala.* The scales were collected from the region just below the dorsal fin and above the lateral line (Jhingran, 1959). The scales were cleaned first in 1% KOH solution to remove adhering tissue and then in water. They were examined by projecting them on a wall screen, using an Elmo slide projector maintaining a magnification of 6.6

times. The point where two straight lines, drawn from the two lobes of the scale intersect at right angles to each other, was taken as the centre of the origin of growth. Measurements were taken from the centre of the origin of growth to the margin of the scale at an angle of 45° to the right, to measure radius of the scale and the distance of various annuli from the scale centre.

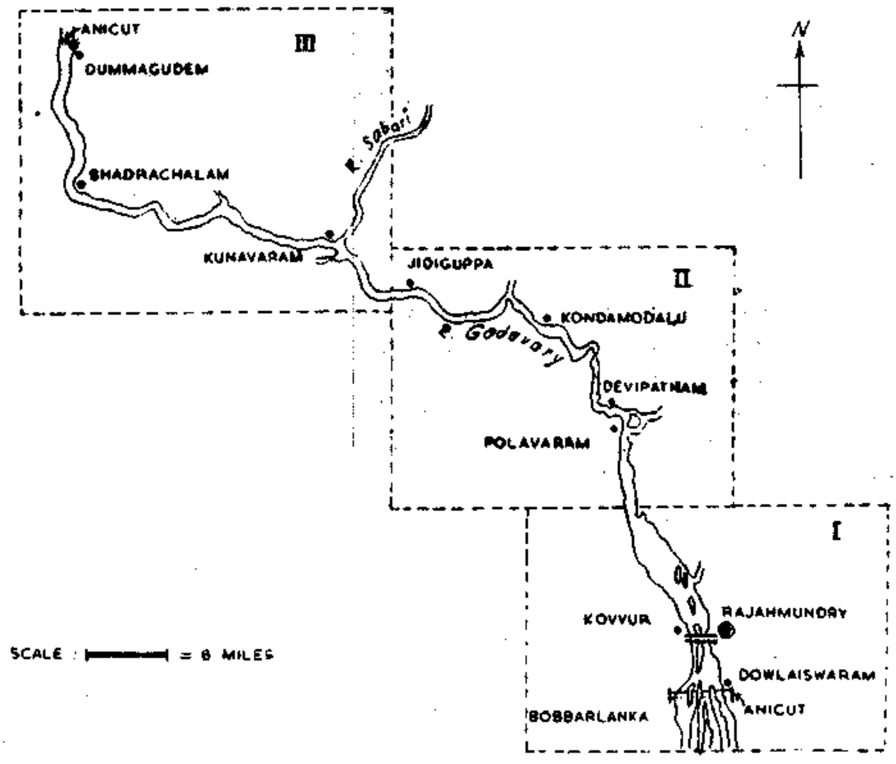


FIG. 1. Areas of investigation and sampling centres along the river Godavari.

Petersen's method was followed to study the size-frequency distribution and 3,000 fish were measured for this analysis; these ranged from 100-915 mm in total length. The total length was measured to the nearest mm and weights were taken to the nearest g.

For the determination of the fecundity of *C. mrigala,* ovaries of 40 specimens ranging from 349 to 810 mm in length were studied. Following the scale adopted by the International Council for the Exploration of the Sea (Wood, 1930), ripe ovaries collected during pre-monsoon period were used in this study. The ovaries were preserved in 4% formalin after noting the length and weight of fresh fish. To minimise the error in fecundity estimations, samples of ova were taken from the preserved ovary at five different regions (two samples from the anterior region, two from the posterior and one from the middle) and the number of ova in each sample was visually counted and then the total number of eggs in the ovary was estimated.

Age Determination

Scales and Petersen's method of length-frequency analysis was employed for the age and growth studies in *C. mrigala*. Probability paper was also used for dissection of polymodal length-frequency distributions (Cassie, 1954; Pantulu, 1962).

Age as interpreted from scale study

An examination of scale of *C. mrigala* revealed the presence of alternating fast- and slow-growth areas. A fast-growth area (transparent zone) and a slow-growth area (opaque zone) were together taken to indicate one year's growth (Fig.12). Each slow-growth zone consists of compactly packed continuous circuli preceded by a transparent zone which is represented by a number of comparatively widely spaced circuli. The distance between the successive annuli decreases in fish of older age groups due to close spacing of annuli on scales. Similar type of annuli described above have been observed by Jhingran (1959) in *C. mrigala* from the river Ganga, Natarajan and Jhingran (1963) in *C. catla* and Yusuf Kamal (1969) in *C. mrigala* from the river Yamuna.

Besides the continuous circuli, there are some discontinuous circuli which show breaks. These were found sometimes in between the age rings and were not considered for age analysis. Thus, only one type of false annuli was distinguished in *C. mrigala* of Godavari unlike *C. mrigala* of Yamuna in which Yusuf Kamal (1969) has observed two types false annuli, viz., those which were not continuous all round the scale and those which appeared like compactly deposited circuli.

For establishing the annual nature of rings, margins of scales during different months of the year were studied. Figure 2 shows the percentage frequency of opaque margins during different months. It was observed that the maximum percentage of scales with opaque margins was found during May-August with a peak in July (54.8%, 58.3%, 81.0% and 57.1%). Further, the average breadth of the transparent zone was minimum in the months of September-October and maximum during November-March. The appearance of both transparent and opaque zones within a period of 12 months indicated that the rings were annual in nature and were formed during May to August.

