

AGE AND GROWTH OF 'GHOL', *PSEUDOSCIAENA DIACANTHUS* (LACÉPÈDE) IN BOMBAY AND SAURASHTRA WATERS

BY K. VENKATA SUBBA RAO

(Central Marine Fisheries Research Institute, Mandapam Camp)

IN an earlier paper the present author (Rao, 1961) had shown that the scales and otoliths of 'Ghol', *Pseudosciaena diacanthus* (Lacépède), a commercially important sciaenid in Bombay and Saurashtra waters, are useful as age indicators of this species. The results of studies on the growth of this fish based on these structures and the length frequency data for the period 1958-62 are presented here. Further, von Bertalanffy growth equation was fitted to the length-at-age data and estimates of the parameters were obtained and compared with similar estimates of other sciaenids from different regions.

MATERIAL AND METHODS

(1) *Length frequency studies.*—The material was obtained from the landings of the bull-trawlers of New India Fisheries Ltd., Bombay, and from the catches of 'Dol' nets at Sassoon Docks, Bombay and Versova (a fishing village near Bombay) according to the procedure already outlined (Rao, 1963). The two pairs of bull-trawlers fished in six regions extending from Bombay to Cutch (Rao, in press). Weekly visits were made to Sassoon Docks (Bombay) and Versova for collection of data and material. At the time of unloading of the catches a random sample, consisting of 50 to 100 'Ghols' generally, was taken for length measurements and when the catches were poor only smaller samples could be obtained. The length of fish referred to in the following pages is the total length in cm from the tip of the snout to the tip of the longest ray of the caudal fin. The length data from the bull-trawlers and the 'Dol' net catches are treated separately. The length measurements of 'Ghol' taken in a month were grouped into 5 cm size groups, the percentage of fish in each size group was calculated and presented as monthly length frequency polygons in Figs. 2 to 10. In all 8,589 fish were measured for length frequency studies.

(2) *Scales*.—Scales, as in the previous work (Rao, 1961), were always selected from the region immediately posterior to the tip of the pectoral fin. They were kept in a weak solution of caustic potash (2 to 3%) for half-an-hour and cleaned in a petri dish with forceps and needle. By this method the dermal tissues and chromatophores could be removed. Two or three scales thus cleaned from each sample were placed on a clear glass slide (microscope) and over this another slide was kept. The two slides were pressed tightly and tied firmly by cellophane tape at the ends. Care was taken to see that the scales mounted between the slides did not slip or fall. These scales (dry mounts) were then observed under a binocular microscope and those which showed clear rings were selected for projection by an ordinary microfilm projector (Fig. 1) which gave a magnification of 8.4 which, in view of the large size of the scales, was quite sufficient for the purpose. The projector was lodged in a case the upper lid of which could be used as a screen. The distances from the focus of the scale to the different

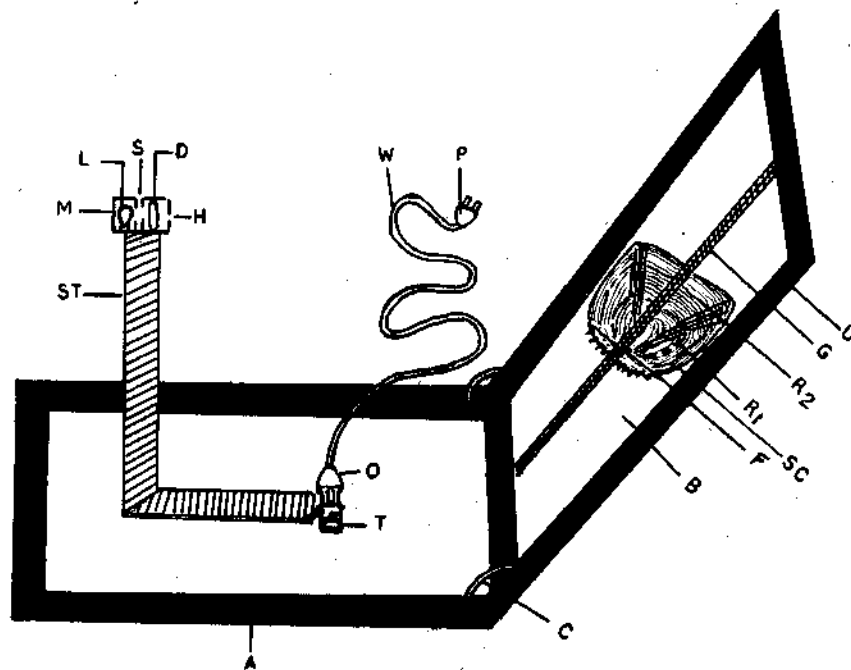


FIG. 1. Diagram of the commercial micro-projector used for projection of scales. (For description see text.) A = case of the projector; U = upper lid (screen); L = light; D = lens; M = metallic chamber; S = vertical slit for holding the mounted slide and card-board frame; C = clamps; B = Bristol board paper on the inner side of the upper lid; G = millimetre graph paper; ST = metallic stand; H = aperture; T = switch; O = adapter; W = wire; P = plug; F = focus of the scale; SC = projected scale image; R_1 , R_2 = first and second growth rings.

growth rings and the edge of the projected scale image were read off from the millimetre graph paper and noted on separate sheets of paper for each sample. For determining the fish length-scale length relationship, the distance from the focus to the edge was measured in 4 to 6 scales from each fish, by a scale divided into 0.5 mm and the mean scale length was then calculated. The range in the lengths of the scales from a fish was narrow. Scale samples from 375 fish, 7.5 to 112.5 cm in length, were used for this study.

(3) *Otoliths*.—It is difficult to take out these massive calcareous structures from the larger fish. The ventral surface of the otolith, especially in the larger fish, is rugose with a massive bulbous excrescence in the central or nuclear part and a shallow depression on the dorsal surface. It is difficult to take out this central mass by cutting with a scalpel and in doing so the otoliths are easily broken, while grinding this part takes much time. Since this bulbous mass covers the nuclear region and also part of the first growth zone, measurements of the lengths from the nucleus to the different growth rings (hyaline) and the edge of the otolith could not be taken. Hence only the total length from the posterior to anterior end along the longest axis was measured on a scale divided into 0.5 mm with the help of dividers. The two otoliths from a fish were identical in all respects.

A few otoliths were ground by hand on carborundum and also by using a 'Wolf' electric grinding wheel. The former was a time-consuming, tedious process while with the latter the otoliths were often broken. So the entire otoliths were examined in water against a black background. For this purpose a petri dish covered with black paper was used. The otoliths were kept immersed in water in the petri dish and examined under reflected light with naked eye or low power of a binocular microscope, the former being more convenient and easy.

RESULTS

(1) *Analysis of Length Frequency Distributions*

A. *Monthly Length Frequency Distributions from 'Dol' Net during 1958-62*

It has been shown by the present author (Rao, 1963) that June to September is the spawning season for 'ghol'. Juvenile ghol's of 2 to 10 cm appear in the 'Dol' net catches at Sassoon Docks from June onwards while at Versova the 'Dol' net operations (suspended due to monsoon) are resumed by the end of August or beginning of September and continued till May.

It is interesting to note that juveniles (2.0-30.0 cm) and larger sized 'ghol' (90.0-120.0 cm) are caught in the 'Dol' net while the middle size groups (60.0-90.0 cm) are generally absent. The monthly length frequency distributions of 'ghol' from 'Dol' net catches during the years 1958-59, 1959-60, 1960-61 and 1961-62 are shown in Figs. 2, 3, 4 and 5 respectively.

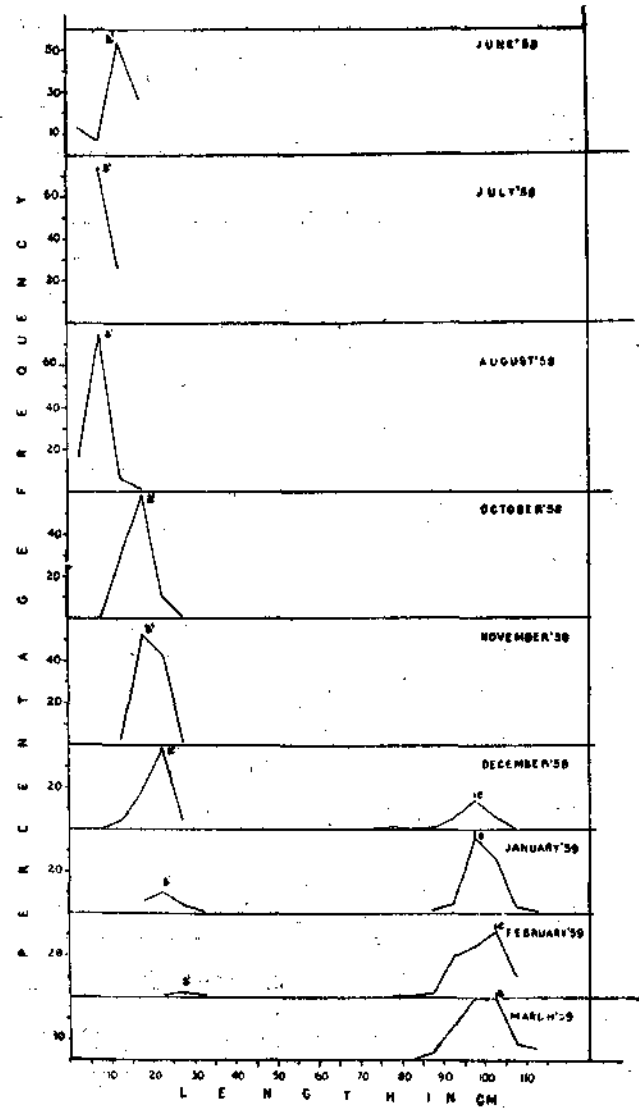


FIG. 2. Monthly length frequency distributions of *P. diacanthus* from the 'Dol' net catches during 1958-59.

1958-59 (Fig. 2).—The length frequency distribution for juveniles in June 1958 shows a bimodal picture (a^1 and a^{1+}) while in the other months it is unimodal. A second mode e (representing the larger sized 'ghols') was observed from December 1958 to April 1959. The modes a^1 and a^{1+} represent the juveniles which are the product of 1958 spawning. Mode a^2 at 2.5 cm in June 1958 can be traced to 27.5 cm in March 1959 by following its gradual progression through the intervening months. Juvenile 'ghol' (25.0-30.0 cm) are landed by 'Dol' nets till March and these disappear

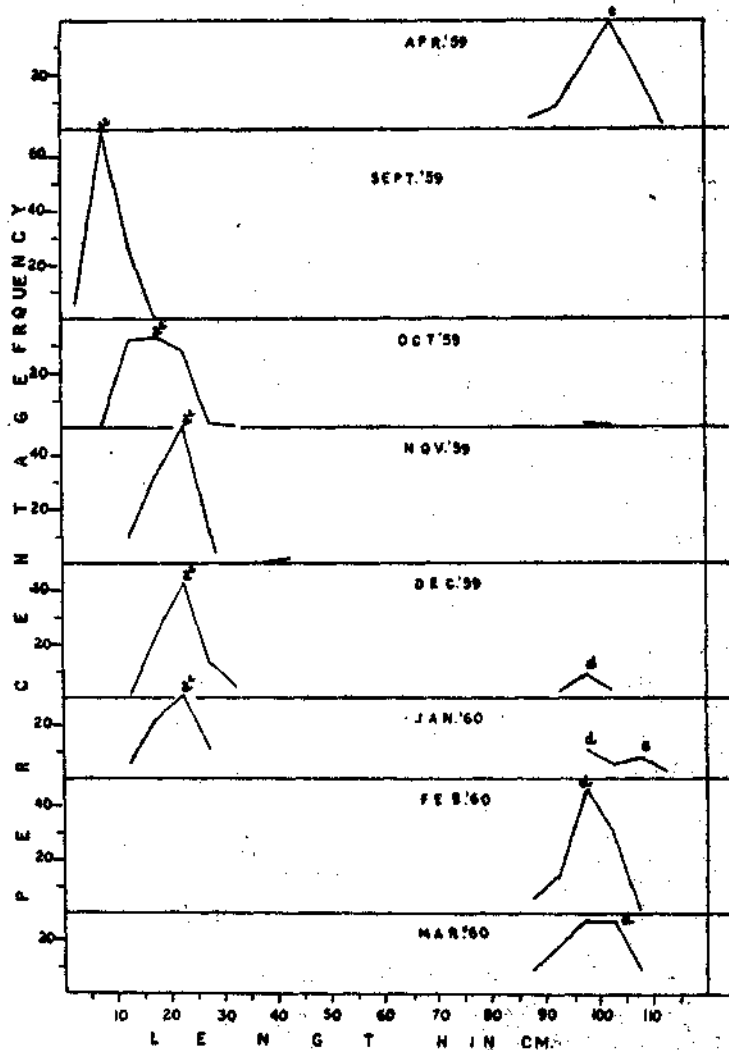


FIG. 3. Monthly length frequency distributions of *P. diacanthus* from the 'Dol' net catches during 1959-60.

from the catches from April, probably because these fish go to deeper waters. The progression of the mode a^1 clearly indicated that juveniles, developed from eggs during a spawning season, *i.e.* June, reach a size of 25.0–30.0 cm by March next when they would be about 9 months old.

The mode e at 97.5 cm in December 1958 could be traced to 102.5 cm in April 1959 and this shift indicates a growth of 5 cm in this period.

1959–60 (Fig. 3).—The mode a^2 at 7.5 cm in September 1959 represents the juveniles developed from the eggs spawned during that season. A modal size of 7.5 cm was attained in the previous year in August. The mode a^2 at 7.5 cm in September 1959 progressed to 22.5 cm in January 1960 showing a growth of 15 cm in 6 months. A modal size of 22.5 cm was obtained in the previous year in the month of December (1958). From February onwards juvenile 'ghol' disappeared from the catches. Stray specimens 25.0–30.0 cm in length were caught in March 1960. The mode d (adults) at 92.5 cm in December 1959 can be traced to 102.5 cm in June 1960 and this shift indicates a growth of 10 cm in 6 months which is similar to that observed for fish under mode e in the previous year. The third mode e appearing at 107.5 cm in January 1960 cannot be traced further and this appears to be the same mode e observed at 102.5 cm in April 1959.

