BIOLOGY AND FISHERY OF THE PIG-FACE BREAM, *LETHRINUS LENTJAN* LACEPEDE FROM INDIAN WATERS

III. AGE AND GROWTH

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INTRODUCTION

Determination of age and growth of a fish is an important aspect of any fishery research programme. The knowledge of the age structure of the population from year to year helps to furnish the mortality and survival rates of various year classes and also the success of yearly recruitments. Analysis of size and age data of the fish gives estimates of growth rate of the fish and also explains the role played by various year-classes in the fluctuation of the fishery. As is well known, the rational exploitation of the fishery depends on adequate information of these vital rates for which accurate assessment of age is essential.

In the course of progress in fishery research, different methods have been evolved for determining the age of the fish. These methods may be broadly classified into two groups, (i) analysis of length frequency data by Petersen's method, which enables in determining the average size of the fish at different ages, (ii) counting the number of periodic rings or zones one certain skeletal structures, *viz.*, scales otoliths, vertebrae, opercular bones and fin rays. If the marks or rings on these structures are periodic in nature, the method enables to determine the age of individual fish.

There have been numerous applications of both the methods of age determination. In some investigations, of course, Petersen's method is the only possible way for determining the age structure of the population. This applies to those fish, found mostly in tropical waters, whose skeletal structures have no recognizable annual rings or zones, or on which irregular rings or zones are formed annually. In temperate countries the age determination of fish by counting the periodic marking in the skeletal structures (scales and otoliths) is well established and has become an accepted routine in many fishery investigations. The literature on the subject pertaining to the fishes of temperate regions in vast. Mohr (1927, 1930, 1934) published bibliographies on the

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subject and Van Oosten (1929) gave elaborate review of the scale method. Graham (1929a, 1929b) made a most valuable survey of several papers on age determination of fishes by the use of scale, otolith and bones. Menon (1950, 1953) reviewed the literature on the use of bones other than otoliths in determining the age and growth rate of fishes, and the work done on the determination of age and growth of fishes of tropical and sub-tropical waters.

But in fishes from tropical waters, the skeletal structures have not been subjected to intensive study. The possibilities of scales and otoliths being useful as age indicators in some species have been demonstrated by recent investigations in India, viz., Nair (1949), Seshappa and Bhimachar (1951, 1954, 1955), Pillay (1954), Radhakrishnan (1954, 1957), Sarojini (1957), Jhingran (1957, 1959), Seshappa (1958), Venkatasubba Rao (1961) and Narayanankutty (1961).

In the present investigations attempts have been made to determine the age of *L. lentjan* by Petersen's method (analysis of length frequency data) and by counting the growth checks or rings on scales and otoliths of the fish.

Material and Methods

The length measurements of 3,356 specimens were taken during the period September 1960—June 1962. All the fish were examined in fresh condition and total length was recorded in each case. The fish were grouped at 1 cm. length interval, with the mid-point representing the particular size group. In a size group, as for instance 4.0—5.0 cm., all fish measuring between 4.1 and 5.0 cm. were included. The fish measuring 5.1 cm. was, therefore, placed in the next group although this group is denoted as 5.0—6.0 cm. and so on. It may be mentioned here that for the length frequency analysis by Peterson's method, the data collected from shore seines alone are taken into consideration since the specimens from hook and lines and basket trap catches were not available regularly in good numbers.

After noting down the total length and the sex of the fish, the otoliths were extracted by making a sharp dorso-ventral cut along the supraoccipital crest. Attention was confined to the largest otolith, 'sagitta' which is widely used for age determination of fishes (Jones and Hynes, 1950). After extraction, the otoliths were washed with water and cleared. It was necessary to grind both the sides of the otoliths on a carborundum, before the zones could be seen clearly. The otoliths were carefully ground, so that the periphery was not damaged. Ground otoliths were washed with water, dehydrated in alcohol and cleaned in xylol. The otoliths when examined without media were not so clear. Otoliths were examined in different media like xylol, cedarwood oil, cresoto-xylol, but cresote oil as recommended by Johnston (1938) was found to be the most satisfactory.

About four scales were taken from each fish and cleaned in 5% solution of potassium hydroxide; they were then washed in water and the semi-dried scales were kept between two thin micro-slides, the ends of which were sealed with cellotape. The scales were examind under binocular microscope.

OBSERVATIONS

The analysis of length-frequency distributions:

It may be recalled that *L. lentjan* has two spawning seasons, viz., December—February and June—August (Toor, 1963). As such, Petersen's method of age determination from length frequency polygon may present some difficulties because there is likely to be somewhat extended recruitment to the fishable stock due to the long spawning period, thereby masking distinct mode formation.

In general, there are two quarters, *viz.*, December—February and June—August, when spawning takes place, though occasional spawning may extend beyond these periods. Hence, the length frequency data are pooled according to quarters corresponding to the spawning period. These pooled data are presented graphically in Figures 1—8 and the subsequent discussions are based on the quarterly length frequency data.

From Fig. 1, it may be seen that during the quarter September to November 1960, three modes or size groups are traceable, viz., A, 12.5; B, 20.5 and C, 23.5 cms. Since there are two spawning periods, the difference between the modes on an average would be six months, provided no group remains unrepresented. Thus, the first group 12.5 cm. should be either three months or nine months old. If the spawning has taken place between June and August, it is too much to expect that the fish has grown up to 12.5 cm. in three months' time. It is logical to conclude that the group represented by this mode 12.5 is 9 months old. In the quarter December—February (1960-61), it may be noticed that this mode has progressed to 17.5 cm. (Fig. 2) thereby showing a growth of nearly 5 cm. in three months. Hence, as stated earlier, it may be assumed that the mode 12.5 in September--November (1960), represented the nine months old fish. It follows that this group was then spawned in December—February (1959—60) quarter and thus at the end of one year, it reaches the modal size of 17.5 cm., as represented by the mode A (Fig. 2) in December —February (1960-61) period. On the strength of the above assumption, it may be assumed that the second mode found in September—November (1960) at 20.5 cm. was obviously represented by the fish 15 months old and the mode at 23.5 cm. by the 21 months old fish. The growth rate after the completion of one year, thus, seems to have slowed down very much, being about 3 cm. in 6 months. If this growth rate is maintained hereafter, the modal size at the end of the second year would be about 26.5 cm.

