STUDIES ON THE SCALES OF *PSEUDOSCIAENA DIACANTHUS* (LACEPEDE) FOR ESTIMATING GROWTH PARAMETERS

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ABSTRACT

The nature of the different types of growth checks on the scales of *Pseudosciaena diacanthus* (ghol) has been described for facilitating an easy identification of the annular margins. The time of ring formation (transparent bands) was found to be annual, taking place during February-April. It has been suggested that the ring formation on the scales may not be due to growth-inhibiting factors.

Back-calculations were made on the basis of total length — scale size relationship, which was found to be a straight line after logarithmic transformation of the two variables. The weighted mean length of all the fish examined was estimated to be 46.39, 64.13, 80.52, 93.44, 101.21 and 105.85 cm, at I + to VI + ages. The maximum age was observed to be VII + years, of a fish measuring 127.0 cm. The results of the back-calculations were checked with the mean lengths at different ages obtained by the length frequency analysis. The length composition was dominated by fish belonging to the IV + age group, with the mean length ranging from 90.25 cm to 93.50 cm.

The logistic curve was found to describe the growth of 'ghol' most adequately. The estimated L_{α} was 118.01 cm for the logistic equation while it was 144.72 cm for the von Bertalanffy growth equation.

INTRODUCTION

The 'ghol' (*Pseudosciaena diacanthus*) is an important fish in the trawler catches off Bombay to Kutch, constituting about 5% of the total catches. Rao (1961) studied the age determination of the fish by means of the number of rings present on the scales. The present study is undertaken with a view to finding out the validity of back-calculation of the length of each fish at ages earlier to the observed age. By virtue of its most straightforward approach (Gulland, 1965), analysis of the growth of a single fish is the most valuable method for finding out the growth rate (which is based on several sets of age-length data of individual fish). The results of back-calculations are verified with the earlier observations (Rao, 1961) and length frequency measurements of the present study.

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In view of the importance of growth parameters in mortality estimations (Beverton and Holt, 1956), a method has been suggested here for determining the appropriate growth pattern and obtaining parameters of better accuracy than the graphical method of Walford (1946).

MATERIAL AND METHODS

Material for the present study was drawn mostly from the catches of the vessels of the New India Fisheries Ltd., supplemented by a few samples from the catches of the Government of India vessels and indigenous gear.

Length measurements of 1,138 juveniles and 1,169 of the bigger size groups were made to the nearest half centimeter. The weights of 180 fish belonging to all sizes were also noted.

Scales for the study were collected from the mid region of the body adjoining the tip of the pectoral fin below the lateral line and three from each fish selected for their clarity were used. Preservation, cleaning and mounting of the scales were carried out following the suggestions given by Chugunova (1963).

A Fer-Color-Portable Projector fitted with a cassar 1: 2.8 lens (f=50 mm) and a built-in screen that could be fixed at a distance of 40.0 cm from the lens was used for projecting the image of the scales. All measurements of growth checks were taken on the projected image (which is magnified 8.42 times the actual scale size) by marking the positions of growth checks on separate strips of paper (including the edge of the scale). The measurements thus obtained were used directly for all further calculations. A total of 250 scales belonging to 115 specimens were examined, out of which the scales of 29 fish (25.2%) were rejected for various reasons mentioned later.