1960–61 (Fig. 4).—The fish under mode a^2 at 2.5 cm in June 1960 are the product of current spawning and these progress to a modal size of 22.5 cm in December 1960. In January 1961 and March 1961 specimens belonging to one size-group only, *i.e.*, 20–25 cm and 30–35 cm groups respectively, were caught while in February catches these were absent. The mode at 22.5 cm in December 1960 persists in January 1961 and can be traced to the mode (a^3) at 32.5 cm in March 1961. Except for the absence of the mode at 27.5 cm in February or March, the progression of the mode a^3 is similar to that for mode a^1 in 1958–59 season. A modal size of 32.5 cm was attained during January–March (9 months) period in 1960–61 season while in 1958–59 season a modal size of 27.5 cm was attained during the corresponding period. The growth rate of juveniles was slightly more in 1960–61 season than in 1958–59 season. The mode c at 97.5 cm in January 1961 progresses to 102.5 cm in April 1961 and this shift shows a growth of 5 cm in 3 months which is similar to that observed for fish of this size in the previous years (modes d and e). The third mode e at 112.5 cm in March 1961 is probably the same that was at 107.5 cm in January 1960. The mode e at 112.5 cm in March 1961 can be traced to 117.5 cm in February 1962. This progression indicates a slow growth rate of 5 cm in 11 months for fish

of this size-group. This slow growth rate appears quite possible because fish with a modal size of 117.5 cm are the oldest among those observed.

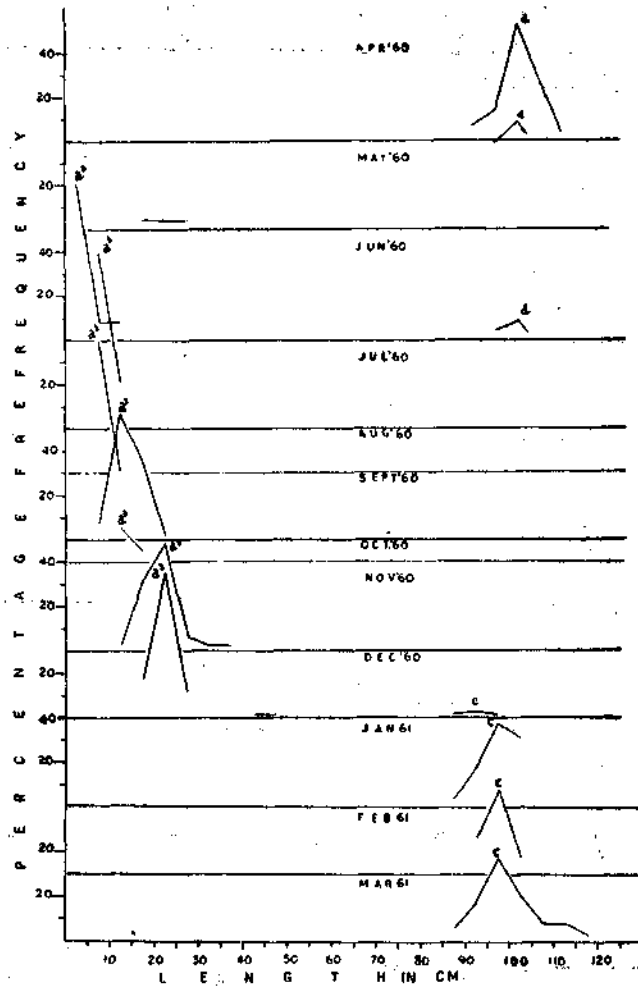


FIG. 4. Monthly length frequency distributions of *P. diacanthus* from the 'Do I' net catches during 1960-61.

1961-62 (Fig. 5).—The mode a^4 at 7.5 cm in June 1961 represents fish developed from the spawning in 1961. When compared with the modal values of 1958 (a^1), 1959 (a^2) and 1960 (a^3) in the month of June, a value of 7.5 cm in June 1961 is slightly high and may correspond to the mode a^{1+} (12.5 cm) observed in June 1958. This may be due to differential growth in the early stages or to earlier commencement of spawning in those years.

The mode a^4 at 7.5 cm in June 1961 can be traced to 22.5 cm in December 1961 and this indicates a growth of 15 cm in 6 months. Juveniles were rare in the catches from January to March 1962. The mode b at 102.5 cm in November progresses to 107.5 cm in February 1962 showing a growth of 5 cm in this period (3 months) which is similar to that observed in the previous year for fish of this size.

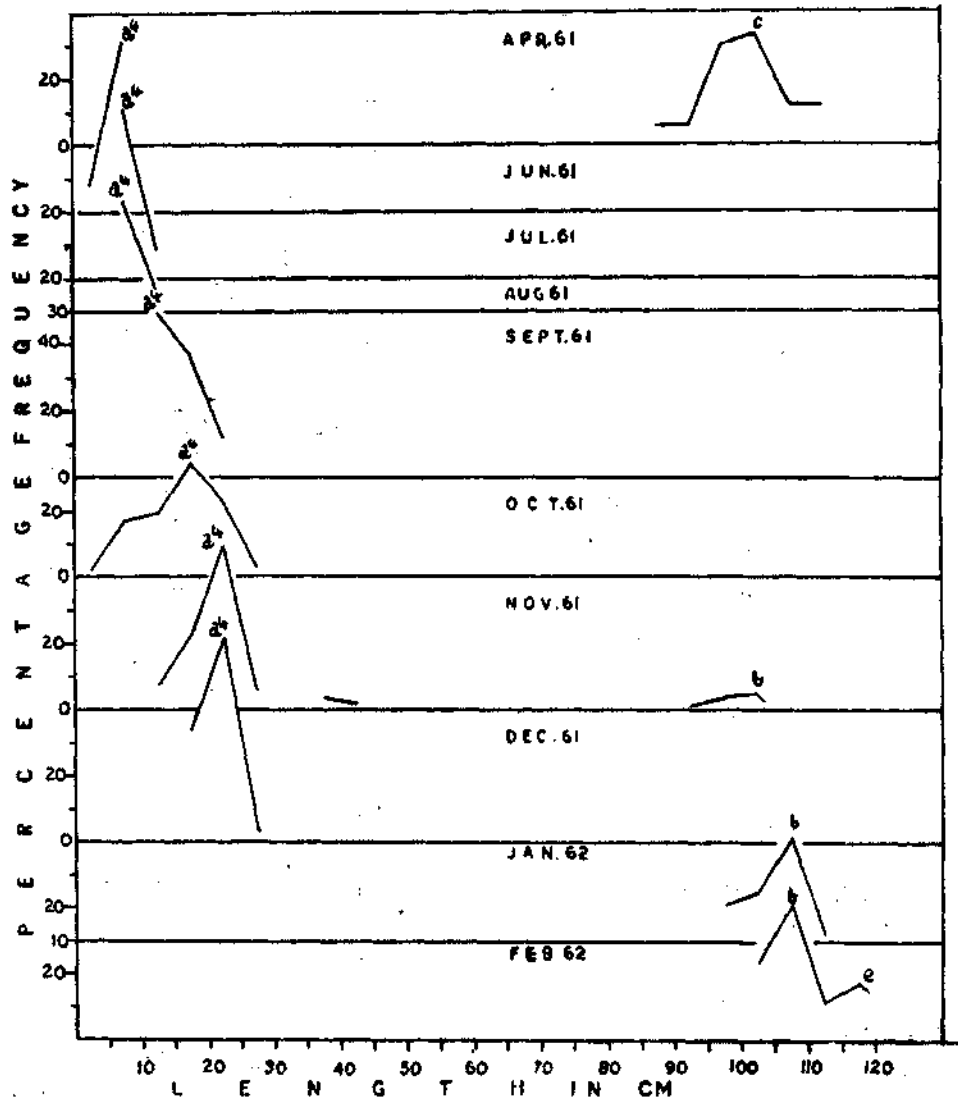


FIG. 5. Monthly length frequency distributions of *P. diacanthus* from the 'Dol' net catches during 1961-62.

The progression of the modes a^1 , a^2 , a^3 and a^4 in the monthly length frequency distributions of juvenile 'ghols' from 'Dol' net during 1958-59, 1959-60, 1960-61 and 1961-62 seasons respectively (Figs. 2 to 5) clearly shows that the juveniles developed from eggs spawned in June with a modal size of 2.5 or 7.5 cm in that month attain a modal size of 27.5 or 32.5 cm by March of next year. This shows a growth of 25 or 30 cm in the first 9 months of the life of *P. diacanthus*. From April onwards fish of this size (30-35 cm) do not appear in the catches and probably go to deeper waters and become vulnerable to trawl. This view is substantiated by the fact that new recruits 30-35 cm in length appear in the catches of the trawlers during January-March.

B. Monthly Length Frequency Distributions from Landings of Bull-Trawlers of New India Fisheries Ltd., during 1958-62

The monthly length frequency distributions of samples from the bull-trawlers of New India Fisheries Ltd., for 1958-62 are shown in Figs. 6 to 10. Here also April-March is the year referred to. For 1958-59, data for the months of February and March 1958 are also presented.

1958-59 (Fig. 6).—Five modes a , b , c , d and e were observed in the length frequency distributions during the year. The mode a at 32.5 cm in April 1958 can be traced to 52.5 cm in March 1959 and this shows a growth of 20 cm in one year. The mode b at 52.5 cm in February 1958 progresses to 67.5 cm in February 1959 showing a growth of 15 cm in one year. The mode c at 72.5 cm in February 1958 shifts to 87.5 cm in March 1959 and this shift shows a growth of 15 cm in one year. The mode d at 87.5 cm in May 1958 can be traced to 97.5 cm in August 1959 and this progression shows a growth of 10 cm in one year and 3 months. In other words, mode a takes the position of mode b , b that of c , c that of d and d that of e after one year. The mode e at 97.5 cm in February 1958 can be traced to the mode at 102.5 cm in December 1958 and this shift shows a growth of 5 cm in 10 months. Mode e cannot be traced further. From the above it is clear that the time interval between the modes is one year. Another mode a^1 at 32.5 cm appears in January 1959 and persists till March 1959.

The studies on the length frequency distribution of juveniles from 'Dol' net have shown that the juveniles developed from the eggs during the spawning season of a year grow to a size of about 30 cm by February or March next when they become vulnerable for trawl. So the mode a^1 in January 1959 represents the new recruits, *i.e.*, fish developed from the eggs spawned in the previous year (June-September) *i.e.*, in 1958. The fish under mode a^1 would

be roughly 6-7 months old in January 1959. Since the fish under mode a^1 in January 1959 belong to the 1958 year class and the time interval between the modes is one year, it follows that the fish under modes a, b, c, d and e belong to 1957, 1956, 1955, 1954 and 1953 year classes respectively. Yearly growth increments deduced from the progressions of modes a, b, c, d and e are 20, 15, 15, 10 and 5 cm respectively.

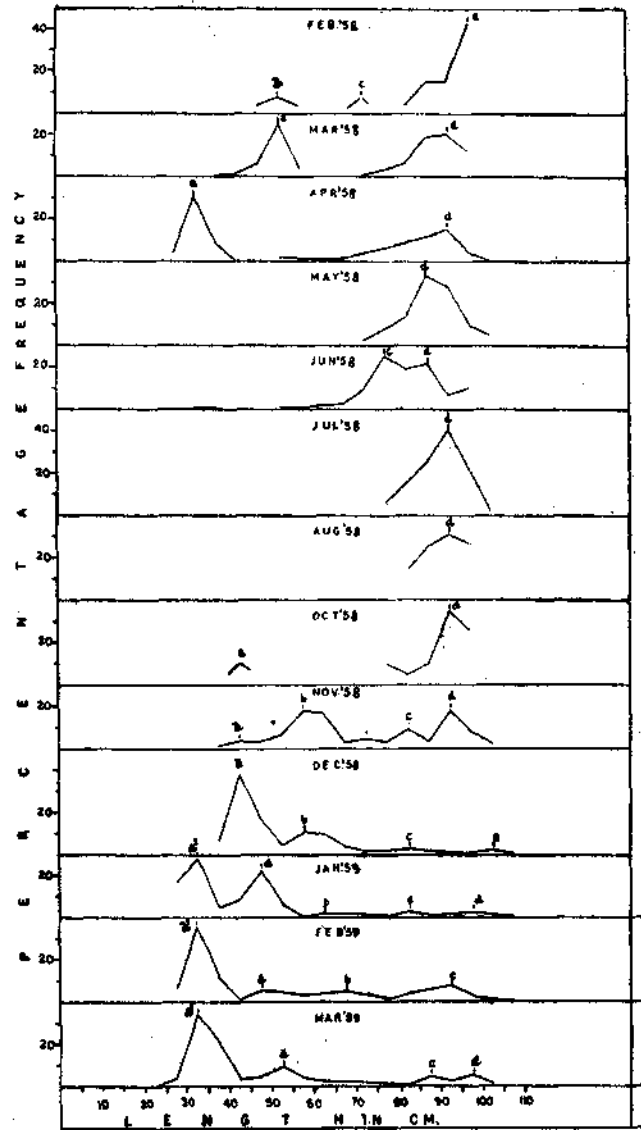


FIG. 6. Monthly length frequency distributions of *P. diacanthus* from the landings of the bull-trawlers of the New India Fisheries Ltd., Bombay, during 1958-59.

1959-60 (Fig. 7).—As in the previous year 5 modes a^1 , a , b , c and d representing the 1958, 1957, 1956, 1955 and 1954 year classes respectively were observed. Mode e representing the 1953 year class was absent.