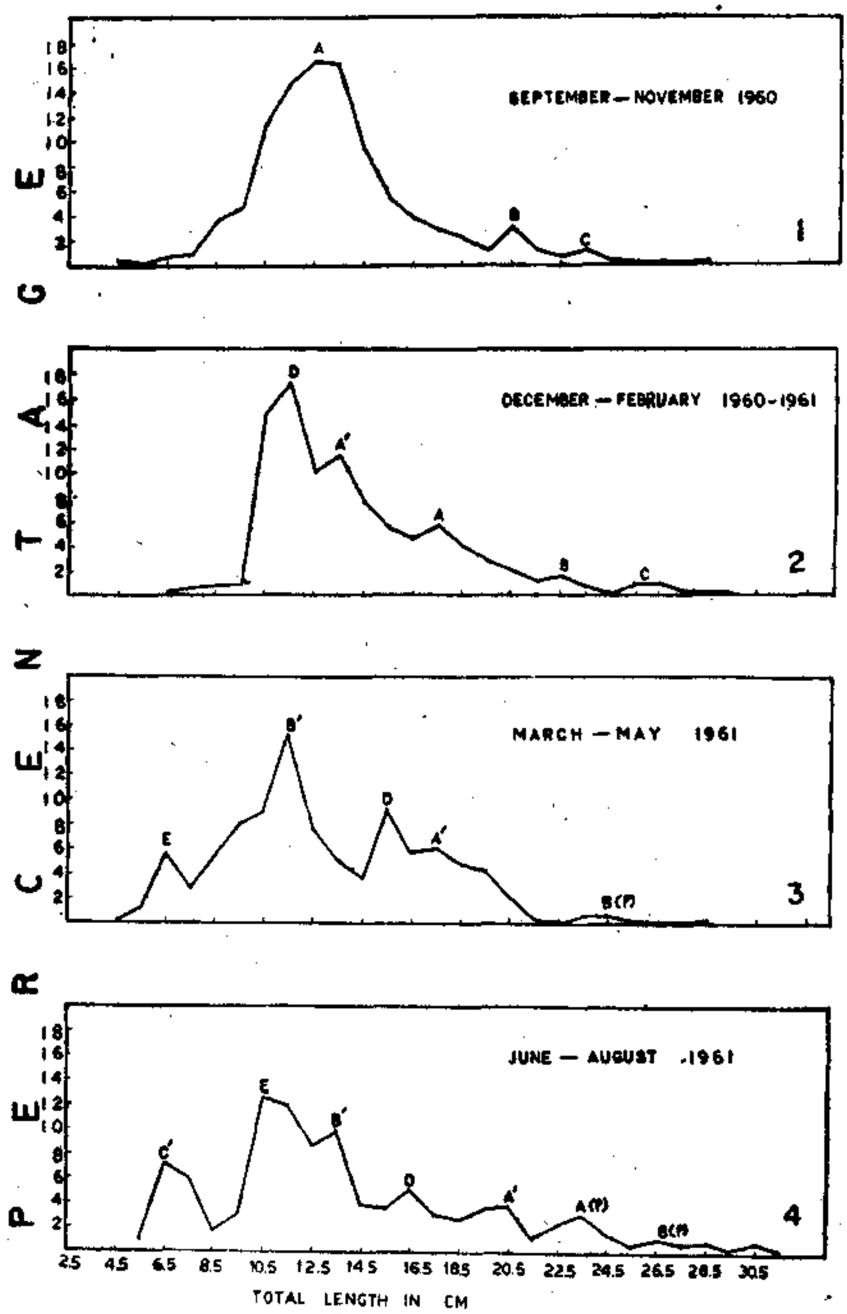


FIG. 1—4. Length-frequency curves of *L. lentjan*.

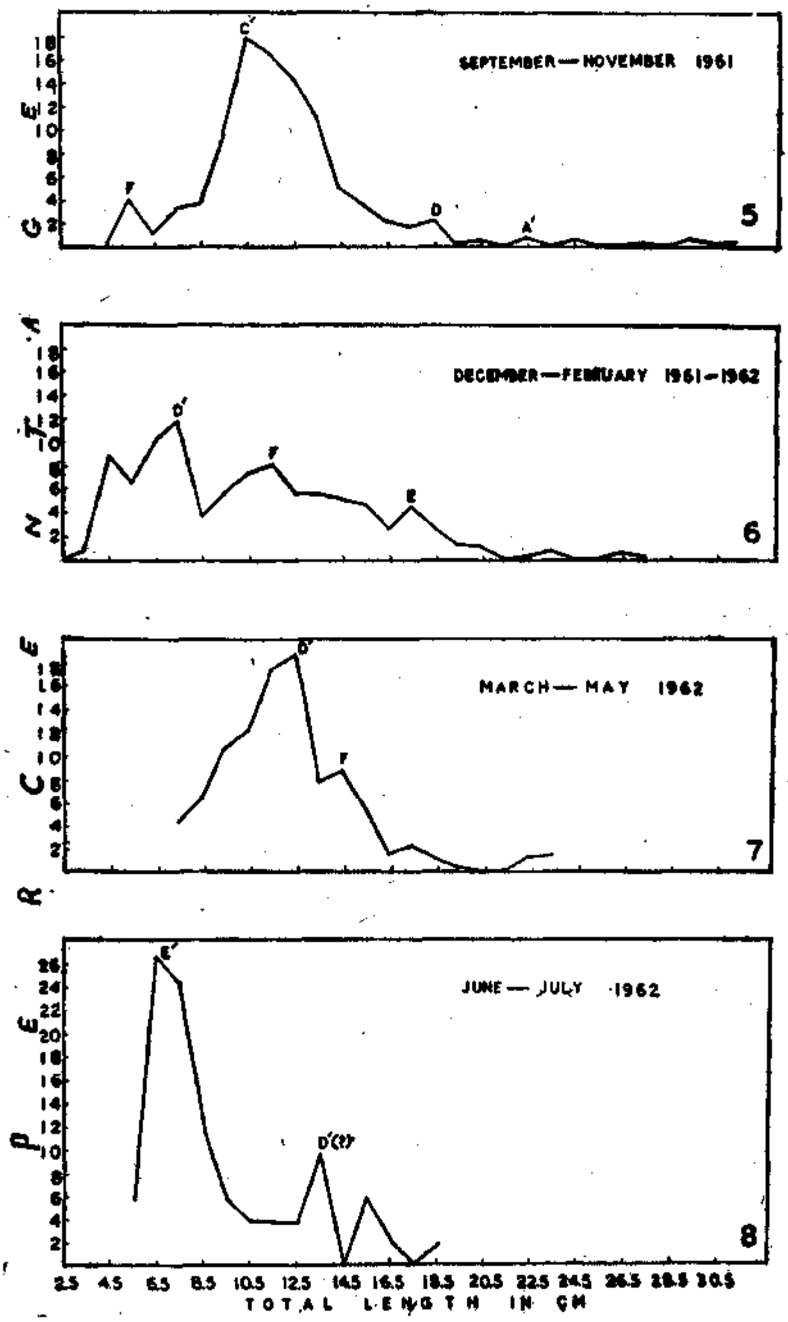


FIG. 5—8. Length-frequency curves of *L. lentjan*.