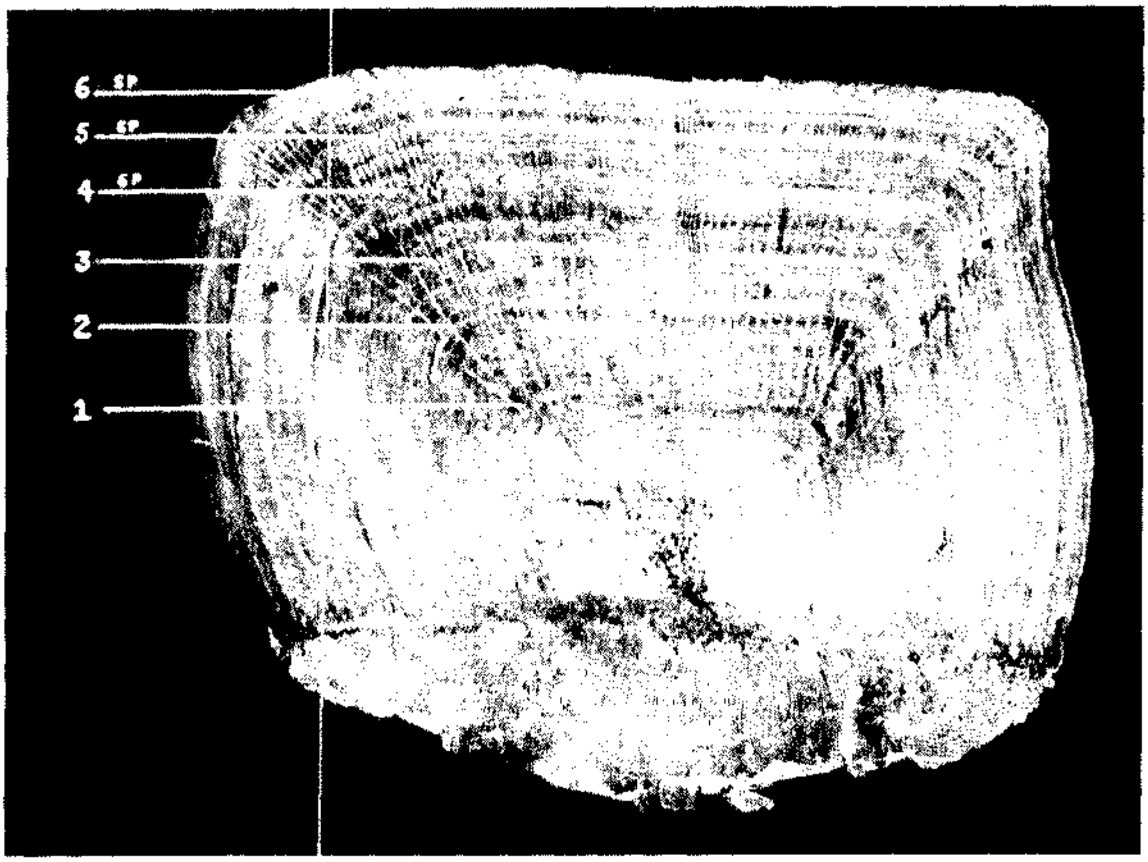
STRUCTURE OF SCALES

Nature of growth rings

A cursory examination of the scales showed that the transparent and opaque bands were broader in fish below 80.0 cm, while in older fish the more recently formed bands were narrow and difficult to determine. Hence, the scale studies were initiated with the smallest fish, in which the growth zones were not obliterated by the superimposition of too many basal plates, this facilitating easy identification of the nature of the growth checks as annuli or supernumerary.

Identification of circular bands for determining the annuli

In the present study the nature of the different growth checks was determined according to Chugunova (*op. cit.*). The opaque bands, representing the annuli are relatively broader than the transparent bands and only those that traverse all round the scale have been regarded as the true annuli. 'Growth checks' that were patchy or broken, or appeared only for a short distance, or extra sharp, were considered as false annuli. The opacity of the true annulus increased gradually



Scale of *P. diacanthus* showing six growth rings (1-6). SP- Spawning ring.
(Total length of fish 102.0 cm. size of scale 20 x 23 mm)

Facing p. 128

towards its margin. In some scales, there are gaps between the circuli in some loci of the antero-lateral fields, signifying partial destruction of the sclerites at the end period of growth. This character was made use of in determining the margin of the first annular ring of some of the older fish. In the case of some other older fish (Pl. I) demarcation of the first few transparent and opaque bands was not clear in the middle region of the scale. But in the lateral regions, the annuli were often clear as dark bands, which were resorted to as guidelines to locate their margin in the middle region. In the absence of any indication of the positions of the first one or two annuli (in the case of older fish only) they were omitted from measurements and the positions of the subsequent annuli only were taken into account for age determination.

The annuli subsequent to the first two or three are different because they were found to coincide invariably with the spawning rings (Pl. I). The spawning rings were found to be sharp, with clearly expressed irregularities, bends and most often wavy in the middle region and in the antero-lateral fields. Usually two such markings for each ring were met with, situated very close to one another. When two or more 'growth checks' of the spawning ring with an intervening narrow transparent region were present, the posterior edge of the most complete ring was considered as the margin of the annular zone. The region denoting new increment following the spawning ring was very transparent.

The appearance of false rings was a serious handicap for determining the position of the annular zones correctly. In the 'O' year class the 'juvenile ring' is invariably present (Rao, 1961) which is likely to be mistaken as the first year growth ring. However, this could be easily identified by its closeness to the focus and other characters of resemblance to a supernumerary ring.

The age of the fish was determined by the number of annuli and the growth in each year by the width of the annular zone.

Time of formation of the annulus

Following the procedure of Sarojini (1957) and Pantulu (1962) the percentage of fish with the narrow transparent bands in different months was calculated for validating the annular nature of the rings.

High values in the percentage of fish with transparent scale edges could be seen (Fig. 1) from January to July with a decreasing trend in the subsequent months up to October. The very high value obtained in April is based on the examination of two specimens only in the month. Though the analysis does not give conclusive evidence, it indicates that the relatively narrower transparent edge was formed during the months of January to July. The beginning of the transparent edge may be treated as the beginning of the annular zone. The possible cause for the formation of the transparent bands may be the accelerated growth of the fish for short periods in the case of juveniles as well as adults (after spawning) or destruction of sclerites at the end of a growth period in some cases, for which a complex of factors may be responsible, instead of one. There is, however, no perceptible difference in the spacing of circuli.

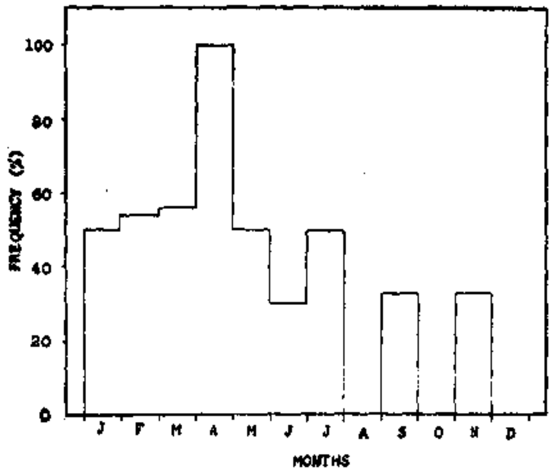


Fig. 1. Percentage of scales with transparent edges in the different months.

BODY LENGTH — SCALE RADIUS RELATIONSHIP

The magnified scale radius on the projected image was used directly for determining the relationship. The logarithms of fish total length and scale radius indicated a straight line relationship. The correlation coefficient r of the data points was found to be 0.9488. Fig. 2 gives the regression line along with the confidence intervals. 4.58% of the points lie outside the confidence belt and are rejected.[2]

The straight line had the equation

$$\log S = -1.2536 + 1.16999 \log L \qquad (1)$$

where S=magnified scale radius and L=length of the fish. Conversely the equation can be written as

$$\log L = 1.0822 + 0.8466 \log S \qquad (2)$$

Since we are interested in calculating the length of a fish corresponding to the size of the scale at the edge of an annular ring, equation (2) was used for all back-calculations.

