STUDIES ON THE AGE AND GROWTH OF THE OIL-SARDINE *SARDINELLA LONGICEPS* VAL. BY MEANS OF SCALES

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Introduction

A sound knowledge of age and growth of fishes is of prime importance in the management and forecast of their fisheries. Conflicting views have been expressed regarding the age and the life span of the oil-sardine based on the studies of the growth-checks of its scales, otoliths and the length-frequency. Hornell and Nayudu (1923) concluded that the fish attains sexual maturity and adult size of 15 cm. at the end of one year and that the life span of the oil-sardine is limited to 2½ years, based on the growth-rings of the scales. Devanesan (1943) detected the first growth ring on the scales of fish of 6.5 cm. in length and six of them in fish of 8.7 cm., and suggested that nine and fourteen "rings" may be expected in the fish of 15 and 18 cm. group respectively and that the fish might live for fourteen years. Nair (1949), working on the oil-sardine otoliths, stated that the fish live for three years; and later (1952) stated that it is probable that the growth-checks detected on the otoliths of the oil-sardine, especially the first two, are formed during the summer when the phytoplankton is scarce and that the third ring formed in some is either due to the same cause or due to the suspension of their feeding activity during spawning. Nair (1960), in a review, suggested that the average life span of the fish is "about 3 to 4 years." Chidambaram (1950) studied the length-frequency of the fish and concluded that its life span is four years. For resolving the above-said divergences of views on age and growth it was felt desirable to undertake a detailed study of its scales; and, therefore, the scale data and the length-frequency data were simultaneously collected at Calicut and Cochin. Balan (1959) in a preliminary note based on scale-studies and length frequency data indicated that the biggest fish have, without doubt, completed three years of their life.

In the present paper, a more critical study is made of the extensive data on the structure of scale, the distribution of scale-rings, fish length—scale length relationship and size frequency distribution collected from 1955 to 1965.

Material and Methods

The material for this study was collected from the commercial catches (caught in the boat seines *Mathikolli vala, Odam vala, Thangu vala* and also

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the gill net), from January 1955 to December 1958 at Calicut and from January 1959 to March 1965 at Cochin, covering a period of ten years.

The data on the gear used for the capture, date and place of capture, the total-length*, weight, sex and sexual maturation of each fish have also been maintained simultaneously.

Scales were pulled out with forceps, cleaned in water and mounted dry between two glass slides without damaging them and were labelled. These scales were examined under the binocular microscope and the number of scale-rings and other details were recorded.

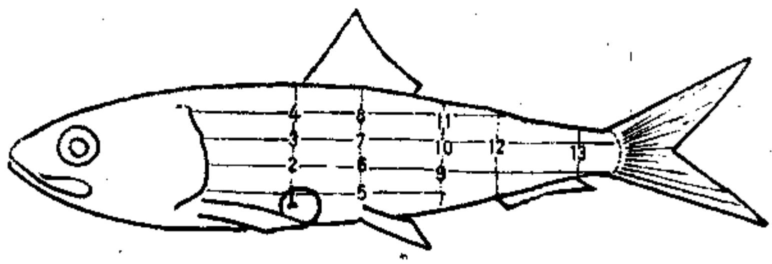


FIG. 1. Body regions from where scales were examined. Region 1 indicates the selected area.

The examination of the scales from 13 regions (Fig. 1) of the fish, as suggested by Phillips (1948) in *Sardinops caerulea*, was carried out. And, from the study of six scales collected from each of these regions of the fish, it was found that the scales occurring in the pectoral region (just above the tip of pectoral fin when it is held horizontal, *i.e.*, region 1 in Fig. 1) were most reliable for the purpose of age-determination, on the grounds that the scale size as well as the number of rings occurring in them showed the least variation. Further, over 90% of the rings observed on the scales of this region were quite distinct and well-defined compared to the rings found on the scales occurring in other regions. Also, the number of regenerated scales was the least in that region. Therefore, six scales from this region of each individual sardine were collected regularly and a total of 2,931 fish were studied counting the number of rings noticed in each scale during the period of investigation. Table I gives the details regarding these.

*Length from tip of snout to tip of ventral caudal fluke.

For studying the fish length—scale length relationship, the distance from the foci** or centres of scales to the inner margins of each year's growth (*i.e.*, the inner margin of each scale-ring) was measured accurately by means of an ocular micrometer that was set in a microscope. All the measurements were made under the same magnification, and as consistently as possible along the median axis from foci to anterior margins of the scales. The length measured from focus to outer edge of the scale, along the median axis, gave the total-length of the scale.

The length-frequency data collected simultaneously from 1955 to 1958 at Calicut and from October 1958 to March 1965 at Cochin, from boat-seine catches have been utilised for comparison with the scale-data to see the extent to which the former are reliable for accurate age-determination.

STRUCTURE OF SCALES

The scales of *Sardinella longiceps* are cycloid and exhibit variations in size in the different regions of the body. The scales which occur in the pectoral axillary region are the biggest and are rather oblong in shape. The sclerites or circuli found on the scales are transverse in disposition (especially those on the scales of pectoral region); but those on the scales occurring nearer the dorsal side, *i.e.*, along the horizontal line passing through the upper margin of operculum, are slightly circular in their pattern of arrangement. These circuli are interrupted by the conspicuous scale radii which are nearly horizontal in distribution. Generally the nucleus of the scale is not conspicuous. Therefore, the nucleus or the focus in the scales of this fish would mean the arbitrary middle point on the lowest horizontal circulus. A scale-ring is seen as a semi-circular mark which breaks the continuity of the circuli. Most of the rings were quite clear in appearance, while a few were less so. Besides the true rings, a few "false" rings were also observed. Those false rings appeared as indistinct marks [similar to those described by Walford and Mosher (1943), for *Sardinops caerulea*].

The true rings can be distinguished by the following characteristics (*vide* also Balan, 1959):

(1) A clear-cut discontinuity or break of the circuli discernible along the entire course of the ring.