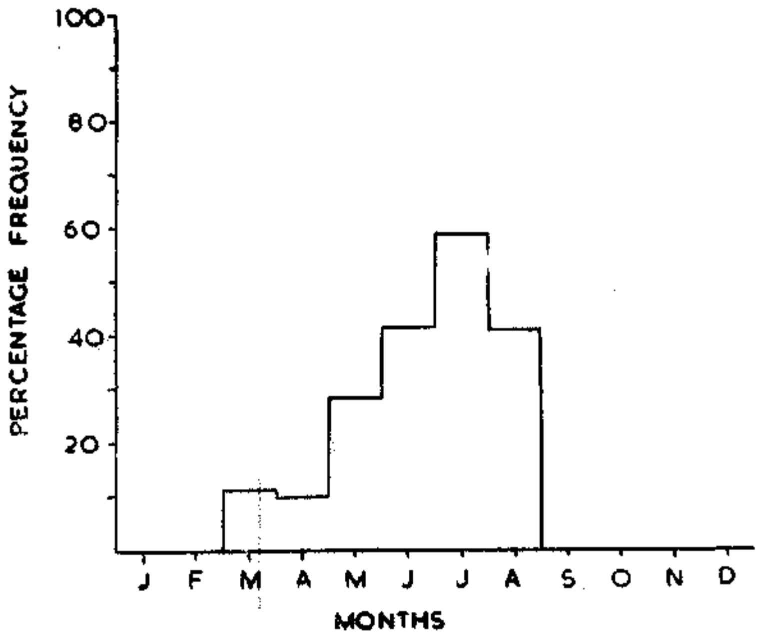


FIG. 2. Percentage frequency of scales with opaque margins during different months.

Probable reasons for annulus formation

In the present study, the period of annulus formation (May-August) coincides with reduced feeding activity of the fish, because the plankton population during these months is poor in the river (Premswaroop *et al*, MS). The period also coincides with high temperatures (32° C to 38° C) and maturation of the gonads and breeding activity of the fish. While discussing the age and growth of *C. mrigala* from the Ganga, Jhingran (1959) mentioned starvation as a probable cause of annulus formation, while Natarajan and Jhingran (1963) indicated that the growth check in *C. catla* was caused by maturation and spawning. Yusuf Kamal (1969) stated that growth retardation in mrigal from the Yamuna was caused by want of required food in the environment. In the present study, it would appear that the annulus formation could have resulted from a cumulative effect of lack of sufficient food, high temperatures, maturation of gonads and breeding activity of the fish.

Relationship between fish length and scale radius

To ascertain the relationship between the size of the scale and length of the fish, values of scale radii, ranging from 18 mm to 130 mm, were plotted against total lengths of corresponding fish ranging between 162 mm and 910 mm (Fig. 3). A linear relationship between the logarithmic values of scale radius and total length of the fish was observed. A straight line was fitted by least squares method and the logarithmic relationship could be expressed as:

$$\log Y = -1.0646 + 1.0691 \log X$$

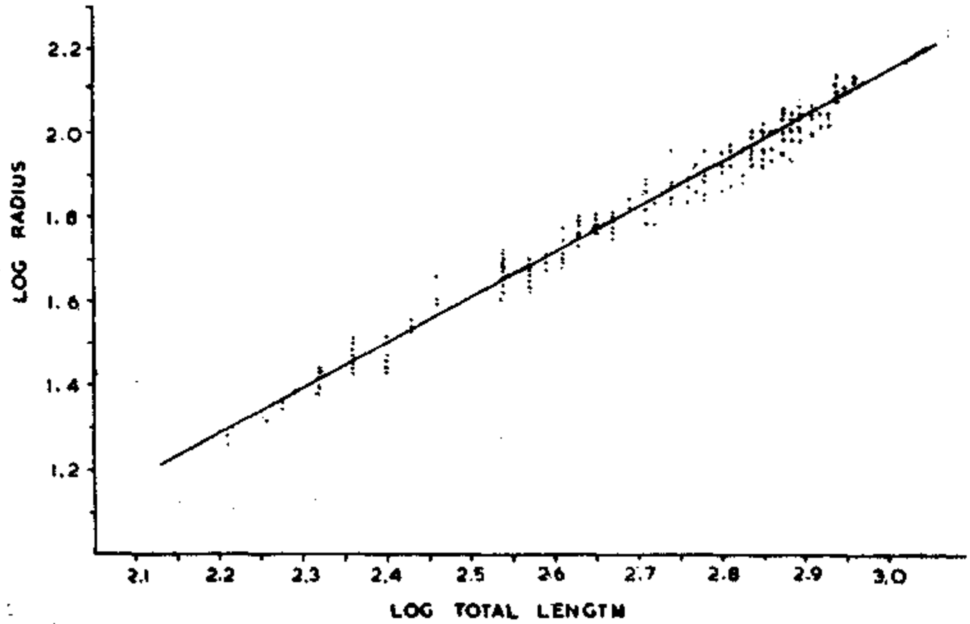


FIG. 3. The relationship between length of fish and scale radius.

where 'Y' is the radius of the scale and 'X' the total length of the fish. The correlation coefficient between the fish length and scale radius was found to be 0.96. To calculate the intermediate lengths from the known values of scale radius, regression equation of total length (L) on scale radius (R) was calculated. It could be expressed as:

$$\log L = 1.1130 + 0.8732 \log R.$$

Jhingran (1959) found the relationship between total length of the fish and diameter of the scale of *C. mrigala* from Ganga to be linear. A similar relationship was observed by Yusuf Kamal (1969) between the total length of the fish and radius of the scale of mrigal from Yamuna.

The following formula was used for back-calculation of lengths (Smith, 1955; Pantulu, 1962).

$$\log l_n = \log L_t + b(\log r_n - \log R_t)$$

where l_n = length at age 'n', L_t = length at the time of capture, r_n = radius of the scale at age 'n', R_t = radius of the scale at the time of capture and 'b' = the slope of the regression.