Several methods are available, for this back-calculation, all of which use the relationship between the scale size and body length of the fish. Perlmutter and

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[2] Royce (1964) while adopting the method for discarding aberrant points commented that though the discarding is questionable only those far removed from the line were dropped. He also says that some such culling is desirable where errors are unavoidable and original data cannot be checked.

Clarke (1949) used two methods. One method calculates L_n directly by using an equation of the regression line (2) in the form

$$\log L_n = \log C + \frac{\log S_n}{\log S} (\log L - \log C) \tag{3}$$

where C=intercept value on the x axis, L=length of the fish when caught, L_n =computed length of the fish at the end of any year n, S=scale radius when caught; and S_n =length of the anterior scale radius upto any annulus n. Equation (3) is essentially a modification of the direct proportion formula suggested by Lee (1920) to account for the influence of the growth of the fish (C in eq. 3), before the appearance of the scales. The second method of Perlmutter and Clarke (*op. cit.*) follows the procedure used by Hile (1941) which is the same as (3) but for the adjustment of observed scale measurements to the empirical values, according to the ratios of the theoretical to the actual size. The close similarity of the results obtained by the two procedures was demonstrated by Perlmutter and Clarke (*op. cit.*).

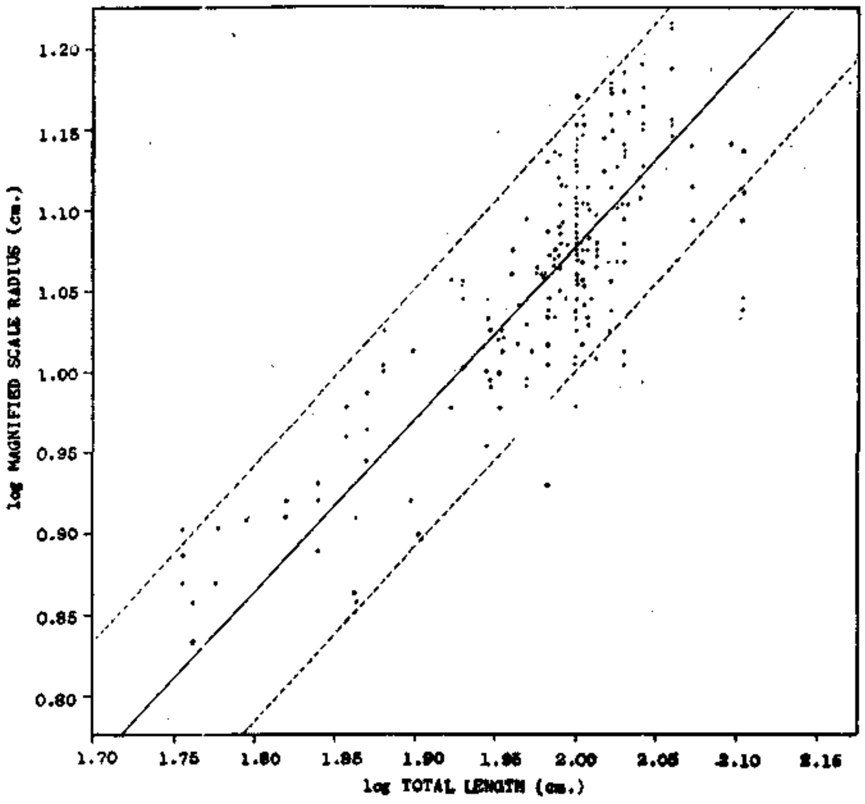

FIG. 2. Total length - scale radius relationship.

Smith (1955) derived from (3) another formula.

$$\log L_n = \log L_t + n\,(\log S_n - \log S_t) \tag{4}$$

where, other notations remaining the same as in (3), L_t = observed body length of the fish, S_t = observed scale measurement and n = slope of the line. Equation (4) is a different form of the regression equation (3) in which 'C' is eliminated, in order to obtain better results (Smith, *op. cit.*) and it was further claimed that the estimated values of L_n are independent of actual scale size, since the values of ($\log S_n - \log S_t$) depend only on the ratio S_n / S_t. As mentioned by the author (Smith, *op. cit.*) there are no advantages or disadvantages in using one or the other equation as demonstrated by the results (Table 1) obtained by using (3) and (4). The one to be used depends on the convenience of the user.

The other merit that estimations of L_n are independent of actual scale size accredited to (4) depends on the constancy of S_n / S_t which holds equally good for both the equations. To show how it works out in actual practice, mean and variance of S_n / S_{n+1}, $S_n / S_{n+2} \ldots S_n / S_{n+k}$, (where S_n is the radius of the first annulus from the focus) are worked out (Table 2), which indicate that the coefficients of variation (Simpson *et al.*, 1960) of the ratios are considerably high, in the light of which the merits of (4) remain diminished.

All further analysis is based on the results obtained by using the modified Lee's method (Perlmutter and Clarke, *op. cit.*) only, employing the values of equation (2) in the form of (3).

RESULTS OF BACK - CALCULATIONS

The year of birth of each fish was determined on the basis of the number of annuli and the weighted mean length of each year class (Table 1) at the different ages was arrived at from individual values of lengths of each year class at different ages.

The estimated average length of the fish at each annulus showed random variation among the different year classes. The variation, however, was remarkably small. There was an initial fast growth in fish of 1955 and 1963 year classes, and slow growth in those of the 1954 year class.

The weighted mean length at each annulus, of all the fish examined, was estimated (Table 1) showing average growth rates of 46.39 , 17.84, 16.37, 12.90, 7.70, 4.67 and 8.02 cm during the seven years respectively. The sudden increase in the growth rate during the seventh year was due to inadequate representation of large-sized fish in the samples.