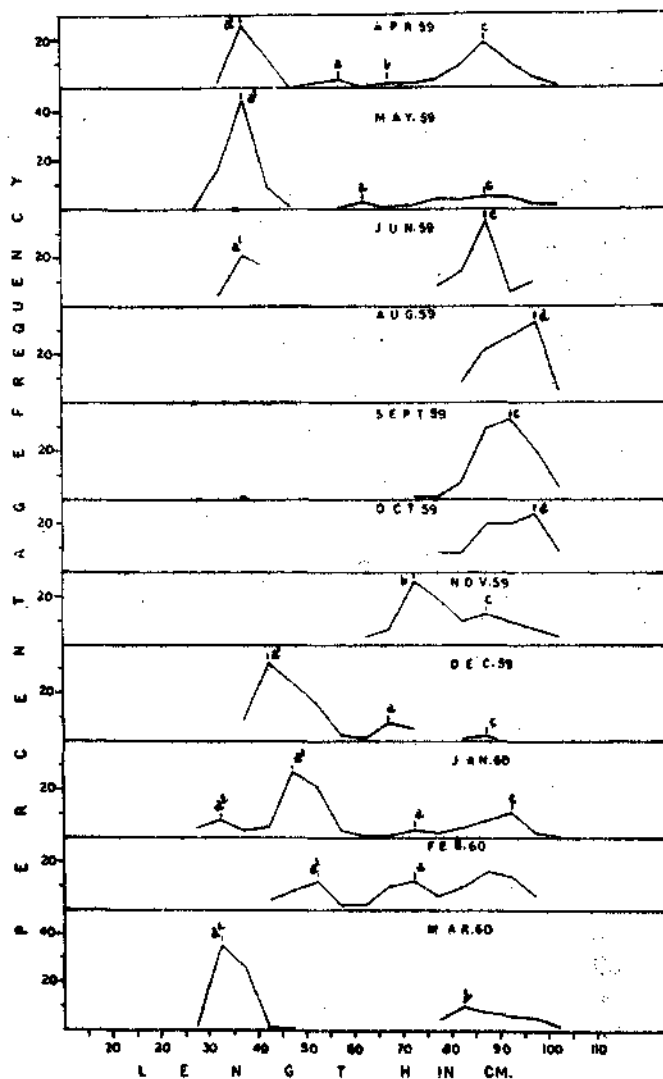


FIG. 7. Monthly frequency distributions of *P. diacanthus* from the landings of the bull-trawlers of the New India Fisheries Ltd., Bombay, during 1959-60.

The mode a^1 at 37.5 cm in April 1959 can be traced to 52.5 cm in February 1960 and this progress shows a growth of 15 cm in 10 months. This mode a^1 can be further traced to 57.5 cm in May 1960 (Fig. 8), the shift

showing a growth of 20 cm in one year, which is similar to the growth shown by mode *a* in the previous season. The mode *a* at 57.5 cm in April 1959 progresses to 72.5 cm in February 1960 showing a growth of 15 cm in 10 months. This mode *a* can further be traced to 77.5 cm in May 1960 (Fig. 8) showing a growth of 20 cm in one year. The mode *b* at 67.5 cm in April 1959 progresses to 82.5 cm in March 1960 and this shift shows a growth of 15 cm in one year. The mode *c* at 87.5 cm in April 1959 progresses to 92.5 cm in January 1960 and 97.5 cm in July 1960 thereby showing a growth of 10 cm in one year and 2 months. The mode *d* at 97.5 cm in August 1959 can be traced to mode *a* at 107.5 cm in October 1960 and this shift shows a growth of 10 cm in one year and 2 months. The fish under mode *a*² at 32.5 cm in January 1960 are the new recruits developed from the eggs of the spawning season in 1959 as mentioned earlier for mode *a*¹. The progression of the modes *a*¹, *a*, *b*, *c* and *d* in one year during 1959-60 show growth increments of 20, 15, 15, 10 and 10 cm respectively and this is similar to the growth increments deduced from the progression of the five modes in the previous year. The positions of the modes *a*, *b*, *c*, *d* and *e* in 1958-59 are taken by modes *a*¹, *a*, *b*, *c* and *d* next year, *i.e.*, in 1959-60, *a*¹ representing the new recruits in 1958-59, *i.e.*, 1958 year class. This again shows that the interval between the modes is one year.

1960-61 (Fig. 8).—Modes *a*², *a*¹, *a*, *b*, *c*, *d* belonging to year classes 1959, 1958, 1957, 1956, 1955 and 1954 observed in the previous year continue in 1960-61. The new mode *a*³ appearing at 32.5 cm in January 1961 represents the new recruits, the product of spawning in the previous year, *i.e.*, 1960, according to the growth rate derived from the length frequency studies of juveniles from 'Dol' net.

The progression of the mode *a*² from 37.5 cm in October 1960 to 57.5 cm in August 1961 and 62.5 cm in December 1961 shows a growth of 25 cm in one year. The mode *a*¹ at 57.5 cm in May 1960 progresses to 72.5 cm in June 1961 indicating a growth of 15 cm in one year. The mode *a* at 77.5 cm in May 1960 shifts to 92.5 cm in June 1961 (Fig. 9) showing a growth of 15 cm in one year. The mode *b* at 87.5 cm in July 1960 progresses to 97.5 cm in July 1961 showing a growth of 10 cm in one year. The mode *c* at 97.5 cm in July 1960 can be traced to 107.5 cm in September 1961 and this shows a growth of 10 cm in one year. The mode *d* at 107.5 cm in October 1960 cannot be traced further.

The growth increments shown by the progression of modes *a*², *a*¹, *a*, *b* and *c* in one year, *i.e.* during 1960-61, are 25, 15, 15, 10 and 10 cm respectively. The annual growth increments deduced from the progression of the

five modes during 1960-61 are similar to the growth increments of the five modes in the previous year, *i.e.*, 1959-60. The annual growth shown by the progression of the first mode (a^3) in 1960-61 is slightly more (5 cm) than that of mode a^1 in 1959-60.

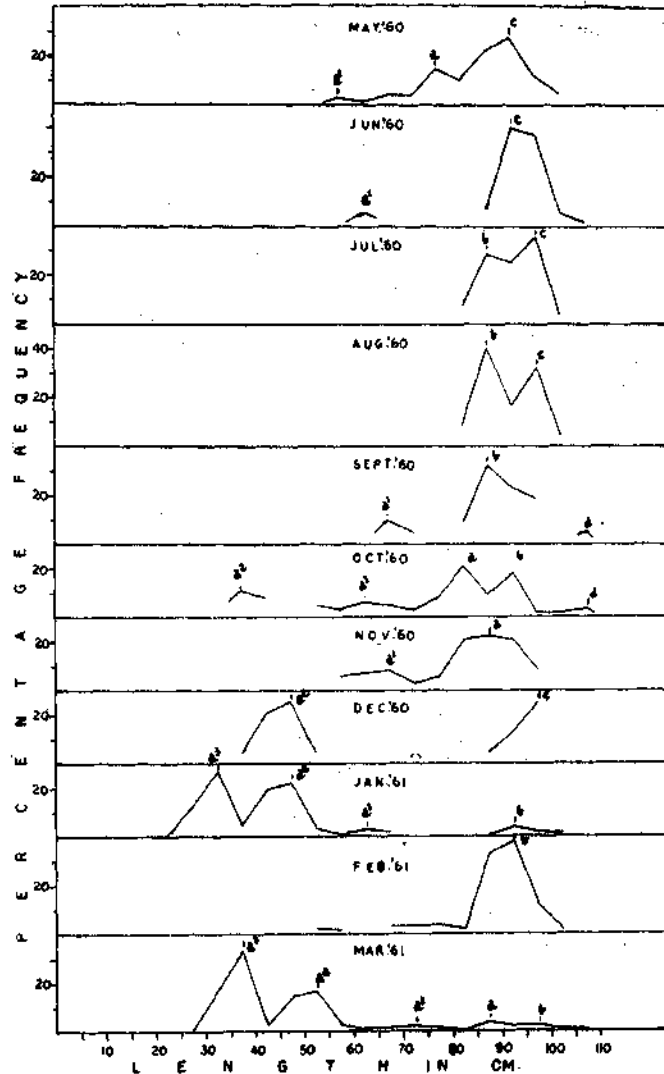


FIG. 8. Monthly length frequency distributions of *P. diacanthus* from the landings of the bull-trawlers of the New India Fisheries Ltd., Bombay, during 1960-61.

1961-62 (Fig. 9).—Modes a^3 , a^2 , a^1 , a , b and c representing the year classes 1960, 1959, 1958, 1957, 1956 and 1955 respectively observed in the previous

year continue in 1961-62. The fish under mode a^4 at 37.5 cm in February 1962 are the new recruits and belong to the 1961 year class. The progression of mode a^3 from 37.5 cm in August 1961 to 47.5 cm in March 1962 shows a growth of 10 cm in 7 months. Mode a^2 at 57.5 cm in August 1961 can be traced to 67.5 cm in March 1962 showing a growth of 10 cm in 7 months. Mode a^1 shifts from 72.5 cm in June 1961 to 87.5 cm in March 1962 and

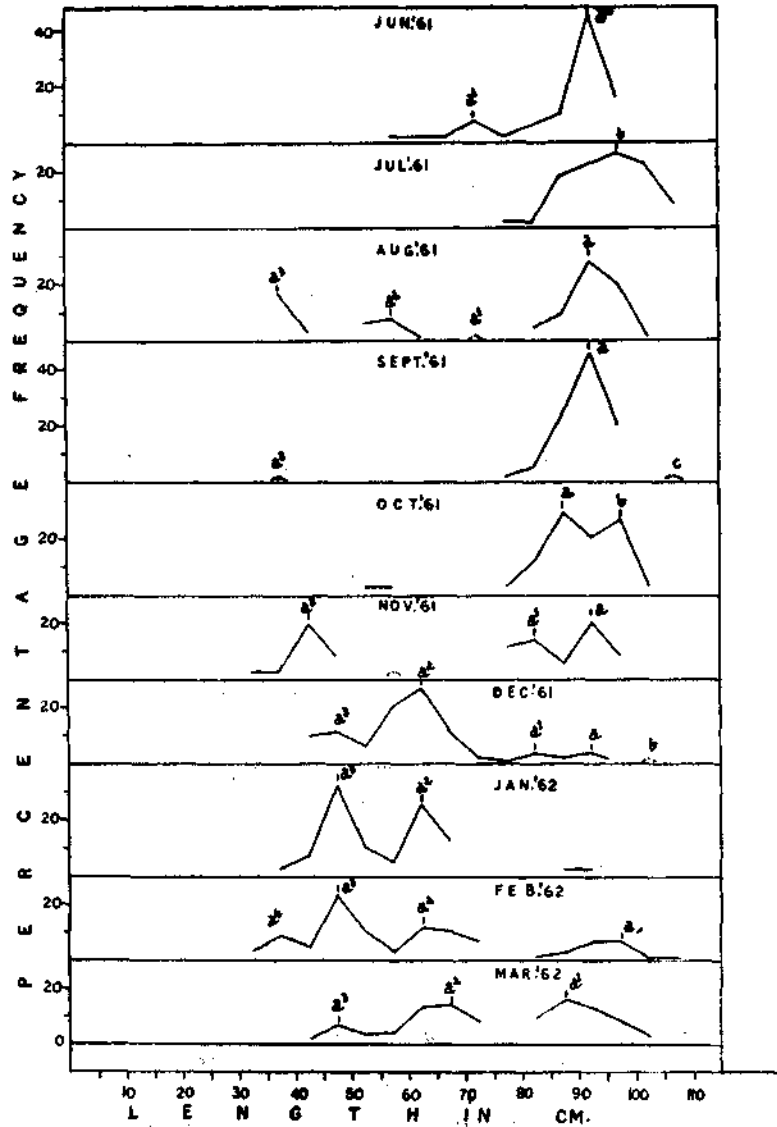


FIG. 9. Monthly length frequency distributions of *P. diacanthus* from the landings of the bull-trawlers of the New India Fisheries Ltd., Bombay, during 1961-62.

this progression indicates a growth of 15 cm in 9 months. Fish under mode *a* progress from 92.5 cm in June 1961 to 97.5 cm in February 1962 and show a growth of 5 cm in 8 months. Fish represented by mode *b* show a growth of 5 cm in 6 months by progressing from 92.5 cm in July to 102.5 cm in December 1961. Mode *c* at 107.5 cm in September 1961 cannot be traced further. Since the data for 1961–62 are available for 9 months (June to March) only the growth of the fish under different modes in one year could not be derived by tracing their progression. Nevertheless growths of 10, 10, 15, 5, 5 cm shown by the progression of modes a^3 , a^2 , a^1 , *a* and *b* in 7, 7, 9, 8 and 6 months respectively compare well with the growth rates derived for the 5 corresponding modes on an annual basis during the previous 3 seasons, i.e., 1958 to 1961.

Pooled data for the period 1958–61 (Fig. 10).—The monthly pooled length frequency distributions of 'ghol' from the bull-trawler landings for the period 1958–61 are shown in Fig. 10. In June (birth month) 5 modes *A*, *B*, *C*, *D* and *E* at 37.5, 62.5, 77.5, 87.5 and 97.5 cm respectively are present. The mode *A* progresses to 62.5 cm in May and shows a growth of 25.0 cm in one year. The mode *B* at 62.5 cm in June can be traced to 77.5 cm in May and this shift shows a growth of 15 cm in one year. The mode *C* shifts from 77.5 cm in June to 92.5 cm in May and this progression also shows a growth of 15 cm in one year. The fish under mode *D* at 87.5 cm in June progress to 97.5 cm in March and thus show a growth of 10 cm in about an year (10 months). The mode *E* at 97.5 cm persists at the same place in August and December and cannot be traced further.

The fish under mode A^1 at 32.5 cm in January are the new recruits developed from eggs spawned in the previous year, which would be about 6–7 months old. It can be seen clearly from Fig. 10 that the mode *A* of June takes the position of *B* in next May, *B* that of *C*, *C* that of *D* and *D* that of *E* and in progressing so, the modes *A*, *B*, *C* and *D* show growth rates of 25, 15, 15 and 10 cm respectively, which is similar to that derived for the first four modes from the monthly length frequency distributions for the years 1958–59, 1959–60, 1960–61 separately. These estimates of growth rates show that the interval between the modes is one year. The mode A^1 at 32.5 cm in January progresses to 37.5 cm in May showing a growth of 5 cm in 4 months. The fish with a modal value of 37.5 cm in May would complete about one year of age as they are the product of spawning in the previous year.

Modal positions during June–September (period of birth).—As stated earlier, June–September is the spawning season for ghol and the modal posi-

tions read off from the monthly length frequency distributions (Figs. 6 to 9) for the years 1958-59, 1959-60, 1960-61 and 1961-62, in this period are shown in Table I. The sizes attained by the different year classes when they enter the trawl fishery during January-April when they are 7-9 months old (Figs. 2 to 5) are also shown in Table I. The positions of the modes I, II, III, IV and V in the pooled monthly length frequency distribution (1958-61) for the month of June are shown separately in Table I.