In the length-frequency curve for December—February (1960-61) in modes are found at 11.5, 17.5 and 22.5 and also at 25.5 cm. (Fig. 2). The mode at 11.5 cm. is a new mode and hence, must be the result of the previous spawning season in June—August, in which case it must be six months, or the result of spawning in previous December—February (1959-60) in which case it must be about one year old. Based on the growth rate discussed above relating to modes A, B and C, this mode which will be designated as D appears to be represented by six months old fish only. The other three modes are the results of growth of the fish belonging to the groups A, B and C found in the previous quarter. They must, therefore, be represented by 12, 18 and 24 months old fish. In addition to these, there is an indication of a mode A at 13.5 cm. The age of the fish of this group should be between 6 and 12 months and assuming it to be 9 months, it means that this group must have arisen from the fish that spawned in March—May. It has been stated that there are two spawning periods viz., December—February and June—August. If that is so, the group A cannot be explained, unless it is assumed that this is a false mode arising from sampling deficiencies, or it is assumed that this group is the result of late spawning in February or March 1960. The latter possibility is indicated when the length-frequency distribution polygors of subsequent quarters are taken into consideration.

In the next quarter, March—May 1961 (Fig. 3) the mode at 15.5 cm. is obviously the new position of mode D. While mode B seen during December—February (1960-61) has practically disappeared from the fishery even though still visible as a mode at about 24 cm. and the mode C at 25.5 cm. seen in the previous quarter cannot be traced in this quarter. The possible mode at 17.5 cm. is the new position of A'. In addition to these, two other modes can also be recognized, viz., E at 6.5 and B' at 11.5 cm. The mode E at 6.5 cm. probably represents the fish which were recruited during previous December—February (1960-61) spawning season and are therefore about 3 months old. Since the mode B' at 11.5 cm. lies between E and D, it may either represent a 6 months old group or a false mode. The mode is so prominent that the latter possibility is out of question. This means B' must represent the fish which were recruited late in the spawning season June—August (1960), probably at the end of August, 1960.

In the quarter June—August (1961), the new positions of the modes A', D, B' and E can be seen at 20.5 cm., 16.5 cm., 13.5 cm. and 10.5 cm. respectively (Fig. 4). The small mode at 23.5 cm. may be the possible position of the mode A seen in December—February (1960-61). In addition, a new mode C' at 6.5 cm. can be seen. This group of fish represented by the mode C' is probably a little more than 3 months since it must have been spawned towards the end of last spawning season, viz., December—February (1960-61).

In the quarter September—November (1961), the new positions of C′, D and A′ are noticed at 10.5, 18.5 and 22.5 cm. respectively (Fig. 5). In addition, a new mode F at 5.5 cm. is found, which must be represented by 3 months old fish and would have, therefore, been recruited in June—August (1961). The groups E and B are not clearly represented.

In the quarter December—February (1961-62) (Fig. 6) the new position of F is seen at 11.5 cm., the mode at 17.5 cm. is possibly the new position of E which was not seen clearly in the previous quarter. The mode A′ of previous quarter cannot be traced with certainty. In addition, there is an indication of a mode D′ at 7.5 cm. which must be the result of spawning in August 1961. There is further evidence of a still smaller group of fish ranging from 2.5 cm. and having a mode at 4.5 cm. The presence of the juveniles (2.5 cm.) indicate that it is a new brood of the current spawning season (December—February, 1961-62).

In the quarter March—May (1962), the modes at 12.5 cm. and 14.5 cm. are possibly the new positions of D′ and F (Fig. 7).

In June and July (1962), the number of specimens was small and only one clear mode is seen at 6.5 cm. which may be designated as E′. The fish representing this mode (E′) must have been recruited sometime in previous spawning season, probably during February (1962) and will be about 3 months old. The possible mode at 13.5 cm. may be the new position of the mode D′ (Fig. 8).

Table I shows the progression of different groups identified and their probable age.

From the Table I, it may be stated that on an average the fish attains the length of about 17.25 cm. (total length) at the end of the first year and 26.25 cm. at the end of second year. The sizes at subsequent ages cannot be traced from length frequency data. But, if it is assumed that the growth rate at the third year of life is about the same as in the second year, the probable size at the end of third year of life will be about 35.5 cm. The size of the fish as obtained from the length-frequency data (Table I) was plotted against the probable age. A free hand drawing shows the possible shape of the growth curve (Fig. 9). This is dealt with in greater detail subsequently.

Age determination from otoliths and scales:

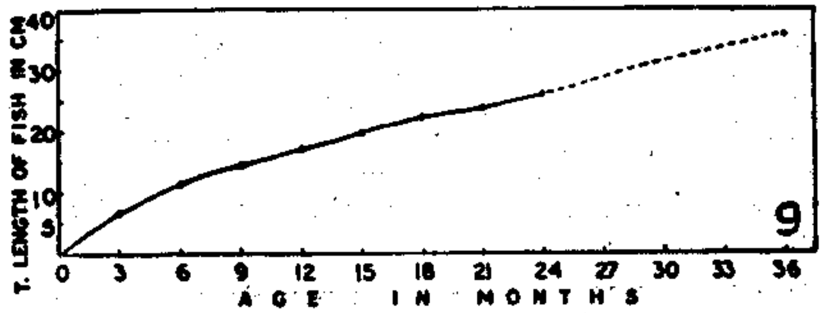
The principle of age determination of individual fish by this method depends on the recognition of periodic growth checks on certain skeletal structures, *viz.*, scales, otoliths, vertebrae, opercular bones and fin rays. It is well known that the growth of a fish is not uniform throughout the year or through its span of