The results of the present study agree with those of Rao (1961) in the values of mean length for the first year and of III+ age but differed with regard to the

TABLE 1. *Average calculated length of 'ghol' in centimeters at the time of formation of annuli in the different years*

Year of birth	Annulus 1		2		3		4		5		6		7		Number
	S	L	S	L	S	L	S	L	S	L	S	L	S	L	
1954	43.14	43.35	59.49	59.82	77.91	78.10	91.32	91.34	—	—	—	—	—	—	2
1955	51.73	50.12	71.43	70.65	83.50	83.50	—	—	—	—	—	—	—	—	2
1956	44.27	44.91	64.41	64.20	—	—	—	—	—	—	—	—	—	—	5
1958	44.50	43.95	61.51	61.12	79.11	78.84	91.30	91.09	100.69	100.60	107.60	107.57	113.22	113.20	2
1959	45.90	45.95	61.07	61.27	77.67	77.80	93.14	93.28	102.51	102.65	109.08	109.34	115.00	115.00	9
1960	45.94	46.21	62.75	62.96	78.07	78.21	89.51	89.66	97.79	97.81	99.87	99.87	—	—	9
1961	45.18	44.64	63.00	62.61	81.38	81.17	93.48	93.44	99.89	99.87	—	—	—	—	31
1962	46.94	47.09	65.10	65.09	82.90	82.87	95.44	95.41	—	—	—	—	—	—	14
1963	51.60	51.09	73.97	73.63	89.56	89.33	—	—	—	—	—	—	—	—	6
1964	46.51	46.46	64.98	64.73	—	—	—	—	—	—	—	—	—	—	4
1965	44.07	44.97	—	—	—	—	—	—	—	—	—	—	—	—	2
Weighted mean	46.66	46.39	64.32	64.13	80.66	80.52	93.49	93.44	101.17	101.21	105.86	105.85	113.87	113.87	
Standard deviation	4.75	4.37	6.68	6.34	7.27	7.14	5.88	5.76	7.36	7.35	7.72	7.61	8.50	8.48	
Number of fish	86		84		74		63		36		14		3		

TABLE 2. *Mean ratios of the first annulus with the other annuli along with coefficients of variation*

Annuli	Mean ratio	Variance	Coefficient of variation
1/2	0.6852	0.0015	5.66
1/3	0.5288	0.0021	8.66
1/4	0.4435	0.0020	10.08
1/5	0.3983	0.0021	11.50
1/6	0.3670	0.0017	11.53
1/7	0.3516	0.0005	6.34

maximum age of the fish, which is eight years according to Rao (1961), but seven years according to the present study, though the maximum size observed was respectively 113.0 cm and 127.0 cm ('dol' net catches). The possible reasons for the differences have been fully discussed in a latter section.

LENGTH-FREQUENCY STUDIES

In the catches of the trawlers as well as the indigenous gear 'O' year class was dominant with an almost total absence of the first and second year groups and sparse representation of the third year group (Table 3, Figs. 3 and 4). A preliminary examination of the catches by the different gears did not reveal any differences in the modal values in respect of the 'O' year group. Hence, the 'O' year group in all the samples were treated together for a study of the growth rate in the first year of life of the fish. The fish in the 'O' year group (below 50.0 cm) were analysed with class intervals of 3.0 cm (Fig. 3) and the remaining length groups at class intervals of 5.0 cm (Figs. 4 and 5).

'O' year class

The availability of these fish was restricted to a few months (November-April). In 1963, modes were observed at 37.5 cm and 19.5 cm in April and November respectively. The November mode continued in January 1964 also. In November 1964, a mode formed at 22.5 cm which shifted to 25.5 cm in January 1965 and 28.5 cm in February 1965. In March 1965 a fresh brood entered the catches with a modal value of 19.5 cm. The older group moved to 34.5 cm in March and 37.5 cm by April 1965. In March 1966 also the 'O' year group was found to form a mode at 37.5 cm.

Giving due allowance to variations in spawning time and sampling errors, the above account shows that the majority of the fish in the 'O' year class grow to a size of 36.0 - 39.0 cm (class interval), at which size they are caught in greater numbers in the months of March and April. The growth rate appears to be rapid during the February-April (1965) period.

Reckoning the age of the 36.0 - 39.0 cm size group, appearing in April, from the time of first spawning (May-June) the average growth of the 'O' year group works out to be 3.5-4.0 cm per month extending over a period of 10-11 months. Thus, the average back-calculated length of 'ghol' (46.0 cm) at age I+ appears to be in accordance with the growth indicated by the length frequency studies.

Other year groups

Observations on fish above 50 cm were restricted to January-April, the peak period of the fishery in all the years (1962-1966). The fishery is sustained by the 85.0 to 105.0 cm size groups (Fig. 4). As the fish in the above size groups (which are mostly obtained during January-April period) is not likely to show any perceptible growth within the short period of their maximum availability, the length measurements were analysed on an yearly basis (Fig. 5) to find out the mean lengths of the