The distribution of annuli in scales of fish of different length groups together with the mean back-calculated length of fish of age up to 8 years is given in Table 2.

TABLE 2. *The distribution of annuli in scales of fish of different length groups together with the mean back-calculated lengths (mm) of* C. mrigala *at various ages.*

Length range in mm	Number of annuli 1	2	3	4	5	6	7	8
161-200	11							
201-240	20	2						
241-280	8	7						
281-320	7	9						
321-360	3	17	3					
361-400		24	14					
401-440		11	35	1				
441-480		3	27	6				
481-520			8	10				
521-560			6	29	3			
561-600				27	8			
601-640				8	51	4		
641-680				6	34	5		
681-720					15	23		
721-760					8	27	1	
761-800					2	25	12	
801-840						7	19	
841-880						1	8	2
881-920							1	4
	49	73	93	88	121	92	41	6 = 564
Back-calculated length in mm	230	358	470	580	676	760	828	885

Determination of age by Petersen's method

It is observed that breeding of carps in Godavari extends over a maximum period of four months from July to October. Since the mrigal has a short breeding period, Petersen's method was found useful in establishing the lengths at various age groups, particularly in the earlier age groups, and in

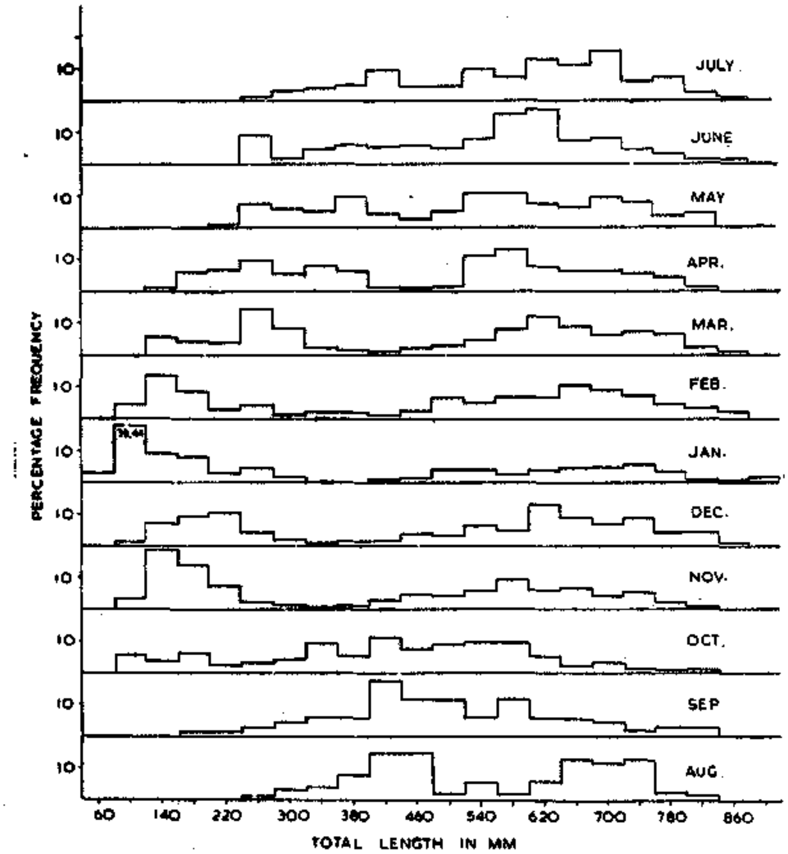


FIG. 4. Length-frequency distribution of *C. mrigala* during different months (data pooled for corresponding months of the years 1963-1967).

ascertaining the validity of age determination by scale studies. Figure 4 shows the histogram of size-frequency distribution of the mrigal for different months over the period 1963-1967 (data pooled for corresponding months of the year). Generally, the first recruitment to the commercial fishery at a modal length of 100 mm occurred in October. Continuous breeding resulted in bimodal distribution as is seen in January-March histograms, and might be responsible for nonshifting of modal lengths during different months. The fish attained 260 mm by April-June. The first year group fish were represented by prominent modes (100-260 mm) in all the months from October to June. 2nd year fish appeared in October, February and April (340 mm), and May and June (380 mm). The modes at 420 mm in July-September, 460 mm in November-December and 500 mm in February appeared to be caused by fish of 3rd year. 4th year fish were represented by modal lengths at 540 mm and 580 mm during August-January, April-June. 5th year fish were prominent in the lengths between 620

TABLE 3. *Comparison of mean lengths (in mm) of* C. mrigala *at various ages as estimated by different methods.*

Age in years	Petersen's method	Probability paper	Scales	Von Bertalanffy's growth equation
1	255	235	230	223
2	340	345	358	363
3	455	452	470	482
4	560	580	580	587
5	636	652	676	681
6	730	740	760	763
7	800	820	828	836
8	900	—	885	900

mm and 660 mm in July, August, November, December and March. 6th year fish were present almost throughout the year and represented by the modes 700 mm and 740 mm. The modal length at 780 mm in July and 820 mm in October appear to represent the fish of 7th year and a mode at 900 mm in January probably represents the fish of 8th year. The mean modal lengths at various ages are shown in Table 3.

Early growth rate

To study early growth rate of the species, samples in the length range of 80-250 mm were collected mainly from seines (Alivivala and Jaruguvala) and cast nets, which are selective for this size group. As the mrigal of the above length range were recruited during October to April, the length-frequency data for these months were plotted for three (biological) years, viz., 1962-65. The modal lengths indicating the growth from month to month, connected by free-hand fits (Fig. 5). From this analysis, it is evident that a modal length at 110 mm in the month of October shifted to 230 mm by April with intermediate modes at 130 mm in November, 170 mm in January and 220 mm in March. Since the breeding extends over 4 months, a bimodal distribution was evident in the 1st age group, as evidenced by second modal length at 170 mm in November, which shifted to 190 mm in December, 230 mm in February and 250 mm by March. A smaller size group recruited at a modal length 90 mm in January, probably a result of late spawning, attained 170 mm by April. Thus an average growth of 20-25 mm per month was observed in Juveniles.