(2) They are concentric with the border of the scale, and are distinctly separated from each other.

(3) At times a ring may be discontinuous, being broken at different points; but the broken segments form more or less a semi-circular pattern and possess the features mentioned under (1) and (2).

**Focus is the arbitrary middle point at the lowest circulus of the sculptured part of the scale.

Eventhough these rings normally occur in the sculptured part of the scales, at times they may be seen extending into the unsculptured posterior part also; such a characteristic feature is generally associated with deep and thick rings.

The narrow posterior unsculptured portion of the scale presents generally a ragged or even frayed appearance.

At times it would appear a particular ring has failed to form on the sardine scales, as was reported in South African Pilchard (Nawratil, 1958) and Australian Pilchard (Blackburn, 1949); it is rather difficult to say whether any particular ring has failed to form on the scales.

While the rings were not well-defined in certain scales, they were clearly discernible in many others collected from the same region of the same individual. Observations of Lee (1920), Creaser (1926) on Sunfish, Van Oosten (1929) on *Leucichthys* (Coregonid), Phillips (1948) on California Sardine, Blackburn (1949 & 1950) on Australian Pilchard, Davies (1957) and Nawratil (1958) on South African Pilchard and Joseph (1962) on California Corbina and spotfin Croaker lend support to this finding.

Sometimes scales collected from the same individual fish revealed one ring and a few others indicated two rings; in such cases, rings indicating the largest number were taken as the correct.

Distribution of Scale-Rings

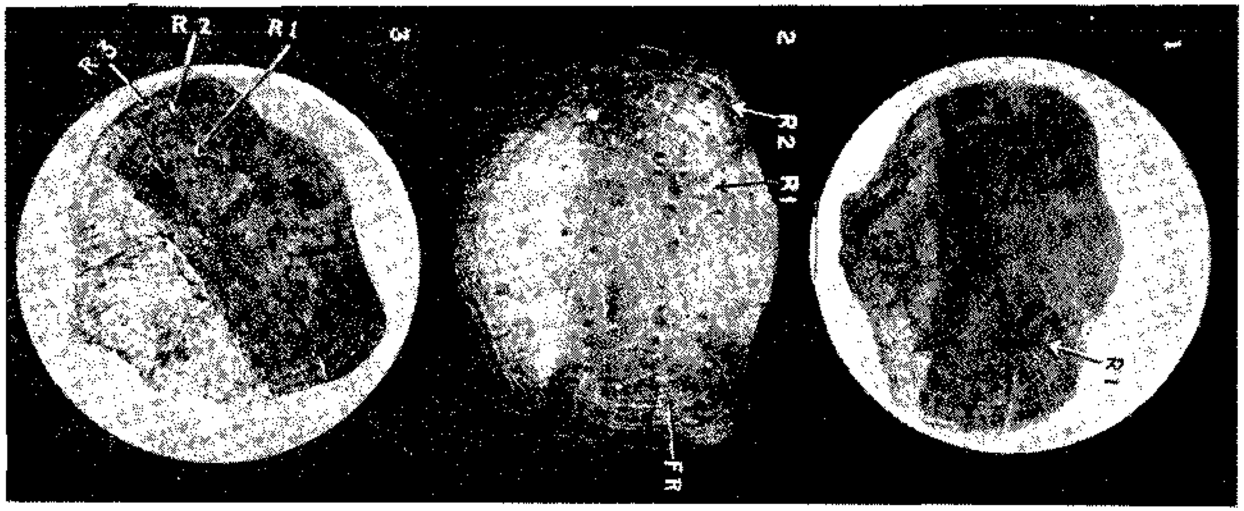
Examination of the data and samples collected has given support to the recognition of these rings as annual and indicative of the age of the individual from which the scales were taken (Balan, 1959). Based on these scale-rings, the year-class compositions of the populations of the oil-sardine have been examined. Table I shows the distribution of growth-rings pertaining to the samples (a total of 2,931 individuals) collected during January 1957—December 1964.

The results of these scale examinations showed that (1) most of the individuals had "rings" developed at the outermost margins of their scales by March-June every year,

(2) these rings first appeared at the edges of scales and gradually went deeper in the scales as further growth progressed at the margins, *i.e.*, the marginal increment increased in size until the next ring was formed, and

(3) young specimens of the new brood were without any ring in their scales.

More widely spaced circuli were noticed after the formation of each ring, thereby indicating that there was fast growth followed by a temporary cessation



Photomicrographs of scales of *S. longiceps*. 1. Showing 1 ring, T. L. of fish 14·3 cm. 2. Showing 2 rings, T. L. of fish 16·3 cm. 3. Showing 3 rings, T. L. of fish 18·3 cm. R1—first ring R2—second ring R3—third ring FR—false ring.

in growth. Thus it has been clearly observed that the fast growing (wider) circuli are alternating with the annuli, year after year. It is, therefore, in line with the observations of Menon (loc. cit.), Van Oosten (loc. cit.), Lee (loc. cit.), Joseph (loc. cit.), Nawratil (loc. cit.), Davies (loc. cit.), Blackburn (1949) and many other investigators in regard to various species of fishes.

It is obvious from Table I that the scales of the fish below 12.0 cm. do not possess any ring. Fish with one ring are dominant at 14.5 cm. The largest number of fish with two rings were found in the size group 17.0-17.9 cm. and those with three rings were found in the size group 18.0-18.9 cm.

It may be added that the fish having one ring start appearing from 12.5 cm.; in the case of 2-ring fish, they start at about 14.0 cm. onwards; but in the case of fish possessing three rings, they start appearing normally from 16.5 cm.

There is some degree of overlap in the case of the age-groups I and II at lengths between 15.0 and 16.0 cm., and between II and III at lengths between 18.0 and 19.5 cm. Extensive overlapping of sizes have also been observed in Australian Pilchard by Blackburn (1949, p. 67) and in the channel catfish by Appelget and Smith. (1951).