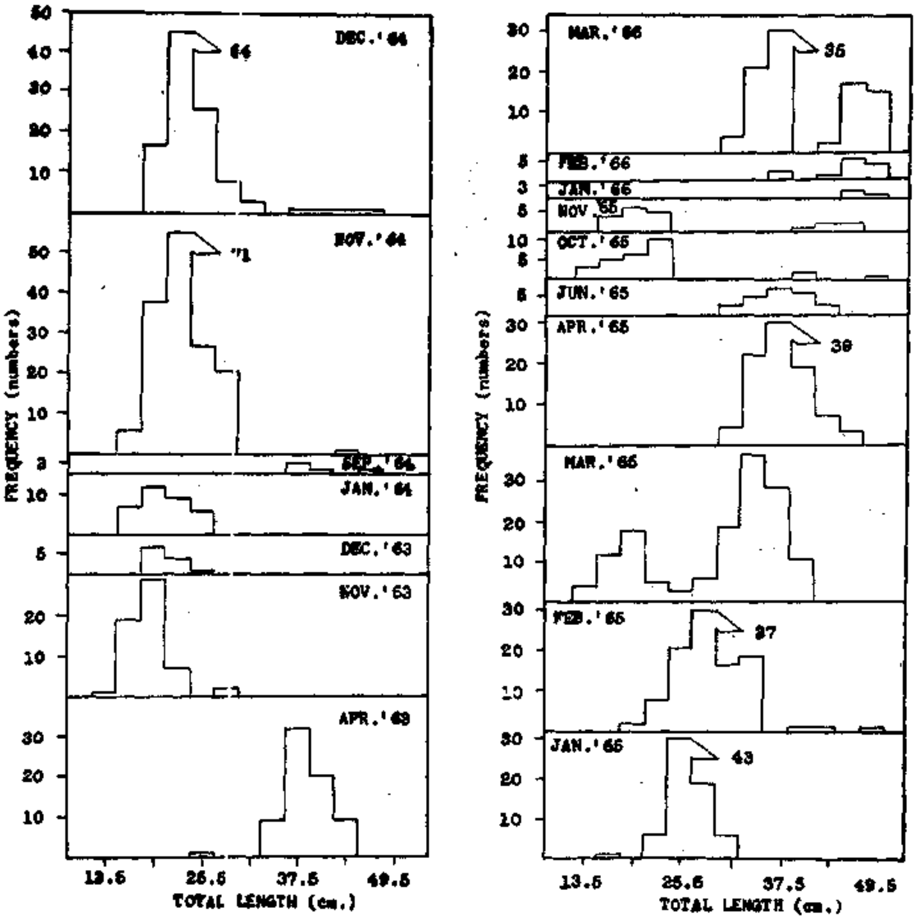

FIG. 3. Length frequency distribution of the 'O' year group in the different months.

different age groups available in the catches. The probability graph paper was used, applying correction due to truncation at lower end (Cassie, 1954) to dissect out the different age groups and find out their means and standard deviations as shown in Fig. 6 and Table 3.

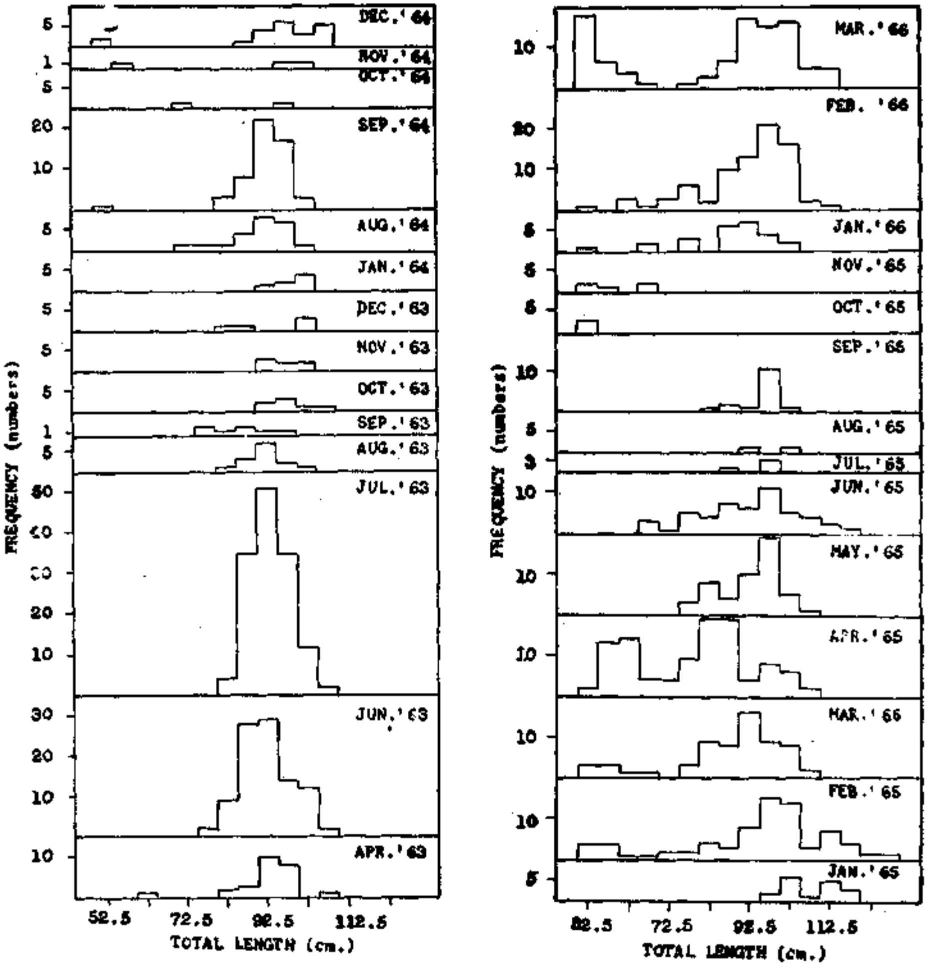

FIG. 4. Length frequency distribution of fish older than the 'O' year group in the different months.

In all the years the fourth year group is well represented in the catches, whose mean value ranges from 90.25 to 93.5 cm with almost uniform standard deviation. The mean lengths of the I, III and IV year groups in 1966 (Fig. 6), II and IV year groups in 1965 and IV year group in 1963 and 1964, are in close agreement with the results obtained by back-calculations, thus amply qualifying the validity of the latter method.