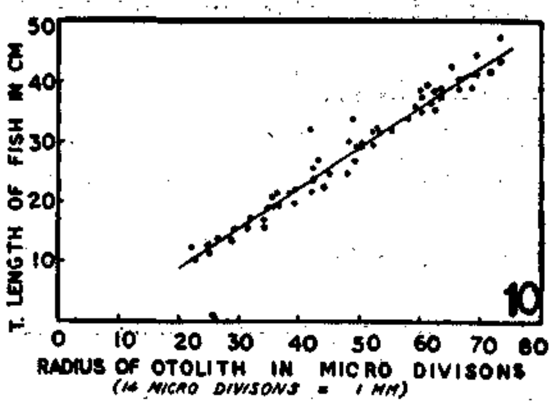
TABLE I

The different modes and their probable age in the length-frequency distribution of L. lentjan *during September* 1960 *to July* 1962

Identified modes	Age in months							
	3	6	9	12	15	18	21	24
A	..	..	12·5	17·5	..	23·5 ?	..	..
B	..	..	..	..	20·5	22·5	24·0 ?	26·5 ?
C	..	..	..	..	..	..	23·5	26·0 ?
D	..	11·5	15·5	16·5	18·5	..	..	..
E	6·5	10·5	..	17·5	..	..	..	..
F	5·5	11·5	14·5	..	..	..	..	..
A'	..	..	13·5	17·5	20·5	22·5	..	..
B'	..	11·5	13·5	..	..	..	..	..
C'	6·5	10·5	..	..	..	..	..	..
D'	7·5	12·5	13·5 ?	..	..	..	..	..
E'	6·5	..	..	..	..	..	..	..
Average size	6·50	11·33	13·83	17·25	19·85	22·83 ?	23·75 ?	26·25 ?

life showing alternating fast and slow rates of growth depending on favourable or unfavourable conditions. This alteration of fast and slow growth rates of the fish expresses itself annually, on these skeletal structures, as periodic fast





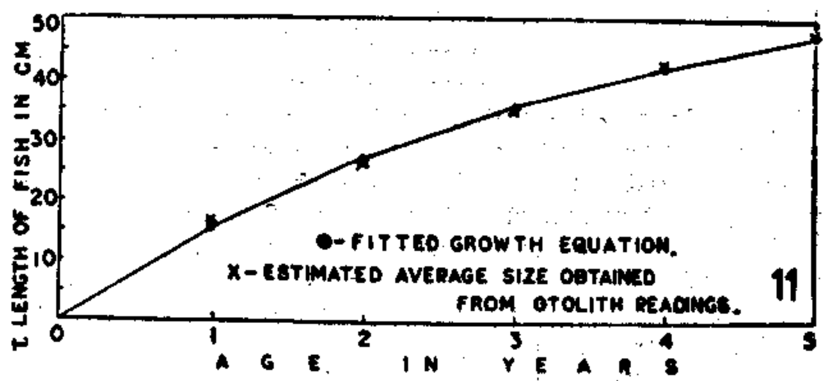


FIG. 9. Growth curve of *L. lentjan* from length-frequency data.

FIG. 10. Relation between the radius (R) of the otolith and total length (L) of *L. lentjan*.

FIG. 11. Estimated average sizes attained from otolith readings of *L. lentjan* & fitted growth curve from Bertallanfy's growth equation.

growing (i.e., wide) and slow growing (i.e., narrow) zones. In case of fishes of temperate zones it has been established that these phases of growth are seasonal and there is a definite relation between the periodic marks on the skeletal parts and the growth of the fish.

But before attempting to interpret the zones or rings on skeletal structures as evidence of age of fish it is essential to provide corroborative evidence, as emphasized by Graham (1929) and Van Oosten (1941), that the zones are annual or periodic in nature. It is well known that this can be done by comparing the results obtained from such study with the results obtained from the length frequency distribution analysis and also by making a seasonal record of zone formation.

In order to find out whether any of these skeletal structures, in case of *L. lentjan*, will be useful in determining the age of individual fish, representative samples of scales and otoliths were examined throughout the course of this investigation.

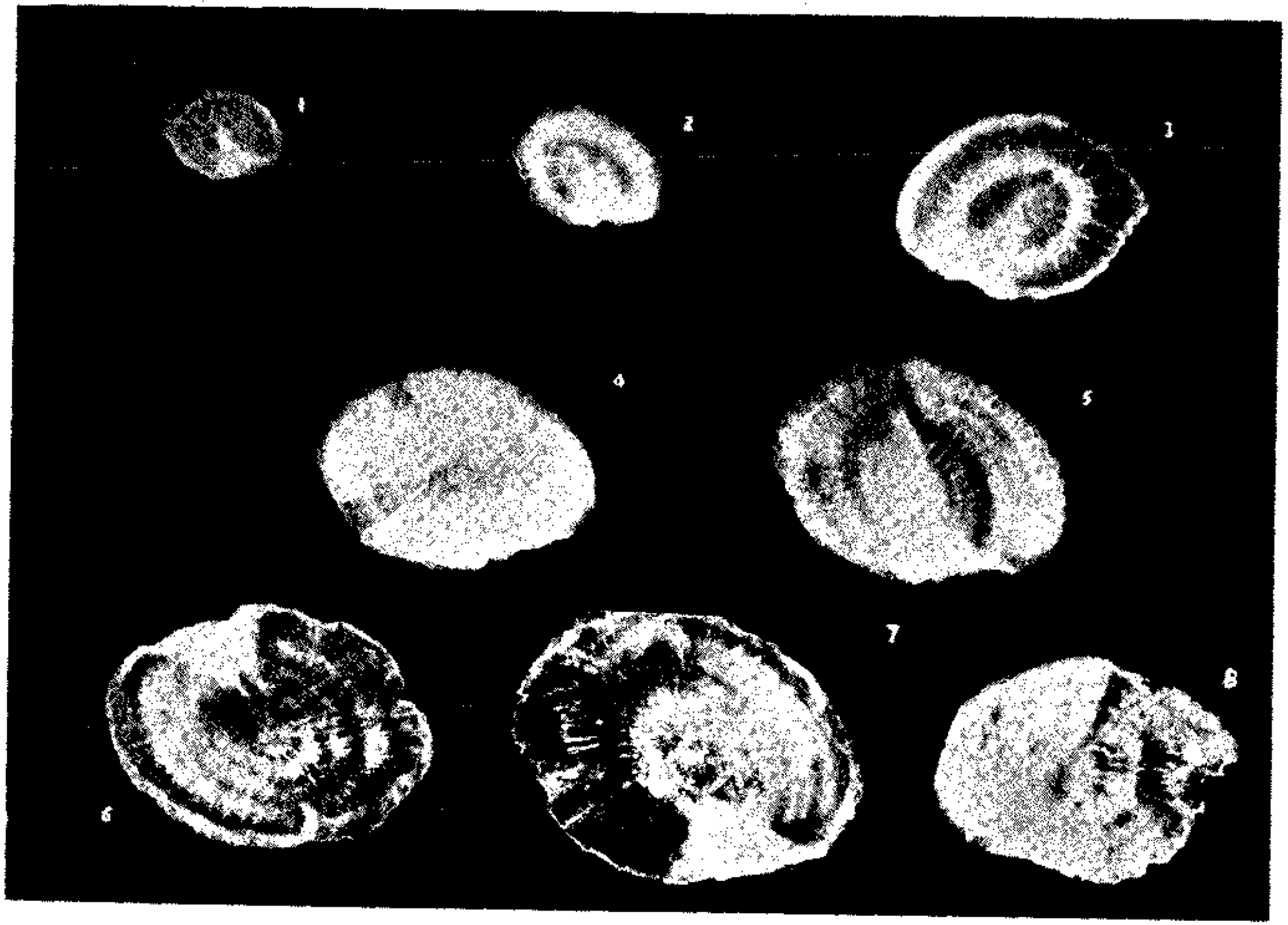
Determination of age from otoliths:

The otolith (Sagitta) in this fish is elliptical, thick in the middle and thin at the periphery. One side is concave while the other is convex. The concavities of the two otoliths face each other. On the convex side there are two to three grooves. The margins of the otoliths of large specimens are slightly crenated.

The otoliths when examined under microscope by using the reflected light showed concentric opaque and transparent regions. The middle area of the ground otolith is normally opaque and white, surrounded by a wide transparent area which is clearer in younger fishes' otoliths. Walford and Mosher (1943) used the following criteria for the identification of the annulus in the otolith of the Californian sardine, "An annulus is a more or less translucent band concentric with the margin of the otolith, the intervening space being opaque. It can usually be traced entirely around the otolith, although it is easily observed at the blunter anterior end than at the sides or posterior end. Annuli tend to be zones rather than lines". It was observed that these criteria are useful in the case of otoliths of *L. lentjan* also. Following this definition, the number of transparent zones on the otoliths were counted. Assuming that each transparent zone is laid annually, the age of each fish was assessed by counting the transparent zones excluding the zone surrounding the nucleus of otolith since the similar zone was seen in juveniles also (Plate I, 1-8). The formation of such transparent zone around the nucleus has been noticed in other fishes and is termed as larval ring, birth mark or metamorphic annuli (Gottlieb, 1956; Sivalingam, 1956; Qasim, 1957b and Sin-ichi Mio, 1960).

The results of the otolith readings are presented in Table II and III.

Plate I



1. Otolith of *L. lentjan* without any growth ring, x 6. T. L., of fish: 11.0 cm. (December, 1960).
2. Otolith of L. *lentjan* showing one growth ring at the margin, x 6. T.L. of fish: 15.3 cm (August, 61).
3. Otolith of *L. lentjan* showing one growth ring and opaque zone at the margin, x 6. T.L of fish: 22.5 cm. (October, 1961).
4. Otolith of *L. lentjan* showing two growth rings (One at the margin, x 6. T. L. of fish: 28·7 cm. (June, 1961).
5. Otolith of *L. lentjan* showing two growth rings, and opaque zone at the margin, x 6. T.L. of fish: 13·4 cm. (November, 1961.)
6. Otolith of *L. lentjan* showing three growth rings (opaque at the margin), x 6. T. L. of fish: 39.6 cm. (November, 1961).
7. Otolith of *L. lentjan* showing 4 growth rings and opaque zone at the margin, x 6. T. L. of fish: 47.35 cm.
8. Otolith of *L. lentjan* showing five growth rings (One at the margin), x 6. T. L. of fish: 49.20 cm. (January, 1962).

TABLE II

Length and age of fish as determined from otoliths

Size group (T.L.) cm.	Mid point	No. of specimens	Age groups 0	1	2	3	4	5
1	2	3	4	5	6	7	8	9
10—12	11	14	9	5	..	..	..	..
12—14	13	21	14	7	..	..	..	..
14—16	15	26	4	22	..	..	..	..
16—18	17	20	..	20	..	..	..	..
18—20	19	14	..	14	..	..	..	..
20—22	21	18	..	17	1	..	..	..
22—24	23	17	..	13	4	..	..	..
24—26	25	20	..	6	14	..	..	..
26—28	27	7	..	..	7	..	..	..
28—30	29	11	..	..	11	..	..	..
30—32 . . .	31	14	..	..	12	2	..	..
32—34	33	5	..	..	1	4	..	..
34—36	35	3	..	..	..	3	..	..

TABLE II

Length and age of fish as determined from otoliths

Size group (T.L.) cm.	Mid point	No. of specimens	Age groups 0	1	2	3	4	5
1	2	3	4	5	6	7	8	9
36—38	27	3	..	..	..	3	..	..
38—40	39	2	..	..	..	2	..	..
40—42	41	1	..	..	..	1	..	..
42—44	43	1	..	..	..	..	1	..
44—46	45	2	..	..	..	..	2	..
46—48	47	1	..	..	..	..	1	..
48—50	49	2	..	..	..	..	..	2
50—52	51	1	..	..	..	..	..	1
TOTAL		203	27	104	50	15	4	3
Average size				18·15	27·52	35·27	44·00	49·66

TABLE III

Summary of the data from Table II

Age groups (years)	Number of species	Size range total length in cm.	Mean length cm.	Growth increment for year (cm.)
1+	104	10·26	18·15	18·15
2+	50	20·34	27·52	9·87
3+	15	30·42	35·27	7·75
4+	4	42·48	44·00	8·73
5+	3	48·52	49·66	5·66

It will be seen from Table II that one or more transparent zones were found in the otoliths of fish more than 16 cm. in size. The presence of one transparent zone was found in the otoliths of fishes ranging from 10 cm. to 26 cm. Two transparent zones were found in the otoliths of fishes ranging from 30 cm. to 42 cm. Four transparent zones were found only in the otoliths of four fishes out of 203 examined and the sizes of these fishes varied from 42 to 48 cm. and five transparent zones were found in the otoliths of three fishes only, ranging in size from 48 cm. to 52 cm. There is some amount of overlapping of sizes of fish in the first three age groups as read from the presence of the transparent zones on the otoliths. No overlapping is noticed in the size range of fish of age four and five when compared with the fish of earlier age groups. This may be due to small number of fish examined in these age groups. From Table III, it will be noticed that the average size of the fish at ages 1, 2 and 3 (years) as determined from otolith readings, agree well with the estimates of average sizes at corresponding ages obtained from the length-frequency distribution studies. The slightly higher estimates obtained from the otolith readings may be due to the reason that the range of size of fish shown in each year class includes not only their actual sizes at the completion of respective years, but also the length increments between one year and the next.