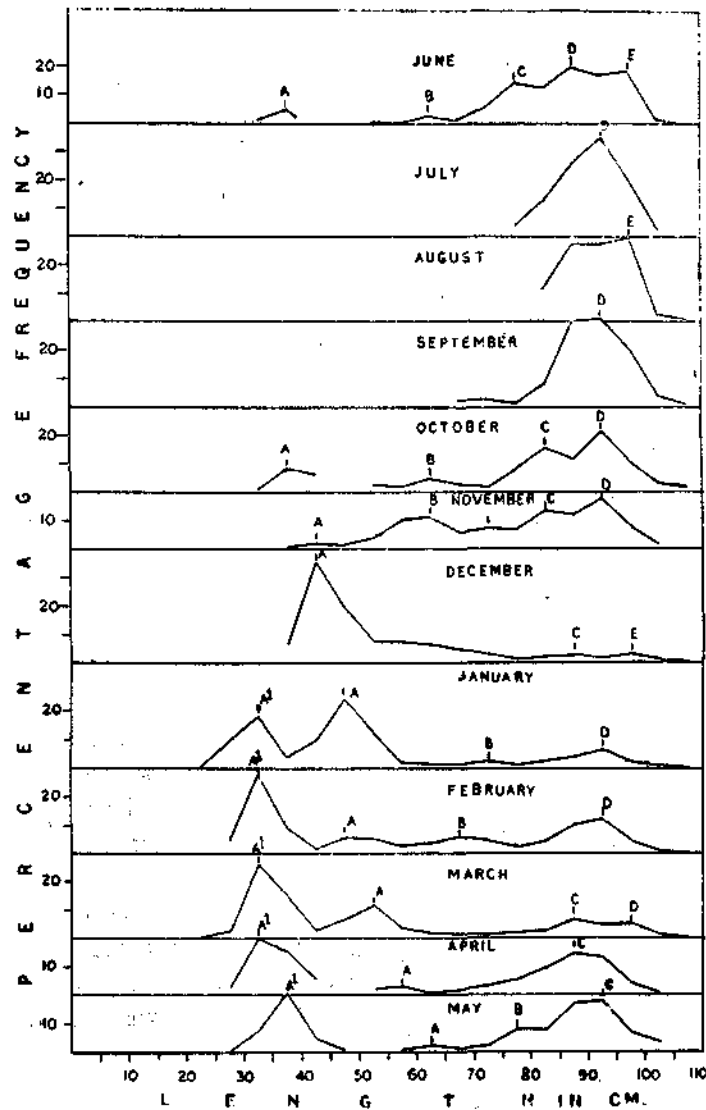


FIG. 10. Monthly pooled length frequency distributions of *P. diacanthus* from the landing of the bull-trawlers of the New India Fisheries Ltd., Bombay, for the period 1958-61.

TABLE I. Sizes in cm (modal positions) of different year classes of *P. diacanthus* at different ages.
 For calculating the size attained at the end of I to VI years, the modal positions of the different year classes during the period June–September (birth time) have been taken into consideration.
 For the year classes 1958, 1959, 1960 and 1961 the sizes attained by them at the end of 7–9 months of life (January–March) when these fish enter the trawl fishery are also given. Figures in brackets indicate the year of capture.

Data from the landings of the bull-trawlers of
 New India Fisheries Ltd., Bombay

Year class	Notation used for the year class	Modal position (cm) when 7–9 months old, i.e., during January–March period	Age in years						
			Modal positions in cm during June–September						
			I	II	III	IV	V	VI	
1961	a ⁴	37.5 (1962)	..	..	..	..	..	..	..
1960	a ³	32.5 (1961)	37.5 (1961)	..	..	..	..	..	..
1959	a ²	32.5 (1960)	37.5 (1960)	57.5 (1961)	..	..	..	..	..
1958	a ¹	32.5 (1959)	37.5 (1959)	62.5 (1960)	72.5 (1961)	..	..	..	..
1957	a	32.5 (1958)	37.5 (1958)	62.5 (1959)	77.5 (1960)	92.5 (1961)	..	..	..
1956	b	..	..	57.5 (1958)	72.5 (1959)	87.5 (1960)	97.5 (1961)	..	..
1955	c	..	..	..	77.5 (1958)	87.5 (1959)	97.5 (1960)	107.5 (1961)	..
1954	d	..	..	..	..	87.5 (1958)	97.5 (1959)	107.5 (1960)	..
1953	e	..	..	..	..	..	97.5 (1958)	..	..
Mean	..	33.5	37.5	60.0	75.0	88.75	97.5	107.5	..
Modal positions in the pooled length frequency distribution in the month of June (month of birth) for the period 1958–61: Data from bull-trawlers			37.5 (Mode A)	62.5 (Mode B)	77.5 (Mode C)	87.5 (Mode D)	97.5 (Mode E)	..	..
Growth increments			..	37.5	25.0	15.0	10.0	10.0	..

It can be seen from Table I that the modal sizes attained by the different year classes at different ages, *i.e.*, in different years of capture are more or less the same and these modal sizes are in close agreement with the positions of the first five modes in the pooled length frequency distribution for the month of June. Since June happens to be the month of birth, the modal positions observed in this month for the pooled monthly length frequency distribution (1958-61) may be considered as fairly accurate for knowing the growth attained of this species at the end of I to V years. Thus the lengths attained by 'Ghol' at ages I, II, III, IV and V could be regarded as 37.5, 62.5, 77.5, 87.5 and 97.5 cm respectively.

Seasonal Growth Rate

In Fig. 11 the positions of modes found in Figs. 2, 3, 6 and 7 are re-plotted against time. The ordinates are the modal sizes and abscissae, the months March 1958 to March 1960. The modal lengths are represented by crosses and are joined by lines according to the present author's interpretation of the sequence of modes of the different year classes. Figure 11

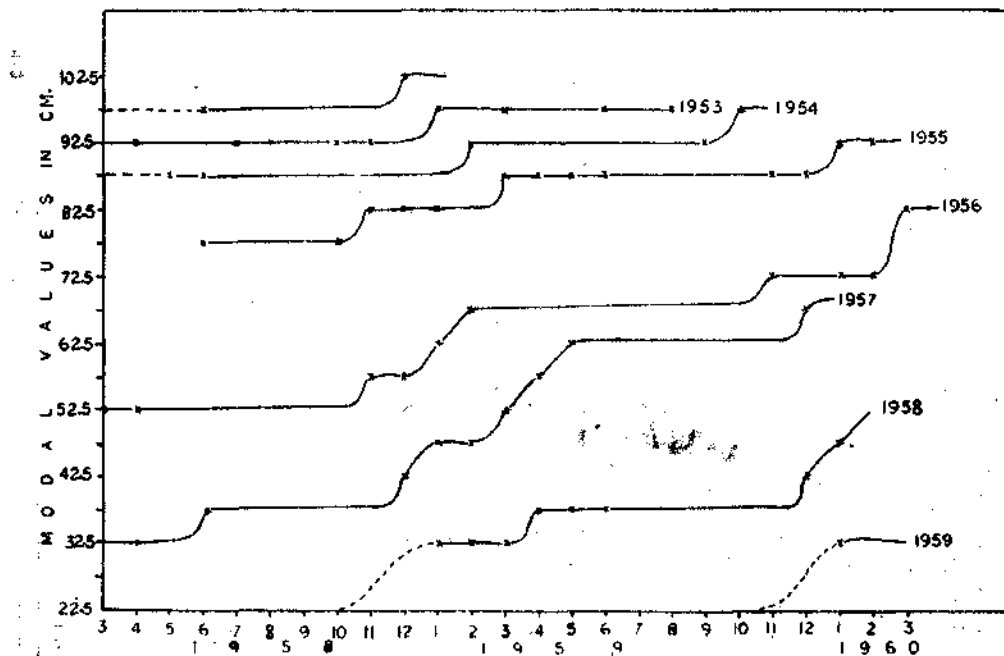


FIG. 11. Modal positions from the length frequency distributions of *P. diacanthus* re-plotted against time and joined by hand according to the present author's interpretation of the sequence of modes to show the seasonal growth rates of different year classes.

shows that the 1957, 1958 and 1959 year classes entered the catches of the trawlers during the period January–March in 1958, 1959 and 1960 respectively. The sharp rise in the growth curves during the period of recruitment or just before, indicates a sudden change in the growth pattern. This may be due to the recruitment migration from the nursery grounds to the main exploited area where the environment and probably the abundance of food are different. It is clear from Fig. 11 that growth took place mainly from November to May for the different year classes in the years 1958–1959 and 1959–1960 and that June to October is the period of slow or no growth.

It has been shown from length frequency studies on 'Dol' net catches that fish with a modal size of 97.5 cm (modes *e*, *d*, *c* and *b*) show a growth of 5 cm (in 3 or 4 months) during December–April and this is nearly half the annual growth for fish of this size deduced from length frequency studies on trawler catches and also from scales and otoliths.

The present author (Rao, 1963) has shown that the 'K' (condition factor) values and gonad weight: body weight ratios increase gradually reaching the peak in April–May. 'K' values were low from July to October. The seasonal growth rates derived above from length frequency studies also show the same pattern.

(2) Scales

In an earlier paper by the present author (Rao, 1961), the nature of the growth rings, their distribution in different size-groups of the fish, the time of their formation and the probable causative factors for the formation of these growth rings have been dealt with. Subsequently (1960–1962) scale samples from 442 fish were examined for further studies and the distribution of growth rings in different size-groups of fish was similar to that observed in earlier studies. Of these, scale samples from 219 fish which showed growth rings (I to VIII) clearly were used for projection and back calculation.

It was pointed out earlier (Rao, 1961) that the fifth and subsequent rings in the scales of older fish differed from the first three or four rings in being more conspicuous. Further examination has revealed the following differences between the first three rings and the fifth and subsequent rings. The fourth ring in some was similar to the first three rings and in others it was like the fifth and subsequent rings.

Rings I to III

The width of the space between circuli comprising the growth ring is less than that between circuli in the V and subsequent rings.

There is a closer approximation of the circuli.

There are only a few narrow breaks in the circuli forming the ring laterally or anterolaterally and areas without circuli inside the ring are absent.

The number of new radii starting from the ring is more than those from the outer rings.

False rings or secondary rings which could be distinguished by their incomplete nature were observed in some scales and quite often these were inside the first growth ring. In some scales the secondary ring near the first ring resembled it so closely that it was difficult to distinguish the latter from the former. "Double ringing," *i.e.*, presence of secondary ring close to the true (annual) ring was observed in respect of outer rings of some scales.

Relationship Between Fish Length and Scale Length

An accurate knowledge of the form of relationship between fish length and scale length is essential before the method of back calculation for knowing the length of fish at the time of formation of different annuli, is applied. The mean scale lengths for 375 fish (ranging from 7.5 to 112.5 cm) are plotted against fish length in Fig. 12. The scatter of the points clearly shows that the relationship between them is linear and of the form $L = a + b S$ (where L = fish length ; S = scale length; a and b are con-

V and subsequent rings

The width of the space between circuli comprising the ring is more than that between circuli in the first three rings.

There is no closer approximation of circuli.

The breaks in the circuli forming the ring are more and wider which result in lengthy areas without circuli, anteriorly and laterally. These areas appear as bright stripes under the reflected light of microscope. This seems to be the reason for the clear and conspicuous nature of these rings.

The number of new radii starting from the ring is less than those from the inner rings or they may even be absent.

stants). The equation for the rectilinear regression calculated by the method of least squares is $L = 1.8765 + 6.7001 S$, the regression line intercepting the L-axis 1.87 cm from origin (Fig. 12). In a specimen 2.5 cm in length observed by the present author scales had been formed.

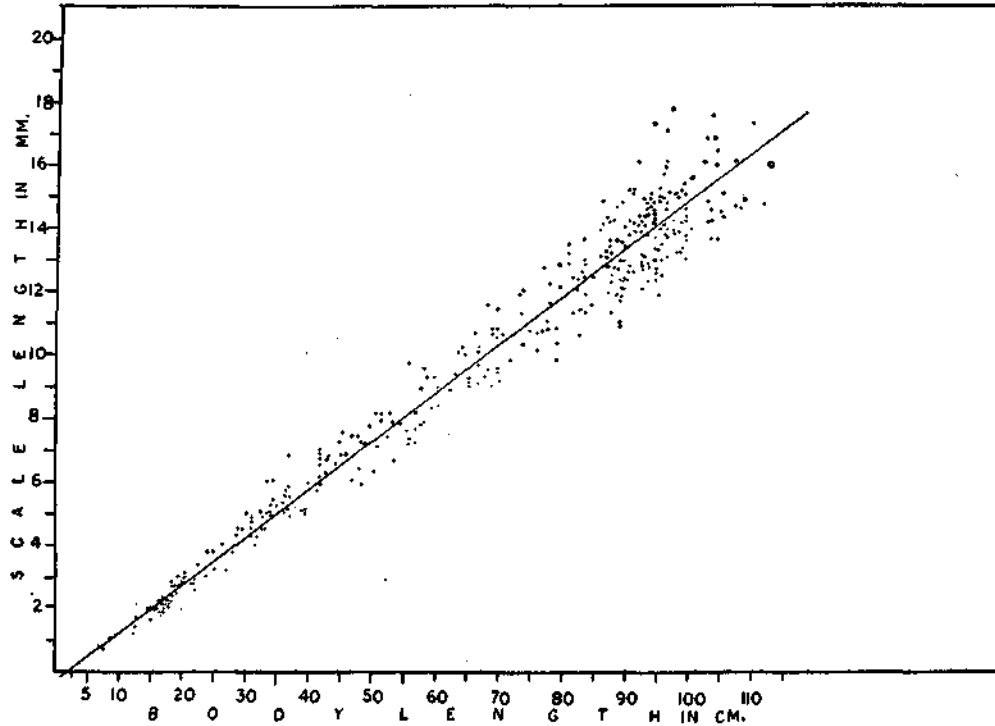


FIG. 12. Scale length-body length relationship in *P. diacanthus*.

Back calculation—For each scale projected, back calculation was done by using the direct proportion formula (Dahl-Lea method) $L_t = S_t/S$ (referred to as method A) and the corrected (Lee method) formula based on above fish length-scale length relationship, $L_t = L S_t/S + a (1 - S_t/S)$ (referred to as method B) where L and S are the lengths of the fish and scale respectively, L_t is the calculated length at age t and S_t is the length of the scale upto the t^{th} annual ring, a is the constant in the equation for regression denoting the length of the fish when the scales are formed (See Lagler, 1956; Saetersdal, 1953, 1958; Jones, 1958).

The back-calculated lengths of fish at the time of formation of the annual growth rings I to VIII by the direct proportion formula (A) as well as the corrected formula (B) are shown in Table II.