It is of interest here that the trend of ring distribution observed during the six years (1959 to 1964) of investigation is similar to that of 1957-1958 period (as already reported, Balan 1959) to a great extent.

Body-Scale Length Relationship

In order that the growth-checks found in scales (or otoliths) may be of use in age determination, it is necessary to find out first that the fish and the scale grow collaterally. Unless this is so, it will not be possible to back-calculate the size of the fish at different ages.

The growth-checks may be periodic or non-periodic in nature. Only when they are periodic in nature, they may be taken to indicate the age, whatever may be the cause for such growth-checks. To find out if such growth-checks are periodic in nature, generally results obtained from the studies of growth-checks are compared with the results obtained from length-frequency distributions and, if they are comparable, reliance could be placed on the annual nature of the rings.

To see if a relationship exists between the size of fish and scale size, a scatter diagram showing the relation between these two is first drawn and this is given in Fig. 2. Apparently, the relationship is a linear one. So, a linear equation $L = A + BS$ was fitted to fish length and scale measurements of 328 oil-sardine, where L is the length of fish in mm. and S the length of the scale

TABLE 1

Distribution of scale-rings of 2931 oil-sardine from 1957 to 1964.

(Figures in parentheses indicate percentages)

	Size Groups (in cm.)													
	7·0 to 7·9	8·0 to 8·9	9·0 to 9·9	10·0 to 10·9	11·0 to 11·9	12·0 to 12·9	13·0 to 13·9	14·0 to 14·9	15·0 to 15·9	16·0 to 16·9	17·0 to 17·9	18·0 to 18·9	19·0 to 19·9	20·0 to 20·9
No. of fish examined.	4	21	52*	48	17	128	437	467	253	421	550	389	109	35
No. of Rings														
0	4 (100)	21 (100)	52 (100)	48 (100)	17 (100)	42 (32·8)	178 (40·7)	131 (28·1)	22 (8·7)	6 (1·4)	2 (0·4)	2 (0·5)	..	..
1	..	..	..	..	..	83 (64·8)	256 (58·6)	312 (66·8)	153 (60·5)	134 (31·8)	89 (16·2)	39 (10·0)	14 (12·8)	3 (8·6)
2	..	..	..	..	..	3 (2·4)	3 (0·7)	24 (5·1)	77 (30·4)	279 (66·3)	420 (76·3)	304 (78·2)	78 (71·6)	18 (51·4)
3	..	..	..	..	..	..	..	..	1 (0·4)	2 (0·5)	39 (7·1)	44 (11·3)	17 (15·6)	14 (40·0)

*Four nos. of fish (9 cm. group) were originally assigned as having one ring each by mistake.

23—3 DCM PRI/M/67

TABLE II

Showing Seasonal distribution of scale-rings in various months.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total No. of Fish
29	55	39	57	54	45	11	11	22	12	7	14	356

in micrometer divisions; A and B are parameters whose estimates are to be found from the data. In this connection, it must be stated that length measurements of fish and scale exist for over 2,900 fish. But, for the sake of convenience, the above 328 sets of measurements were chosen at random. The least square estimate of A and B are: A = 49.964 and B = 0.645.

Taking these estimates of A and B, the length of fish at the time of formation of growth-checks (L_t) could be easily found out if the relation between the size of the fish and the size of the scale is rewritten as $L_t = L\frac{S_t}{S} + \frac{A(I-S_t)}{S}$ where S is the total-length of the scale, S_t is the length of the scale up to the t[th] growth-check was formed. Using this formula based on 328 fish, the lengths of fish corresponding to the different growth-checks found in scales recalculated; but because of bulkiness of the material, it is not presented here.

Looking into the back-calculated values of the fish corresponding to the successive growth-checks of the 328 fish it is found that the fish length varied

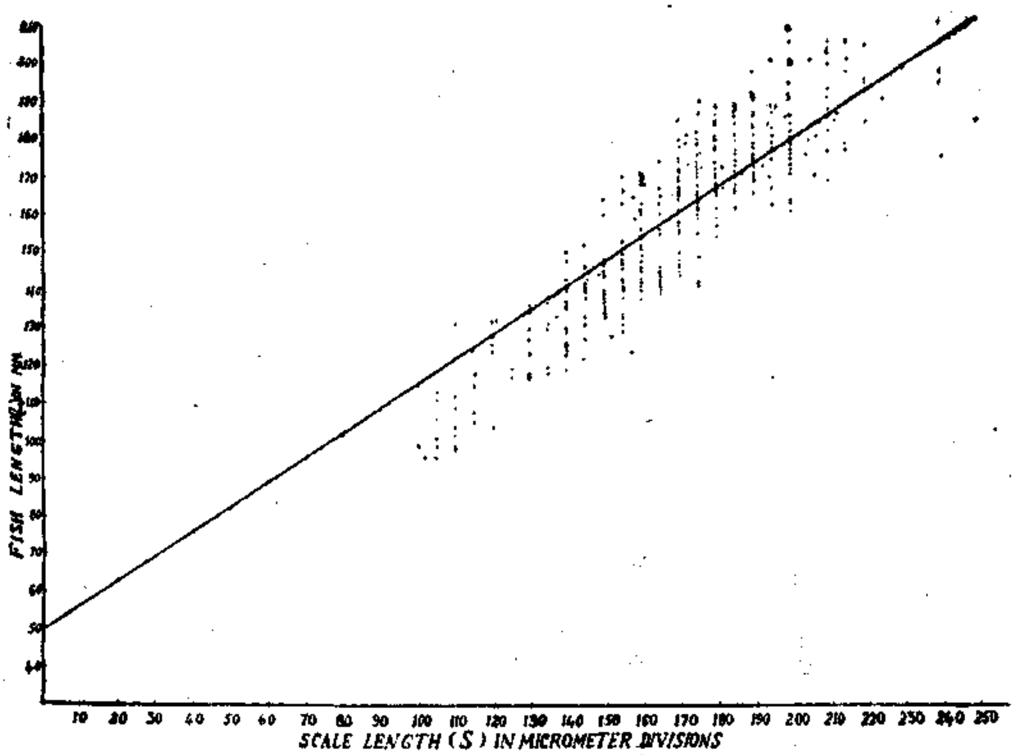


FIG. 2. Scatter diagram showing fish length—scale length relation.