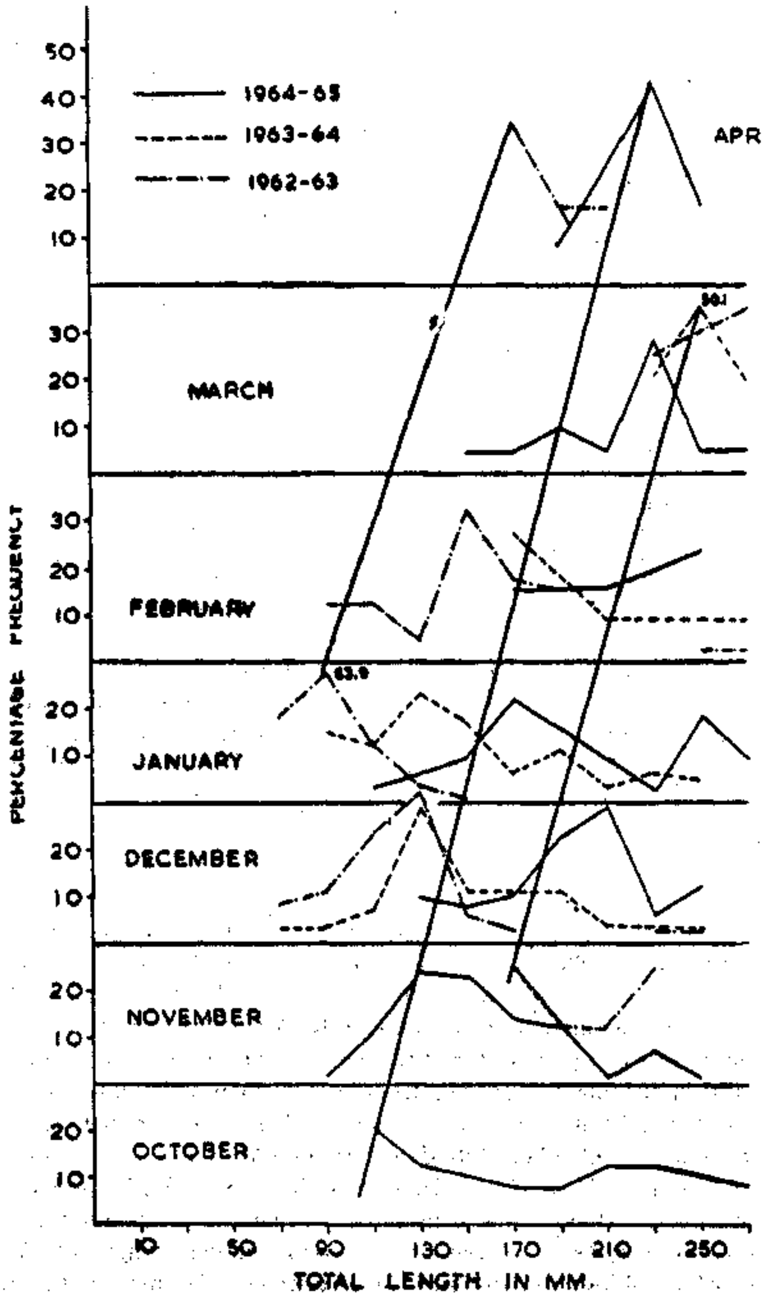


FIG. 5. Length-frequency distribution of *C. mrigala* showing early growth rate.

Determination of age by the use of probability paper

Probability paper has been used in the dissection of polymodal length-frequency distributions (Cassie, 1954; Ricker, 1958 and Pantulu, 1962). The length-frequency distributions of *C. mrigala* has been further analysed by this method for comparison with other methods. The modal lengths at various ages (Table 3) closely corresponded with the values obtained by Petersen's method and scale study.

GROWTH

The Von Bertalanffy equation for growth in length (Beverton and Holt, 1957) was fitted to the age length data of *C. mrigala*. This equation is written as

$$l_t = l\propto(1-e^{-k(t-t_o)})$$

where l_t = length at age 't', $l\propto$ = the ultimate attainable length, k = a measure of catabolic rate, t_o = a constant, the theoretical age at length zero and 't' = age of the fish (Beverton and Holt, 1957).

$l\propto$ and 'K' were estimated using Ford-Walford (1933 and 1946) growth transformation, wherein values at l_t were plotted against those at l_{t+1} (Fig. 6). A straight line relationship was obtained. By fitting the least-