TABLE II. Mean back-calculated lengths (cm) from the scales at the end of each year of life of *Pseudosciaena diacanthus*

Age at capture	No. of fish	Mean	Mean back-calculated lengths							
			l_1		l_2		l_3		l_4	
			A	B	A	B	A	B	A	B
I	42		38.0619	38.4654	..	..	..	..	..	..
II	23		41.4742	42.2626	62.8599	63.0930	..	..	..	..
III	26		39.8328	40.8374	63.4031	63.8923	80.5566	80.7225	..	..
IV	42		41.9248	42.9482	61.3479	64.9219	80.9559	81.1994	89.2371	89.3298
V	53		41.8952	42.9708	63.5490	64.3097	80.3656	80.7199	90.0404	90.2212
VI	16		43.6303	44.7503	65.2624	65.9972	80.1717	80.6454	90.6642	90.9881
VII	12		42.6168	43.7812	64.3317	65.1307	79.3552	79.9047	91.9688	92.3071
VIII	5		44.4376	45.9007	62.0532	62.9307	78.5199	79.1302	88.8631	89.3079
Total ..	219	Mean	41.5847	42.7024	63.6867	64.3250	79.9874	80.3870	90.1547	90.4308

Age at capture	No. of fish	Mean	Mean back-calculated lengths							
			l_5		l_6		l_7		l_8	
			A	B	A	B	A	B	A	B
I	42		..	..	..	..	..	..	..	..
II	23		..	..	..	..	..	..	..	..
III	26		..	..	..	..	..	..	..	..
IV	42		..	..	..	..	..	..	..	..
V	53		95.9891	95.9655	..	..	..	..	..	..
VI	16		98.3403	98.4945	104.1494	104.2087	..	..	..	..
VII	12		99.3065	99.5226	105.3003	105.4167	109.5940	109.6393	..	..
VIII	5		97.5826	98.1828	104.9503	105.1436	110.1141	110.2183	114.0022	114.0425
Total ..	219	Mean	97.8546	98.0413	104.8020	104.9430	109.8540	109.9288	114.0022	114.0425

A = According to direct proportion formula; B = According to the corrected formula; $L = a + bS$

The age at capture, the number of fish whose scales are used for back calculation and the mean back-calculated length at each age are also given in Table II. The lengths of fish at the time of formation of rings (ages) I to VIII obtained by the scale (back calculation) method using the corrected formula (method B) are 42.70, 64.32, 80.39, 90.43, 98.04, 104.94, 109.93 and 114.04 cm respectively and the respective growth increments are 21.62, 16.07, 10.04, 7.61, 6.90, 4.99 and 4.11 cm. The lengths at ages I to V back-calculated from the scales are in close agreement with the values derived by length frequency studies. The differences in the mean back-calculated lengths (L_t) at ages I to VIII between the two methods (A and B) were found to be 0.97, 0.64, 0.40, 0.28, 0.19, 0.14, 0.07 and 0.04 cm respectively. It can be seen that the difference in the mean back-calculated lengths between the two methods diminishes gradually from ages I to VIII and for the older age groups with 7 or 8 rings the difference in the back-calculated values of lengths at the time of formation of 7th or 8th ring by the two methods is negligible.

Body Length-Scale Length Ratio in Different Size Groups of 'Ghol'

To find out whether there was much variation in the body length scale length ratios in different size-groups, the entire range of fish length was divided into 6 size-groups (1-19, 20-39, 40-59, 60-79, 80-99 and 100-119 cm), and from each size-group the body length-scale length ratios for 15 to 20 fish were determined. The mean body length-scale length ratios for the above 6 size-groups were found to be 8.00, 6.80, 6.99, 6.80 and 7.18 respectively. It is interesting to note that except for the first size-group, the ratios from the other groups show little variation and can be said to be fairly constant. In Fig. 13 are plotted the body length-scale length ratios against body length and it can be seen that the majority of points lie within a narrow range (6.5 to 8.0) showing that there is not much variation.

In this connection it may be mentioned that van Oosten (1929) has found that the body length-scale length ratios of the lake herring (*Leucichthys artedi*) of age group III and older decrease slowly but consistently with each older age group. That is, the percentage of increase in length with age is greater in the scale than in the body of the herring. He also found that the decrease in the body length-scale length ratios with age is not due to the age variations in the body length-head length proportion which remains virtually constant with age. In the case of *P. diacanthus* the high value of body length-scale length ratio (8.0) for the first size-group

(1-19 cm) indicates that in the early life of this fish the scales increase in size relatively faster than the body. The fairly constant body length-scale length ratio for the other size-groups (20.0 cm and above) shows that after this length of 20.0 cm is attained, the scales and body grow in length proportionately. 'Ghol' attains a size of 20.0 cm in 5 or 6 months.

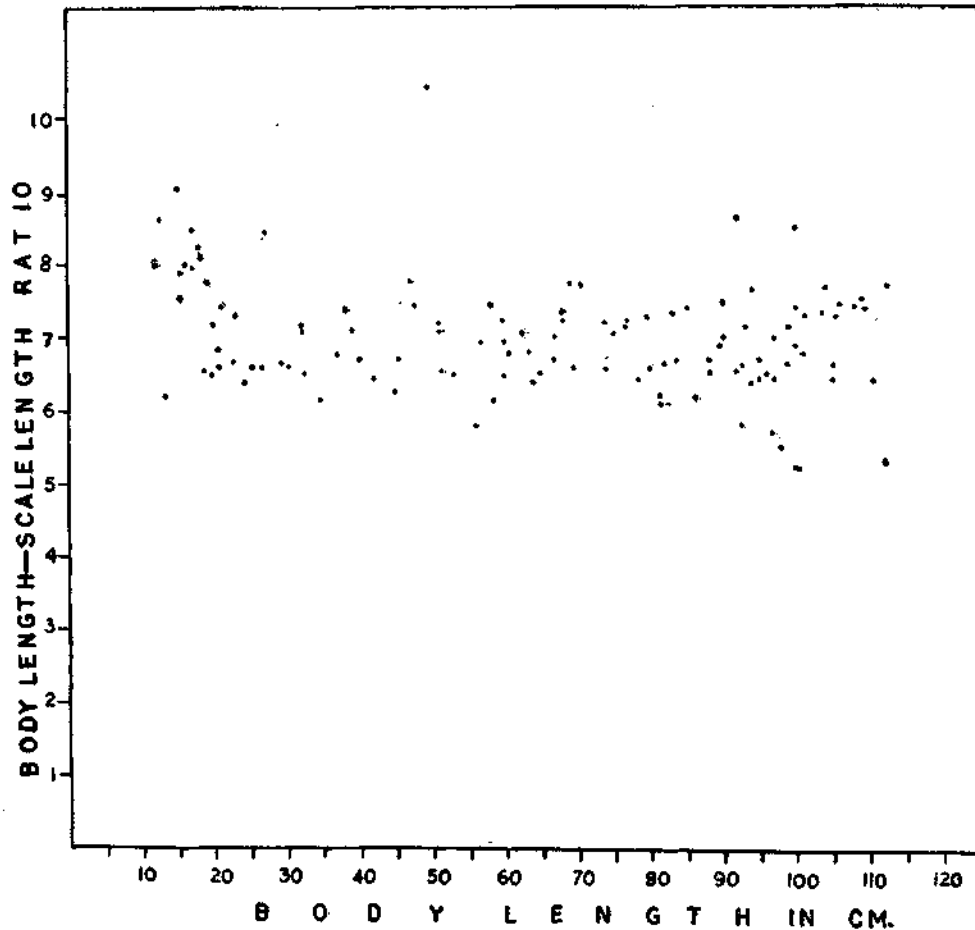


FIG. 13. Body length-scale length ratios of *P. diacanthus* plotted against body lengths.

Lea (1910) introduced the scale method of back calculation for determining the growth of fish and since then this method has been used by many workers (Lea, 1913, 1929, 1938; Lee, 1912, 1920; Mottram, 1916; Huntsman, 1918; van Oosten, 1929; Dannevig and Høst, 1931; Fry, 1943; Hile, 1950; Blackburn, 1949, 1950). In India only very few workers have attempted the back calculation method, Jhingran (1959) has investigated the

growth of *Cirrhina mrigala* from the river Ganga while Sarojini (1957) studied the growth of grey mullet *Mugil parsia* by the back calculation method. Amongst marine fishes of India, this method has been used for studying the growth of *Cynoglossus semifasciatus* (Seshappa and Bhimachar, 1954) and *Cynoglossus macrolepidotus* (Kutty, 1967).

One of the most well-known objections to the reliability of this method was put forward by Lee (1912), who found that "with increasing age the groups of fish all show a decreasing rate of growth in the calculated values for each year of their lives". Lee's Phenomenon (apparent change in growth rate) has been found in a number of fish species (e.g., Lee, 1912; van Oosten, 1929; Robertson, 1936; Watkin, 1933 and others).

In the case of *P. diacanthus* it can be seen from Table II that the lengths of fish when one year old (I_1) calculated from the older age groups increase gradually which is opposite of what is expected if there is Lee's phenomenon. The same holds good for the lengths of fish calculated when 2 years old (I_2) and 3 years old (I_3). The values for lengths at ages 2 to 6 (I_2 to I_6) back-calculated from fish with 8 rings in the scales are lower than those from others and this may be due to fewer number of fish (5). From this it appears that Lee's phenomenon is not evident in the growth calculations from the scales of 'Ghol' and in fact a reverse trend is indicated. There are several instances in which the phenomenon was not recorded (e.g., Nall, 1930, for sea trout, and Saetersdal, 1953, for haddock).

(3) Otoliths

The growth rings are in the form of hyaline (translucent) rings concentric with the margin and alternating with opaque zones.

Body length-otolith length relationship—The total otolith lengths (from posterior end to anterior end) are plotted against body lengths for 207 fish (6.1 to 110.5 cm in length) in Fig. 14. The scatter diagram indicates a linear relationship which can be adequately described by two regression lines, one fitted for body lengths up to 55-60 cm and the other for body lengths beyond 60.0 cm. There seems to be a change in the relationship from 55-60 cm (body length).

Back calculation—Due to the difficulty (presence of bulbous excrescence in the nuclear region) already mentioned, the intermediate and total lengths (from nucleus to different hyaline rings and edge) of otoliths could not be measured and so back calculation was not possible. Fairbridge

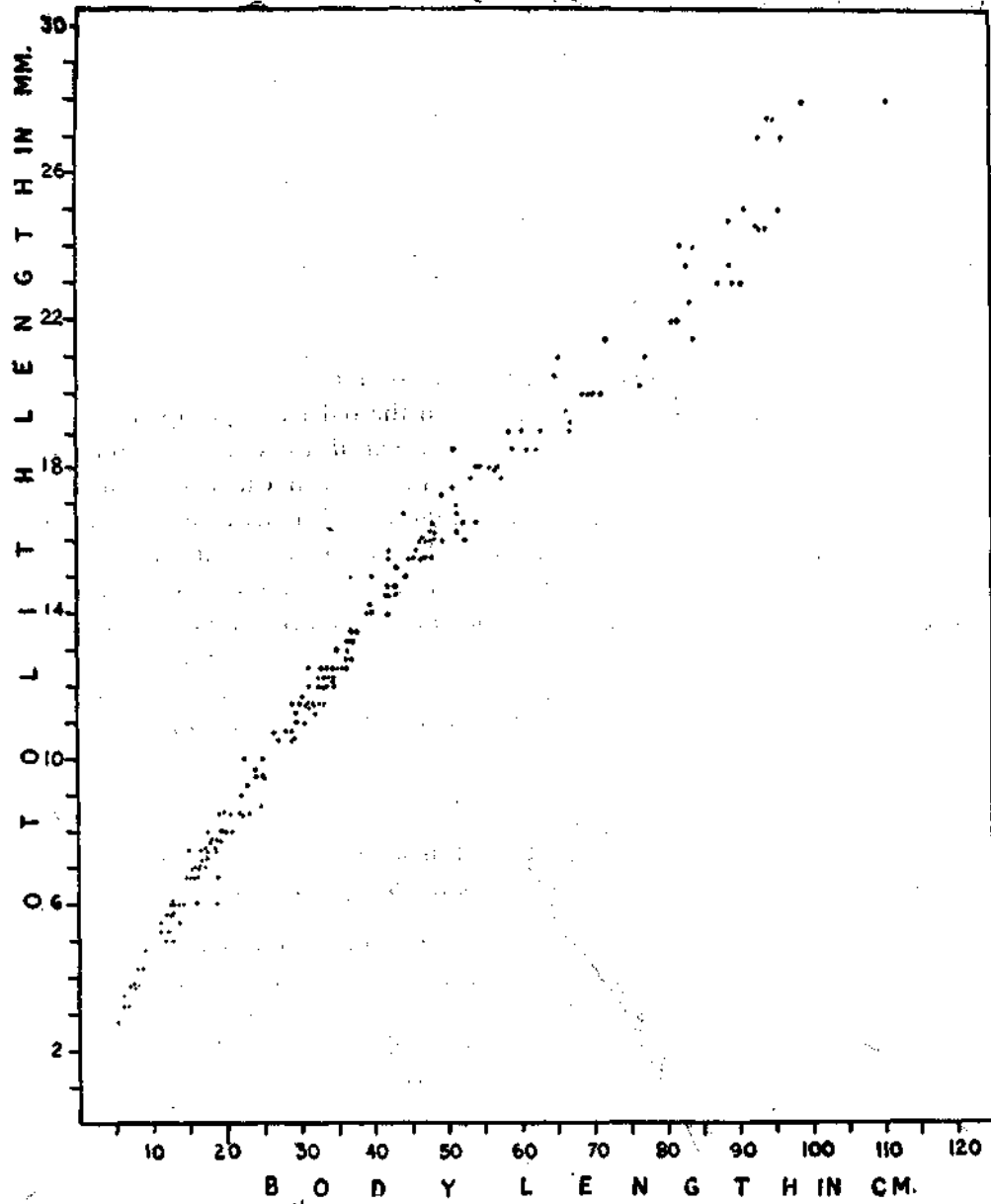


FIG. 14. Scatter diagram showing the relationship between total otolith length and body length in *P. diacanthus*.