from 10.6 to 16.0 cm. when the first ring was seen, and from 14.3 to 19.2 cm. when the second ring was seen and from 16.7 to 20.0 cm. when the third ring was seen. The average size of the fish when the first ring was found was 14.3 cm., the corresponding values when the second and the third rings were found were 16.4 and 18.4 cm. respectively. Thus marked variations are noticeable in the lengths of the fish corresponding to each ring. According to Blackburn (1949, p. 82 in Australian Pilchard) "There is considerable variation in the lengths of the fish at the time of formation of each age-ring, some fish having consistently greater lengths than others at all such periods throughout life, and in consequence seeming to have a faster growth."

As in many other species of fishes, the growth-rate of oil-sardine up to the end of the first year of their life is quite fast as mentioned above. Nevertheless, relatively small values that have been obtained for a few individual cases of back-calculated one-year old fish may be due to the contraction of the central field of scales as was observed in Murman herring by Makushok (1963); according to him "Our material limited as it is, shows that the contraction of the central field of the scale undoubtedly occurs. This is particularly distinctly seen in the various age groups when the lengths are back-calculated for the first year of life (i.e. l_1) as can be seen in Table 2" (p. 24).

Period of Ring Formation

To find out the time of formation of rings, the following procedure was adopted. The average scale lengths up to the formation of successive rings were found out. The average growth between the i_{th} and $(i+1)^{th}$ rings was thus $(\bar{r}_{i+1}-\bar{r}_i)$. If the scale shows some growth after the i_{th} ring and measures r, then $\frac{12(\bar{r}-\bar{r}_i)}{\bar{r}_{i+1}-\bar{r}_i}$ will give the approximate time that has elapsed since the formation of the i_{th} ring and thus counting backwards from the time of collection of fish from which the scale was taken, the month of formation of the i^{th} ring could be found out. The results of such calculations on a random sample of scales from 356 individuals are presented in Table II. From the table it will be seen that the peak period, when the ring formation takes place, is from February to June. Out of 356 fish whose scales were examined in detail, it was found that 250 (forming 70%) had their ring formation during this period.

Thus it may be generally accepted that the ring formation is annual in nature and the presence of the number of rings in the scales will be a valuable guide in the determination of age of the fish in years.

It is interesting here that whether the consummation of the spawning act of the fish takes place or not, the rings have been observed to occur in the fish above the 15 cm. length in the normal course during the definite period, each year. At the most the ring formation may be synchronous with the period of spawning only of a few limited fish which spawn early at the very beginning (i.e., in May-June) of the season of spawning. Also, it may be pointed out that there is no evidence in these data to prove that there is a spawning check in the scales of the adult sardine unlike the one indicated for the Indian Mackerel, occurring along the west coast, by Seshappa (1958).

LENGTH-FREQUENCY DISTRIBUTION

The length-frequency data on oil-sardine collected from 1955 to 1965 have been examined and used to compare with the results obtained by the scale-method. The details of the annual length-frequency distribution are given in