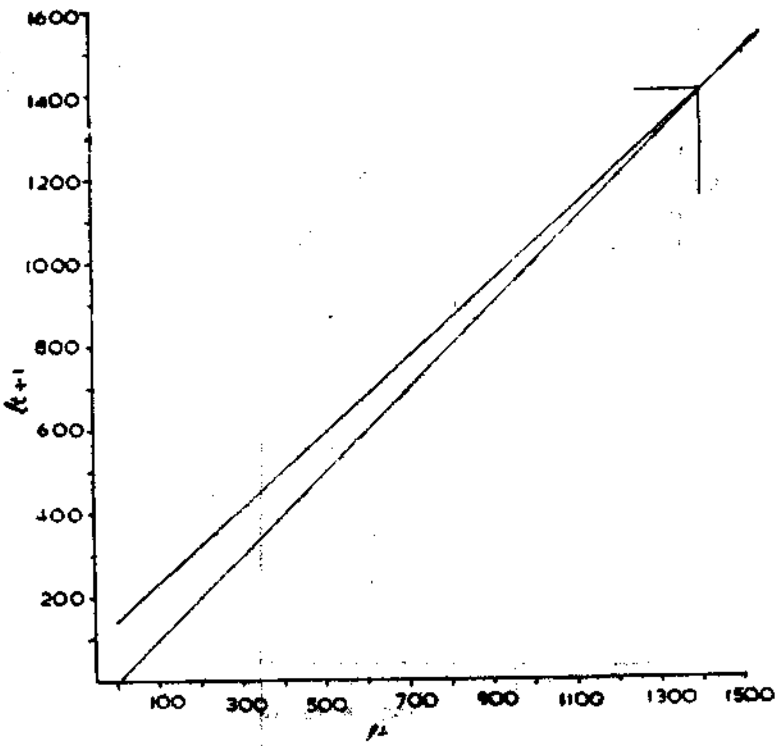


FIG. 6. Ford-Walford plot of growth of *C. mrigala*.

square line to this data, the resultant slope 'b' was calculated ($b = e^{-k}$). From the intersection of the least-square line with the bisector drawn through the origin, $l\alpha$ was calculated ($l\alpha = 1400$ mm). 'K' has been estimated to be 0.1220.

For the estimation of 't_o' the growth equation was written as (Von Bertalanffy, 1938):

$$\log_e (l\alpha - l_t) = (\log_e l\alpha - k t_o) - kt.$$

The values of $\log_e (l\alpha - l_t)$ were plotted against corresponding ages. The regression was calculated by least squares (Fig. 7) and this line has a slope of $(-K)$ and the intercept 'a' $= \log_e l\alpha + K t_o$, from which 't_o' was calculated.

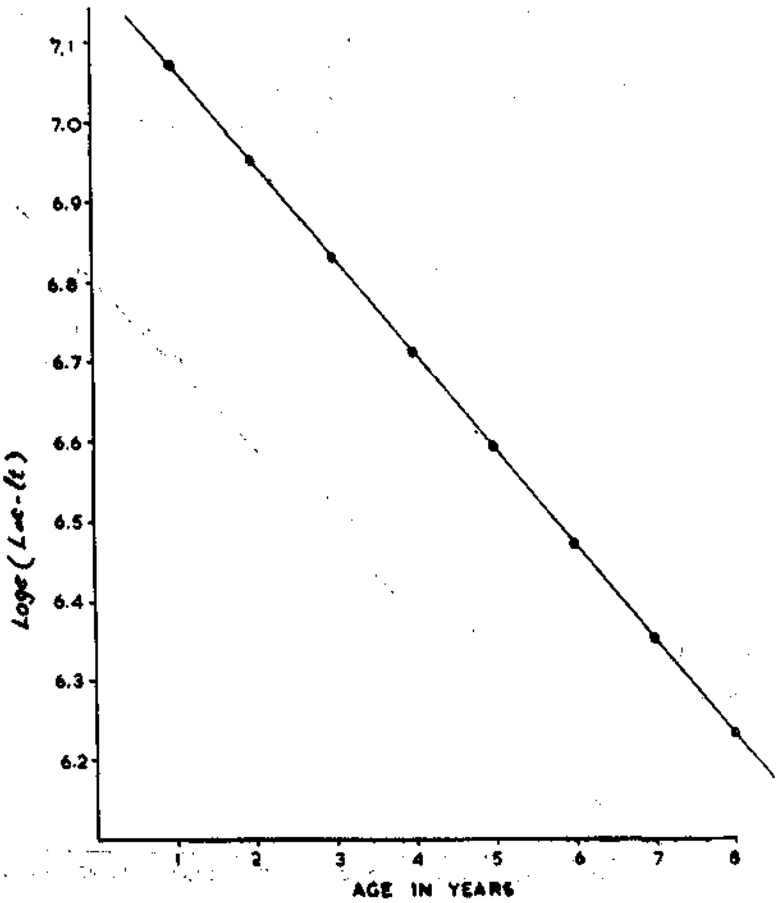


FIG. 7. 't_o' of *C. mrigala* estimated by plotting $\log_e (l_\alpha - l_t)$ against age 'n.'

The Von Bertalanffy's growth equation for *C. mrigala* can be expressed as

$$l_t = 1400\,(1\text{-}e^{\;0.1220\,(t+0.4622)}\;).$$

The lengths at various ages calculated by this equation are given in Table 3.

Length - Weight Relationship

The length-weight relationship of *C. mrigala* from river Godavari, based on 516 observations ranging from 80 mm to 890 mm in total length and between 57 g and 8750 g in weight, was studied (Fig. 8). The sexes were combined, as it was found difficult to segregate males and females in the field.