(1951) observed that one of a pair of otoliths in New South Wales tiger flathead (*Neoplatycephalus macrodon*) occasionally is "crystallized" (in this condition the organic matter is in part or in whole not developed or has been resorbed, leaving a mass of large calcite crystals); these otoliths are usually useless for age determination and discarded. Rarely both otoliths are more or less "crystallized". Such a mass of large calcite crystals is observed in the otoliths of all 'ghols' but they have been used for counting the number of growth rings though not for back calculation.

Gross examination of otoliths.—428 pairs of otoliths were examined under reflected light against black background and the number of hyaline (translucent) rings in them noted. The distribution of these translucent rings in the different size-groups of fish are shown in Table III. The mean

TABLE III. Frequency distribution of rings in the otoliths of 'Ghol,' *Pseudosciaena diacanthus* (Lacépède)

Size group in cm*	Number of fish examined	Number of rings in the otoliths						
		0	I	II	III	IV	V	VI
-4	5	5	..	..	..	..	..	..
5-9	16	16	..	..	..	..	..	..
10-14	27	27	..	..	..	..	..	..
15-19	63	63	..	..	..	..	..	..
20-24	52	52	..	..	..	..	..	..
25-29	27	24	3	..	..	..	..	..
30-34	33	23	10	..	..	..	..	..
35-39	26	6	20	..	..	..	..	..
40-44	18	..	18	..	..	..	..	..
45-49	22	..	22	..	..	..	..	..
50-54	18	..	18	..	..	..	..	..
55-59	8	..	6	2	..	..	..	..
60-64	9	..	1	8	..	..	..	..
65-69	9	..	..	9	..	..	..	..
70-74	6	..	..	6	..	..	..	..
75-79	7	..	..	3	4	..	..	..
80-84	10	..	..	2	7	1	..	..
85-89	5	..	..	..	3	2	..	..
90-94	10	..	..	..	1	9	..	..
95-99	6	..	..	..	..	3	3	..
100-104	..	..	..	..	..	..	..	..
105-109	..	..	..	..	..	..	..	..
110-114	1	..	..	..	..	..	..	1
Total	428	266	98	30	15	15	3	1
Average length (cm) of fish with rings			44.05	68.21	82.24	92.06	97.60	110.5

* Total length in cm from the tip of the snout to the tip of the longest ray of caudal fin.

lengths of fish with I to VI rings were found to be 44.05, 68.21, 83.24, 92.06, 97.60 and 110.50 cm respectively. The first five values are in close agreement with those of scales (Rao, 1961).

Time of formation of the hyaline rings.—For knowing the time of formation of the hyaline rings, the nature of the edge of the otoliths in different months was studied. In all 168 pairs of otoliths showing growth rings were used for this purpose. The percentage of otoliths with hyaline edge in different months is shown in Fig. 15. The percentage of otoliths with translucent edge gradually increased from September and remained high (59.1–57.9) during the period November–January and dropped from February. Otolith samples could not be examined in May while in June and July very few could be examined and these had opaque edges. All the otolith samples examined in August had opaque edges. From this it appears that these hyaline rings are formed during the period November to January. The present author in his earlier studies (Rao, 1961) had observed the first translucent ring at the edge in otoliths from fish 38.0–46.0 cm in length collected during October–November

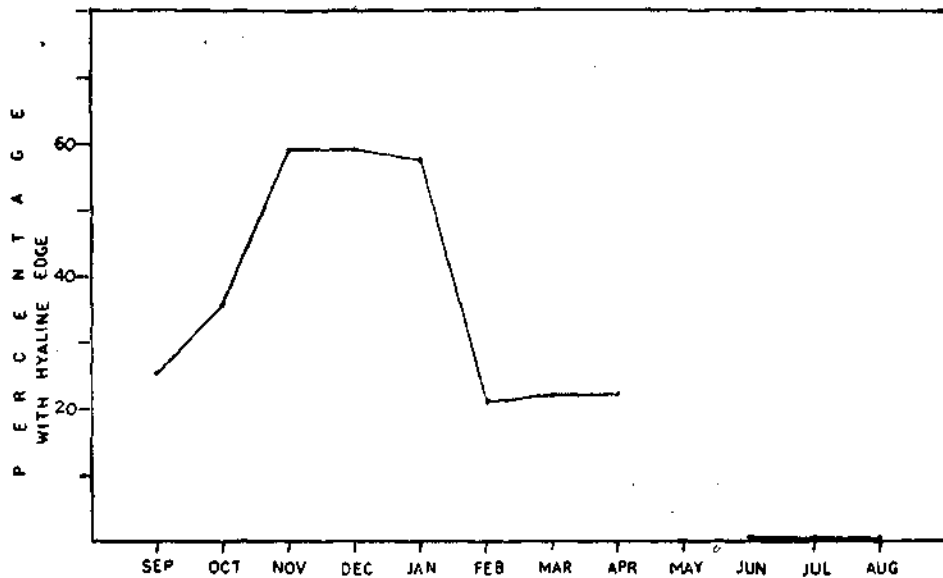


FIG. 15. Monthly percentages of otoliths with hyaline edges in *P. diacanthus*.

The first hyaline ring is formed in the majority of the fish examined after completion of one year, i.e., in the next October–January period when they would be about 1 year and 4 months old. Juvenile 'ghols' 25–30 cm

and the second ring is formed in the next October-January period. Since the first ring is absent in otoliths of 'ghol' (25-30 cm) caught in inshore waters ('Dol' net), it is possible that this ring is formed in 'ghol' of this size from deeper waters caught in the trawl. From the length of the fish and date of collection, it can be determined whether the first ring is formed before completion of one year, i.e., in the year of birth or after completion of one year. Since the majority of fish show the first growth ring in the otoliths after completion of one year (1 +), in the case of fish of the same size showing 2 rings in the otoliths, the 2nd ring corresponds to the annual ring (1 +). While ageing the otoliths this has to be kept in view.

Besides the annual hyaline ring formed in the year of birth, i.e., before completion of one year, in some juveniles (10-20 cm) a narrow hyaline (streak) ring outside the nucleus was observed. This narrow hyaline ring (streak) can be easily distinguished from the broader annual hyaline zones and, probably, may be the impression of some event connected with change or disturbance in the environment during the early part of the life-history of this species. This may correspond to what is called the "larval ring" for red mullet (*Mullus barbatus*) by Gottlieb (1956) and for New South Wales Tiger flathead (*Neoplatycephalus macrodon*) by Fairbridge (1951). A similar ring around the nucleus (check ring) was observed in the cod from Spitsbergen Bank of Barents Sea (Trout, 1958). According to the above authors the 'larval rings' may represent the adoption of a bottom mode of life after their planktonic existence as larvae. According to Kotthaus (1958) 2 to 4 secondary rings are laid in the otoliths of some species before the end of first year of life, e.g., red fish (*Sebastes marinus*), plaice (*Pleuronectes platessa*), Adriatic sardine (*Chupea pilchardus*) and *Drepanopsetta platessoides*. He is of the opinion that the secondary rings in red fish are formed as a result of regular migrations, connected with the changes in the food supply. Kutty (1961) has found that 2 to 3 rings are formed in the otoliths of juvenile 'koth' (*Otolithoides brunneus*) from Bombay and Saurashtra waters while their scales showed only one growth ring.

(4) Growth Curve of the Fish

A preliminary plot of the length at ages estimated by the different methods (length frequency, scales and otoliths) indicated that the growth curve of *P. diacanthus* could be adequately expressed by the von Bertalanffy equation for growth in length (Beverton, 1954; Beverton and Holt, 1957)

$$L_t = L_{\infty} (1 - e^{-k(t-t_0)})$$

in length from the inshore waters around Bombay showed only the opaque zone during the year of their birth (October–December/January), *i.e.*, before completing one year, and the scales of this size-group also did not show the first growth ring (Rao, 1961). However, for a few fish from the trawler catches a hyaline ring was observed in their otoliths during the year of their birth (October–December/January) when they would be 5–6 months old

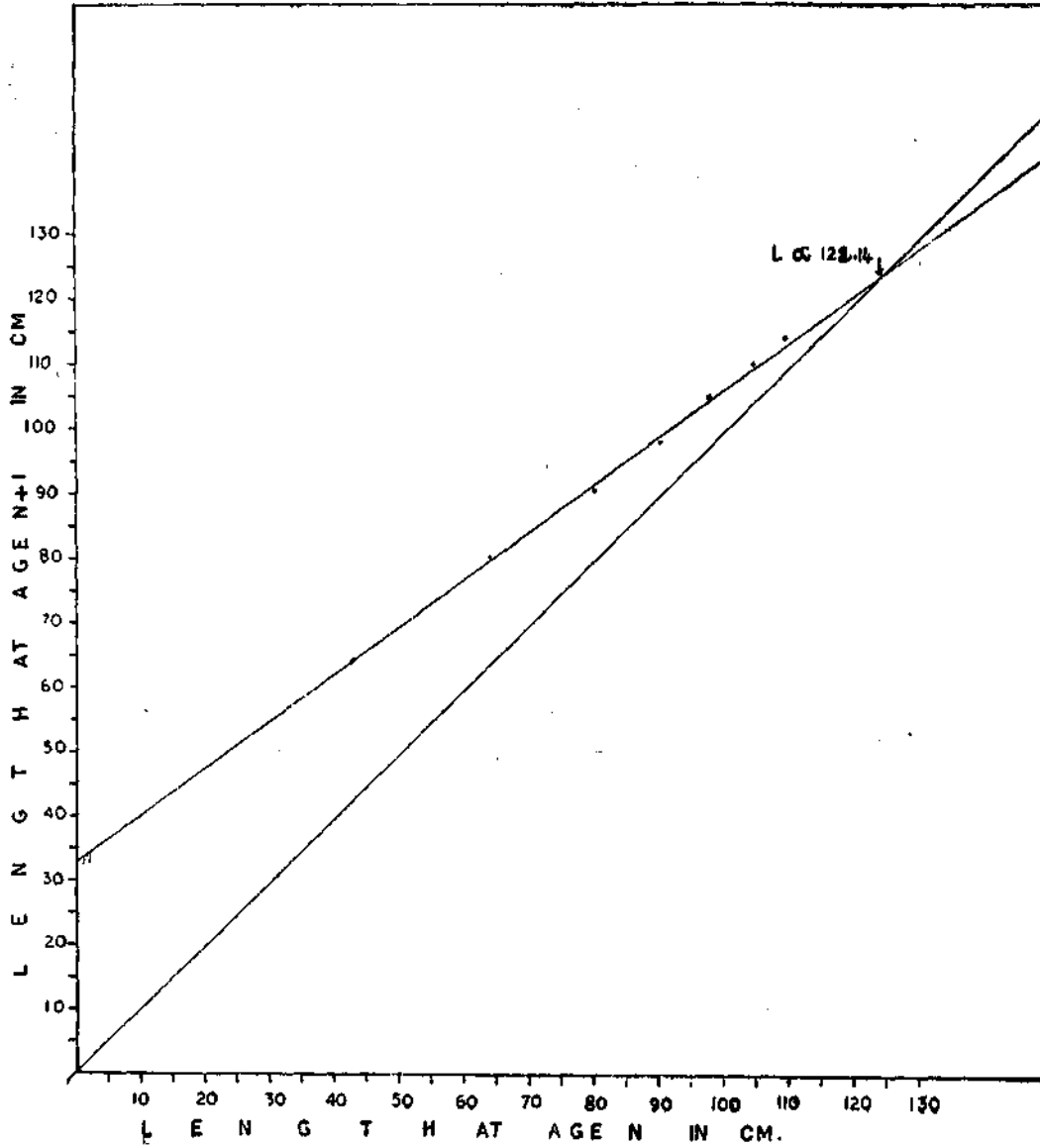


Fig. 16. Ford-Welford plot of growth of *P. diacanthus*.

where L_t = length at age t ; L_∞ = the asymptotic size of the fish; K = a constant equal to $1/3$ of catabolic coefficient; t = age of fish; t_0 = the age at which L_t is theoretically zero; e = base of the Napierian logarithm. For actual fitting of the curve only the lengths (at different ages) back calculated from the scales were used.

The parameters K and L_∞ were estimated from the Ford-Walford Plot (Beverton and Holt, 1957; Ford, 1933; Walford, 1946) of L_{t+1} against L_t where L_t and L_{t+1} are the lengths at age t and $t+1$ years which gives a straight line relationship. This is shown in Fig. 16. The regression line was fitted by the method of least squares. The intersection of this line with the bisector through the origin gives L_∞ and this quantity is identical with L_∞ defined in von Bertalanffy equation (Beverton, 1954; Beverton and Holt, 1957).