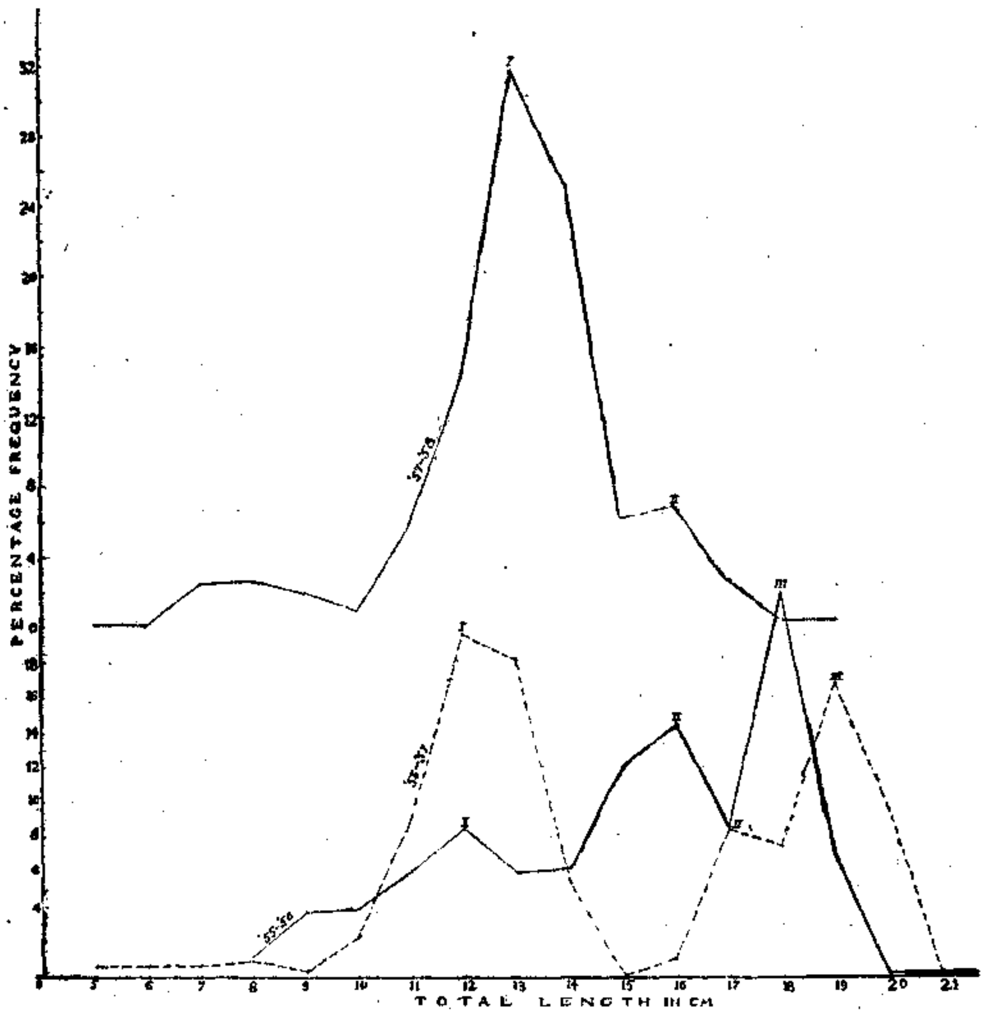


FIG. 3. Annual length-frequency distributions of oil sardine for 1955-56—1957-58.

TABLE III

Annual length—frequency distribution of oil-sardine, from 1955-64 (modal values in cm.) at successive years.

	I year	II	III
1955-56	12·0	16·0	18·0
1956-57	12·0	17·0	19·0
1957-58	13·0	16·0	Not traceable
1958-59	14·0	15·0	16·5
1959-60	13·5	15·0	17·5
1960-61	14·5	16·5	17·5
1961-62	12·5	15·0	16·5
1962-63	12·5	16·5	Not traceable
1963-64	13·5	17·0	Do.
Average	13·0	16·0	17·5

the frequency curves (Fig. 3). It may be pointed out that small differences were encountered between the age-groups estimated by the scale-method and length frequency method. The modal progressions based on frequency percentages pooled for each year are described below.

(a) At Calicut, in 1955-56, the mode representing the one-year old fish was at 12.0 cm. The mode corresponding to the 2-year old fish was at 16.0 cm; however, it showed further progression and stood at 18.0 cm. when the fish completed three years of life.

In 1956-57, the corresponding length modes for the one, two and three years were 12.0, 17.0 and 19.0 cm. respectively, thereby indicating higher values for the latter two generations than in the previous year.

In 1957-58, the one-year mode was at 13.0 cm.; the two-year class mode being at 16.0 cm. The mode to represent the three-year fish was not traceable. This was mostly due to the scarcity of the big-sized fish in the commercial catches.

In 1958-59 at Cochin, the length of the fish at one year was 14.0 cm.; but when they attained two years they had the size of 15.0 cm. only, and the three-year old fish were 16.5 cm. in length.

In 1959-60, the one-year old fish recorded the size of 13.5 cm. which progressed to 15.0 cm. when the fish attained two years. The 17.5 cm. size was attained at the age of three years.

In 1960-61, comparatively faster growth was observed for the one-year old fish when it grew to 14.5 cm. The two-year old fish were 16.5 cm. in size; the fish attained the size of 17.5 cm. at the age of three years.

In 1961-62, the one-year old sardine were only 12.5 cm. in length. While the fish completed two years, they grew to 15.0 cm. When the fish became three years old, they were 16.5 cm. long.

In 1962-63, the size of the one-year old fish remained the same as in the previous year (12.5 cm.), while the two-year old ones attained 16.5 cm. The three-year old fish were not seen adequately represented in the catches.

In 1963-64 season, the fish representing the one-year brood were 13.5 cm. in length. The two-year class was represented by the 17.0 cm. size. As in the previous year, the three-year old fish were not found sufficiently represented in the fishery. As was observed by Nair (1952) for the 1949-50 sardine season at Calicut, the 1957-58, 1962-63 and 1963-64 seasons were also conspicuous by the absence of the three-year old fish in the catches. It may be due to the non-fishability of the large-sized fish in sufficient numbers.

The average modal values calculated from the 1955 to '64 years' data indicated that the one-year olds were 13.0 cm. in total-length. The 16.0 cm size was attained on completion of two years. The growth, thereafter, appeared to be rather slow, and the modal size recorded was 17.5 cm. at the age of three years (*vide* Table III).

Variations observed in the sizes of the fish constituting the different age-classes in different years may, perhaps, be on account of the shifting of the period of spawning and/or of the post-larval recruitment; it is also in line with the remarks of Nair (1960). However, in this connection it may also be added that difficulties in the interpretation of different length modes pertaining to different ages have been experienced also in the case of Pacific Pilchard by Walford and Mosher (loc. cit.) who observed, "Nothing can be told by inspection of frequency curves in figs. 1 & 3 about the ages of the fish larger than these sizes; they may be all one-year olds; or there may be an admixture of older fish." (p. 6)

(b) The monthly progression of the size-groups during the different years from 1955 to 1965 are described in next page.

(1) AT CALICUT

In the 1955-56 season at Calicut, the oil-sardine having the mode at 8.5 cm. entered the fishery in August followed by those of 12.0 cm. mode in September. In October and November, the large-sized fish having the modes at 18.5 and 18.0 cm. constituted the bulk of the catches and these fish undoubtedly belonged to the older generations. In December and January (1956), the 18.5 and 19.0 cm. modes belonging obviously to older age-groups dominated in the catches. The fishery collapsed, towards the end of January, after the appearance of the fish having the 19.0 cm. mode. Thereafter, there was no sardine fishery till the end of June. Thus the pattern of occurrence of the size groups was somewhat peculiar during that season.

In July of 1956-57 season also, the 18.5 cm. group constituted the mode in the catches, followed by 19.0 cm. group in August. In September, October and November, it is remarkable that the older generations continued to dominate, their modes persisting at 19.5, 19.5 and 20.0 cm. respectively. In December, though late, the young fish having the mode at 11.5 cm. entered the fishery in good strength. In January, the mode progressed to 13.0 cm., being followed by the 13.5 cm. mode in February and March. In April and May, the mode grew to 14.0 cm. There was no fishery in June. In July, the mode progressed to 16.0 cm. Thus a total length increment of 4.5 cm. was noticeable from December to July.