In most of the otoliths some opaque zones were noticed at the periphery surrounding a transparent zone. This means that some growth has taken place after the completion of the transparent zone. To get an accurate estimate of the average size at different ages, it was felt necessary to back-calculate the size of the fish at each stage of completion of transparent zone. For an effective back calculation of the size of the fish at the completion of particular year, it is first necessary to suppose that the growth of fish and the growth of the otolith are related in some easily calculable way. Generally it has been supposed that the growth of fish and its otolith is proportionally or at least linearly related, although Fry (1943), e.g., has considered the relationship of the form $y = b \times^n$ for several species of fish. Sheriff (1922) attempted to show that a parabolic fish length/scale length relationship was more appropriate than a linear one in the herring, by showing that the sum of squares of deviations from the best fitting quadratic were less than the best straight line, fitted by the method of least squares. It is obvious, however, from the figures that the reduction in the sum of squares due to the quadratic term is non-significant so that it may be concluded that a straight line fitted the data quite adequately (Jones, 1958). Thomson (1923, 1929) gave illustrations of fish length/scale length relationship in North Sea and Iceland haddock. He fitted the straight lines and quadratic curves to the data and in each instance the reduction in the sum of squares due to the curvilinearity of the regressions was significant at 1% level.

It has been explained by earlier workers that when the fish length/scale— or otolith length relationship is proportional, the length of a fish at some previous age t is given by

$$Lt = \frac{L.\ rt}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where L and R are the length of fish and scale or otolith respectively; Lt is the calculated length at age t and rt is the length of the scale or otolith up to the ring.

If the fish length/scale or otolith length relationship is linear but of the form L = a + bR (where a and b are constants), then (1) must be replaced by:

$$Lt = \frac{Lrt}{R} + a\left(1 - \frac{rt}{R}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The plotting of the radius of the otoliths (R) against the lengths of the fish (L) in case of a sample of 101 fish showed that a linear relationship of the form L = a + bR exists, (Fig. 10) where L is the total length of the fish and R is the radius of otolith (from its nucleus to the shortest axis) and 'a' and 'b' are two constants. To find out the values of 'a' and 'b' the method of least squares was applied. Given below are the sums of L, R and also the sum of squares and products (L^2, R^2 and LR):

No. of specimens — 101

L = 2172·30 (in cm.)

R = 3963·00 (in micro-divisions, 14 m.d. = 1 mm.)

L^2 = 53004·29

R^2 = 168463·00

LR = 93919·10

The corresponding corrected sums of squares and products are as below:

L^2 = 6282·64

R^2 = 12964·30

LR = 8683·21

The regression coefficient b calculated from the above values works out to be b = 0.6698. The least square estimate of a is found to be, a = −4.7734. Thus, the relation between the L of fish and R of the otolith can be written as L = − 4.7734 + 0.6698 R.

Frequently it is thought that the coefficient 'a' should correspond to the length of fish at an age when the scales or otoliths were first laid down. This, however, is not so as has been explained by Jones (1958) in the case of scales: "In the adult fish the body is covered by overlapping scales. At the moment of formation the centres of these scales can be regarded as tiny points scattered through the skin. Therefore, for the first few weeks after formation, these scales will have to grow very rapidly if they are ever to overlap one another. In fact, during this period they must grow faster than the body itself. Once the scales are fully formed the degree of overlapping of adjacent scales can be expected to remain approximately constant so that once the scales are overlapping, the growth of the scale, relative to that of the fish, must decrease very greatly, otherwise they would soon outgrow the fish itself. For purpose of calculation, it is the intercept 'a' that is required". The same argument holds good for the otoliths also. Just after the formation, the otoliths grow more rapidly than body and once they have grown to some length the linear relation between the otolith radius and fish length holds as described by the equation: L = a + bR or L = − 4.7734 + 0.6698 R. For purpose of back calculation the value of a, however, is used. Using the formula (2) given earlier the back calculated sizes of fish were obtained at the completion of first year, second year, third year, fourth year and fifth year, for a sample of 30 fishes and the results are presented in Table IV.

TABLE IV

Random sample of 30 fish, and their total lengths (L), radius (R) of their otoliths and the radii (r_1)—to the annuli

Fish No.	Total length (L)cm.	Radius of otolith (R) m.d.	Radius up to end of transparent zones					Estimated length of fish at the time of completion of various transparent zones				
			r_1	r_2	r_3	r_4	r_5	L_1	L_2	L_3	L_4	L_5
1	22·50	44	32	..	..	..	..	15·06	..	..	..	..
2	27·00	43	29	40	..	..	..	16·02	26·23	..	..	..
3	29·80	50	29	44	..	..	..	15·28	25·65	..	..	..
4	24·50	48	30	..	..	..	..	13·49	..	..	..	..
5	42·50	65	28	41	55	..	..	15·59	25·04	35·22	..	..
6	47·50	73	32	46	58	66	73	18·13	28·16	36·76	42·49	47·50
7	32·00	41	23	34	..	..	..	15·27	25·72	..	..	..
8	28·50	50	34	45	..	..	..	14·64	25·17	..	..	..
9	26·50	48	34	48	..	..	..	16·37	26·50	—	—	..
10	31·00	53	29	45	..	..	..	15·07	26·02	..	—	..
11	44·50	69	32	41	56	66	..	18·07	24·51	35·21	42·35	..
12	16·80	34	31	..	..	..	..	14·89	..	..	..	..
13	27·10	49	31	[illegible]	..	..	..	15·39	25·56	..	..	..