The value of ' t_0 ' was estimated by two methods; (1) by plotting $\text{Log}_e(L_\infty - L_t)$ against t (Beverton, 1954) as shown in Fig. 17. (2) by estimating ' t_0 ' from the equation

$$t_0 = 1/K \text{Log}_e(1 - L_t/L_\infty) + t$$

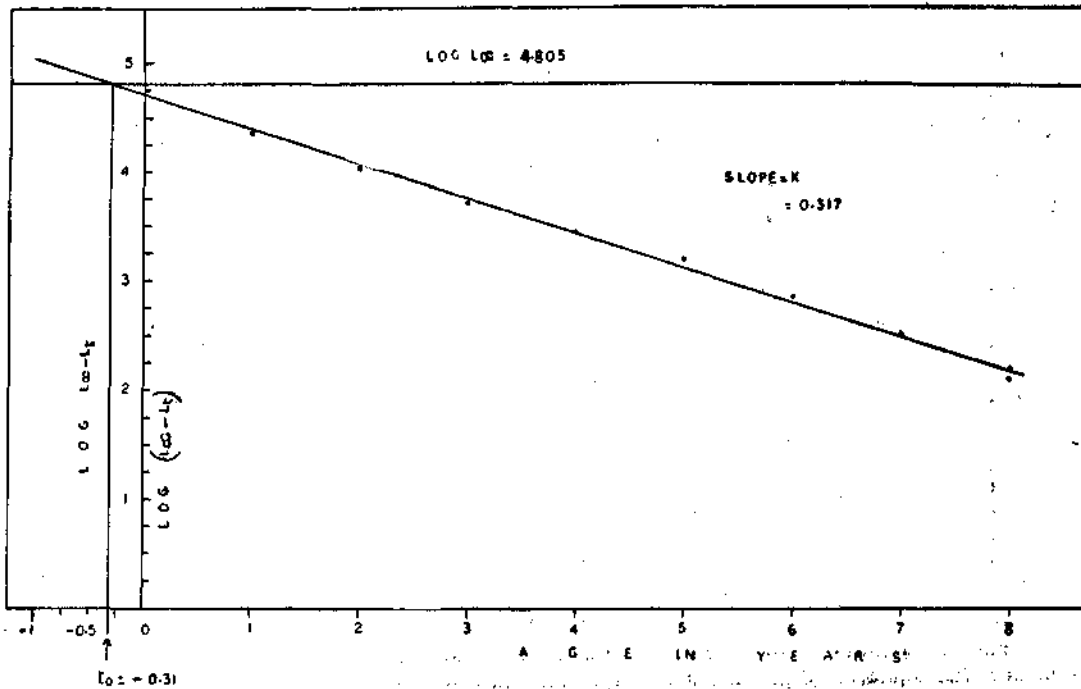


FIG. 17. $\text{Log}_e(L_\infty - L_t)$ plotted against age ' t ' for estimation of t_0 in *P. diacanthus*.

for L_t values at ages I to VIII back calculated from scales and calculating the average. Both the methods gave identical values. The estimates of various parameters of von Bertalanffy equation were:

$$t_0 = -0.31; K = 0.315; L_\infty = 122.14$$

Hence the von Bertalanffy equation for *P. diacanthus* would be

$$L_t = 122.14 (1 - e^{-0.315(t+0.31)})$$

In Fig. 18 the continuous line represents the estimated growth curve. It can be seen that the curve fits the length-at-age data estimated by different methods. It may be mentioned that the maximum length of 122.0 cm was recorded by the present author for *P. diacanthus* from the Gulf of Cutch landed at Jamnagar during the 'Ghol-Dara' fishery season of 1961 (Bhatt

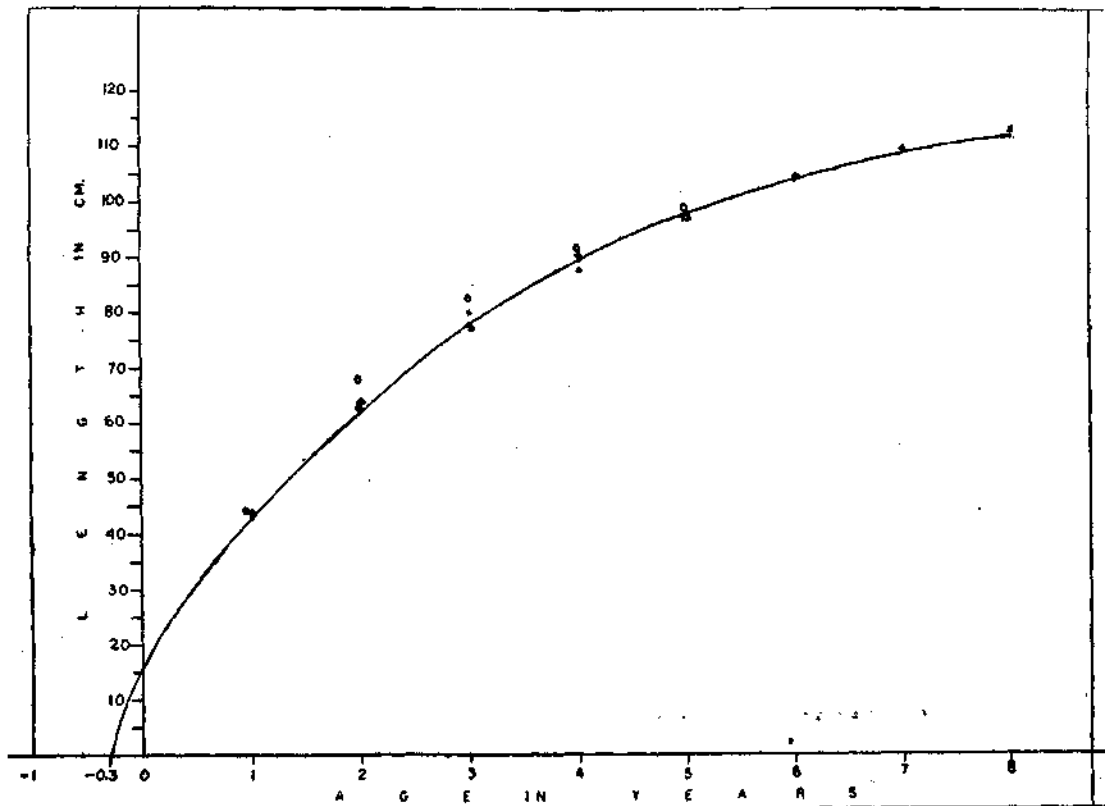


FIG. 18. Growth curve of *P. diacanthus*, obtained by fitting von Bertalanffy equation. Solid circles represent lengths at different ages estimated by the equation; solid triangles, crosses and open circles represent lengths at ages estimated from the length frequency studies, scales and otoliths respectively.

et al., 1967). Specimens 120.0 cm in length were observed from the 'Dol' net catches at Versova near Bombay.

The theoretical lengths at different ages as calculated by von Bertalanffy equation (Table IV) showed a very high degree of agreement with lengths at ages derived from length frequency studies, scales (back calculation) and otoliths (average size of fish with I to V rings in the otoliths).

TABLE IV. *Comparison of estimates of lengths at different ages by various methods*

Age (years)	Length frequency	Otoliths	Scales	von Bertalanffy growth equation
1	37.5	44.05	42.70	42.67
2	62.5	68.21	64.32	61.90
3	77.5	83.24	80.39	77.94
4	97.5	92.06	90.43	89.71
5	97.5	97.6	98.04	98.34
6	..	..	104.94	104.68
7	..	..	109.93	109.32
8	..	..	114.04	112.73

DISCUSSION

Though growth rings on skeletal parts of tropical fishes have been observed by many workers, only in a few cases (Seshappa and Bhimachar, 1951; Jhingran, 1959; Pantulu, 1961, 1962; Pantulu and Singh, 1962) have their validity as age indicators been established by critical studies on the lines suggested by Graham (1929 *a* and *b*). According to Graham (*loc. cit.*) there are five tests for deciding the validity of any method of age determination in fishes.

- (1) Agreement with Petersen's method.
- (2) Seasonal record of the ring or zone formation.
- (3) Observation of the stock over a long period of years.
- (4) Marking experiments.
- (5) Tank or pond experiments with fish of known age.

The following three points from the studies on the age and growth of *P. diacanthus* presented in this paper answer the first three tests mentioned by Graham (*loc. cit.*) satisfactorily which is a fair vindication of the validity of the method.

- (1) There is close agreement between the first five modes in the length frequency distributions during June–September (period of birth), the back calculated lengths at the time of formation of the first five rings in the scales and the average length of fish with I to V rings in their otoliths (*vide* Table IV).
- (2) The studies on the seasonal nature of the edges (margins) of the scales and otoliths show clearly that only one ring is formed in a year and at the same period during each year.
- (3) It was possible to trace and follow the different year classes in the fishery from length frequency studies during the period 1958–62.

The narrow bright stripe in the 5th and subsequent rings observed in *P. diacanthus* appears to be similar to the “bright stripe without striae beyond the ring of break” observed by Zamakhaev (1940) and Tchougounova (1940) in the Caspian shads (*Caspilosa caspia*, *C. volgensis* and *C. bergi*). These authors observe: “In some places wider stripes without striae are formed or stripes with faintly visible and separate striae. In the new zone of growth beyond the ‘ring of break’ the direction (angle) of the striae is changed in some parts of the scale. These changes of direction of striae are found almost always at the spots where the shoulders and sides meet.” In the case of ‘ghol’ no such change in the direction of the striae (circuli) was observed. Zamakhaev (*loc. cit.*) and Tchougounova (*loc. cit.*) call them as ‘spawning rings’ and have offered a mechanical hypothesis of a sudden loss of subcutaneous fat during the spawning season as the cause for the formation of these spawning rings. ‘Spawning rings’ have been observed in the scales of Australian pilchard, *Sardinops neopilchardus* (Blackburn, 1949, 1950). It is to be noted that in the case of the Caspian shad and the Australian pilchard two rings, one the yearly (annual) ring and the other spawning ring are formed in a year in the scales after attainment of maturity. These rings are found close to each other and sometimes the spawning ring which is formed after the yearly ring may be superimposed over the yearly ring or even obliterate it (Zamakhaev, 1940; Blackburn, 1949, 1950). Though both the rings are formed in the same season, their differential nature (structure) could be made out when they occur one inside the other

(Zamakhaev, 1940; Blackburn, 1949, 1950). Such specific type of 'spawning zones' were observed by Rollefsen (1933) in the otoliths of the mature cod "Skrei" and have been found in the Iceland cod, Greenland cod, Norwegian saithe and Arctic haddock (Saetersdal, 1958). The present author (Rao, 1963) has shown that the minimum size at maturity of *P. diacanthus* is 85.0 cm and fish of this size would be about 4 years old with 3 or 4 growth rings in their scales; that the 'K' (condition factor) values were high from April to June, falling suddenly in July–August. The 'K' values were low till January and increased gradually thereafter. Similar seasonal trend was observed in the mean monthly gonad weight-body weight ratios. Further the present author could not find any relationship between intensity of feeding and the formation of the rings in the case of adults as 95% of the big 'ghols' examined had extroverted stomachs (Rao, 1963). The differential nature of the 5th and subsequent rings in the light of above earlier observations, provides strong evidence that the formation of the 5th (sometimes 4th) and subsequent rings may be related to the event of spawning in this species, as in the case of the Caspian shad or Australian pilchard. 'Poor condition' due to the metabolic strain of spawning seems to be the causative factor in the formation of the 5th and subsequent rings, in which case they are similar to the 'spawning rings' noticed by Zamakhaev (1940) and Blackburn (1949). From the length frequency studies it is shown that growth for *P. diacanthus* starts from November and is fast from February to April or May and that June to October is the period of nil growth. It is possible that the rings are formed before the growth is resumed after spawning, i.e., when they are in 'poor condition' after spawning. The same may be the case with the hyaline rings in the otoliths though spawning zones of the type described by Rollefsen (1933) were not observed. Hickling (1933) is of the view that the growth rings (hyaline) in the otoliths of the mature hake are formed due to the 'poor condition' of the fish after spawning while in the immature hake an inherent physiological rhythm is suggested as a possible causative factor.

It has been pointed out earlier (Rao, 1961) that the opaque zone formation in the otoliths of juvenile 'ghol' caught around Bombay by 'Dol' nets, is related to high feeding intensity. In the immature fish, low feeding intensity, low bottom temperatures and sudden change in the hydrological conditions during the period October–January as mentioned earlier (Rao, 1961) may be responsible for the formation of the growth checks.

Though the causative factors may be different, the growth rings in the scales of immature and mature 'ghol' are formed during the same period,

i.e., September–January. It is to be noted that only one ring is formed on the scales in a year in ‘ghol’ unlike in the mature Caspian shad or Australian pilchard where two rings are formed in the same season.

van Oosten (1929) is of the view that Lee’s phenomenon is due chiefly to the variability of the body length-scale length ratio from year to year and the fault of the scale method is that it cannot follow these changes in any particular age group. The absence of Lee’s phenomenon in *P. diacanthus* according to the above view can be explained by the fairly constant body-length/scale length ratios in different size-groups of ‘ghol’ referred to already. Taylor (1958) has found for Georges Bank haddock that the regressions of l_2 on l_1 , l_3 on l_1 etc., are linear for each age of capture, the regression lines tending to intersect at a common point. He observes that Lee’s phenomenon becomes progressively less with increasing l_1 and that its occurrence in the reverse form should in fact be expected beyond the point of intersection. The absence of Lee’s phenomenon in ‘Ghol’ suggests that the ranges of sizes at age one may be near the point of intersection of regression lines mentioned above, in which case the phenomenon would not be observed. It has frequently been suggested that the apparent change in growth rate (Lee’s phenomenon) arises from size segregation of fast and slow growers according to maturity (Lea, 1913; Saetersdal, 1958) or selective mortality (Jones, 1958; Taylor, 1958) by the fishing gear of the larger and faster growing fish. The absence of Lee’s phenomenon in ‘ghol’ may indicate that size segregation and selective mortality factors may not be operating.

From the data presented earlier by the present author (Rao, 1961) and Kutty (1961), Longhurst (1964)* has derived values of $K = 0.87$ and $K = 0.25-0.28$ for *Pseudosciaena diacanthus* and *Otolithoides brunneus* respectively. These values seem to be high, particularly the K value for *P. diacanthus*. With the same data the present author has obtained values of $K = 0.3025$ and $K = 0.1744$, for *P. diacanthus* and *Otolithoides brunneus* respectively. The K values calculated for a few sciaenids from published data by the present author and also others are shown in Table V along with other relevant information.

It can be seen from Table V that the K values of the sciaenids from different regions range from 0.12 to 0.71. The values for *Pseudolithus senegalensis* and *P. elongatus* (0.71 and 0.61 respectively) are high and if these two are excluded the range in K values is not much (0.12 to 0.51). It may be mentioned that the K values for sardines range from 0.2 to 1.6

* Dr. Longhurst in a personal communication to the present author states that there is some arithmetical error in his calculation of K values for *P. diacanthus* and *O. brunneus*.

TABLE V. Estimated 'K' values of a few sciaenids from different regions

Sl. No.	Species	Regions	L_{∞} Total length in cm	K	Estimate by	Reference (source of age and growth data)	Remarks
1	<i>Roncador stearnsi</i>	Californian waters	47.6 ..	0.287 0.32	Present author Longhurst (1964)	Joseph (1962) do.	..
2	<i>Mentacirrhus undulatus</i>	..	.. 44.4	0.51 0.385	Longhurst (1964) Present author	do. do.	..
3	<i>Pseudolithus senegalensis</i>	Tropical West Africa (Nigeria)	47.8	0.71 0.20	Longhurst (1964) do.	Longhurst (1964) Collignon (1967)	..
4	<i>Pseudolithus typus</i>	..	61.2	0.37	do.	Longhurst (1964)	..
5	<i>Pseudolithus elongatus</i>	..	45.0	0.61	do.	do.	..
6	<i>Pseudosciaena diacanthus</i>	Arabian Sea Bombay-Sau- rashtra waters	122.14	0.315	Present author	Present author	..
7	<i>Otolithoides brunneus</i>	..	170.25	0.174	do.	Kutty (1961)	..
8	<i>Argyrosomus nili</i>	Formosa strait- East China Sea	58.5	0.116	do.	Liu (1956)	Lengths at ages I to VI are taken as 15, 20, 23, 27, 30 and 33 cm respectively
9	<i>Sciaenops ocellatus</i>	Texas coast, Gulf of Mexico	105.0	0.30	do.	Bearson (1923)	..
10	* <i>Pogonias cromis</i>	..	105.0	0.17	do.	do.	* For these species the author has given only l_1 l_2 (lengths at the end of first and second year) and the maximum lengths L_{max} . recorded by him for these species has been taken as L_{∞} . A Ford-Walford plot was drawn joining the point l_2 plotted against l_1 with the L_{max} by a straight line cutting the bisector through the origin at L_{max} . From this graph the slope of the regression (fitted line) was calculated and 'K' values estimated.
11	<i>Cynoscion nebulosus</i>	..	70.25	0.16	do.	do.	
12	* <i>Micropogon undulatus</i>	..	39.0	0.35	do.	do.	
13	* <i>Leiostomus xanthurus</i>	..	34.0	0.43	do.	do.	