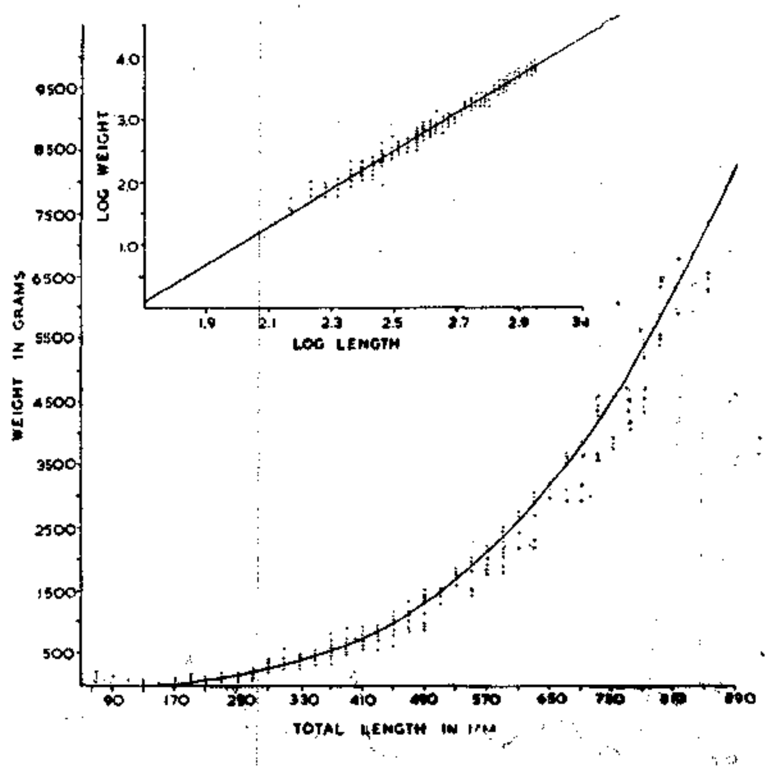


Fig. 8. Length-weight relationship of *C. mrigala.*

The length data were grouped into 20-mm size classes. Weights of fish were taken against the corresponding lengths of fish. The scatter diagram drawn between the length and weight showed a parabolic relationship (Fig. 8). The relationship confirmed the general formula $W = aL^n$, where W = weight of the fish, L = length and 'a' and 'n' are constants. The values of 'a' and 'n' were determined by least squares after converting the data to logarithms. The formula correlating the length and weight of the species was found to be

$$W = 10^{-9} \times 6853\ L^{3.0830}.$$

Relative condition

Le Cren (1951) stated that the condition factor K is affected by length as well as several other factors like environment, food supply and degree of parasitism. As this makes its interpretation difficult, he suggested that the effect of length and its correlated factors may be eliminated by using a relative condition factor K_n. which is based on the empirical and calculated length-weight relationship. In his work on perch, *Perca fluviatilis* he indicated that K_n is function of fatness and condition of the gonads.

The relative condition can be expressed as $\frac{\bar{W}}{\hat{W}}$. $\bar{W}$ is the observed weight of the fish and $\hat{W}$ is the calculated weight. The K_n values were calculated separately for each length group combined for all months and for all length groups combined in different months of the year. Fluctuations in K_n of mrigal in relation to length (Fig. 9) showed maximum values of K_n amongst juveniles of mean length 190 mm which could have been the effect of high feeding activity in this size group. Several minor fluctuations in the values of

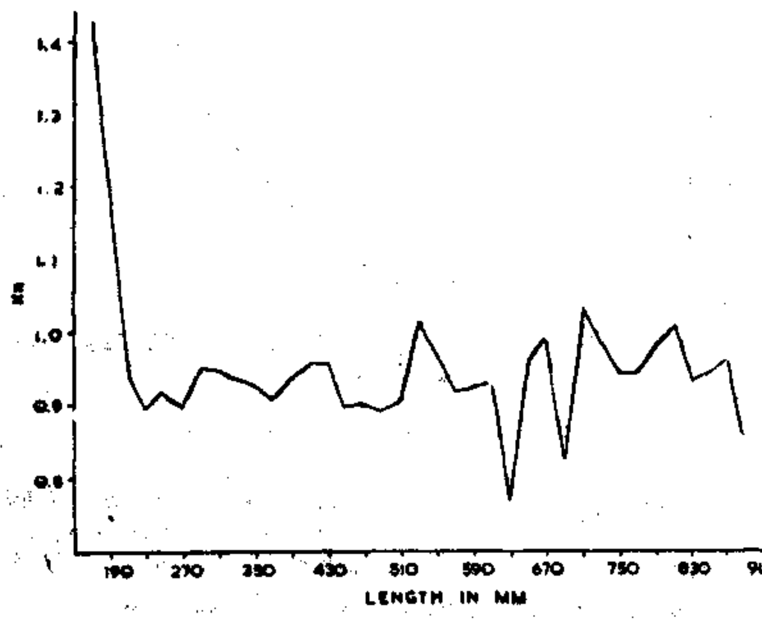


FIG. 9. Mean K_n values of *C. mrigala* at different lengths.

K_n observed for size groups 191 to 530 mm could be caused by fluctuations in metabolic activities. Fluctuation observed in the values of K_n in the higher length groups, 530 to 890 mm appear to be mainly due to the maturity of gonads and repeated spawnings.

Relative condition during different months showed (Fig. 10) that *C. mrigala* attained peak condition in June and declined to minimum in July|

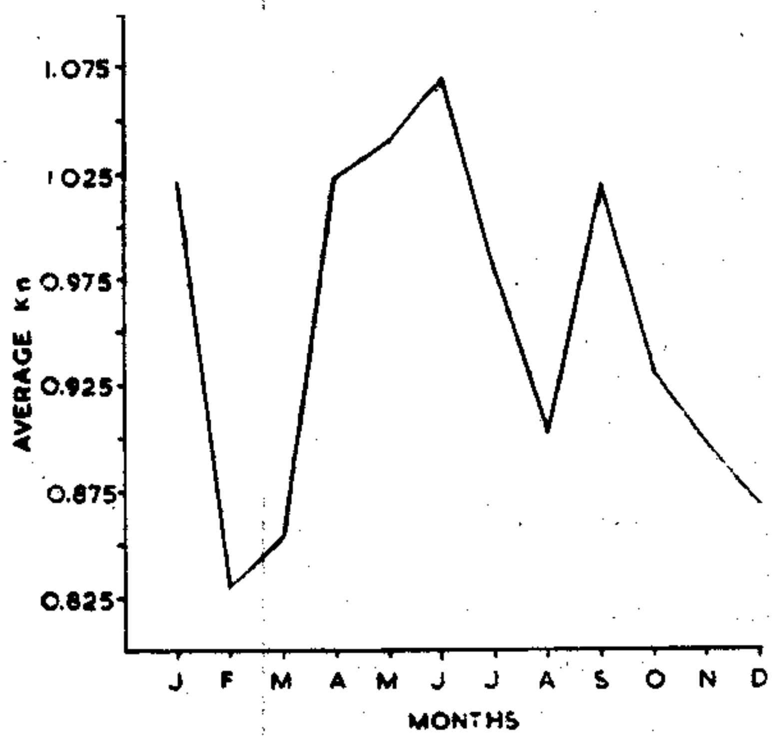


FIG. 10. Monthly fluctuations in K_n values of *C. mrigala*.