TABLE IV

Monthly distribution of modal lengths (cm) of oil-sardine, commencing from each year's season.*
(Figures in brackets indicate percentages)

Months	At Calicut			At Cochin						
	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
July	+	18·5 19·0 & (24·0)	16·0 (36·5)	+	+	11·0 (36·0)	15·5 (26·0)	14·5 (24·0)	17·5 (17·0)	17·0 (29·0)
August	8·5 (12·0)	19·0 (35·0)	8·0 (28·0)	..	12·0 (34·0)	12·0 (16·0)	16·0 (28·0)	15·5 & 16·0 (28·0)	13·0 (20·5)	10·5 (28·0)
September	12·0 (20·0)	19·5 (33·0)	11·5 (21·0)	..	13·5 (17·0)	14·5 (34·0)	11.5 (16·0)	4·5 & 16·0 (18·0)	13·5 (35·0)	11.5 (15·0)
October	18·5 (16·0)	19·5 (44·0)	13·0 (28·0)	14·0 (22·0)	13·0 (42·0)	14·5 (30·0)	12·0 (25·0)	10·5 (18·5)	13·5 (56·0)	13·0 (35·0)
November	18·0 (22·0)	20·0 (22·0)	13·0 (25·0)	16·0 (26·5)	13·5 (28·0)	14·5 (31·0)	12·0& 12·5 (23·0)	12·0 (39·0)	+	13·0 (27·0)
December	18·5 (31·0)	11·5 (14·0)	13·0 (22·0)	14·0 (30·0)	13·5 (31·0)	14·5 (35·0)	12·5 (24·0)	12·0 (22·0)	14·5 (19·5)	13·0 (36·0)

23—3 DCMFRI/M/67

January	19·0 (31·0)	13·0 (14·0)	14·0 (19·0)	14·0 (31·0)	13·5 (35·0)	14·5 (36·0)	12·0 & 12·5 (23·0)	17·0 (31·0)	14·0 (16·0)	12·5 (24·0)
February	+	13·5 (33·0)	13·0 (30·0)	14·5 (14·0)	14·5 (26·0)	14·5 (32·0)	12·5 (28·0)	16·5 (21·0)	13·5 (24·0)	13·0 (28·0)
March	+	13·5 (32·0)	13·5 (30·0)	15·0& 17·0 (16·5)	15·0 (32·0)	14·5 (33·0)	12·0& 12·5 (24·0)	13·0 (30·0)	14·5 (24·0)	12·5 (23·0)
April	+	14·0 (33·0)	14·0 (28·0)	15·5 (17·0)	14·5 (33·0)	14·5 (34·0)	12·5 (29·0)	13·0 (23·0)	16·5 (24·0)	..
May	+	14·0 (35·0)	14·5 (29·0)	15·0 (21·0)	15·0 & 16·5 (16·0)	15·0 (30·0)	13·5 (35·5)	14·0 (20·0)	16·5 (26·0)	..
June	+	+	14·5 (29·0)	+	16·0 (30·0)	15·5 (31·0)	13·5 (24·0)	17·0 (21·5)	17·5 (22·5)	..

* Boat-seine catches.

\+ Nil catch.

.. No data available.

The 1957-58 season commenced with the entry of the youngest fish in the catches in August in good bulk having the mode at 8.0 cm. This mode progressed to 11.5 cm. in September, followed by 13.0 cm. in October. Though the modal length stood standstill at 13.0 cm. during the months of November and December it advanced to 14.0 cm. in January. In February and March the mode shifted slightly backwards (13.0 cm. and 13.5 cm. respectively). In April again the mode reached 14.0 cm. as in the previous year. In May and June, the mode indicated a slight progress by attaining 14.5 cm. Thus an overall increase in the modal length by 6.5 cm. was recorded during the ten months from August to June.

(2) At Cochin

At Cochin, the rich 1958-59 season commenced in October only.

In October 1958 the fish with 14.0 cm. mode appeared in the fishery and this size persisted (except in November when the mode was 16.0 cm.) till the end of January 1959. In February and March, the modal sizes were 14.5 and 15.0 cm. respectively; in March, there was another mode at 17.0 cm. also; an increment of 3.0 cm. was, thus, noticed from October to March. Even though the modal size was at 15.5 cm. in April, it was only 15.0 cm. in May. The fishery collapsed by the close of that month.

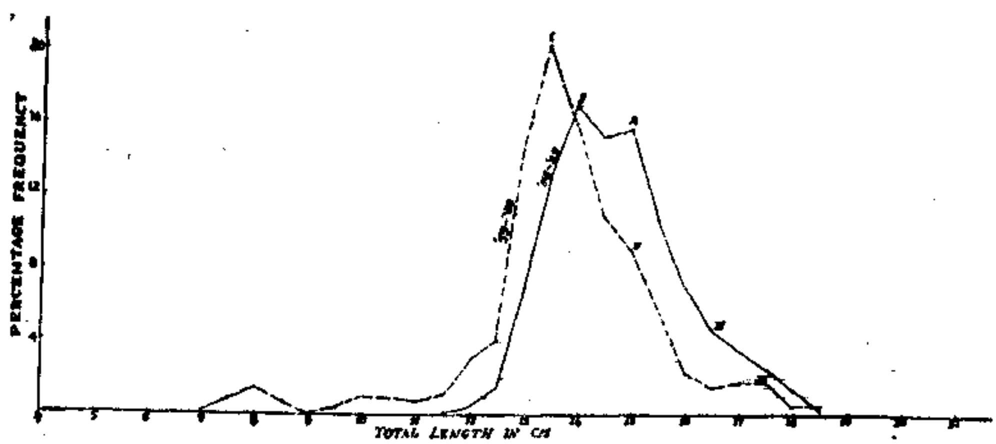


Fig. 4. Annual length-frequency distribution of oil sardine for 1958-59 and 1959-60.