(Holt, 1960). The high K values for *P. senegalensis* and *P. elongatus* may be due to their geographical position near the equator. For the other sciaenids no trend could be made out between K values and the geographical areas (distance from the equator) in which they occur. Geographical trends in the K values have been observed in some sardine species by Holt (*loc. cit.*). Excepting *Argyrosomus nibe* which shows a low K value (0.116) for a low L_{∞} (58 cm), low K values are associated with high L_{∞} (e.g., *Otolithoides brunneus*, *Pogonias cromis*) and *vice versa* (Table V). This trend had been observed by Holt (1960) in the sardines also.

SUMMARY

The age and growth of 'ghol,' *Pseudosciaena diacanthus* a commercially important sciaenid of Bombay and Saurashtra waters was studied by three methods: (1) length frequency distributions, (2) scales and (3) otoliths.

The length frequency studies show that growth is fast during the first year of life of this fish and diminishes gradually later. 'Ghol' grows to a size of 30 cm in 7-9 months, 37.5 cm at the end of I year and 62.5, 77.5, 87.5 and 97.5 cm at the end of II, III, IV and V years respectively. November to May was observed to be the period of growth. The growth was fast during February-May.

The lengths at the time of formation of growth rings (annuli) I to VIII were back-calculated from scales and found to be 42.70, 64.32, 80.39, 90.43, 98.04, 104.94, 109.93 and 114.04 cm respectively.

The mean lengths of fish with I to VI hyaline rings in the otoliths were 44.05, 68.21, 83.24, 92.06, 97.60 and 110.5 cm respectively.

There is a close agreement in the lengths at ages I to V derived from length frequency studies, back calculation of scales and otoliths which is a fair vindication of the validity of the method of age determination.

von Bertalanffy growth curve for length-at-age data was fitted for *P. diacanthus* and the values of the various parameters of the equation estimated. The estimated K values of a few sciaenids from different regions are given and compared.

The differences between the first 3 rings and the 5th (sometimes 4th also) and subsequent rings and other available evidence suggests that the first 3 rings are probably formed due to poor feeding, low bottom temperatures and sudden change in hydrological conditions while the 5th and

subsequent rings are related to the spawning of the fish. The 'poor condition' of the fish after spawning may be the probable causative factor.

Though the causative factors may be different the first 3 and subsequent growth rings are formed during the same period, September to January and only one ring is formed in a year. Specific spawning zones as in the cod were not observed in the otoliths of *P. diacanthus*. As in scales only one ring is formed in a year during the period November–January. The first growth ring was observed in the otoliths of some fish from the trawler catches before they had completed one year. A hyaline ring (streak) was observed around the nuclear part in the otoliths of some juvenile 'ghol' and this may correspond to the 'larval ring' found in some fish.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, Mandapam Camp, for encouragement in the pursuit of this work. The author is thankful to Shri K. Virabhadra Rao and Dr. K. V. Sekharan for critically going through the paper and offering valuable suggestions.

REFERENCES

- Beverton, R. J. H. 1954 .. Notes on the use of theoretical models in the study of the dynamics of exploited fish populations. *Misc. Contrib. No. 2, U.S. Fishery Lab., Beaufort, N. Car.* (Mimeo).
- Beverton, R. J. H. and Holt, S. J. 1957 On the dynamics of the exploited fish populations. *Fish. Invest. Lond.*, Series 11, 19.
- Bhatt, Y. M., Kutty, M. N., Rao, K. V. S. and Punwani, D. M. 1967 'Ghol-Dara' fishery in the Gulf of Cutch. *Indian J. Fish.* 11 (1) A (1964), 135–56.
- Blackburn, M. 1949 .. The age, rate of growth and general life-history of the Australian pilchard (*Sardinops neopilchardus*) in New South Wales waters. *C.S.I.R.O. Austr. Bull.*, No. 242.
- Blackburn, M. 1950 .. Studies on the age, growth, and life-history of the pilchard *Sardinops neopilchardus* (Steindachner), in southern and western Australia. *Aust. J. mar. Freshw. Res.* 1, 221–58.
- Collignon, J. 1957 .. Sea Perch (otolit.), fishery: *CSA Symp., Launda, O.C.W.* 40 (Mimeo).
- Dannevig, A., and Høst, P. 1931 .. Sources of error in computing l_t , I_t , etc., from scales taken from different parts of the fish. *J. Cons. Int. Explor. Mer.* 6, 64–93.

- Fairbridge, W. S. 1951 .. The New South Wales tiger flathead, *Neoplatycephalus macrodon* (Ogilby). 1. Biology and age determination. *Aust. J. mar. Freshw. Res.*, 2, 117-78.
- Ford, E. 1933 .. An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. *J. mar. biol. Ass. U.K.*, 19, 305-84.
- Fry, F. E. J. 1943 .. A method for the calculation of the growth of fishes from scale measurements. *Publ. Ont. Fish. Res. Lab.*, 6, 5-18.
- Gottlieb, E. 1956 .. The age and growth of the red mullet *Mullus barbatus* L. in Israel waters. *Sea. Fish. Res. Stat. Bull* No. 12, Haifa.
- Graham, M. 1929 a .. Studies on age determination in fish. Part I. *Fish. Invest. Min. Agric. Fish. Lond.*, Ser. 11, 11 (2).
- Graham, M. 1929 b .. Studies on age determination in fish. Part II. A survey of literature. *Fish. Invest. Lond.*, Ser 11, 11 (3).
- Hickling, C. F. 1933 .. The natural history of the hake. IV. Age determination and growth-rate. *Fish. Invest. Lond.* Ser 11, 13 (2), 120.
- Hile, R. 1950 .. A monograph for the computation of the growth of fish from scale measurements. *Trans. Amer. Fish. Soc.*, 78 (1948), 156-62.
- Holt, S. J. 1960 ... A preliminary comparative study of the growth, maturity and mortality of sardines. In *Proceedings of the World Scientific Meeting on the Biology of Sardines and Related Species*. Vol. 11. Subject synopsis 2, 553-61.
- Huntsman, A. G. 1918 .. The scale method calculating the rate of growth in fishes. *Trans. roy. Soc. Can.*, 12 (3), 47-52.
- Jhingran, V. G. 1959 .. Studies on the age and growth of *Cirrhhina mrigala* (Ham.) from the River Ganga. *Proc. nat. Inst. Sci. India*, 25 B (3), 107-37.
- Jones, R. 1958 .. Lee's phenomenon of "apparent change in growth rate," with particular reference to haddock and plaice. *International Commission for North-West Atlantic Fisheries Spec. Pub.* No. 1, 229-42.
- Joseph, D. C. 1952 .. Growth characteristics of two Southern California surf fishes, the California corbina and spot fin croaker, family Sciaenidae. *Fish. Bull., Dep. Fish. Game Calif.*, No. 119, 1-54.
- Kotthaus, A. 1958 .. Age and growth of red fish, *Sebastes marinus* (L.). *International Commission for North West Atlantic Fisheries Spec. Pub.* No. 1, 217-22.
- Kutty, M. N. 1961 .. Scales and otoliths of the 'Koth' *Otolithoides brunneus* (Day) as age indicators. *Indian J. Fish.*, 8 (1), 145-51.
- Kutty, M. K. 1967 .. Observations on the growth and mortality of the large-scaled tongue sole *Cynoglossus macrolepidotus* (Bleeker). *Proc. nat. Inst. Sci. India*, 33 B (1 and 2), 94-110.
- Lagler, K. F. 1956 .. *Freshwater Fishery Biology* (Second Edition). W. M. C. Brown Company, Dubuque, Iowa, p. 421.
- Lea, E. 1910 .. On the methods used in the herring investigations. *Pub. Circ. Cons. Explor. Mer.*, No. 53, 7-25.

- Lea, E. 1913 .. Further studies concerning the methods of calculating the growth of herrings. *Pub. Circ. Cons. Explor. Mer.*, No. 66.
- Lea, E. 1929 .. The herring's scale as a certificate of origin. Its applicability to race investigations. *Rapp. cons. Explor. Mer.*, 54, 21-34.
- Lea, E. 1938 .. A modification of the formula for the calculation of the growth of herring. *Rapp. eqs. Explor. Mer.*, 108 (1), 13-22.
- Lee, R. M. 1912 .. An investigation into the methods of growth determination in fishes. *Publ. Circ. Cons. Explor. Mer.*, No. 63.
- Lee, R. M. 1920 .. A review of the methods of age and growth determination in fishes by means of scales. *Fish. Invest. Min. Agric. Fish., Lond.*, Ser. 11, 4 (2).
- Liu, F. H. 1956 .. Studies on black croaker (*Argyrosomus nibe* J and T) of the northern trawling ground of Taiwan. *Rept. Inst. Fish. Biology, Ministry of Economic Affairs and National Taiwan Univ.*, 1 (1), 62-67.
- Longhurst, A. R. 1964 .. Bionomics of the Sciaenidae of tropical West Africa. *J. Cons. int. Explor. Mer.*, 29 (1), 93-114.
- Mottram, J. C. 1916 .. Methods of estimating the size of fish from the scales. *Salm. Trout Mag.*, 13.
- Nall, G. H. 1930 .. The life of the sea trout. *London seeley, service*, 46-50.
- Pearson, J. C. 1929 .. Natural history and conservation of the red fish and other sciaenids on the Texas coast. *Bull. U.S. Bur. Fish. Washington*, 44 (1928), 129-224. (Doc. No. 1046).
- Pantulu, V. R. 1961 .. Determination of age and growth of *Mystus gulio* (Ham.) by the use of pectoral spines, with observations on its biology and fishery in the Hooghly estuary. *Proc. nat. Inst. Sci. India*, 27 (B) (4), 1-30.
- Pantulu, V. R. 1962 .. On the use of pectoral spines for the determination of age and growth of *Pangasius pangasius*. *J. Cons. int. Explor. Mer.*, 27 (2), 192-216.
- Pantulu, V. R. and Singh, V. D. 1962 .. On the use of otoliths for the determination of age and growth of *Anguilla nebulosa* McClelland. *Proc. Indian Acad. Sci.*, 55 (5) B, 263-75.
- Rao, K. V. S. 1961 .. Studies on the age determination of 'Ghol' *Pseudosciaena diacanthus* (Lacépède) by means of scales and otoliths. *Indian J. Fish.*, 8 (1), 121-26.
- Rao, K. V. S. 1963 .. Some aspects of the biology of 'Ghol' *Pseudosciaena diacanthus* (Lacépède). *Indian J. Fish.*, 10 (1) A, 413-459.
- Rao, K. V. S. 1970 .. Trend of 'Ghol' landings by the New India Fisheries bull-trawlers for 1959-62 operating in Bombay and Saurashtra waters. *Indian J. Fish.*, 12 (2) A (1965), 97-122.
- Robertson, J. A. 1936 .. The occurrence of Lee's phenomenon in the sprat, and the size-relation between fish and scale. *J. Cons. int. Explor. Mer.*, 11, 219-28.

- Rollesfen, G. 1933 .. The otoliths of the cod. *Rep. Norweg. Fish. Invest.*, 4 (3), Bergen.
- Saetersdal, G. 1953 .. The haddock in Norwegian waters. II. Methods in age and growth investigations. *Rap. Norweg. Fish. Invest.*, 10.
- Saetersdal, G. 1958 .. Use of otoliths and scales of the Arctic haddock. *International Commission for North-West Atlantic Fisheries Spec. Pub. No. 1*, 201-06.
- Sarojini, K. K. 1957 .. Biology and fisheries of the grey mullets of Bengal. I. Biology of *Mugil parsia* Hamilton with notes on its fishery in Bengal. *Indian J. Fish.*, 4 (1), 160-207.
- Seshappa, G. and Bhimachar, B. S. 1951 .. Age determination studies in fishes by means of scales with special reference to the Malabar sole. *Curr. Sci.*, 20, 260-62.
- Seshappa, G. and Bhimachar, B. S. 1954 .. Studies on the age and growth of the Malabar sole, *Cynoglossus semifasciatus* Day. *Indian J. Fish.*, 1, 145-62.
- Taylor, C. C. 1958 .. A note on Lee's phenomenon in Georges Bank haddock. *International Commission for North-West Atlantic Fisheries Spec. Pub. No. 1*, 243-51.
- Tchougounova, N. I. 1940 .. Methods of growth studies of *Caspiolosa saposhnikovi* (Grimm). *Trans. Inst. mar. Fish. Oceanog. U.S.S.R.*, 14, 21-46 (In Russian).
- Trout, G. C. 1958 .. Otoliths in age determination. *International Commission for North-West Atlantic Fisheries Spec. Pub. No. 1*, 207-14.
- van Oosten, J. 1929 .. Life-history of the lake herring *Leucichthys artedi* (Lesueur) of Lake Huron as revealed by its scales, with a critique of the scale method. *Bull. U.S., Bur. Fish.*, 44. Washington. *Doc. No. 1053*, 265-428.
- Walford, L. A. 1946 .. A new graphic method of describing the growth of animals. *Biol. Bull. Woods Hole*, 90, 141-47.
- Watkin, E. E. 1933 .. Studies on the commercial herring shoals of the smalls. *Rapp. Cons. Explor. Mer.*, 84, 42-62.
- Zamakhaev, D. T. 1940 .. Spawning marks on the scales of some Caspian shads. *Trans. Inst. Mar. Fish. Oceanog. U.S.S.R.*, 14, 1-20 (In Russian).