14	15·00	29	28	..	..	..	..	14·70	..	..	..	..
15	20·60	36	34	..	..	..	..	19·20	..	..	..	..
16	32·00	53	29	44	..	..	..	15·30	25·65	..	..	..
17	24·70	45	34	45	..	..	..	17·62	24·70	..	..	..
18	29·30	50	32	46	..	..	..	19·76	26·58	..	..	..
19	33·80	58	38	48	58	..	..	19·15	27·24	33·80	..	..
20	23·70	42	35	..	..	..	..	18·86	..	..	..	..
21	37·40	60	30	44	55	..	..	16·31	26·01	34·03	..	..
22	39·60	61	33	45	54	..	..	19·18	28·06	34·71	..	..
23	21·50	42	34	..	..	..	..	16·51	..	..	..	..
24	15·30	34	32	..	..	..	..	14·09	..	..	..	..
25	30·00	48	32	45	..	..	..	18·42	27·91	..	..	..
26	31·70	52	30	44	..	..	..	16·49	28·84	35·01	..	..
27	35·70	59	31	49	58	..	..	16·49	28·84	35·01	..	..
28 . . .	19·70	39	35	..	..	..	..	17·19	..	..	..	..
29	16·30	32	30	..	..	..	..	15·03	..	..	..	..
30	26·20	42	30	41	..	..	..	17·33	25·58	..	..	..
				Mean........				16·49	26·27	34·96	42·42	47·50

TABLE V

Back-calculated lengths of fish from otolith readings (summary of data from Table IV)

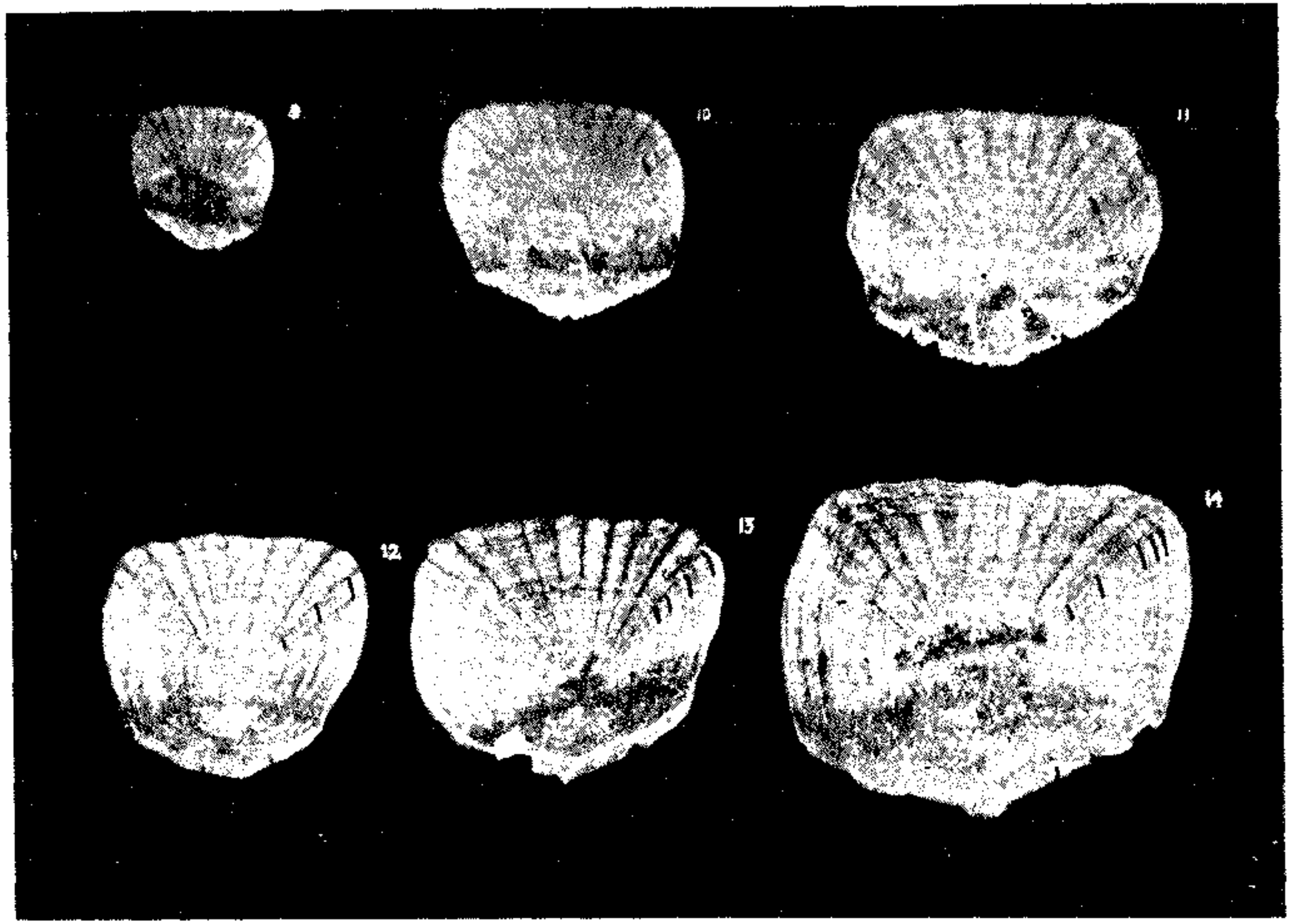
Age of the fish (years)	Back calculated lengths (cm)	Growth increment per year (cm.)
1 . . .	16·49	16·49
2 . . .	26·27	9·78
3 . . .	34·96	8·89
4	42·42	7·26
5 . . .	47·50	5·08

It could be seen from Table V that the results obtained from the back calculations agree very well with the estimated sizes of the fish obtained for the first three years by the length-frequency distribution method. From the length-frequency analysis the average size at the end of first year was found to be 17.25 cm. as compared to 16.49 cm. obtained from otolith readings and the corresponding average sizes at the end of the second year from the two methods were 26.25 cm. and 26.27 cm. respectively. The results obtained from length-frequency analysis and scale and otolith readings are quite agreeable. The slightly higher estimate of the size of the fish at the end of first year as obtained from Petersen's method is not significant.

Determination of age from scales :

The growth checks on the scales of *L. lentjan* are seen as breaks or interruptions in the general pattern of circuli (Pl. II, 9-14). Closer approximation of a few circuli, apparently not forming a ring, was observed in the scales of younger fishes and was not counted as growth check. The scales of *L. lentjan* also showed the false rings which were not complete and continuous all round the nucleus of the scale, and quite often tend to join the definite growth checks. The growth checks or annuli are complete, narrow and continuous all round the focus of the scale.

As in the case of otoliths, it was assumed, to start with, that each of these growth checks in the scale is an annual feature. On the basis of this



9. A scale of *L. lentjan* without any growth ring, x 4. T. L. of fish 11·0 cm. (December, 1960).
10. A scale of of *L. lentjan* showing one growth ring, x 4. T. L. of fish: 18·0 cm. (November, 1960).
11. A scale of *L. lentjan* showing two growth rings, x 6. T. L. of fish: 28·7 cm (June 1961).
12. A scale of *L. lentjan* showing three growth rings, x 3½ T. L. of fish: 39.6 cm. (March, 1962).
13. A scale of *L. lentjan* showing four growth rings, x. 5. T. L. of fish: 46·5 cm. (September 1961).
14. A scale of *L. lentjan* showing five growth rings, x 4½. T. L. of fish: 49.2 cm. (January) 1962).

assumption, the length of the fish and the probable age of the fish as determined from the number of growth checks in the scales were found out in case of 296 fish. The details are presented in Table VI and VII. The photographs of scales showing the presence of growth checks are given in Plate II, 9-14.