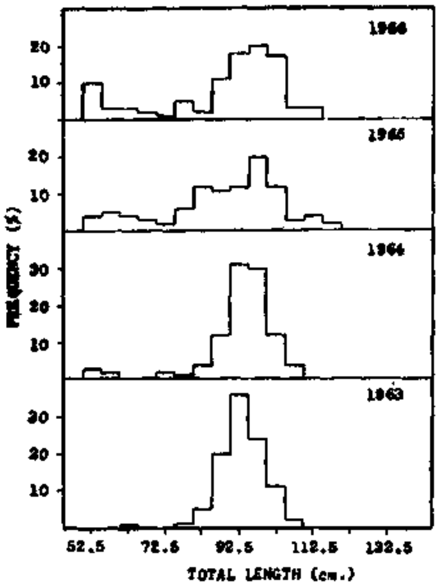

FIG. 5. Length frequency distribution of pooled monthly samples of fish above 50.0 cm in each year.

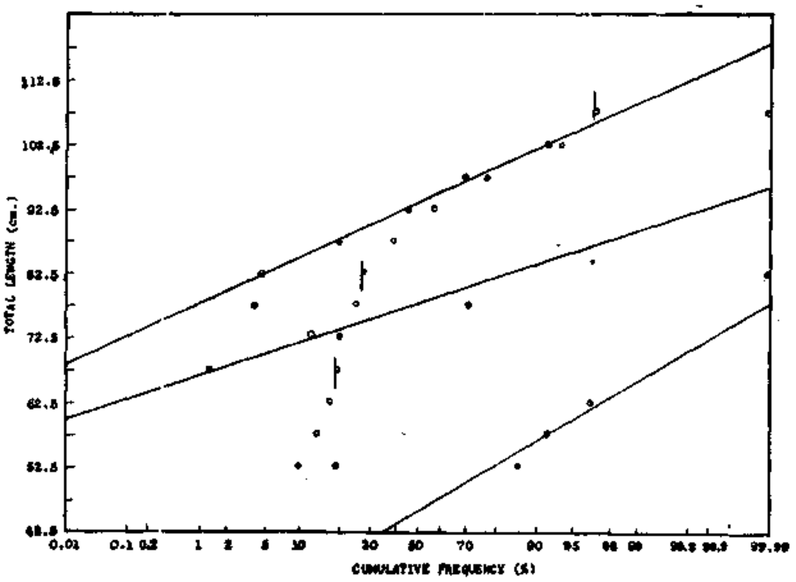

FIG. 6. Separation of the 1966 (New India Fisheries catches) samples into the different length groups on a probability graph paper.

TABLE 3. *Mean and standard deviation of the different age groups (Probability graph paper method, Fig. 6)*

Age	Years 1963		1964		1965		1966	
	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.
1	—	—	—	—	—	—	45.75	8.53
2	—	—	—	—	63.00	5.51	—	—
3	—	—	—	—	—	—	77.50	4.84
4	91.00	6.31	91.50	6.59	90.25	7.06	93.50	6.59

ESTIMATION OF GROWTH PARAMETERS

It is well known that the available growth equations can be generalised (Tomlinson and Abramson, 1961). With age as the dependent variable and length as the independent variable, the von Bertalanffy growth equation

$$L_t = L_\alpha \left[1 - e^{-k(t-t_0)}\right] \tag{5}$$

is of the form

$$Y = A + BC^t \tag{6}$$

where $A > O$, $B < O$, $O < C < 1$

and $A = L_\alpha$, $B = -L_\alpha e^{k t_0}$, $C = e^{-k}$. Replacing in (6) Y, A and B by their logarithms we get the form of the Gompertz, where $A > O$, $O < B$ (after proper adjustment), and $C < 1$; and replacing Y by $1/Y$ we get the form of the logistic, where $A > O$, $B > O$, $O < C < 1$. The growth laws are generally specified as

$$Y(t) = f(t, A, B, C), \quad (O < C < 1) \tag{7}$$

Consequently a technique useful with reference to any one of the patterns should be useful with reference to the other two.

Using the data of lengths of fish at several time points, Walford (1946) attempted the estimation of certain growth characteristics with no explicit reference to a growth curve. He proceeded on certain assumptions which are equivalent to supposing that Y(t) follows the von Bertalanffy growth law taken, say, in the form (6); and from this standpoint, his attempts mean a partial estimation of A and C, which are important in estimating mortality of fish, based on length data (Beverton and Holt 1956). These parameters are independent of the time origin and hence remain as absolute growth characteristics, even if the time origin could not be chosen with some biological significance, such as the starting of the "self inhibiting phase" (or the time of hatching in a few cases).

In view of the similarity of the three growth patterns, it is easily seen that Walford's technique can be extended to solve the parameters A and C in the other two equations also. The method of least squares, which has been so far widely used for solving analytically A and C of the Walford line with reference to the von Bertalanffy growth equation, can also be used for the other two.

Let Y_1, Y_2 .... Y_n be the mean lengths corresponding to equidistant times, t_1, t_2 .... t_n, and let $h = t_{i+1} - t_i$. Let us suppose that the length $Y = Y(t)$ and $\log Y = \log Y(t)$ and $1/Y = 1/Y(t)$ is related with time through the von Bertalanffy, the Gompertz and the logistic respectively. Using the method of least squares the lines $Y = \alpha + \beta X$ are fitted to the data (Y_i, Y_{i+1} ; $\log Y_j$, $\log Y_{i+1}$; and $1/Y_i$, $1/Y_{i+1}$) and estimators for $L_{\propto}$, $\log L_{\propto}$ and $1/L_{\propto}$ are the Y coordinates of the common points of this line (Fig. 7) and

$Y = X$. Thus

$$L_{\propto}, \log L_{\propto} \text{ and } 1/L_{\propto} \hookrightarrow \alpha/(1-\beta) \qquad (8)$$

The slope of the line is an estimator for e^{-kh}.

$$\text{Thus } e^{-kh} \hookrightarrow \beta \qquad (9)$$

$$\text{leading to } k \hookrightarrow 1/h \log_e (1/\beta) = -1/h \log_e \beta \qquad (10)$$

α and β may be analytically calculated for the three growth patterns without drawing a graph.