The fishery began in August in the 1959-60 season with the fish having 12.0 cm. mode. In September and October, the modes were at 13.5 and 13.0 cm. respectively. From November, till the end of January 1960, the modes were at 13.5 cm. In February and March the modes were at 14.5 and 15.0 cm. respectively. The mode which was at 14.5 cm. in April progressed to 15.0 cm. in May; during that month there was an additional mode at 16.5 cm. also;

The mode in June was at 16.0 cm. only and the fishery closed by the end of that month. Thus an overall increase in length of 4.0 cm. was noticed from August to June, being 4.0 mm. per month.

The fishery began in July in the 1960-61 season with the occurrence of juveniles having mode at 11.0 cm. which progressed to 12.0 cm. in the next month. In September, the mode was at 14.5 cm. It is remarkable that this dominant mode persisted till the end of April 1961. In April, May and June the modal sizes were at 14.5, 15.0 and 15.5 cm. respectively. In July and August, the modes were at 15.5 and 16.0 cm. respectively. In the course of 13 months (July to August) an overall increase in size of 5.0 cm. was noticeable, thus recording about 4.0 mm. per month.

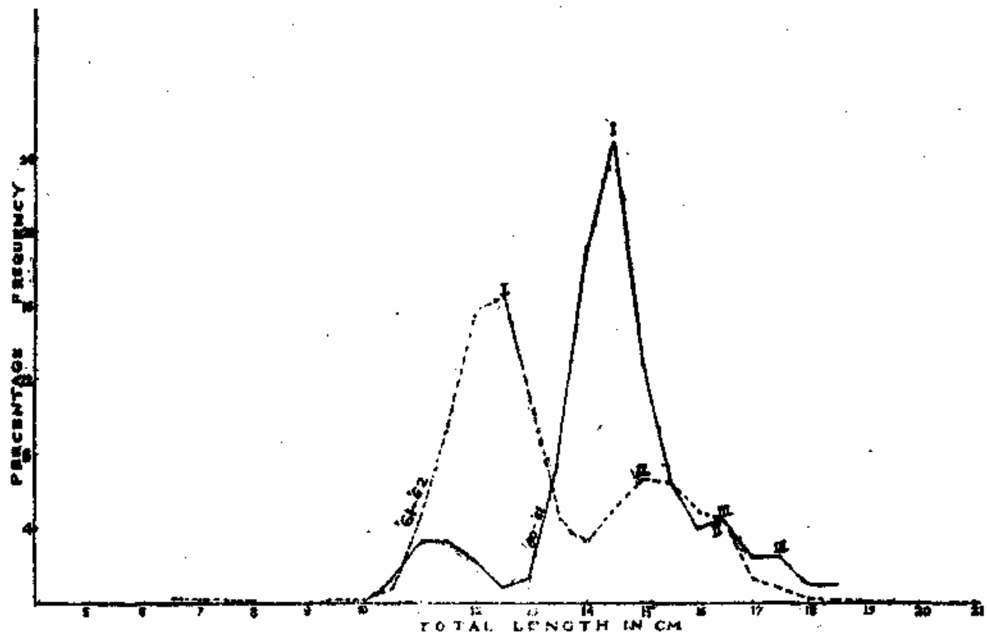


FIG. 5. Annual length-frequency distribution of oil sardine for 1960-61 and 1961-62.

The fishery began with the juveniles having the mode at 11.5 cm. in September of the 1961-62 season, which progressed to 12.0 cm. in October. In November, there were two modes at 12.0 and 12.5 cm.; in December, the mode was at 12.5 cm. In January 1962, the two modes seen were at 12.0 and 12.5 cm.; the latter mode continued in February. In March also, there were two modes as in January at 12.0 and 12.5 cm. In April and May the modes were at 12.5 and 13.5 cm. respectively. In June and July, the modes remained at

13.5 and 14.5 cm. respectively. In August, there were two modes at 15.0 and 16.0 cm. The increase in length during the eleven months from September to August was 4.5 cm., being about 4.0 mm. per month.

In September of 1962-63 season, the modes were at 4.5 and 16.0 cm. in the beginning of the sardine fishery season. In October, the fish with a mode of 10.5 cm. appeared in the fishery. But in November and December, the mode stood at 12.0 cm. In January and February 1963, the large-sized fish supported the catches and their modes were at 17.0 and 16.5 cm. respectively. In March and April, the mode was only at 13.0 cm. In May, the mode shifted to 14.0 cm. In June and July the modes were at 17.0 and 17.5 cm. respectively. Thus it is seen that from October to July an increase in modal values from 10.5 to 17.5 cm. was noticeable.

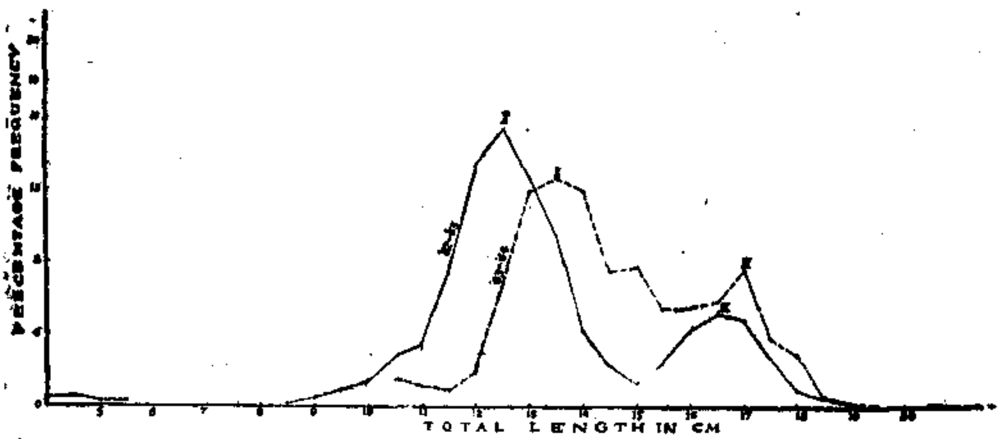


FIG. 6. Annual length-frequency distribution of oil sardine for 1962-63 and 1963-64.