TABLE VI

Length and age of fish as determined from scales

Size group (T.L.) cm.	Mid point	N	Age groups					
			0	1	2	3	4	5
10—12	11	18	11	7	..	..	..	..
12—14	13	24	14	10	..	..	..	..
14—16	15	35	7	28	..	..	..	..
16—18	17	20	..	20	..	..	..	..
18—20	19	15	..	15	..	..	..	..
20—22	21	16	..	16	..	..	..	..
22—24	23	31	..	11	20	..	..	..
24—26	25	26	..	5	21	..	..	..
26—28	27	13	..	..	13	..	..	..
28—30	29	17	..	..	17	..	..	..
30—32	31	12	..	..	10	2	..	..
32—34	33	14	..	..	3	11	..	..
34—36	35	10	..	..	..	10	..	..
36—38	37	8	..	..	..	8	..	..
38—40	39	4	..	..	..	4	..	..
40—42	41	8	..	..	..	2	6	..
42—44	43	13	..	..	..	..	13	..
44—46	45	4	..	..	..	..	4	..
46—48	47	4	..	..	..	..	2	2
48—50	49	4	..	..	..	..	..	4
TOTAL		296	32	112	84	37	25	6
Average size				17·55	26·64	35·38	43·16	48·33

TABLE VII

Summary of the data from Table VI

Age groups (years)	Number of specimens	Size range (T.L.) cm.	Mean length (cm.)	Growth increment per year (cm.)
1+	112	10-26	17·55	17·55
2+	84	22-34	26·64	9·09
3+	37	32-42	35·38	8·74
4+	25	42-48	43·16	7·78
5+	6	46-50	48·33	5·17

The average sizes of the fish at first, second, third, fourth and fifth years as obtained from scale studies (Table VI and VII) correspond fairly closely with the results obtained from other methods.

As the general results obtained from the scale studies agree well with the results obtained from the otolith studies (Table III and V), no attempts were made to undertake detailed measurements of scale radius and radii of annuli in order to back calculate the average size of the fish at successive ages.

Growth equation:

The growth rates during successive age interval have already been described. Several authors have attempted to describe this varying growth rates at succesive age intervals by a single growth equation. The most successful and widely used growth equation is the one due to Bertalanffy which is written as,

$$L_t = L_\alpha \left(1 - e^{-k(t-t_0)}\right) \qquad \ldots\ldots\ldots (1)$$

where L_t=length of the fish at age 't';

L_α=asymptotic length of the fish;

k=coefficient of growth;

t=age of the fish at the time of capture;

t_0 =an adjustment in the time axis when theoretical length of the fish is equal to zero

The equation can also be written as:

$$L_{t+1} = a + b\,L_t \qquad \ldots\ldots\ldots (2)$$

where $b=e^{-k}$, and $L_\alpha = \frac{a}{1-b}$

By fitting the Bertalanffy growth equation (2) to the data obtained by back calculations from otolith readings (Table V), the sizes of the fish at successive ages were estimated and the results are presented in Table VIII.

TABLE VIII

Back-calculated lengths of fish (from otolith readings) and estimated sizes as obtained by Bertalanffy growth equation

Age (years)	Mean, back calculated length (cm.)	Estaimted size from the growth equation	
		(all values)	(omitting the fifth value)
1	16·49	15·14	15·25
2	26·27	26·71	26·90
3	35·16	35·54	35·79
4	42·42	42·28	42·57
5	47·50	47·42	47·75

It has already been remarked that the size at the end of the fifth year may be slightly underestimated as the fifth transparent zone was not yet completed.

Assuming that the size of the fish is 'zero' at zero age, and fitting equation (2) to the data of age and estimated size of the fish as given in Table VIII the least square estimates of a and b are found to be:

$a = 15.22$; $b = 0.7622$, which gives $k = 0.27$ and $L_\infty = 64.02$ cm.

The estimated sizes of the fish at the completion of first, second, third, fourth and fifth years, as calculated from the fitted Bertalanffy equation, are given in column 3 of Table VIII. If the mean size at the end of fifth year is not taken into consideration, the least square estimates of a and b are found to be: $a = 15.20$; $b = 0.7642$, giving $k = 0.27$ and $L_\infty = 64.46$ cm. The estimated size of the fish at successive ages as obtained from this growth equation are shown in the fourth column of Table VIII. The agreement seems to be close in both cases and it can be said that the Bertalanffy growth equation describes the growth rate of this fish in an admirable way. The growth pattern is shown in Fig. 11.

SUMMARY

In view of the two spawning seasons, viz., June—August and December—February, the length-frequency data were pooled together according to quarters

corresponding to the spawning periods. By tracing the progression of modes in these quarterly periods it was possible to estimate the average size of the fish at the end of first and second year of the life of the fish and some indications of the size the fish would attain at the end of the third year were also obtained.

The examination of otoliths and scales showed growth checks. It was assumed first that each growth check was annual in nature. Based on this assumption, the average sizes at successive ages were obtained. These estimates agreed well with the corresponding estimates obtained from the method of length-frequency distribution for the first three years.

In general, the estimates of sizes obtained from counting of growth checks in otoliths and scales were silghtly higher than those obtained from length-frequency distribution. This was because the age of a fish in these methods was fixed by the number of growth checks and the growth subsequent to the last growth check was not taken into consideration.

The length of the fish was found to be linearly related to the radius of the otolith; from this relation, the lengths of the fish at the completion of first year, second year, third year, fourth year and fifth year were back-calculated. The average values at successive ages obtained thus agreed well with the results from the length-frequency method.

The Bertalanffy growth equation was fitted to the data of fish size at successive ages as obtained by back calculations from otolith readings. The fit was remarkably good. The asymptotic length of the fish was found to be about 64 cm. and the growth coefficient $k = 0.27$. The estimated sizes of *L. lentjan* at the end of first, second, third, fourth and fifth years are 15.14 cm., 26.71 cm., 35.54 cm., 42.28 cm., and 47.42 cm. respectively.

As is generally known for fishes, the growth of *L. lentjan* during the first year is rapid and with increase in age a decrease in the rate of growth has been observed.

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