The correlation coefficient r is computed in each case to determine the most appropriate growth curve for the data on hand, by considering the line $Y = \alpha + \beta X$, for which r is nearest to 1, as the most appropriate.

In the present study, the parameters A and C are estimated using the individual average back-calculated lengths corresponding to the different ages of 6 year-old and 7 year-old fish only, so as to minimise the computational work while covering the entire range of age-length data. This procedure obviously resulted in having a new set of mean lengths at different ages. The caloulated growth parameters for the three growth patterns are given in Table 4, which shows that the logistic is the most appropriate growth pattern for the age - length data of 'ghol'.

TABLE 4. *Estimated values of $L_{\propto}$, k and r for the three growth patterns*

	estimators						
Growth pattern	$\bar{X}$ (cm)	$\bar{Y}$ (cm)	α (cm)	β	$L_{\propto}$ (cm)	k	r
von Bertalanffy	76.63	88.58	25.39	0.82456	144.72	0.1930	0.9809
Gompertz	1.8656	1.93775	0.6318	0.7000	127.60	0.3565	0.9853
Logistic	0.01430	0.01182	0.0036	0.5740	118.01	0.5550	0.9869

Fitting of logistic

Yoshihara (1951) attempted the fitting of logistic curve by truncating the left hand asymptotic at the point t=O. Brody (1927, 1945) divided the S-shaped curve at the inflexion point and fitted the two halves with separate curves. Ricker (1958) showed the relationship between the part of the logistic having decreasing slope and von Bertalanffy growth equation, as being

$$t_o = \frac{\log_e(-B/A)}{k} \tag{11}$$

where B and A are as in (6) and k as in (5). Calculation of t_o using (11) amounts to approximation of the logistic by von Bertalanffy growth equation as t increases, based on the property that $e^{k(t-t_o)}$ becomes sufficiently large as t increases, rendering $1/e^{k(t-t_o)}$ sufficiently small tor carrying out the approximation. In the case of

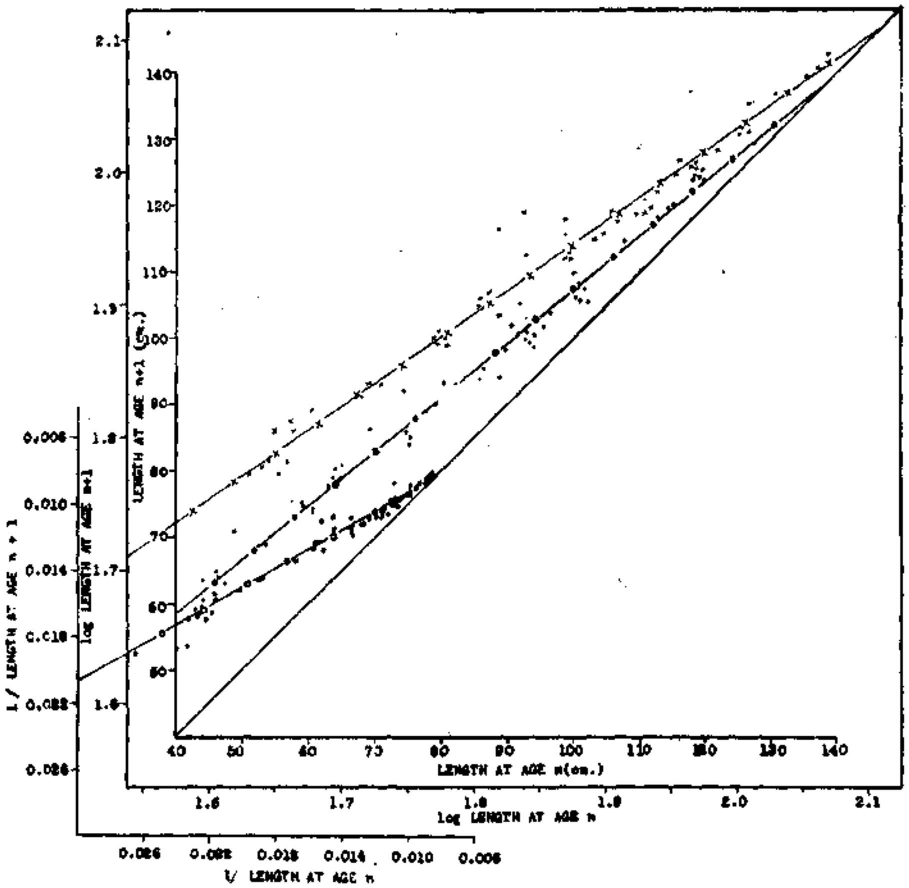

FIG. 7. Walford line for the von Bertalanffy, Gompertz and logistic growth equations.

fishes having a short life span with the age-length data on an yearly scale, the approximation is not valid enough. In such cases, the following method is suggested to estimate t_0 in the logistic making use of the estimators A and C obtained for the von Bertalanffy from (8) and (9) and an average t_0 from (11) calculated separately for each individual set of mean lengths at different ages of a fish. From (6) we have

$$\log(-B) = \frac{\log(A-Y) - t \log C}{n} \tag{12}$$

where n is the number of mean lengths at different ages. The value of log (—B) in (12) is substituted in (11).