August. The high condition in June might be due to developing gonads and low K_n in July|August might be due to spawning. A second peak in K_n in September and a fall in October to December was also observed. This second peak corresponds to the spent condition of fish in post breeding months. The increase in K_n in January can be attributed to the high feeding activity as has been observed from an examination of gut contents, but the fall in K_n in February is attributable to loss of weight for building up of gonadial matter for early spawners and partly due to errors in random sampling.

Maturity and Fecundity

Ovaries in II and III stages of maturity were observed in the month of March while ripe fish were seen in June-July. The minimum length of fish recorded with fully mature ovary was 349 mm.

The occurrence of mature fish in zone II in the months of May to July might be a breeding concentration and, therefore, this region may be the probable breeding ground of the species. It is interesting to note that in some years mature females were occasionally encountered in late March and April months. This may, however, be explained by the fact that during some years' floods in the Sabari, a torrential tributary which opens into the river Godavari, would raise the water level in zone II region, creating suitable spawning conditions for the few early spawners. The major spawning occurred during the normal flood season as evidenced by the occurrence of 2- to 3-day old fry in the shooting-net catches.

Estimates of fecundity were made from 40 mature ovaries collected during the months April to July. The fecundity per individual ranged from 75,900 at a length of 349 mm to 11,23,200 at 810 mm. Figure 11 illustrates the relationship between the total length and fecundity. The logarithmic transformation of the relationship between the two variables can be expressed as:

$$\log F = -1.2225 + 2.4683 \log L.$$

The fecundity of *C. mrigala* for different age groups was estimated and given in Table 4. The fecundity showed an increase with increase in age and up to maximum observed ages no inflexion appeared in fecundity curve. The fecundity was maximum in 7th age group.

TABLE 4. *Average fecundity of* C. mrigala *for different age groups.*

Age	Length range in mm	Average fecundity in lakhs	Average weight of the fish in g	Average weight of gonad in g
2	349-398	1.60	578	116
3	466-500	2.89	1200	200
4	536-610	5.64	1812	428
5	615-688	5.96	3515	444
6	705-792	7.44	4710	624
7	782-830	8.14	6165	675

Discussion

Cirrhinus mrigala, a transplanted species in the river Godavari acclimatised successfully to the river's environment. It also formed a substantial commercial fishery and contributed on an average 6.39% to the total riverine landings during the years 1963-69. For formulation of optimum management policies, a knowledge of age composition of commercially important species and its related biological parameters are most essential. In the present study, the usefulness of the markings on the scales of *C. mrigala* as reliable indicators for estimation of age and growth was shown. The validity of the studies on age and growth by the use of scales are corroborated by the observations, such as, 1) positive correlation between growth of the fish and scale radius, 2) annual nature of the markings or rings on the scales and 3) high degree of agreement

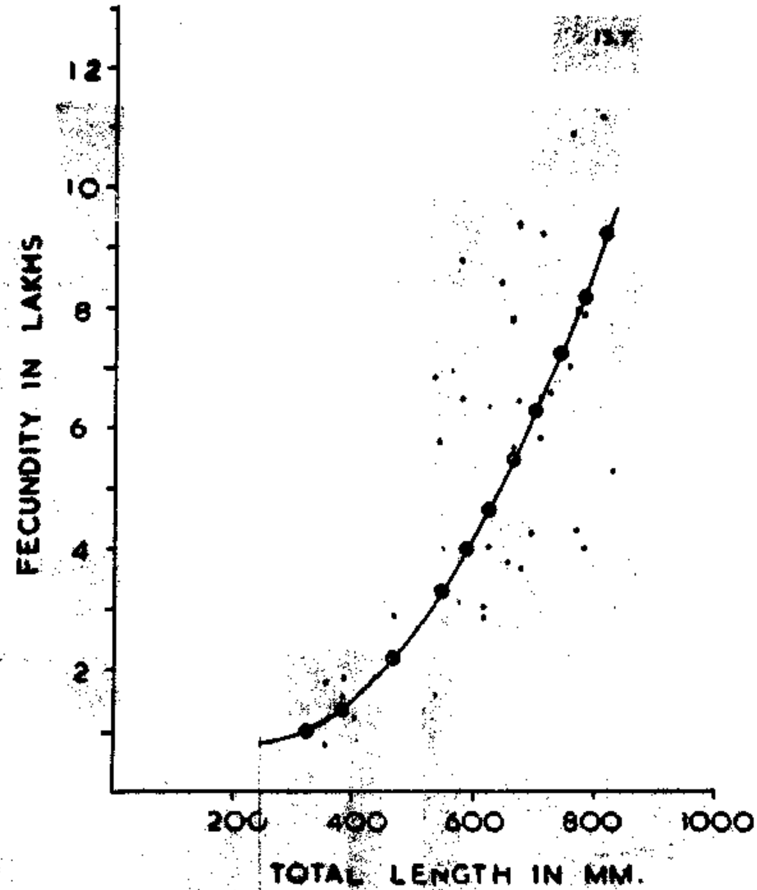


FIG. 11. The relationship between total length and fecundity of *C. mrigala*.

of the lengths derived through length-frequency analysis, scale study and Von Bertalanffy's growth equation. Similar observations were made by Jhingran (1959), Yusuf Kamal (1969) and Natarajan and Jhingran (1963) and confirmed the validity of scale method in age and growth studies in *C. mrigala* from the rivers Ganga and Yamuna and *C. catla* from Jamuna respectively.