In August of 1963-64 season, the juveniles with the 13.0 cm. mode entered the fishery. In September and October, the mode progressed to 13.5 cm. It may be added that in November there were no boat-seine catches. In December and January (1964), the modes were at 14.5 and 14.0 cm. respectively. In February, the mode shifted to 13.5 cm. But in March, it progressed to 14.5 cm. again. In April, May and June, the modal values were 16.5, 16.5 and 17.5 cm. respectively. The modal increment recorded was 4.5 cm. from August to June.

The juvenile fishery commenced from August, in the 1964-65 season, with the mode at 10.5 cm. In September and October, the modes indicated progress and reached 11.5 and 13.0 cm. respectively. The latter mode persisted in the months of November, December and February. But in January and March the mode shifted to 12.5 cm. (*vide* also Table IV).

TABLE V

Lengths (in cm) of oil-sardine at the various ages, as observed by different authors

Authors	Years				Remarks
	1	2	3	4	
Hornell & Nayudu (1923) . . .	15·0	16·0	..	..	Suggested a life span of 2½ years.
Devanesan (1943)	6·5	..	..		Presumed a life span of 14 years when the fish are 18 cm. in size.
Chidambaram (1950)	10·0	14·5	18·3	20·5	About 4 years.
Nair (1949, 1952 & 1960) . . .	10·0	15·0	19·0	..	The fish 21 cm long being in the fourth year.
Balan (1959)	12·3	16·3	18·5	..	Based on length frequency only, completed 3 years.
Balan (present paper)	13·0	16·0	17·5	..	Based on only averages size frequency from 1955-64. Fish (17·5 cm.) completed 3 years.
	14·3	16·4	18·4	..	Based on scale studies (by back-calculation).

Discussion

Nair (1952) suggested that each of the first two "rings" observed on the oil-sardine otoliths is formed during the summer period every year when the phytoplankton is scarce and that the third ring formed in some otoliths is either due to the same cause, or as a result of suspension of their feeding during spawning. Menon (1950) advanced the view that generally in fishes, there is an inherent physiological rhythm which is the causative factor for the formation of these growth-checks. He later (1952-53) stated "It appeared that the rhythm of concentration and dispersion of the food material of the fish gives the marks in the scales, increasing the growth, if there is concentration provoked with the phase of dispersion." Seshappa and Bhimachar (1951) attributed the monsoon rings formed in *Cynoglossus semifasciatus* to the lack of food of the sole during the monsoon period. In the case of *Sardinops neopilchardus*, Blackburn (1949) postulated that the formation of rings may be regarded as a sudden check in growth due to assumption of shoaling habit of the species.

It has already been shown that the period of ring formation is between February and June every year, though formation of rings continues in minor strength almost throughout the year. During this period, as was stated by Nair (loc. cit.), the annual rings in their scales may be formed due to the reduced feeding activity. Being synchronous with this planktonic scarcity, the rise in temperature of the environment in summer may act, in combination, as an additional causative factor towards the formation of rings in the scales. Opinion expressed by Hornell and Nayudu (loc. cit.) regarding this is also essentially in agreement with the former (food scarcity as the causative factor). Moreover, at present, it is difficult to state whether the rings denote shoaling habit or spawning or any other activity of the fish. Since direct observations relating to the causes of ring formation have not been made, the above views are only tentative.

Presence of only one ring (as a remnant) in some individuals above the 16.0 or 17.0 cm. size may be due to the fact that there may be some tendencies of ring absorption in the adults of this species also as in the scales of Japanese carp *Cyprinus carpio* reported by Ichikawa (1953) consequent on their starvation and that reported by Cating (1953) in the shad, *Alosa sapidissima*. According to Blackburn (1949) "Great difficulty was encountered because of omitted and secondary rings on the scales, and these cases mostly did not seem to be confined to only certain scales from the same fish." (p. 81)

False rings though present in a few scales are not quite significant as they are not useful in age-determination purposes. They may, perhaps, be the manifestations which register certain minor events in the life history of the fish. Views of Blackburn (1949) are also in line with this.

Compared to the results derived from the scale-method, relatively smaller length values (13.0 and 17.5 cm.) for the one-year old and the three-year olds respectively have been obtained from length-frequency distribution data. Since such small variations may arise due to sampling fluctuations, it is suggested that both the methods may be continued for the estimation of the relative abundance of the various year-classes in the commercial catches.

SUMMARY

The age and growth rate of the oil-sardine have been determined by examining their scales (from 2,931 individuals) and length-frequency distribution from 1955 to 1965 at Calicut and Cochin.

By measuring scales from a selected body area, the relationship between the fish-length and scale-length has been expressed as:

$$L_t = \frac{L\,S_t}{S} + \frac{A(1-S_t)}{S}$$

The back-calculated lengths of the sardine on the basis of detailed scale measurements showed that the fish attained average lengths of 14.3, 16.4 and 18.4 cm. at the age of one, two and three years respectively. It is significant that generally those below the 12.0 cm. length had no ring in their scales.

The growth is quite fast till the fish have completed one year. The period of ring formation is mostly between February and June every year in all the age-classes, whether the fish have spawned or not. These evidences strongly indicate that these scale-rings are regular annuli registering the age in years.

Comparison of length-frequency distribution with the results of the scale-method revealed that excepting for the two-year olds, the length modes representing the one-year and the three-year old fish are silghtly lower than the values obtained through the latter method.

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