Estimation of t_0 in the logistic

The logistic can be written as

$$L = \frac{L_\alpha}{1 + e^{-k(t-t_0)}}$$

It can be seen that at $t = t_0$, $L_t = \frac{L_\alpha}{2}$. Hence t_0 can be estimated by considering the x coordinate corresponding to $Y = L_\alpha/2$.

$$\frac{L_{\alpha l}}{2} = L_{\alpha v}\left[1-e^{-k_v(t_{ol}-t_{ov})}\right] \tag{13}$$

where the suffixes l and v stand for the logistic and von Bertalanffy respectively.

From (13) it can be derived that

$$t_{ol} = t_{ov} - \frac{1}{k_v}\log_e\left(1-\frac{L_{\alpha l}}{2L_{\alpha v}}\right) \tag{14}$$

Empirical growth of 'ghol'

Empirical growth of 'ghol' was worked out using the von Bertalanffy growth equation

$$L_t = 144.72\left\{1-e^{-0.193[t-(-0.69)]}\right\} \tag{15}$$

and the logistic

$$L_t = \frac{118.01}{1 + e^{-0.555(t-2.024)}} \tag{16}$$

The results of L_t obtained by using (15) and (16) are presented in Table 5.

The table shows clearly that calculated values of L_t for the von Bertalanffy growth pattern are very much different from the observed values compared to the

TABLE 5. *Observed values of L_t and the calculated values of L_t*

t	Observed mean length at age t	Calculated L_t (Logistic)	Calculated L_t (von Bertalanffy)
1	44.13	42.63	37.63
2	60.89	58.71	56.95
3	76.87	74.56	72.85
4	90.31	88.54	85.88
5	100.11	99.00	96.15
6	105.72	106.34	104.88
7	115.24	110.98	111.79

values of L_t estimated by making use of the logistic growth pattern. This further substantiates the validity of the latter growth pattern as the more appropriate one for describing the growth of 'ghol', besides its high value of r. In less clear cases a χ^2 test may be conducted.

LENGTH-WEIGHT RELATIONSHIP

The length-weight curve was fitted by the parabolic equation $W=CL^n$, where W=weight of the fish in kilograms, L=total length in centimetres and C and n are constants. The length-weight relationship of 'ghol' is expressed as

$$\log W = -4.6719 + 2.8188 \log L \tag{17}$$

DISCUSSION

The tendency of investigators on the age and growth of tropical fishes was always to follow the lead given by observations on fishes of temperate waters, which resulted in inadequate explanations of the phenomenon of ring formation. This inadequacy did not, however, deter them from considering the scales and other structures as useful recorders of growth, as a comparison of mean lengths at different ages obtained by ring count with those obtained from length frequency studies often justified the counting of rings as a valid method.

Rao (1961) who studied the age and growth of 'ghol' by means of scales, started with the assumption that formation of growth rings is due to slow growth, attributed to low feeding (particularly in the case of juveniles), along with spawning in the case of adults. The period August to January was found by him to be the time of ring formation, which is obviously too long a period of slow growth, particularly for the juveniles, which seems to be affected by low feeding. It was, however, contradicted in a separate statement by him, that high feeding intensity was recorded during September to December in the case of juveniles (below 25.0 cm) declining to a minimum by March-April. The confusion is a direct result of the erroneous assumption that formation of growth rings is due to slow growth. In the present study, the time of formation of rings, based on the appearance of narrow transparent bands representing fast growth, was found to be during February-April.

The results obtained in the present study differ slightly from those of Rao (*op. cit.*) in certain other respects too. In the present study the margins of the growth zones were located taking care to avoid the supernumerary rings, which appear to be a possible source of error. The average size of fish, when false rings appear was observed to be 57.0 cm between I-II years, 75.0 cm between II-III years, 85.0 cm between III-IV years and 98.0 cm between IV-V years. Though the number of supernumerary rings between the annular margins was usually one, occasional appearance of more than one was also noticed between annuli I-II, II-III and III-IV. The average sizes of 'ghol' at ages I+, III+, V+ and VI+ were respectively 46.4 cm, 80.5 cm, 101.2 cm and 105.9 cm according to the present study and 44.6 cm, 80.9 cm, 99.5 cm and 104.3 cm according to the earlier study. The results of the two studies are fairly close, the discrepancies of mean lengths at II+ and IV+ages fall within the one standard deviation limit (Table 1).

The problem of deciphering the growth checks becomes accentuated in the case of older fish, in which the more recently formed bands are narrowly spaced. In the present study the scope for error is minimised by considering the beginning of the narrow transparent band immediately following a wide opaque band as the beginning of a growth zone and as the margin of the previous growth zone (Pl. I). Thus the opaque band may still be called the 'annular band' or 'annulus'.

The nature of the 'annulus' on the scales of 'ghol' is seen to be entirely different from that of fishes in temperate waters. Alternation of narrow transparent bands with wide opaque bands, which usually represent respectively periods of faster and slower growth (normal growth of the fish) gives rise to the appearance of rings on the scales. It has been already shown that the formation of the transparent rings is an annual feature. *The ring formation on the scales of* ***ghol*** *is not due to cessation* of growth or slow growth, but it may be due to fast growth arising out of a complex of favourable conditions - either internal or external, or due to the destruction of sclerites periodically. The phenomenon of ring formation on the scales of ***ghol*** thus appears to be different from what was observed in the case of fishes of temperate waters. Other tropical fishes also (Figs. 1 and 2 of Sarojini, 1957) show alternating transparent and opaque bands, as evidence of annual rhythms in growth. Sometimes, the growth rhythms may be biannual, (Gopalakrishnayya, 1967) in which case, two transparent bands together with their preceding opaque bands form an annual growth zone. With proper modification in the case of each species, the growth rings (transparent bands) on scales may be used successfully in the tropical fishes for age determination and back-calculation of lengths at previous ages.

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