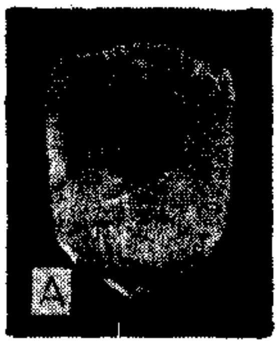
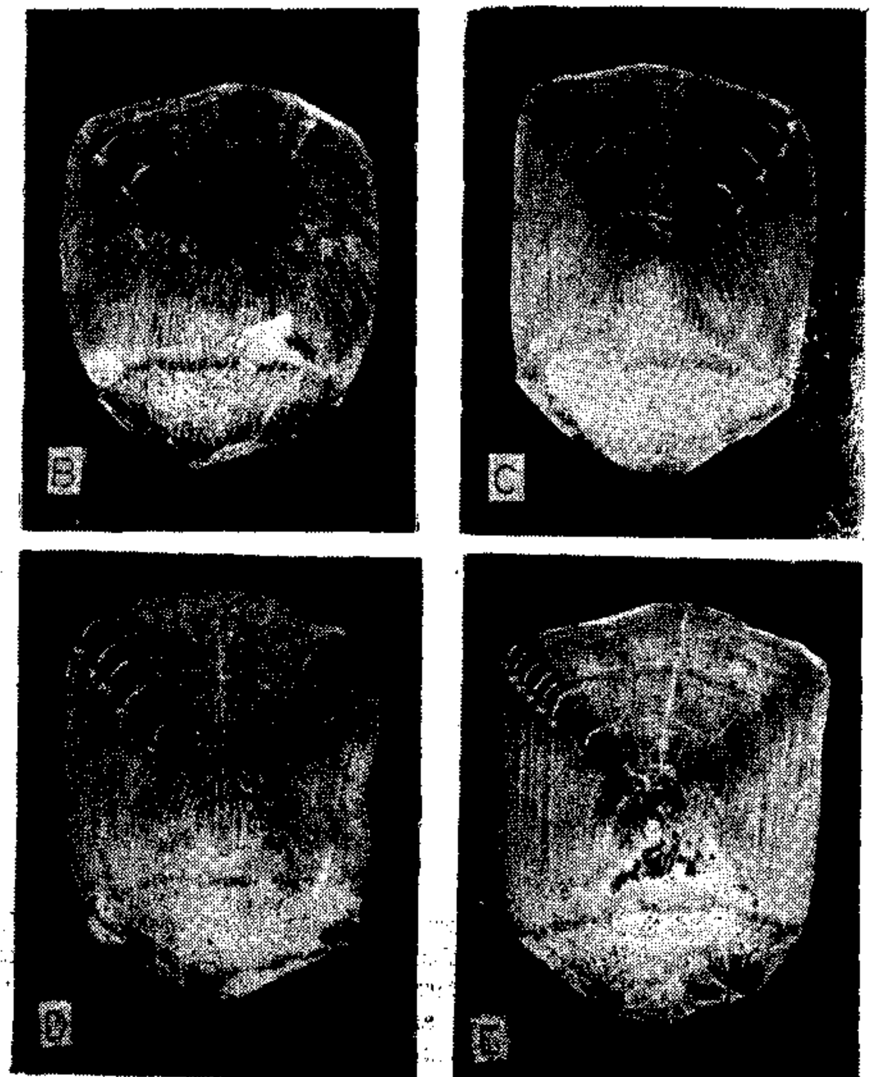


FIG. 12. Photographs of scales of *C. mrigala.*

A: Scale of 251-mm fish showing one annulus.
B: Scale of 478-mm fish showing three annuli.
C: Scale of 577-mm fish showing four annuli.
D: Scale of 664-mm fish showing five annuli.
E: Scale of 779-mm fish showing seven annuli.



Chacko and Ganapathi (1951) found that the fish grew to 450-580 mm in one year in some tanks and swamps of Godavari and Krishna deltaic region. They also reported that in Chetpet fish farm the fish attained a size of 550-650 mm in one year. Jhingran (1969) observed that the mrigal in Ganga attained 290 mm in the first year of its life. Yusuf Kamal (1969) found that the mrigal in the river Yamuna attained more or less the same size as that of mrigal from the river Ganga. The lengths at various ages assessed for *C. mrigala* from the river Godavari were compared with those presented for the same species from the rivers Ganga and Yamuna. *C. mrigala* from the rivers Ganga, Yamuna and Godavari attained comparable length by the end of first year; 290 mm, 268 mm and 230 mm respectively. Thereafter, the mrigal from the Ganga and Yamuna showed a very fast growth rate to second year (511 mm and 458 mm) and continued to have fast growth up to 4th year by which time they attained a length of 797 mm and 736 mm respectively. Thereafter, the rate of growth showed a sudden decline maintaining the same trend till 8th year. In the present study, it was observed that the growth from 1st to 2nd year was less rapid than that from the rivers Ganga and Yamuna and the species attained 470 mm by the end of 3rd year and 480 mm by the end of 4th year. Thereafter, the decrease in growth rate was more gradual up to the 8th year. Thus, maximum difference in growth appeared to occur in the second year. The differences may probably be attributed to the different environmental factors in the three river systems.

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